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 2010 - 2014. Harvest regimes will be developed to achieve objectives (i.e., total or Southern U.S. exploitation rate ceilings, and / or spawning escapement goals) for each of fifteen management units. This Plan describes the technical derivation of these objectives, and 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 accounts for 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 Chinook 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. However, the Puget Sound ESU currently includes many weak populations. Providing adequate conservation of weak stocks will necessitate foregoing some harvestable surplus of stronger stocks.

The ER ceilings stated for management units (Table 1) are ceilings, not annual target rates. The objective for annual, pre-season fishery planning is to develop a fishing regime that will exert exploitation rates that do not exceed the objectives established for each management unit. For the immediate future, annual target rates that emerge from pre-season planning will, for many management units, be lower their respective ceiling rates. While populations are rebuilding, annual harvest objectives will intentionally be conservative, even for relatively strong and productive populations.

To protect the extant populations in the ESU, low abundance thresholds (Table 1) are established at a level above that which a population may become demographically unstable, or subject to loss of genetic integrity. If abundance (i.e., escapement) is forecast to fall to or below this threshold, harvest impacts will be further constrained, by Critical Exploitation Rate Ceilings, so that escapement will exceed the low abundance threshold or the ceiling rate is not exceeded.

Exploitation rate ceilings for some management units are based on the best available information on the recent and current productivity of each management unit. Quantification of recent productivity (i.e., recruitment and survival) is subject to uncertainty and bias. The implementation of harvest regimes is subject to management 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, so they reflect current status.

Harvest management strategies and objectives embodied in this Plan differ among management units, with reference to the current abundance and productivity of the component population(s), limiting factors constraining natural production, management and production objectives for local hatchery programs, and the role of the populations in recovery of the ESU.

Criteria for exemption of state / tribal resource management plans from prohibition of the 'take' of listed species, are contained under Limit 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 from increasing, and that populations with critically low abundance be guarded against further decline, such that harvest will not significantly reduce the likelihood of survival and recovery of the ESU.

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

Table 1. Exploitation rate ceilings, expressed as total, southern US (SUS), or pre-terminal (PTSUS) exploitation rates, and upper management and low abundance thresholds, for Puget Sound Chinook management units.

Management Unit	Exploitation Rate Ceiling	Upper Management Threshold	Low Abundance Threshold	Critical Exploitation Rate Ceiling
Nooksack North Fork South Fork		4,000 2,000 2,000	 1,000 [1] 1,000 [1]	7% / 9% SUS [3]
Skagit summer / fall Upper Skagit Sauk Lower Skagit	50%	14,500	4,800 2200 400 900	15% SUS even years 17% SUS odd years
Skagit spring Upper Sauk Upper Cascade Suiattle	38%	2,000	576 130 170 170	18% SUS
Stillaguamish North Fork Summer South Fk & MS Fall	25%	900 [1] 600 [1] 300 [1]	650 [1] 500 [1] N/A	15% SUS
Snohomish Skykomish Snoqualmie	21%	4,600 [1] 3,600 [1] 1,000 [1]	2,800 [1] 1745 [1] 521 [1]	15% SUS
Lake Washington Cedar River	20% SUS	 1,680	 200	10% PT SUS
Green	15% PT SUS	5,800	1,800	12% PT SUS
White River spring	20%	1,000	200	15% SUS
Puyallup fall	50%	500 (South Prairie Cr.)	500	12% PT SUS
Nisqually	47%			
Skokomish	50%	3,650	1,300 [2]	12% PT SUS
Mid-Hood Canal	15% PT SUS	750	400	12% PT SUS
Dungeness	10% SUS	925	500	6% SUS
Elwha	10% SUS	2,900	1,000	6% SUS
Western JDF	10% SUS	850	500	6% SUS

[1] natural-origin spawners.
[2] The threshold is escapement of 800 natural and/or 500 hatchery (see Appendix A).
[3] Expected SUS rate will not exceed 7% in 4 out of 5 years (see Appendix A)

1. Objectives and Principles

This Harvest Management Plan (Plan) establishes management guidelines for annual harvest regimes, as they affect Puget Sound Chinook, for the 2010 - 2014 management years. The Plan guides the implementation of fisheries in Washington, under the co-managers' jurisdiction, and considers the total harvest impacts of salmon- and steelhead-directed fisheries on Puget Sound Chinook, 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 harvest to the extent necessary to enable rebuilding of natural Chinook populations in the Puget Sound evolutionarily significant unit (ESU), provided that habitat capacity and productivity are protected and restored. It includes explicit measures to conserve and rebuild abundance, and preserve diversity among all the populations that make up the ESU. The ultimate goal of this plan, and of concurrent efforts to protect and restore properly functioning Chinook habitat, is to rebuild natural productivity so that natural Chinook populations will be sufficiently abundant and resilient to perform their natural ecological function in freshwater and marine systems, provide related cultural values to society, and sustain commercial, recreational, ceremonial, and subsistence harvest.

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

1.1 Scope of the Plan

This Plan defines allowable levels of harvest-related mortality on Puget Sound Chinook. Constraints on fishing are primarily focused on Treaty Indian and non-Indian commercial, tribal ceremonial and subsistence, and recreational salmon 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. 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, and may request the PFMC to modify them, to achieve management objectives for Puget Sound Chinook (PSSMP Section 1.3).

Fisheries mortality in Alaska, Oregon, and British Columbia is also accounted to assess, as completely as possible, total fishing mortality on Puget Sound Chinook. Mortality of Puget Sound Chinook in other Washington commercial and recreational fisheries, e.g. those directed at rockfish, halibut, shellfish, or resident trout, is not directly accounted.

The co-managers and the National Marine Fisheries Service (NMFS) have adopted a Recovery Plan for Puget Sound Chinook (NMFS 2007, Ruckleshaus et al. 2005) that states abundance and productivity goals for each population, which are the ultimate objectives for all aspects of recovery planning. The Recovery Plan addresses all 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.

1.2 Objectives

To promote recovery, the Plan is built on the following objectives:

- Conserve the productivity, abundance, spatial structure, and diversity of the populations that make up the Puget Sound ESU.

- Achieve compliance with the ESA jeopardy standard, as stated in the salmon 4(d) rule, that exempts harvest from the prohibition on take if it does not "appreciably reduce the likelihood of survival or recovery" of the ESU (NMFS 2005a).

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

- Provide opportunity to harvest surplus hatchery Chinook from Puget Sound and the Columbia River, and sockeye, pink, coho, and chum salmon.

- Account all sources of landed and non-landed fishery-related mortality, in all fisheries, when assessing total exploitation rates.

- 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 provides the basis for co-management of the salmon resource by the treaty tribes and the State of Washington and mandates equitable sharing of harvest opportunity among tribes, and among treaty and non-treaty fishers.

- 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.

Abundance and productivity of Puget Sound Chinook populations is currently between 10% and 25% of historical levels. For the purposes of this harvest Plan, we consider all populations to be threatened, and at risk of extinction, if appropriate actions aren't taken. Therefore, harvest of these populations must be limited as part of a comprehensive recovery plan that addresses impacts from harvest, hatchery practices, and degraded habitat.

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 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 Chinook quantify harvest rates and catch distribution for Puget Sound Chinook.

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 harvest opportunity among tribes, and among treaty and non-treaty fishers.

The Pacific Salmon Treaty defines limits to harvest in fisheries that take Puget Sound Chinook. The principles of the original abundance-based Chinook management framework, as described under the Chinook Chapter to Annex IV of the PST in 1999, remain in effect, but the 2008 Agreement placed further constraints on certain fisheries in Southeast Alaska and British Columbia. Constraints on Individual Stock Based Management (ISBM) fisheries in the southern U.S. are unchanged in the 2008 Agreement, and a procedure for determining compliance with that obligation during pre-season planning is defined in this Plan.

Most of the harvest-related Chinook mortality in fisheries governed by this Plan will occur in fisheries directed at abundant 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, are taken into account in developing this plan.

This Plan sets limits on annual fishery-related mortality for each Puget Sound Chinook management unit. The limits are expressed either as exploitation rate ceilings, or natural escapement thresholds. 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 harvest management in rebuilding the Puget Sound ESU. But for most populations, until habitat constraints to productivity are alleviated, the Plan's constraints on harvest may only assure that population abundance will remain stable or persist, if habitat conditions do not further deteriorate. For some populations, the Plan's constraints on harvest are designed to provide levels of natural escapement that exceed estimates of MSH escapement under current habitat conditions. Providing these 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 harvest 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, the Plan's extraordinary measures to further reduce harvest mortality may not reduce their risk of extinction.

The development and implementation of the fishery mortality limits in this Plan incorporate measures to manage the risks and compensate for the uncertainty associated with quantifying the abundance and productivity of populations, where the information is available for such assessment. In addition, the 'management error' associated with forecasting abundance and estimating the impacts of a given harvest regime is built into the simulation of the future dynamics of individual populations, which is the basis for selecting exploitation rate objectives for some units. Furthermore, the Plan commits the co-managers to ongoing monitoring, research and analysis, to better quantify and determine the significance of risk factors, and to modify the Plan as necessary to minimize such risks.

The 2001, 2003, and 2004 versions of the Plan (PSIT and WDFW 2001; 2003, and 2004) responded to the conservation standards of Section 4(d) of the Endangered Species Act (ESA), after Puget Sound Chinook were listed as threatened. However, management objectives and tools have been evolving since the early 1990s in response to the declining status of Puget Sound stocks. Concern over the declining status of Puget Sound and Columbia River Chinook has motivated conservation initiatives under the management authorities of the Pacific Salmon Commission and of the PFMC. Efforts continue within these forums to address the current status of Puget Sound Chinook. 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 changing needs of this fishery resource.

Harvest-related mortality must be assessed in the context of constraints imposed by habitat conditions on Chinook recovery. Non-harvest mortality is several orders of magnitude greater than the impact of harvest. If an adult female lays 5,000 eggs, and only two to six of those survive to adulthood, the non-harvest mortality rate exceeds 99.9%. Consequently, a small increase in survival to adulthood has a much greater effect on abundance than reduction of harvest. Recovery is contingent on increasing productivity, i.e. the recruitment per female spawner. Listing of the Puget Sound ESU has engendered a broad effort, shared by federal, tribal, state, and local governments and the private sector, to protect and restore habitat, but until that effort is broadly effective, Chinook abundance and productivity will not increase.

2. Fisheries and Jurisdictions

Puget Sound Chinook 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 are harvested in commercial, subsistence, personal use, and recreational fisheries throughout Southeast Alaska (SEAK). From 1999 through 2008, total landed catch ranged from 236,500 to 499,300 (Table 2). The SEAK fishery is managed to achieve the annual all gear PSC allowable catch through plans established by the Alaska Board of Fisheries.

Commercial fisheries employ troll, gillnet, and purse seine gear. Commercial troll landings accounted for an average of 66% of total harvest from 1999-2008, while net gear accounted for 14%. 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, then shifts to a coho directed fishery in August. Gillnet and seine fisheries within State waters target pink, sockeye, and chum salmon, with substantial incidental catch of coho, and relatively low incidental catch of Chinook.

Table 2. Chinook catch in southeast Alaska fisheries, 1999-2008 (CTC 2009)

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	338,411	71,618	86,575	496,604
2006	282,315	70,384	85,794	438,493
2007	268,149	55,884	82,848	406,881
2008	151,926	46,149	38,371	236,446

Total Chinook landed in SEAK recreational fisheries ranged from 38,400 to 86,6000 from 1999-2008, 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 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 2000, 30% of the harvest mortality of Elwha, and 60% of Hoko, 11% of Stillaguamish summer, and 27% of Skagit summer Chinook occurred in Alaska (CTC 2008).

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 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 mortality. Conservation measures have limited Chinook retention in many areas.

Chinook catch in the Northern B.C. and WCVI troll fisheries increased dramatically in 2002 (Table 3). These increases resulted in increases in exploitation rates for many Puget Sound Chinook management units in these fisheries. Skagit summer/falls, and Nooksack / Samish, South Puget Sound, Hood Canal, and Strait of Juan de Fuca 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 3. Chinook catch in British Columbia commercial troll and tidal sport fisheries, 1999 - 2008 (CTC 2009)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Northern BC troll	56,499	9,800	13,100	103,038	137,357	167,508	174,806	151,485	83,235	52,147
WCVI troll	5,307	63,400	77,491	132,921	151,826	174,128	148,798	109,004	94,921	95,170
Georgia Strait troll	80	270	0	506	17	17	0	0	0	0
WCVI outside sport	31,106	38,038	40,179	32,115	23,995	42,496	53,928	37,905	46,229	50,559
QCI & No. coast sport	41,927	30,700	41,400	55,100	54,300	74,000	68,800	64,500	61,000	55,470
Central coast sport	10,300	7,400	7,650	7,330	8,385	10,677	9,017	9,400	6,130	2,909
JDF, GS, JS sport	66,209	49,442	58,481	79,394	54,196	67,189	54,461	45,856	50,032	34,829

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, under co-management by the WDFW and Treaty Tribes. The Pacific Fisheries Management Council (PFMC), pursuant to the Sustainable Fisheries Act (1996), oversees annual fishing regimes in these areas. Tribal fleets operate within the confines of their usual and accustomed fishing areas. Principles governing the co-management objectives and the allocation of harvest benefits among tribal and non-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 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 Quilleute, Queets, Quinault, Hoh, and Grays Harbor systems. These fisheries primarily target Columbia River Chinook (CTC 2002). Puget Sound Chinook make up a low percentage of the catch, with South Sound and Hood Canal stocks exploited at a slightly higher rate than North Sound and Strait of Juan de Fuca Chinook.

The ocean troll fishery has been structured, in recent years, as Chinook-directed fishing in May and June, and Chinook- and coho-directed fishing from July into mid-September, to enable full utilization of Treaty and non-Treaty Chinook and coho 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 harvest occurs 10 to 40 miles offshore, whereas the coho 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 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 31,000 to 101,000 (Table 4).

Recreational fisheries, in Washington Ocean areas, are also conducted under specific quotas for each species, and allocations to each catch area. WDFW conducts creel surveys at each port to estimate catch and keep fishing impacts within the overall quotas. Most of the recreational effort occurs in Areas 1 and 2, adjacent to Ilwaco and Westport. Generally recreational regulations are not species directed, but certain time / area strata have had Chinook non-retention imposed, as conservation concerns have increased, and to enable continued opportunity based on more abundant coho stocks. Since 1999, recreational Chinook catch in Areas 1 – 4 has ranged from 8,500 to 57,800 (Table 4).

Puget Sound Chinook 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 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 stocks.

Table 4. Commercial troll and recreational landed catch of Chinook in Washington Areas 1 - 4, 1999 - 2009 (PFMC 2009)

	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	45,261

Amendment 14 to the PFMC Framework Management Plan restricts the direct oversight of conservation to those Chinook stocks whose exploitation rate in fisheries 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) have exceeded two percent, in a specified base period. 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 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 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. The magnitude of ceremonial and subsistence harvest of Chinook is small relative to commercial and recreational harvest, and is carefully monitored, particularly where it involves critically depressed stocks.

Commercial Chinook 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 areas 4B, 5 and 6C, and a spring/summer season in Area 4B, which is managed concurrently with the ocean fishery in neighboring areas. Annual harvest over the past 5 years has ranged from 400 to over 20,600 in the winter fishery, and from 100 to 4,500 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 (tribal fleets), with time/area and gear restrictions. In each catch area, harvest is focused on the target species or stock according to its migration timing through that area. Management periods are defined as that interval encompassing the central 80% of the migration timing of the species, in each management area. Because the migration timings of different species overlap, the actual fishing schedules may be constrained during the early and late portion of the management period to reduce impacts on non-target species. Incidental harvest of Chinook also occurs in net fisheries directed at sockeye, pink, and coho salmon.

Due to current conservation concerns, Chinook-directed commercial fisheries are of limited scope and most are directed at abundant 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 are also used in-season to acquire management and research data in the Skagit River, Elliott Bay, Puyallup River, and Nisqually River. Typically, these involve two or three vessels making a prescribed number of sets at specific locations, one day per week, during the run's passage.

Total commercial harvest of Chinook 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 1). Harvest has increased slightly in recent years, averaging 115,000 since 2000.

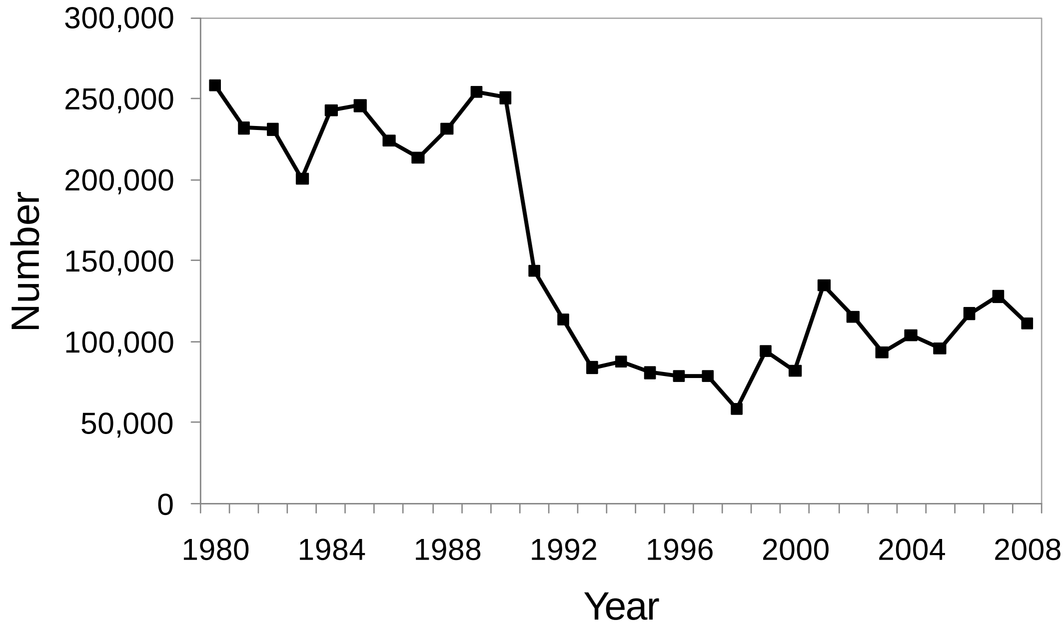

Figure 1. Commercial net and troll catch of Chinook in Puget Sound fisheries, 1980 – 2008 (WDFW LIFT database).

Commercial sockeye, pink, coho, and chum fisheries

Net fisheries directed at Fraser River sockeye 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 stocks and pink salmon.

Management has constrained sockeye harvest in recent years to account for lower survival and pre-spawning mortality of sockeye. Harvest averaged 312,000 between 2000 and 2007, ranging from 12,000 to 711,000 (Table 5). Fraser pink salmon return in odd years, with odd-year catches averaging 475,000 over the same period. Pink salmon harvest has also been somewhat constrained due to concerns for co-migrating late run sockeye. Most of the pink salmon harvest is taken by purse seine gear. Specific regulations to reduce incidental Chinook mortality, including requiring release of all live Chinook from non-treaty purse seine fishery hauls, have reduced incidental contribution total catch. All fishing-related Chinook mortality is accounted.

Table 5. Net harvest of sockeye, pink, and Chinook salmon in Washington fisheries under Fraser Panel Management, 2000-2008

	Species	2000	2001	2002	2003	2004	2005	2006	2007	2008
Strait of Juan de Fuca	sockeye	41,974	34,973	45,600	36,536	15,359	6,153	25,417	2,213	34,427
	pink	91	7,117	173	50,103	522	5,862	165	410	570
	Chinook	640	974	1,074	908	628	181	938	83	4,547
Rosario and Georgia Straits	sockeye	434,166	216,232	404,551	233,345	176,738	200,524	685,194	9,771	24,444
	pink	218	474,512	21	811,126	135	335,013	223	474,868	49
	Chinook	950	965	2,228	4,817	5,086	4,356	5,232	2,582	27

Commercial fisheries directed at Cedar River sockeye stocks occur in Shilshole Bay, the Ship Canal, and Lake Washington. Smaller scale commercial fisheries targeting Baker River sockeye occurred in the Skagit River. The Cedar River stock does not achieve harvestable abundance consistently, but significant fisheries did occur in 2000, 2002, 2004, and 2006. These fisheries generally involved low incidental Chinook 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), when abundance is projected to exceed escapement requirements. Because of the timing overlap of pink and Chinook salmon in the Nooksack region, pink harvest is a bycatch taken in the fall Chinook fishery that occurs after August 1, after the bulk of the pink run has passed. New pink-targeted opportunities occurred in 2007 in Marine Area 10 (Seattle Area), Elliott Bay, and the Duwamish, corresponding to the large increase in abundance of pinks in the Green and Puyallup River systems in recent years. Terminal pink fisheries can involve significant incidental catch of Chinook, due to the large overlap in run timing of the two species. Catches in each of the terminal areas have been variable since 2001 (Table 6), and largely reflect the patterns of pink abundances returning to those areas during that time.

Table 6. Commercial net harvest of pink salmon from Nooksack, Skagit, Snohomish, and South Puget Sound terminal areas, 2001-2007.

Terminal area	2001	2003	2005	2007
Bellingham Bay/Nooksack	12,437	1,637	2,198	674
Skagit Bay/River	199,868	218,285	20,964	5,998
Stillaguamish/Snohomish	86,735	155,418	21,138	21,230
South Puget Sound	658	3,758	2,362	13,904

Commercial fisheries directed at coho salmon also occur around Puget Sound and in some rivers. Coho are also caught incidentally in fisheries directed at Chinook, pink, and chum salmon. From

2003-2008, total landed coho catches have been relatively stable between 200,000 and 300,000, with a larger catch of 563,000 occurring in 2004 (Table 7). The largest catches occurr in South/Central Puget Sound, with in-river fisheries targeting hatchery coho in the Green and Puyallup, and marine fisheries targeting net pen production in deep South Sound.

Table 7. Landed coho harvest in Puget Sound net fisheries, 2003-2008. Regional totals include freshwater catch.

Region	2003	2004	2005	2006	2007	2008
Strait of Juan de Fuca	6,744	11,850	5,450	3,285	5,789	1,940
Georgia & Rosario Strait	9,293	22,912	3,543	676	1,679	822
Nooksack-Samish	43,472	90,039	35,814	21,817	34,958	31,124
Skagit	23,150	35,638	19,817	5,511	17,059	8,635
Stillaguamish-Snohomish	10,616	88,892	36,522	31,892	29,979	40,661
South Puget Sound	128,174	225,561	144,061	145,384	85,968	112,351
Hood Canal	33,225	86,433	60,150	58,201	48,060	40,087
Total	256,677	563,329	307,362	268,772	225,499	237,628

Marine and freshwater fisheries targeting fall chum salmon occur in many areas of Puget Sound in most years. Since 2003, chum harvests in Puget Sound have been large, ranging from 735,000 to more than 2,000,000 (Table 8). Due to the later migration timing of fall chum, most Chinook caught incidentally in marine areas are blackmouth. Incidental Chinook catch is low.

Table 8. Landed chum harvest in Puget Sound commercial fisheries, 2003 - 2008. Regional totals include freshwater catch.

Region	2003	2004	2005	2006	2007	2008
Strait of Juan de Fuca	683	5,406	2,075	4,700	6,890	6,091
Georgia & Rosario Strait	81,632	166,170	77,536	105,838	27,316	75,402
Nooksack-Samish	20,336	35,347	19,084	36,738	26,905	10,788
Skagit	19,015	19,117	18,335	106,380	17,873	7,416
Stillaguamish-Snohomish	41,193	164,695	44,165	199,588	190,736	84,570
South Puget Sound	449,151	751,430	324,302	611,479	703,524	360,217
Hood Canal	939,101	965,619	248,902	581,880	514,574	477,614
Total	1,551,111	2,107,784	734,399	1,646,603	1,487,818	1,022,098

Recreational Fisheries

Recreational salmon fisheries occur in marine 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

28,200 since 2002 (Figure 2). Marine area coho harvest has also decreased from an average of over 220,000 in the late 1980's, to less than 70,000 since 2002.

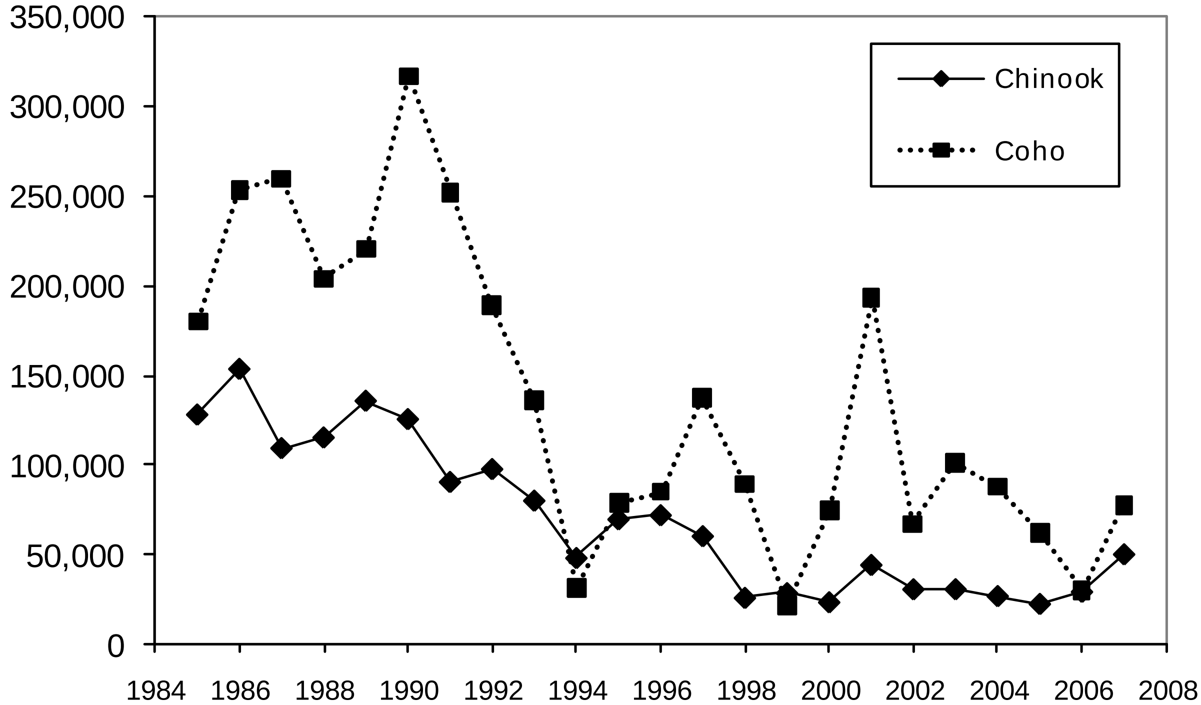

Figure 2. Recreational salmon catch in Puget Sound marine areas, 1985 - 2007 (WDFW CRC estimates, 2007 data are preliminary)

Freshwater recreational catch has shown an increasing trend since the late 1980's (Figure 3), likely in response to constraints placed on marine opportunity, and to the increasing abundance of some stocks.

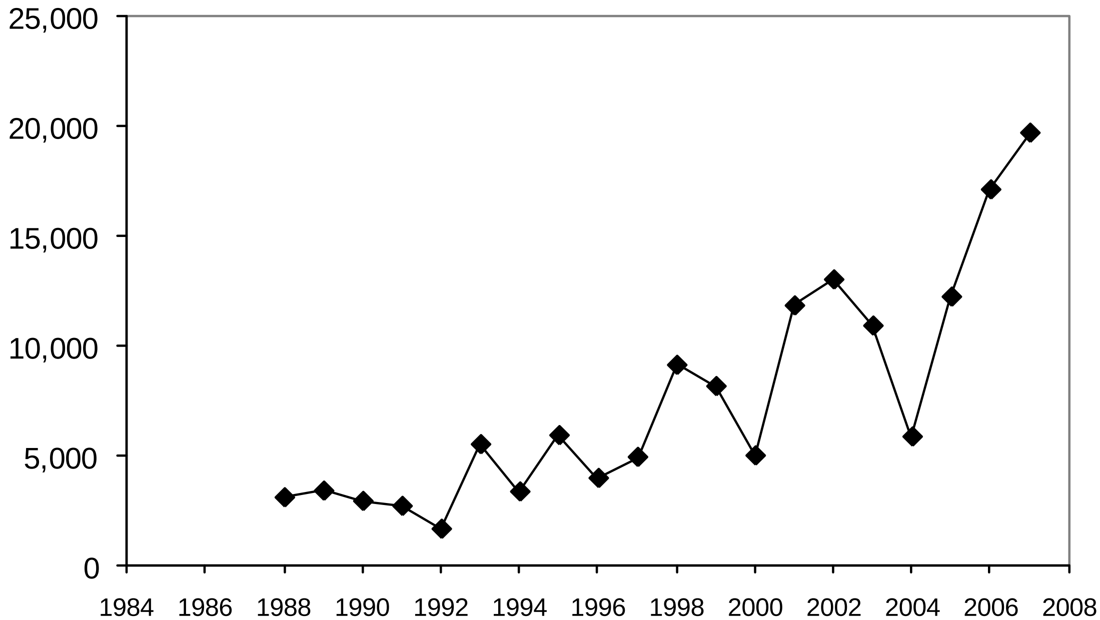

Figure 3. Recreational Chinook harvest in Puget Sound freshwater areas, 1988 - 2007 (WDFW Catch Record Card estimates, exclude jacks; 2007 data are preliminary).

Recreational Chinook catch has been increasingly constrained in mixed-stock areas to avoid overharvest of weak Puget Sound populations. Time and area closures, and mark-selective regulations fisheries have been implemented to limit impacts on weak wild stocks. Recreational fishery mortality 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.

2.5 Non-Landed Fishery Mortality

In all fisheries, each type of commercial and recreational gear exerts ‘non-landed’ mortality on Chinook. The rates currently used to assess non-landed mortality are shown below (Table 9). Hook-and-line fisheries are regulated by size limits, recreational bag limits, non-retention periods, and mark-selective periods. A proportion of the fish not kept will die from hooking trauma. A large body of relevant literature expresses a broad range of hooking mortality rates. Rates are assumed to be higher for commercial troll than for recreational gear, and higher for small fish.

As bag limits on recreational fisheries have decreased, the proportion of non-landed mortality has risen accordingly. The Washington co-managers and the PFMC have periodically reviewed the literature, and adjusted the non-landed mortality rates associated with hook-and-line fisheries, so that fisheries simulation models used in management planning express the best available science. For hook and line gear, the release mortality (or "shaker mortality") rate refers to the percentage of fish which are brought to the boat and released, because they are below the legal size limit, or because regulations preclude retention (due to species or adipose mark status). Drop-off mortality rate is calculated as a proportion of the landed catch, but refers to fish that are hooked but escape before being brought to the boat.

Table 9. Chinook incidental mortality rates applied to commercial and recreational fisheries in Washington.

Fishery	Release Mortality	Drop-off / Drop-out
Ocean Recreational	14%	5%
Ocean Troll - barbless hooks	26%	5%
- barbed hooks	30%	5%
Puget Sound Recreational	>22" - 10%	5%
	<22" - 20%	5%
Puget Sound Freshwater Recreational	10%	0%
Gillnet		Pre-terminal- 2%
	Skagit Bay 52%	Terminal marine - 3%
		freshwater – 0%
Purse Seine	immature fish - 45%	0%
	mature fish - 33%	0%
Beach Seine		
Skagit Bay pink fishery	50%	
Reef net	0%	0%

The various types of net gear also exert non-landed mortality. Studies to quantify rates are difficult to design and implement, so few reference data are available. 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. Few studies have been conducted to estimate the rates of encounter or the rates of mortality for fish encountered. Currently, the dropout incidental mortality effect is estimated assuming the effect is 3% of landed catch in pre-terminal areas and 2% in terminal fisheries. Purse seine gear, for the non-treaty fleet, has been modified, by regulation, to reduce the catch of immature Chinook by incorporating a strip of wide-mesh net at the surface of the bunt. Nonetheless, small Chinook are caught by seine gear, and are assumed more likely to be killed than mature Chinook. Non-treaty seine fishers have been required to release all Chinook in all areas of Puget Sound in recent years. Mortality rates vary due to a number of factors, but studies have shown that two-thirds to half of Chinook survive seine capture, particularly if the fish are sorted immediately or allowed to recover in a holding tank before release. Because total catch is typically small for beach seine and reef net gear, Chinook may be released without harm. Research continues into net gear that reduces release mortality, with promising results from recent tests of tangle nets (Vander Haegen et al. 2004). In any case, non-landed mortality is accounted by managers, according to the best available information, to quantify the mortality associated with harvest.

2.6 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 stocks. Pursuant to U.S. v Washington (384 F. Supp. 312), the Puget Sound Salmon Management Plan (1985) provides fundamental principles and objectives for comanagement 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 Chapter of the Treaty, which is implemented by the Pacific Salmon Commission, establishes ceilings on Chinook exploitation rates in southern U.S. fisheries. The thrust of the original Treaty, and subsequently negotiated agreements for Chinook, 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 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 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, 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 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 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 fisheries subject to the Treaty that are not AABM fisheries are classified as ISBM fisheries, including freshwater Chinook fisheries. As provided in the new 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 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 the new agreement is 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. As a result exploitation rates for most Puget Sound stocks will decline 2 – 3% in these fisheries.

Distribution of Fishing Mortality

A significant portion of the fishing mortality on many Puget Sound Chinook 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 10). Of the Puget Sound indicator stocks, more than half of total mortality of Nooksack spring, Skagit spring, Skagit summer/fall, and Hoko fall Chinook occurs in Alaska and Canada. Washington troll fisheries account for smaller portions of total exploitation, accounting for more than 10% for only one stock, the Skokomish. Puget Sound net and U.S. sport fisheries account for the majority of mortality on Samish, South Puget Sound, and Nisqually fall stocks.

Table 10. 2000-2006 average distribution of fishery mortality, based on coded-wire tag recoveries, for Puget Sound Chinook indicator stocks (CTC 2008).

Indicator stock	Alaska%	Canada	US troll %	US net%	US sport %
Nooksack spring fingerling	9.6%	81.2%	2.5%	2.0%	4.7%
Samish fall fingerling	0.8%	31.3%	7.4%	50.7%	9.8%
Skagit spring fingerling	6.2%	69.4%	2.0%	2.3%	20.2%
Skagit spring yearling	1.1%	58.3%	1.4%	2.7%	36.5%
Skagit summer/fall fingerling	27.4%	59.9%	0.9%	5.3%	6.4%
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%
White River spring yearling	0.0%	5.7%	8.0%	8.9%	77.4%
Nisqually fall fingerling	0.2%	16.2%	7.3%	47.3%	29.1%
Skokomish fall fingerling	1.7%	40.2%	10.7%	16.5%	30.9%
Hoko fall fingerling	61.6%	34.6%	1.6%	0.0%	2.2%

Note: Stillaguamish average of 2000, 2001 and 2006; White average of 2000 and 2006.

Trends in Exploitation Rates

Post-season FRAM ('validation') runs, which incorporate catch and stock abundance from post-season assessments, are available for management years 1983-2006, and can show trends in the total exploitation rate of Puget Sound Chinook over that time. 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, fisheries management has reduced exploitation rates steadily since the 1980's. Total exploitation rates on Skagit, Stillaguamish, and Snohomish units have declined dramatically since the 1980's, with recent averages equaling roughly one-third to one-half of earlier values **(**Figure 4**).** Exploitation rates on Nooksack, Skagit, and White river spring Chinook stocks have shown similar declines over the same time period (Figure 5).

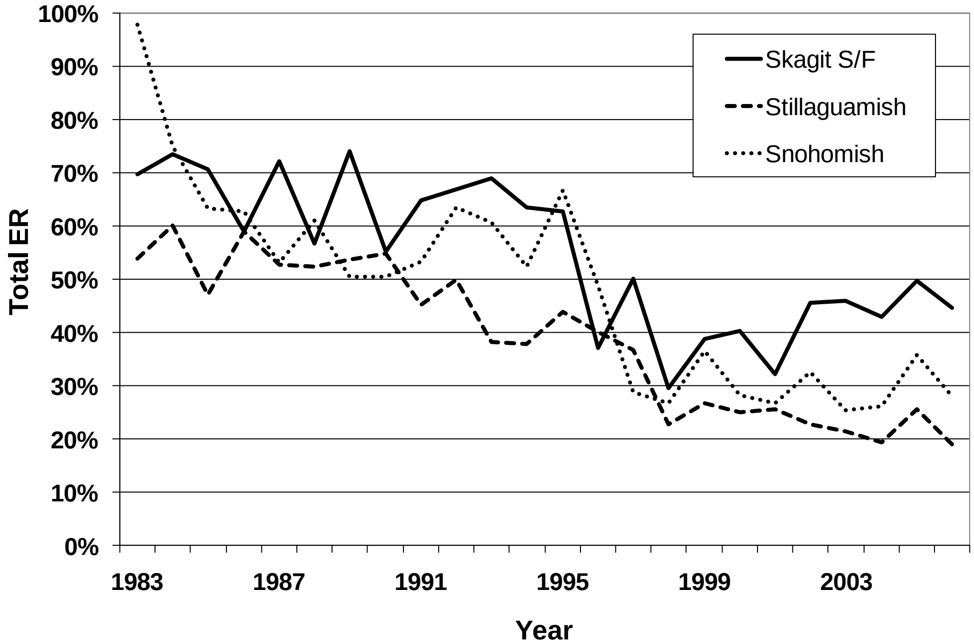

Figure 4. Total exploitation rate for Skagit, Stillaguamish, and Snohomish summer/fall Chinook management units, 1983-2006 (based on 2009 FRAM validation run).

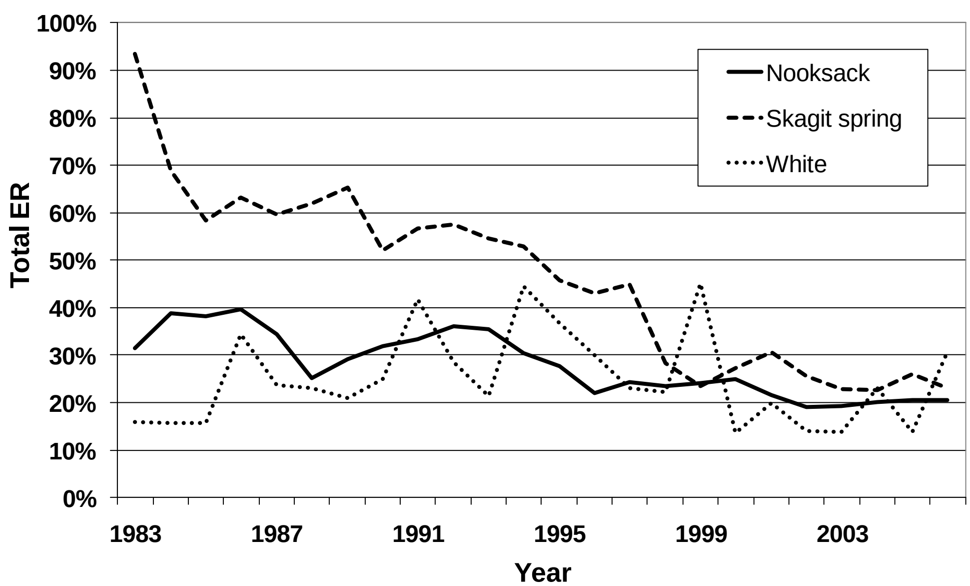

Figure 5. Total exploitation rate for Nooksack, Skagit, and White spring Chinook management units, 1983-2006 (based on 2009 FRAM validation run).

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.

3.1 Population Structure

The Puget Sound Chinook ESU comprises 22 extant populations originating in 12 river basins (Table 2). This Plan also includes management objectives for Chinook originating in the Hoko River, in the western Strait of Juan de Fuca. The intent of this Plan is to manage fishery-related risk, in order to conserve genetic and ecological diversity of populations throughout the ESU.

Puget Sound Chinook were delineated into stocks in the Salmon and Steelhead Stock Inventory (WDF et al. 1993); the 2001 Harvest Plan was generally based on the SASSI stock designation. To assist their delineation of historical population structure, the TRT (Ruckelshaus et al. 2006) examined juvenile freshwater life history, age of maturation, spawn timing, and physiographic characteristics of watersheds. This Plan conforms with the Puget Sound Technical Recovery Team's (TRT) population delineation (Ruckelshaus et al. 2006) that was developed as part of recovery planning.

Puget Sound Chinook populations are classified, according to their migration timing, as spring, summer, or fall Chinook, but specific return timing toward their natal streams, entry into freshwater, and spawning period varies significantly within each of these 'races'. Run timing is an adaptive trait that has evolved in response to specific environmental and habitat conditions in each watershed. Fall Chinook are native to, or produced naturally, in the majority of systems, including the lower Skagit, Snoqualmie, Cedar, Green, Puyallup, Nisqually, Skokomish, mid-Hood Canal, and Hoko rivers, and in tributaries to northern Lake Washington. Summer runs originate in the Elwha, Dungeness (spring/summer), upper Skagit, lower Sauk, Stillaguamish, and Skykomish rivers. Spring (or 'early') Chinook are produced in the North / Middle and South Forks of the Nooksack River, the upper Sauk River, Suiattle River, and Cascade River in the Skagit basin, and the White River in the Puyallup basin.

Puget Sound Chinook populations primarily exhibit subyearling ('ocean type') smolt life history. A small (less than 5 percent) proportion of juvenile fall Chinook and a larger and variable proportion of juvenile spring and summer Chinook 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 typically proceeds north from the Washington coast as far north as southeast Alaska. A large, for some stocks a majority, of their harvest occurs in the southern waters of British Columbia. Adult Chinook become sexually mature at the age of three to six years; most Puget Sound Chinook mature at age-3 or 4. A small proportion of males mature precocious after shorter ocean residence, or as parr.

Puget Sound Chinook 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 the 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 de Fuca, Nooksack River early, Skagit and North Fork Stillaguamish rivers, South Fork Stillaguamish and Snohomish rivers, central and southern Puget Sound and Hood Canal late, and White River early. (Ruckelshaus et al. 2006). The genotype of populations in South Sound and Hood Canal reflect use of Green River-origin broodstock used for large-scale hatchery production. Indigenous early- and/or late-timed populations were extirpated in the Snohomish, Puyallup, Nisqually, Skokomish, and Elwha systems; genetic analyses of extant returns to these systems do not detect continued native genotypes.

This Plan does not establish harvest objectives where Chinook 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

A population is a biological unit. A management unit, in contrast, is an operational unit, whose boundaries depend on the fisheries acting on that unit. This Plan aggregates populations of similar run timing in some rivers into management units, for the purpose of managing harvest. This is due largely to the spatial and temporal commingling of these populations throughout the areas where they are harvested, which precludes population-specific management.

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 often 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. , which the co-managers began working on soon after the decision. One outcome of this work was the Puget Sound Salmon Management Plan (PSSMP), which established the basis for management units, escapement goals, management periods, and other details necessary for harvest management. In general, management units were 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. With this understanding, the co-managers defined the natural Chinook management units in Puget Sound (Table 11). 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 escapement goals for Puget Sound were based on recent year average observed escapement (Ames and Phinney, 1977).

Table 11. Management units and their component natural Chinook populations in Puget Sound. The production category of each population is noted in parentheses.

Management Unit	Component Populations
Nooksack Early	North/ 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	North Fork Stillaguamish River Summer (1) South Fork & mainstem Stillaguamish River Fall (1)
Snohomish	Skykomish River Summer (1) Snoqualmie River Fall (1)
Lake Washington	Cedar River Fall (1) North Lake Washington Tributaries 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) 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 three rivers comprise one population.
[2] The Hoko River is not part of the listed Puget Sound ESU.

Of the 15 management units covered in this Plan (Table 11), six contain more than one population. The other nine management units comprise one population. This Plan includes management measures intended to conserve the genetic 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 in Appendix A). This significant change in management means that management units are no longer the smallest units considered in management of Puget Sound fisheries. It 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.

3.3 Population Categories

The co-managers' Comprehensive Management Plan for Puget Sound Chinook 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 11):

- 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 is from an introduced stock and is influenced by ongoing hatchery contribution. The indigenous population is functionally extinct. Habitat condition may not currently support self-sustaining natural production.

- Category 3 units - natural production occurs only because of returns to a local hatchery program, or due to 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 11). The Hoko River population, outside of the ESU, is also designated Category I.

Natural production of Category 2 populations in the Sammamish, Puyallup, Nisqually, Skokomish, and mid-Hood Canal systems is comprised of Chinook now genetically indistinguishable from those used for local hatchery production because of extensive interbreeding, and because the Green River stock was used to initiate and perpetuate the hatchery programs.

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 production in these systems was included in the original ESA listing, because it is essential to the recovery of the ESU (NMFS 1999). The NMFS subsequently listed hatchery production in 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 (NMFS 2005a, NMFS 2005b).

The listed, ‘production’ hatchery programs were initiated with the objective of enhancing fisheries, 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. 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 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, allowable harvest rates have been reduced with this Plan’s current revision to assure their viability and to preserve future options to manage for higher natural-origin production as recovery potential improves in response to habitat restoration.

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 production. In these areas, terminal harvest is frequently managed to remove a very high proportion of the returning Chinook, but assuring sufficient escapement 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 into adjacent streams is also likely, but while some natural production may occur in these systems, their habitat is not suitable to independently sustain Chinook production.

4. Management Thresholds and Exploitation Rate Ceilings

4.1 Upper Management Thresholds

An upper management threshold (UMT) is set for each MU (Table 12)**Error! No bookmark name given.**. Consistent with the PSSMP, this threshold is the escapement level associated with achieving optimum productivity (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 annually when considering fishing plans, taking into account the expected fishing mortality in Southeast Alaska, British Columbia, and Washington waters (including incidental, test, and ceremonial and subsistence catches in southern U.S. fisheries). If spawning escapement is projected to substantially exceed the UMT, higher levels of fishing impact may be allowed, subject to conditions further specified in Chapter 5. The UMT is generally used in this Plan as a benchmark for evaluating population status, either pre-season or post-season.

Derivation of UMTs varies among MUs, dependent on the quality and types of data available to quantify current productivity. While the intent is to set the UMT at a level associated with achieving optimal natural spawner abundance under current habitat condition, estimates of this level are uncertain. For some Category 1 populations UMTs are intentionally set above the estimated or assumed average MSH level, to address this uncertainty and reduce the risk of under-escapement. The method used for each MU is described in its Management Unit Profile (i.e., Appendix A).

Setting the UMT at the current MSH escapement level or higher is a conservative strategy that assigns harvest management its rightful share of the burden of conservation, assures long-term increases in abundance, and does not impede recovery. As habitat conditions improve, this threshold can be increased to account for increased productivity or capacity.

4.2 Low Abundance Thresholds

When the spawning abundance of a salmon population falls to a very low level, there is a significant increase in the risk of demographic instability, loss of genetic integrity, and extinction. This point of biological instability (i.e. the critical threshold) has not been quantified for all salmon populations, but genetic and demographic theory has drawn its boundaries (McElhany et al. 2000). At very low spawner abundance, ecological and behavioral factors can 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 smolt production. However, the abundance level at which these factors exert their effect will differ markedly between populations.

Table 12. Exploitation rate ceilings, low abundance thresholds and critical exploitation rate ceilings for Puget Sound Chinook management units.

Management Unit	Exploitation Rate Ceiling	Upper Management Threshold	Low Abundance Threshold	Critical Exploitation Rate Ceiling
Nooksack North Fork South Fork		4000 2000 2000	 1,000 [1] 1,000 [1]	7% / 9% SUS [3]
Skagit summer / fall Upper Skagit summer Sauk summer Lower Skagit fall	50%	14,500	4,800 2200 400 900	15% SUS even-years 17% SUS odd-years
Skagit spring Upper Sauk Upper Cascade Suiattle	38%	2,000	576 130 170 170	18% SUS
Stillaguamish North Fork Summer South Fk & MS Fall	25%	900 600 300	650 [1] 500 [1] N/A	15% SUS
Snohomish Skykomish Snoqualmie	21%	4,600 3,600 1,000	2,800 [1] 1745 [1] 521 [1]	15% SUS
Lake Washington Cedar River	20% SUS	 1,680	 200	10% PT SUS
Green	15% PT SUS	5,800	1,800	12% PT SUS
White River spring	20%	1,000	200	15% SUS
Puyallup fall	50%	500 (South Prairie Cr.)	500	12% PT SUS
Nisqually	Stepped reduction to 47% in 2014			
Skokomish	50%	3,650	1,300 [2]	12% PT SUS
Mid-Hood Canal	15% PT SUS	750	400	12% PT SUS
Dungeness	10% SUS	925	500	6% SUS
Elwha	10% SUS	2,900	1,000	6% SUS
Western JDF	10% SUS	850	500	6% SUS

[1] natural-origin spawners
[2] The threshold is escapement of 800 natural and/or 500 hatchery (see Appendix A)
[3] Expected SUS rate will not exceed 7% in 4 out of 5 years (see Appendix A)

The Low Abundance Threshold (LAT) set for each MU (Table 12), which triggers extraordinary conservation measures in fisheries, is set well above the critical threshold, so that more restrictive management of fisheries can be applied to reduce the risk of a population becoming unstable. The derivation of the LAT varies, according to the quality and quantity of data available to describe population productivity and abundance. In some cases, the threshold is set at or above an historical low escapement from which the population rebounded (i.e. survivors from that low brood escapement produced a higher number of subsequent spawners). In other cases, where spawner-recruit and management error data were deemed sufficient, we calculated a threshold at which the probability of falling below the calculated point of instability was acceptably low. In other cases, where specific data were lacking, we used values from the literature that estimated minimum effective population sizes that would avoid demographic instability or loss of genetic integrity (e.g., Franklin 1980; Waples 1990; Lande 1995; McElhany et al. 2000).

For example, thresholds for Skagit summer and fall populations were calculated as the forecast escapement level for which there is a 95 percent probability that actual escapement will be above the point of instability (i.e., 5 percent of the replacement escapement level). This calculation accounted for the difference between forecast and actual escapement in recent years, and the variance around recruitment parameters. For the Stillaguamish management unit, escapement of 500 was identified as the low abundance threshold, because this level has resulted in recruitment rates of 2 – 5 adults per spawner. For other Puget Sound populations the low abundance threshold was set in accordance with the scientific literature, or more subjectively, at annual escapement of 200 to 1,000 (see Appendix A).

4.3 Exploitation Rate Ceilings

This Plan sets fisheries exploitation rate (ER) ceilings as the principle mechanism for achieving spawning escapement levels for each population that are consistent with current habitat function. Exploitation rate management was first implemented in the late 1990s for Puget Sound Chinook, (i.e. before the ESU was listed) because the former harvest strategy, based on achieving fixed escapement goals, was not adequately conservative, or provided no management guidelines that could be consistently applied across fisheries when the run size was less than the escapement goal. FRAM estimates of exploitation rate also tend to be more accurate than estimates of spawning escapement. The same transition to exploitation rate management has been implemented for Puget Sound coho. Harvest strategy must be suited to existing data and tools for forecasting annual abundance and projecting harvest mortality. The co-managers determined that exploitation rate management was more averse to risk than a fixed escapement goal management strategy, because estimates of exploitation rates were considered more robust and because techniques were available for providing sufficiently accurate post-season estimates of harvest mortality in fisheries coast-wide.

In this Plan, ER ceilings are established for each MU and may be applied to all fisheries or only to Southern U.S. fisheries (Table 12). The derivation of ER ceilings for some management units relies on available data that quantifies current productivity as determined by current habitat and freshwater survival conditions. For other MUs the ER ceilings are derived by analyzing exploitation rates associated with recent fisheries regimes and the likelihood of achieving optimal escapement levels.

When escapement is projected to exceed the LAT, the ER ceiling defines the maximum level of fishing-related mortality allowed for that MU. When escapement is projected to be less than the LAT, then the maximum level of fishing-related mortality is further constrained by implementing a lower, critical exploitation rate (CER) ceiling. with the intent of increasing projected escapement above the LAT The CER ceilings reflect maintenance of harvest opportunity on hatchery-origin Chinook, and sockeye, pink, coho, and chum stocks, while affording protection to listed Chinook populations. The CER ceilings were constructed by evaluating the exploitation rates associated with recent year fisheries that provided fishing opportunity on abundant Chinook hatchery stocks and other species.

The CER ceilings (Table 12) are defined as total SUS ceiling exploitation rates for most management units. For the Lake Washington, Green, Puyallup, Nisqually, Mid Hood Canal and Skokomish units, 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).

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, utilizing data found sufficient to quantify current productivity. The ER ceiling for these MUs was selected as the highest exploitation rate that met the more restrictive of the following two risk criteria:

- A very low probability (less than five percentage points higher than under zero harvest) of abundance declining to a critical threshold, or A high probability (at least 80%) of the spawning escapement increasing to a specified threshold (see Appendix A), or

- the probability of escapements falling below this threshold level differs from the probability associated with a zero harvest regime by less than 10 percentage points.

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. These data enable reconstruction of historical cohort abundance, and variability in marine and freshwater survival, from which a spawner recruit function can be fitted. With initial escapement and annual exploitation rate specified, a simulation using the spawner recruit function predicts recruitment, harvest mortality, and escapement for 25 years, under variable marine and/or freshwater survival and specified management error typical of recent years. Management error includes the differences between anticipated and actual Chinook catch, changes in the harvest distribution of contributing stocks, and error in forecasting abundance.

The data methods used for derivation of the recruitment functions, upper and lower threshold values, and selection of the ER Ceiling, for each of the four management units, are detailed in Appendix A.

The risk tolerance criteria, stated above, were chosen subjectively, through joint technical cooperation by tribal, state, and federal biologists, as adequately conservative for depressed Chinook populations; they were not specified as jeopardy standards in the NMFS' salmon 4(d) rule. The upper 'rebuilding escapement threshold' is not equivalent, for all management units, to the UMT, previously described, which define harvestable surplus. The critical abundance threshold is not equivalent to the LAT applied as a trigger for more conservative harvest constraints.

The simulations 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, the ceiling rates ER ceilings were set by reviewing recent fisheries regimes that resulted in stable or increasing spawning escapement, and maintained harvest opportunity on surplus hatchery-origin Chinook, coho, sockeye, pink, and chum. For these management units, southern U.S. (SUS), or pre-terminal SUS exploitation rate ceilings were established. 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 on protected populations of Puget Sound Chinook (as defined by the 4(d) rule), unless there is robust evidence of harvestable surplus. If a management unit does not have a harvestable surplus, then harvest-related mortality will be constrained to incidental impacts. Any fisheries directed at listed Puget Sound Chinook will be implemented cautiously. Should they occur, directed fisheries would still result in escapement levels somewhat higher than the UMT (i.e., they would not emulate a fixed escapement goal management strategy).

The Plan reflects the PSSMP mandate for equitable sharing of the conservation burden. Southern US fisheries will continue under these circumstances, to enable harvest of more abundant species and stocks, and to access the harvestable surplus of more abundant Puget Sound Chinook. 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 weak, listed Chinook populations, in order to avoid impeding their rebuilding, while providing sufficient opportunity for the harvest of other species, abundant returns of hatchery-origin Chinook, and available surpluses from stronger natural Chinook stocks. For the duration of this Plan, directed fisheries that target listed Chinook populations are precluded, unless a harvestable surplus exists, and except for very small-scale tribal ceremonial and subsistence harvest, and research-related fisheries in a few areas.

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 protected, Puget Sound-origin Chinook. Total mortality includes all landed and non-landed mortality.

Landed and non-landed incidental mortality of listed Chinook will occur in fisheries directed at non-listed hatchery-origin Chinook and other salmon species, but will be strictly constrained by harvest limits that are established expressly to conserve naturally-produced Chinook.

The annual management strategy, for any given Chinook management unit, shall depend on whether a harvestable surplus is forecast. This Plan prohibits directed harvest on natural populations of Puget Sound Chinook, unless they have harvestable surplus. If a management unit does not have a harvestable surplus, harvest-related mortality will be constrained to incidental impacts. Directed and incidental fishery impacts are constrained by stated harvest rate ceilings or escapement goals for each management unit. The following rules define how and where fisheries can operate:

- Fisheries may be conducted where there is reasonable expectation that 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 listed Chinook populations or management units that lack harvestable surplus, not to develop a fishing regime that exerts the highest possible impact that does not exceed violate 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, harvest impacts will be reduced to the minimal level that still enables fishing opportunity on non-listed 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 a majority of the fishery impacts accruing to 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.

- A management unit shall be considered to have a harvestable surplus if, after accounting for expected Alaskan and Canadian catches, and incidental, test, and tribal ceremonial and subsistence catches in southern U.S. fisheries, an MU is expected to have a spawning escapement greater than its UMT, and its projected ER is less than its ER ceiling. In that case, additional fisheries (including directed fisheries) may be implemented until the exploitation rate ceiling is met, consistent with the Rules for Allowing Fisheries (above), or its expected escapement equals the upper management threshold. In this case, impacts may not be limited to incidental harvest mortality. The array of fisheries that may harvest the surplus can be widened, to include terminal-area, directed fisheries.

- Directed fisheries targeting harvestable surplus for any management unit will be implemented cautiously. Consistent forecasts of high abundance, substantially above the upper management threshold, and preferably corroborated by post-season or in-season assessment, would be necessary to initiate such fisheries. Alternatively, a terminal area inseason update 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). The decision to implement a directed fishery will also consider the uncertainty in forecasts and fisheries mortality projections. A directed fishery would not be planned to remove a very small surplus above the UMT. Implementing a new directed fishery, in an area where one has not recently occurred, will require reasonable assurance that abundance has increased to the level that will support a fishery. In practice this implies that increased abundance has occurred for a period of prior years, and that forecasts are reliable, before implementing a new directed fishery.

- 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 exploitation rate for MUs with no harvestable surplus will not be allowed to exceed their exploitation rate ceilings. In the event that the projected ER exceeds the ceiling ER, the incidental, test, and subsistence harvests must be further reduced until the ceiling ER Ceiling is not exceeded. An exception to this rule, however, applies for stocks that are managed for a total ER ceiling, in cases where the combined Northern ER is projected to be greater than the difference between the ER ceiling and the 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 2008 Pacific Salmon Treaty Chinook Agreement, such that the SUS ISBM fishery index will not exceed the Treaty-mandated ceiling (see Section IV, Pacific Salmon Treaty). The SUS ISBM fishery comprises the aggregate of Washington 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 is expected to be lower than its low abundance threshold, Washington fisheries will be further shaped until either the escapement for the unit is projected to exceed its low abundance threshold, or its projected exploitation rate does not exceed the CER ceiling (see section 5.3, below).

- The comanagers 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. For the 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 (Table 12). 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. 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 C provides a qualitative description of baseline tribal fisheries that virtually excludes harvest directed at natural Chinook (with exceptions for ceremonial and subsistence harvest), and shapes fisheries directed at other species to reduce incidental mortality of natural Chinook. Reducing tribal fisheries to those specified in the minimum fishery regime (MFR - Appendix B), 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 MFR, however, is presented only as a standard, and not as a guarantee – under critical status, it is the CER ceiling that is the overriding management constraint, whether it accommodates the MFR fisheries or not

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 Chinook 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, and non-listed species.

The CER ceilings (Table 12) are defined as total SUS ceiling exploitation rates for the Nooksack, Skagit, Stillaguamish, Snohomish, White, Dungeness, and Elwha management units. For the Lake Washington, Green, Puyallup, Nisqually, Mid Hood Canal and Skokomish units, 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).

It is not the co-managers' intent to construct a regime that incurs mortality at the level of the CER ceiling implemented for each MU in critical status. During pre-season planning the co-managers may, by agreement, set the annual management objective for any critical unit 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 either the CER ceiling or the agreed, lower ceiling, fisheries that incur projected increased impacts on critical units must be balanced by reductions in impacts associated with other southern U.S. fisheries. The effects of management regimes 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 reduce exploitation rates on Puget Sound MUs by only about 2 – 3%, and do not offset the increase in mortality on some Puget Sound stocks that occurred in 2003 – 2005 (CTC 2006). The NMFS determined the 2008 Agreement met the ESA conservation standards (NMFS 2008).

We anticipate that, for some Puget Sound MUs whose ceilings are stated as total ER ceilings, and whose abundance is not critical, the high interception rate in northern fisheries may result in situations where, to not exceed 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. In this situation, the following adjustments to the ER ceiling will be made:

1. If an MU that has a total ER ceiling is not at critical status; and

2. If the combined Canadian plus Alaskan ER on that MU is projected to exceed the difference between that MU's ER ceiling and its CER ceiling

then the constraint for that MU in that year will be its CER ceiling.

Modeling exercises have demonstrated potential for this to occur for several Puget Sound units that are unlikely to fall into critical status in the duration of this plan. The CER ceiling, in this circumstance, would constrain SUS fisheries to the same degree as if that unit were in critical status. While this measure 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, 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 FRAM, but, based on the best available information on the distribution of stocks, will be judged to have beneficial effect.

5.4 Pre-season Planning

Annual 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 the public, particularly commercial and recreational fishing interest groups, access to salmon status information 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 are:

Abundance forecasts are developed for Puget Sound, Washington coastal, and Columbia River Chinook management units in advance of the management 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 in the western Strait of Juan de Fuca).

An initial regime for Puget Sound fishing is evaluated. Recreational fisheries are initially set at levels similar to the previous year's regime. Incidental Chinook harvest in pre-terminal net fisheries is projected from recent-year catch data, and the anticipated scope of fisheries for other species in the upcoming year. Terminal area net fisheries in Chinook management periods are scaled to harvest surplus production and achieve natural and / or hatchery escapement objectives. The fishery regimes for pre-terminal and terminal net fisheries directed at other salmon species are initially set to meet management objectives for those species.

The FRAM is configured to simulate this initial regulation set for all Washington fisheries, based on forecast abundance of all contributing Chinook management units. Spawning escapement for each population, and total and SUS exploitation rates, projected by this model run, are then examined for compliance with management objectives for each Puget Sound Chinook management unit, and their component populations.

The initial model runs reveal conservation concerns for any management units in critical status (i.e. where escapement falls short of the low abundance thresholds), and a more general perspective on the achievement of management objectives for all other management units. In accordance with the preceding rules that control harvest levels, regulations governing directed and incidental Chinook 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 for all MUs.

5.5 Compliance with Pacific Salmon Treaty Chinook Agreements

The fishing regime developed by pre-season planning will be examined for compliance with the 2008 PST Chinook agreements. The non-ceiling index for the SUS Individual Stock Based Management (ISBM) fishery will not exceed the Treaty-mandated ceiling. If the ISBM index is projected to be exceeded, U.S. fisheries must be further reduced until the mandated ceiling is achieved.

In 2008, the parties to the Pacific Salmon Treaty agreed to a revised abundance-based Chinook 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 stock groups. With respect to Puget Sound Chinook, this agreement refers to the abundance status (i.e. spawning escapement) of certain indicator stock groups with respect to their identified escapement goals[1]. The summer/fall indicator group includes the Hoko, Skagit, Stillaguamish, Snohomish, Lake Washington, and Green units; the spring indicator group includes Skagit spring and Nooksack early units. Stepped reductions in ISBM fisheries will be imposed when two or more of these indicator units are projected not to meet their escapement objectives. These reductions will comply with the pass through provisions and general obligations for individual stock-based management regimes (ISBM) pursuant to the Chinook chapter within the US/Canada Pacific Salmon Treaty.

Escapement projected by the FRAM, at the conclusion of pre-season planning, will be compared to PST objectives. According to the PST agreement: "the United State shall reduce by 40%, the total adult equivalent mortality rate, relative to the 1979-82 base period, in the respective ISBM fisheries that affect those stocks." The reduction shall be referred to as the "general obligation".

For those stock groups for which the general obligation is insufficient to meet the agreed escapement objectives, the jurisdiction within which the stock group originates shall implement additional reductions:

i. reductions as necessary to meet the agreed escapement objectives; or

ii. which taken together with the general obligation, are at least equivalent to the average of those reductions that occurred for the stock group during the years 1991-96.

The Chinook Technical Committee defined the non-ceiling fishery index (CTC 1996). The PST defers to any more restrictive limit mandated by the Puget Sound Chinook 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.

[1] 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 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 State/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, for example, may be shortened so that harvest quotas are not exceeded. 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 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 management units 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 involves a significant change from the pre-season, agreed fishing regime, or a change in the expected ER (with reference to the effective ceiling), or substantially different escapement (with reference to the thresholds). The notification will include a description of the change, an assessment of the resulting fishing mortality, and an explanation of how impacts of the action still achieve objectives for affected MUs.

5.8 Enforcement

Non-treaty commercial and recreational fishery regulations are enforced by the WDFW Enforcement Program. The Enforcement Program’s 137 general-authority commissioned fish police officers 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 over enforcement of tribal commercial 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. Prosecution of violations of tribal regulations occurs through tribal courts and governmental structures.

6. Management of Hatchery-Enhanced Populations

Harvest management strategies and objectives embodied in this Plan differ among management units, with reference to the following factors:

1. Current abundance and productivity of the component population(s).

How does current productivity compare with identified recovery targets? Is abundance near or below the point of biological instability or LAT established by this Plan? Is current escapement optimizing natural production under existing habitat conditions? Is the extant, naturally spawning stock suited to achieving recovery objectives?

2. Limiting factors constraining natural production.

What limiting factors currently constrain natural production: habitat condition, harvest rate / escapement, fitness, and in what sequence should they be addressed? Continuing freshwater and nearshore habitat degradation may outpace habitat restoration efforts. Will immediate further harvest constraint materially improve the status of the population?

3. Hatchery management and production objectives.

Hatchery production imposes risks and provides benefits to abundance, distribution, and diversity. How many generations has the current hatchery program operated? What degree of genetic risk does the program currently impose? Do hatchery releases cause negative ecological interactions with naturally produced juveniles or adults? Would natural production persist absent the hatchery program? Should the contribution of hatchery origin adults to natural spawning be changed?

4. The role of the MU in recovery of the ESU.

ESU recovery objectives include persistence of all extant populations in Puget Sound, rebuilding the natural production for as many populations as possible, but prioritizing watersheds with the highest recovery potential. The NMFS Recovery Plan also emphasizes the need to maintain regional diversity, including two to four populations in each of five regions, but this prescription lacks immediate relevance in some regions due to the daunting, current constraints on recovering this level of diversity.

The Endangered Species Act 4(d) Rule requires that the Plan’s intended actions not appreciably reduce the likelihood of the survival and recovery of the ESU. ESU recovery is not synonymous with recovery of all individual populations within the ESU. Although specific criteria for recovery of the ESU have not been defined, possible recovery scenarios could include some populations with recovery goals achieved, some populations stable but still rebuilding, and some populations remaining at high risk. Harvest management strategies of this Plan are designed to have a beneficial effect on population recovery when implemented in coordination with revisions to hatchery management and success with habitat protection and restoration. For some populations, the effectiveness of harvest constraints to promote recovery is very limited under existing habitat and hatchery conditions.

The prudent course is to experimentally implement different approaches to implementing harvest strategies suited to local conditions and population status. Fundamental to these approaches is our intent to set or adjust ER ceilings in logical sequence, after proven restoration of habitat function, and informed by our understanding of fitness and other aspects of the productivity potential for stocks in each watershed. Local strategies will consider hydrology, the functionality of different habitat types needed to support the diverse life histories desired in a recovered population, and the suitability of the extant stock to thrive under those conditions.

Harvest Management Strategy I

Harvest management Strategy I will limit fishing-related impacts on populations or management units with the following attributes:

- Extant population(s) are indigenous, and contribute distinct or unique morphologic, behavioral and / or genetic diversity to the ESU, and are critical to its recovery.

- Local hatchery program(s) utilize indigenous broodstock, are of small scale, operated for research purposes, or expressly to maintain the viability of a local, critically depressed population,

- Effective habitat restoration and protection plan(s) are in place in the watershed such that natural origin spawners will be likely to produce recruits at a greater than 1:1 ratio in most years.

Where the required biological data are available to quantify the current productivity, ER ceilings are derived (see Chapter IV) to achieve natural escapement levels with a high probability of achieving or exceeding optimum natural production and harvest, with a very low probability of falling to the critical threshold.

Strategy I determines the harvest objectives for the following populations or MUs:

Population /Management	Associated hatchery program(s)
Nooksack Early	Kendall Creek & South Fork - conservation programs
Skagit Spring	Marblemount – research (indicator stock program
Skagit Summer Fall	Marblemount - summer and fall research program
Stillaguamish	Harvey Creek – conservation & indicator stock program
Snohomish	Wallace River – harvest enhancement and indicator stock program
Cedar	NA
White	White River & Minter Creek – conservation & indicator stock
Dungeness	Dungeness – conservation program
Elwha	Elwha Channel – conservation program

Conservation hatchery programs supplement the abundance of North / Middle and South Fork Nooksack, North Fork and South Fork Stillaguamish, White, Dungeness, and Elwha Chinook populations to maintain viability of these populations.

Spring, summer, and fall Chinook populations in the Skagit and Snoqualmie rivers, and Cedar River Chinook are the only populations in the ESU that are not significantly supplemented by hatchery production. Spring, summer, and fall programs in the Skagit River are operated for the purposes of harvest management research. Broodstock utilized for the summer and fall programs are collected from natural-origin (unmarked and untagged) adults. Hatchery returns spawn naturally, though in most years they comprise a small proportion of the natural escapement. Broodstock for the spring programs are collected from the Cascade River. Some adult returns spawn naturally, but their distribution differs from the natural stocks, and they are not accounted as part of natural escapement for the spring populations.

The Wallace River Hatchery program enhances harvest and functions as an indicator stock. Returns from this program contribute to natural spawning in the Skykomish system, primarily in the lower Wallace River and the Skykomish River immediately downstream of the Wallace confluence. Natural spawning in the Snoqualmie River includes some adults originating from the Wallace River and Tulalip Hatcheries, but there are no Chinook hatchery programs operating in this system. The contribution rates of the hatchery and natural components are estimated annually. Natural spawning in the Cedar River includes some stray returns from the Issaquah Hatchery program.

Harvest Management Strategy II

Harvest management strategy II will limit fishing-related impacts on a populations or management units with the following attributes:

- A major portion of the natural spawning escapement is comprised of first generation hatchery-origin Chinook. Life history characteristics, migration timing, and genetic identity of natural spawners are indistinguishable from those of the local hatchery stock. These characteristics influence the fitness of populations.
- Habitat degradation in the watershed outpaces habitat restoration efforts such that there is low likelihood of 1:1 returns on natural production in most years.

Strategy II determines the harvest objectives for the following populations or MUs:

Population /Management Unit	Associated hatchery program(s)
Sammamish	Issaquah Creek
Green	Soos Creek and Keta Creek
Puyallup	Clark Creek and Voight Creek
Nisqually	Clear Creek and Kalama Creek
Skokomish	George Adams and Rick’s Pond
Mid Hood Canal	Hamma Hamma River

Chinook broodstock has not been transferred among these systems in recent years; escapements to the hatcheries, in some cases augmented by natural-origin adults, now provide local broodstock for all these programs.

The Puget Sound Chinook Recovery Plan envisions rebuilding natural production in these systems using extant, listed populations, but their potential to achieve recovery objectives will remain uncertain until habitat constraints are alleviated, and, life history characteristics are either manipulated, or they evolve naturally over the longer term, to improve fitness. Indigenous Chinook populations were extirpated in all southern Puget Sound and Hood Canal systems, except for the Green River. Genetic analyses of recently collected samples have not detected residual native genotypes. These hatchery programs were initiated to mitigate for lost natural production. The programs in the Nisqually and Skokomish rivers operate under legally-defined mitigation agreements, to offset production losses associated with hydroelectric project operations in those systems.

Harvest will be constrained to result in stable natural escapement, trending toward if not achieving UMTs. Natural- and hatchery-origin adults will contribute to achieving this objective. Harvest rates will enable naturally-produced adults to replace themselves (brood year accounting), assuming constant habitat conditions. The natural-origin component of natural escapement will vary, but should not decline unless habitat condition deteriorates further.

Harvest strategy II allows total exploitation rates around 50% for several hatchery-enhanced populations. This will result in stable natural escapement, substantially supplemented by hatchery-origin adults, and stable presence of natural-origin spawners. According to all available direct and circumstantial evidence natural production of the populations addressed by this strategy is low and may not be self-sustaining. Continuation of this strategy for at least the duration of this Plan will not compromise or preclude adoption of future alternative strategies for achieving recovery objectives. The success of alternative strategies, such as the use of spawning escapement goals that limit hatchery influence, are unlikely to have a significant effect on the trajectory toward recovery as long as habitat conditions remain the principal constraint. Though habitat restoration programs are underway in most systems, habitat degradation in many systems outpaces restoration. When habitat function is significantly improved, more aggressive strategies to constrain harvest and reform hatchery programs to alter the current NOR / HOR ratio will be warranted to take full advantage of the increasing the potential for natural production.

The harvest management strategy for the Nisqually population is an example local strategy that reflects the unique attributes of this watershed. Comprehensive habitat restoration and protection measures have already been implemented. With near-term improvement in habitat function likely, harvest rates will be 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. The contribution of first-generation hatchery fish will be controlled with a mainstem weir. The escapement objective may subsequently change in accordance with measured changes in productivity.

The strategy for Nisqually Chinook envisions higher harvest rates on hatchery production as the total exploitation rate on natural origin production transitions to an ER ceiling below 50% (i.e, substantially lower than the last ten years). 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 also involving selective fishing methods). Subsequent further reduction in the ER ceiling may be implemented if the initial strategy is shown to result in higher productivity or if escapements are demonstrated to not fully utilize habitat capacity.

The Nisqually strategy will also test the potential for using an introduced (Green River) fall-timed hatchery stock for recovery, and the hypothesis that the fitness of the extant naturally-spawning Chinook can be improved by restricting the contribution of first-generation hatchery fish on the spawning grounds. Hatchery programs will continue to operate in the Nisqually system, but operation of the weir will isolate their limit their interaction with naturally-produced Chinook.

The strategy for the Skokomish MU will test a markedly different hypothesis for recovering historical life history patterns. It recognizes the introduced fall-timed stock may not be suited to achieve recovery objectives. An early-timed stock will be introduced first 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 natural Chinook will be restricted by an ER ceiling of 50% (substantially lower than recent year exploitation rates). Objectives for the extant stock may be modified in the future, as the Comprehensive Skokomish Chinook Recovery Plan is developed and implemented. The George Adams Hatchery program will continue to operate, serving its original harvest enhancement purpose, with measures implemented to maintain the current genetic diversity of the hatchery stock.

Hatchery programs have historically supported a significant level of harvest for units now managed under Strategy II. The hatchery programs were initiated because natural productivity was diminished by habitat degradation. Many of these units were formerly managed as ‘secondary’ (PSSMP 1985), to achieve hatchery escapement goals, which allowed relatively high harvest rates. The ESA requires a more conservative harvest regime, attentive to recovery potential.

7. 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 achieve the conservation standards of the ESA.

ESA Conservation Criteria

This Plan constrains harvest of all management units so that fishing mortality does not impede rebuilding and eventual recovery of the ESU. However, rebuilding and recovery is, for all populations, contingent on restoring the functionality of habitat. Harvest constraint will play an essential 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 populations to more substantially higher abundance, and eventually to their recovery goals, depends on the restoration of higher productivity that will only be possible when habitat function is restored.

The conservation standard of the ESA, as expressed in the salmon 4(d) rule regarding the limit for state / tribal harvest management plans (Limit 6), is that harvest-related mortality must not "appreciably reduce the likelihood of survival and recovery of the ESU". The 4(d) rule further defines 'survival and recovery' as protecting the abundance, productivity, spatial distribution, and diversity of the ESU. Conditions for applying Limit 6 state that harvest actions should: 1) maintain healthy populations at abundance above their recovery thresholds; (no Puget Sound Chinook population currently exceeds its recovery threshold); 2) not impede the recovery of populations whose abundance is above their low threshold but below their recovery threshold; and 3) not impose increased demographic or genetic risk on populations at critically low abundance, unless imposing greater risk does not appreciably reduce the likelihood of survival and recovery of the entire listed ESU (50 CFR 223, FRN 65(132): 42476).

Under current habitat constraints, fisheries will be managed so that spawning escapement from some populations will achieve or rebuild toward a level sufficient to optimize natural production (i.e. 'MSH escapement'). That level is determined by habitat function. Achieving this objective assures that harvest is not impeding eventual recovery. Chinook productivity during their freshwater life history phases may be limited by spawning area, spawning substrate quality, flow conditions, sediment transport, rearing habitat area and quality, or other environmental factors. Marine survival also strongly influences recruitment to adulthood. Although the ability to quantify optimum escapement for populations varies, the harvest strategy is based on the fundamental assumption that recruitment is limited by habitat condition. Escapements greatly exceeding the habitat-defined optimum will not result in higher recruitment than would occur at capacity; it may result in lower recruitment, depending on the density dependence of local productivity.

Given the uncertainty about optimum escapement in many systems it is prudent to enable escapement to range higher than point estimates of MSH. Productivity (and MSH) varies annually due to the variability in the complex array of factors that influence survival. Where data are sufficient, analysis provides a point estimate of MSH and its statistical variance. Enabling escapement to range upward from the point estimate of MSH (which is based on recent average survival and recruitment) will capitalize on favorable environmental conditions. This strategy will also enable estimation of recruitment across a broad range of escapement, and more precise quantification of productivity. This strategy assumes the potential downside risk of exceeding MSH, due to density dependence, is acceptable, while intentionally avoiding the greater risk of under-escapement. Exploitation rate management, as implemented since 2001, has been demonstrated to result in positive or stable natural escapement trends for most Puget Sound populations. Freshwater and marine survival conditions varied during this period.

For some populations at critically low abundance, harvest will be severely constrained. Extraordinary measures defined by the Plan are expected to assure that the abundance of these populations will remain above their point of instability. For some of these depressed populations, harvest constraint can only maintain escapement at the optimum level associated with current habitat quality. Because natural production (survival) is so low for these weak populations, some will require hatchery supplementation to ensure their persistence. Further harvest constraint of SUS harvest will not materially improve the likelihood that these populations will survive in the long term.

Considering the significant influence that harvest has on abundance (i.e. spawning escapement), the objectives and conservation measures contained in this Plan were developed with specific intent to maintain all populations at their current status and allow them to rebuild as other constraining factors are alleviated. This chapter describes how the Plan's objectives protect the abundance and diversity of the ESU.

7.1 Harvest Objectives Based on Natural Productivity

The harvest objectives for each management unit are stated as ceiling exploitation rates or escapement goals for naturally spawning or, for some units, natural-origin Chinook. Though fisheries in some areas are shaped to harvest surplus hatchery production, the primary objective is to assure protection and conservation of the abundance and diversity of natural populations.

Specifying the exploitation rate ceilings and abundance thresholds for all management units in terms of natural production was a significant change, relative to management practices prior to listing. Formerly, management of some management units was based primarily on harvesting surplus hatchery production, without regard to the consequences of these high harvest rates on natural-origin Chinook. This Plan establishes specific escapement thresholds for all Category 2 populations, to ensure that natural production remains viable.

Prior to 1998, Chinook harvest objectives were stated as escapement goals for many Puget Sound management units. The PSSMP stated the preference that escapement goals be based on achieving maximum sustainable harvest, which implied the ability to quantify optimum escapement, by estimating current natural productivity (i.e. spawner – recruit functions) and capacity. However, the escapement goals that were established by the co-managers for 'primary' management units did not all have a biological basis; most were an historical average of escapement during a period of higher abundance and survival than more recent years (i.e. 1968 - 1977 for summer fall stocks, 1959 - 1968 for Skagit River spring stocks). For most units, these historical escapements were a result of fishing levels in the base years, and were not related to the current capacity or quality of spawning or freshwater rearing habitat, or marine survival, particularly as habitat conditions were further degraded through the 1980s and 1990s. Pursuant to the PSSMP, the co-managers could, by consensus, agree to different escapement objectives on an annual basis. These goals were in effect until the late 1990s. Continuing decline in stock status, and the subsequent listing of Puget Sound Chinook with its requirement to develop recovery goals, prompted re-assessment of the old escapement goals, and development of new harvest strategies for many management units designed to achieve natural spawning escapement objectives.

This Plan sets harvest and escapement objectives for all management units to conform with their current or recent natural productivity, to the extent possible with available data. Those objectives may be refined as new data and analyses become available.

Accounting for Uncertainty and Variability

Uncertainty and annual variability are present in all estimates of productivity of salmon populations. To manage the associated risk, we have accounted and compensated for the uncertainty and variability in the technical methods used to derive harvest objectives. Derivation of ER ceilings was 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, variability in freshwater and marine survival rates were estimated and parameterized in spawner – recruit functions;

- Simulations of population dynamics to derive ER ceilings incorporated variance in productivity and freshwater and marine survival reflective of recent years. We assumed these parameters provided the best prediction of future population performance.

- Even when recent survival was relatively high the simulation will conservatively assume lower survival;

- Management imprecision associated with forecasting and harvest modeling were incorporated into population simulations.

- The productivity of populations will be re-assessed periodically. Significant changes may result in adjustment of harvest objectives.

7.2 Protection of Individual Populations

This Plan establishes harvest objectives (i.e. ceiling exploitation rates and/or escapement thresholds) for management units, but annual fisheries planning will also respond to the status (i.e., projected spawning escapement) of individual populations comprising some MUs. The FRAM projects aggregate natural escapement for complex MUs, so extra-model calculations are needed to project escapement for component populations.

To reduce the risk of escapement declining to the critical level that may jeopardize demographic or genetic integrity, a low abundance threshold is established for each population that triggers further constraint of harvest. Thus, the prescribed management response to critical status may be implemented when natural escapement for only one population in a complex MU is projected to fall below its LAT.

Populations exceeding their low abundance thresholds

Harvest of some Category 1 populations is managed such that there is a high probability escapement will attain or exceed the level associated with optimum current productivity or habitat capacity, thus assuring harvest will not impeding their recovery. This strategy carries some risk of exceeding the spawning capacity of habitat, and potentially lowering productivity (recruits per spawners), but will enable higher production when environmental conditions are more favorable to survival. Enabling escapement to exceed MSH will experimentally test the current productivity of populations, better define recruitment under a broader range of escapement, and detect improved productivity as habitat is restored.

The decision to manage harvest under exploitation rate ceilings, as opposed to fixed escapement goals, also recognizes the current limits of management tools. Given the current accuracy of abundance forecasting, and the capability of the fishery simulation model, exploitation rates for a specified fishery regime can be projected with greater accuracy than spawning escapement. Exploitation rates may also be consistently and accurately estimated post-season, enabling continual, adaptive assessment of management performance.

The Plan sets total exploitation rate objectives for the Puyallup, and White that have been demonstrated to provide adequate seeding of spawning habitat. Habitat-based analysis (see Appendix A) suggests that productivity is low in the Puyallup system. The number of natural-origin adults spawning has exceeded the MSY escapement level from this analysis. Hatchery-origin adults have contributed significantly to natural spawning. Returns to the White River have increased under the current exploitation rate objective, exceeding the UMT of 1,000 in seven of the last eight years. Research is underway to refine estimates of current productivity and habitat capacity in these systems.

Changes in harvest management for the Nisqually MU are part of an experimental effort to improve the fitness and productivity of the introduced, Green River-origin fall stock. An extensive habitat restoration and protection program has created conditions favorable to conducting this experiment. Fisheries in the Nisqually River will be managed to sequentially reduce the mortality of natural-origin Chinook. Total exploitation rates will not exceed 64% in 2010-11, 56% in 2012-13, and 47% in 2014 (see Appendix A). Concurrently, operation of a weir in the Nisqually mainstem starting in 2010 will control passage of first generation, hatchery-origin adults to upstream spawning grounds. Escapement of natural-origin adults will increase and comprise more than 90% of upstream spawners.

The Skokomish MU will be managed so that the total ER will not exceed 50%. Achieving this objective will involve reduction of SUS fisheries' impacts, relative to recent years. However, recent analyses have suggested the extant stock may not have potential for achieving Chinook recovery objectives in the Skokomish system. The Skokomish Chinook Recovery Plan will prioritize restoration of early-timed life history by re-introducing a spring stock in the North Fork, and later, the South Fork. When the Recovery Plan is reviewed and adopted as part of the Puget Sound Chinook Recovery Plan, harvest objectives and strategies for the extant, introduced, fall-timed stock may change.

A ceiling exploitation rate for SUS fisheries of 20% is established for the Lake Washington MU. The intent of management is unchanged from the 2004 Plan, to provide stable or increasing natural escapement to the Cedar River. In years of relatively high abundance, when projected escapement, verified by in-season assessment, exceeds the UMT, additional terminal fishing opportunity will be provided to harvest more surplus Issaquah Hatchery returns. Issaquah Hatchery-orin adults are expected to continue to comprise a minority of natural spawners in the Cedar River. This Lake Washington regime is expected to maintain significant natural spawner abundance in the Sammamish River and its tributaries. Though the historical presence of an independent population in the Sammamish is uncertain (Ruckelshaus et al. 2006), the extant stock is genetically identical to the Green River-origin stock that was used to initiate the Issaquah Creek Hatchery program. Current habitat conditions in the Sammamish do not currently support a self-sustaining (naturally- produced) Chinook population. The Lake Washington MU harvest strategy will maintain stable natural escapement to the Sammamish, but harvest conservation measures will continue to focus on protection of the Cedar population.

Management Units in Critical Status

Critical or near-critical status is expected to persist for the North/Middle Fork and South Fork Nooksack, South Fork Stillaguamish, Dungeness, and Mid-Hood Canal populations, requiring continued severe constraint of SUS fisheries, and hatchery recovery programs to maintain 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 have been held to low levels: 1 – 4% for the Nooksack, 6 – 7% for the Stillaguamish, 5 – 8% for Mid Hood Canal, and 2 – 4% for the Dungeness and Elwha MUs. To the extent that escapement for these populations has fluctuated or declined in recent years, factors other than harvest mortality in SUS fisheries have been the apparent cause.

7.3 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. Exploitation rate ceilings were first implemented for the some MUs in 1998. Total or SUS ER ceilings were implemented in the 2001 and 2004 versions of this Plan. Exploitation rates for all Category 1 MUs have fallen substantially relative to ERs in the preceding decade (Table 13). In some cases the reduction in SUS harvest was offset by increasing interception in northern fisheries.

Table 13. Southern U.S. fishery exploitation rates for Puget Sound Chinook (post-season FRAM estimates A. Hagen-Breaux WDFW, pers comm October, 2010).

	2001	2002	2003	2004	2005	2006	2001-06 avg	1994-98 avg
Nooksack	5%	2%	3%	4%	4%	5%	4%	7%
Skagit S/F	8%	12%	8%	6%	10%	8%	9%	17%
Skagit Spr	21%	15%	13%	11%	13%	12%	14%	32%
Stillaguamish	16%	12%	12%	7%	10%	8%	11%	28%
Snohomish	14%	20%	13%	10%	13%	11%	13%	32%
Lk Washington	12%	9%	12%	12%	13%	18%	13%	19%
Green	22%	34%	28%	31%	19%	27%	27%	30%
White	16%	11%	11%	19%	13%	29%	17%	29%
Puyallup	62%	57%	47%	52%	36%	27%	47%	48%
Nisqually	65%	65%	67%	56%	46%	63%	60%	74%
Skokomish	43%	36%	42%	33%	26%	36%	36%	31%
Mid Hood Canal	11%	8%	9%	12%	7%	8%	9%	28%
Dungeness	3%	5%	5%	4%	2%	3%	4%	17%
Elwha	3%	5%	6%	4%	3%	3%	4%	16%

The effect of harvest constraint is manifest in the increasing escapement trend for most Puget Sound MUs (Table 14). We assessed fifteen-year escapement trends from median values in successive 5-year periods, and concluded the trend (i.e., the slope of the trend line) was biologically significant if the slope exceeded 5% of the y-intercept (Geiger and Zhang 2002). Of the 22 Chinook populations comprising the Puget Sound ESU, 14 exhibit positive escapement trends over the past fifteen years (1994 – 2008), all but one trend is biologically significant. Five populations exhibit negative trends, but none are significant. Trends for three populations were not assessed because they lack a 15-year time series of escapement estimates.

Table 14. Fifteen-year (1994-2008) trends in natural spawning escapement for Puget Sound Chinook populations.

MU	Population	15-year trend	
		slope	slope/y_0
Nooksack	North / Middle Fk	N/A	
	South Fork	N/A	
Skagit spring **	Suiattle	-6.00	0.01
	Upper Sauk	41.00	**0.31**
	Cascade	15.50	**0.09**
Skagit S/F**	Lower Sauk	24.30	**0.06**
	Upper Skagit	1026.70	**0.40**
	Lower Skagit	218.60	**0.50**
Stillaguamish**	North Fork	-15.59	0.02
	South Fork - MS	-7.90	0.03
Snohomish	Skykomish	279.50	**0.14**
	Snoqualmie	152.80	**0.24**
Lake Washington	Sammamish	N/A	
	Cedar River	32.60	**0.13**
Green		65.70	**0.07**
White		165.50	**6.28**
Puyallup		-19.63	0.01
Nisqually		136.20	**0.42**
Skokomish		21.40	**0.05**
Mid Hood Canal		-12.20	0.04
Dungeness		90.40	**0.46**
Elwha		30.50	0.02

7.4 Equilibrium Exploitation Rates

Managing harvest under exploitation rate ceilings, based on quantified natural productivity, assures stable or increasing escapement for those management units. The underlying recruitment function, which is based on current performance, predicts that productivity declines as abundance (escapement) increases, such that for any level of escapement an exploitation rate may be identified that assures replacement of the parent brood. Setting the exploitation rate objective conservatively, with a view to recent abundance, assures a high probability that escapement will trend upward. The following analysis illustrates this concept for the Skagit River summer / fall and spring management units.

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) was 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 and Figure 7. 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.

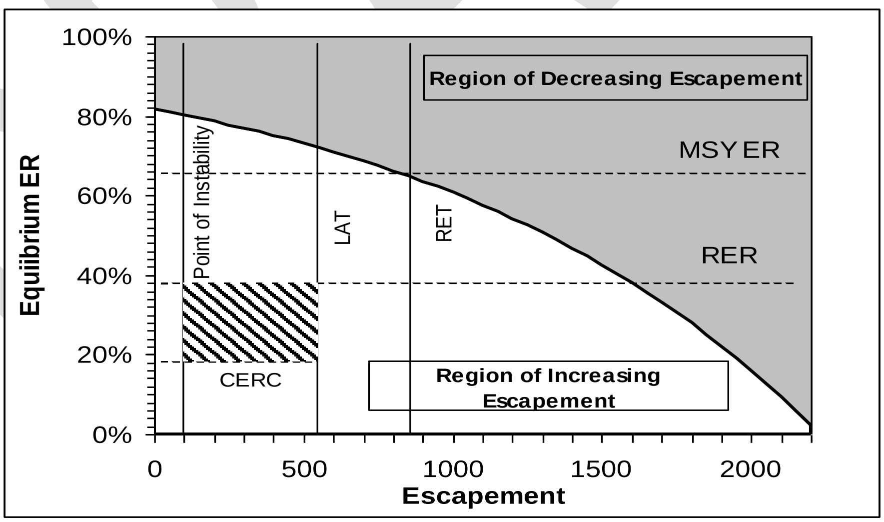

Figure 6. The equilibrium exploitation rate, at each escapement level, for Skagit spring Chinook.

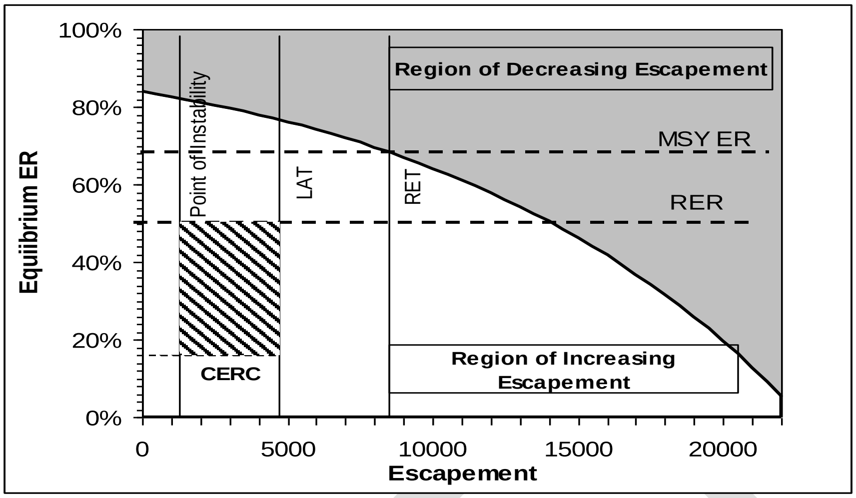

Figure 7. The equilibrium exploitation rate, at each escapement level, for Skagit summer/fall Chinook.

For Skagit Chinook, the NMFS' "viable threshold" is the same thing as the "rebuilding escapement threshold" that was used in the ER ceiling analyses and derivations. For Skagit spring Chinook, this is the MSY escapement level, which, from the Ricker spawner-recruit parameters that were used in the ER ceiling analysis, is about 850 spawners (Figure 6). The Limit 6 "critical threshold", however, is NOT the same thing as the "critical threshold" defined in this plan – the Limit 6 threshold is a point of instability below which the spawner-recruit relation destabilizes and the risk of extinction increases greatly. The low abundance threshold in this plan, in contrast, is a buffered level that is set sufficiently above the point of instability that the risk of getting an escapement below the point of instability, through management error or uncertainty, is low. The critical threshold for Skagit spring Chinook, in this plan, is 576 spawners; the point of instability (i.e., the Limit 4 "critical threshold"), calculated using the Ricker parameters from the ER Ceiling analysis and Peterman's (1977) rule-of-thumb, (i.e., that the point of instability is 5% of the replacement level), would be about 110 spawners (Figure 6).

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, as shown in the crosshatched region in Figure 6, 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), which satisfies the criterion that the plan must allow abundances in this range to increase to the viable level. 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 1700 (Figure 6). For escapements above that level, if harvest met the ER ceiling each year (which is not what is expected under this plan), escapements would tend to decrease in the next cycle; however, they would be expected to stabilize around an escapement of about 1700, 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 increase in productivity. This plan deals with abundances below the point of instability largely by trying to prevent abundance from getting that low. For Skagit springs, the trigger for reducing SUS impacts to the minimum regime occurs at a threshold of 576, which is over 5 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). 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 4 times higher than the calculated point of instability – escapements have exceeded 1,000 during each of the last 3 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).

For Skagit summer/fall Chinook, the rebuilding escapement threshold is approximately 8500 spawners; the low abundance threshold is 4800; and the calculated point of instability is approximately 1100. As with Skagit springs, in the range between the point of instability and the MSH escapement level, the ER ceiling is well within the region of increasing escapement (Figure 7), which satisfies the criterion that the plan must allow abundances in this range to increase to the viable level. For escapements greater than the calculated MSH level, the ER ceiling allows for increasing escapements up to an escapement of about 13,500 (Figure 7). If escapement was higher than that, and harvest met the ER ceiling each year (which, again, is not what is expected under this plan), escapements would be expected to stabilize around an escapement of about 13,500, which is well above the viable threshold. Thus, this plan also satisfies the criterion that, for escapements above the viable threshold, summer/fall abundance will, on average, be maintained in that region.

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 summer/fall 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 7).

As previously noted for Skagit spring Chinook, the combined impacts from northern fisheries and constrained SUS fisheries, that would be implemented if the summer / fall unit were to decline to critical status, would be expected to exert total exploitation rates well below the equilibrium rate, and assure higher subsequent escapement well below the equilibrium ER that applies to escapements between the LAT and the point of instability, so, on average, equilibrium pressures would force escapement to increase.

As with spring Chinook, it is not possible to project any relation between escapement and recruitment for escapements below the point of instability. To prevent summer/fall escapements from falling below this level, the trigger for reducing SUS impacts to the minimum regime occurs at a threshold of 4800, which is over 4 times higher than the calculated point of instability, and, at that threshold and exploitation rate, is well within the region of increasing escapement (Figure 7). The same equilibrium momentum would, on the next cycle, tend to increase escapements further, rather than reduce them, if escapement did drop below the point of instability and then experienced a fortuitous recruitment. In terms of actual observations, the lowest observed Skagit summer/fall Chinook escapement has been 4900 (in 1997 and 1999), which is over 4 times higher than the calculated point of instability, and escapement has exceeded 13,500 during each of the last 3 years, which is well above the calculated MSH escapement level. Thus, for Skagit summer/fall Chinook, this plan should not increase the genetic and demographic risk of extinction.

7.5 Recovery Goals

The Washington co-managers identified recovery goals for 16 Chinook populations, based on assessment of the potential productivity associated with recovered habitat conditions (Table 15). 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 the number of spawners that will provide maximum surplus production (i.e. MSH) under properly functioning habitat conditions, assuming recent marine survival rates. The upper boundary represents the equilibrium escapement under these conditions, (i.e. the number of adults surviving to spawn is equal to the parent brood-year escapement).

For most MUs, the upper management thresholds and recent escapements are substantially below the lower end of the recovery range (Table 15), reflecting their different points of reference with regard to habitat quality. Notable exceptions include the Upper Skagit summer, Cascade spring, and Suiattle spring populations, where recent escapement has exceeded the MSH escapement level set as the lower boundary of the recovery goals. These three examples notwithstanding, UMTs established in this plan represent MSH escapement under current habitat conditions, demonstrating that current conditions limit the potential for recovery for most populations.

Table 15. Escapement levels and recruitment rates for Puget Sound Chinook populations, at MSH and at equilibrium, under recovered habitat conditions.

	MSH		Equilibrium
Population	Escapement	Adult R/S	Escapement [1]
North Fork Nooksack	3,400	3.3	14,000
South Fork Nooksack	2,300	3.6	9,900
Upper Cascade Spring	290	3	1,160
Suiattle Spring	160	2.8	610
Upper Sauk Spring	750	3	3,030
Lower Skagit Fall	3,900	3	15,800
Upper Skagit Summer	5,380	3.8	26,000
Lower Sauk Summer	1,400	3	5,580
North Fork Stillaguamish	4,000	3.3	18,000
South Fork Stillaguamish	3,600	3.4	15,000
Snoqualmie	5,500	3.6	25,000
Skykomish	8,700	3.4	39,000
Puyallup	5,300	2.3	18,000
Nisqually	3,400	3	13,000
Mid Hood Canal	1,320	2.9	5,200
Dungeness	1,170	3	4,740

[1] Recruitment (returns per spawner) at equilibrium, by definition, equals 1.0.

With the exceptions noted above, the recovery goals are not of immediate relevance to current harvest management objectives. A subset, at least, of management units will have to recover for the ESU to be de-listed, but ESU recovery (i.e. that subset or alternative subsets of recovered units) has not been defined. The recovery goals, as stated by the co-managers, exceed the increase in abundance and productivity necessary for delisting.

7.6 Harvest Constraint Cannot Effect Recovery

Recovery (i.e., increase in abundance to levels well above the UMTs) for most populations cannot be accomplished solely by constraint of harvest. If harvest mortality is not excessive, and spawning escapement is not reduced to the point where depensatory mortality and other ecological factors become significant and threaten genetic integrity, harvest does not affect productivity. Productivity is primarily constrained by the quality and quantity of freshwater and estuarine environment that determines embryonic and juvenile survival, and oceanic conditions that 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 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, though stable, have not increased. 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.

Abundance (escapement) data for the North Fork Stillaguamish population is cited here as an example. Fingerlings released by the summer Chinook supplementation program are coded wire tagged, enabling accurate estimation of their contribution to escapement. Average total exploitation rates (i.e., FRAM validation estimates) for 2001-06 are 40% of the average for the preceding decade. SUS ERs fisheries over the last nine years have fallen 60% compared with the preceding decade (Table 13). The return of hatchery-origin Chinook exhibits an increasing trend over the last 15 years, while natural-origin returns exhibit a declining trend (Figure 8).

Harvest constraint has, for most populations, resulted in stable or increasing trends in escapement. For many populations this includes a large proportion of hatchery-origin adults. But the trend in NOR returns strongly suggests that recruitment will not increase substantially unless constraints limiting freshwater survival are alleviated. Spawner-recruit functions for the North Fork Stillaguamish population, under current and recovered habitat conditions, provide an example (Figure 9). Derived from EDT analysis of habitat capacity under current and recovered conditions, they demonstrate that natural production is now constrained to a ceiling (asymptote) far below that associated with recovery (‘properly functioning condition’ or ‘PFC+’).

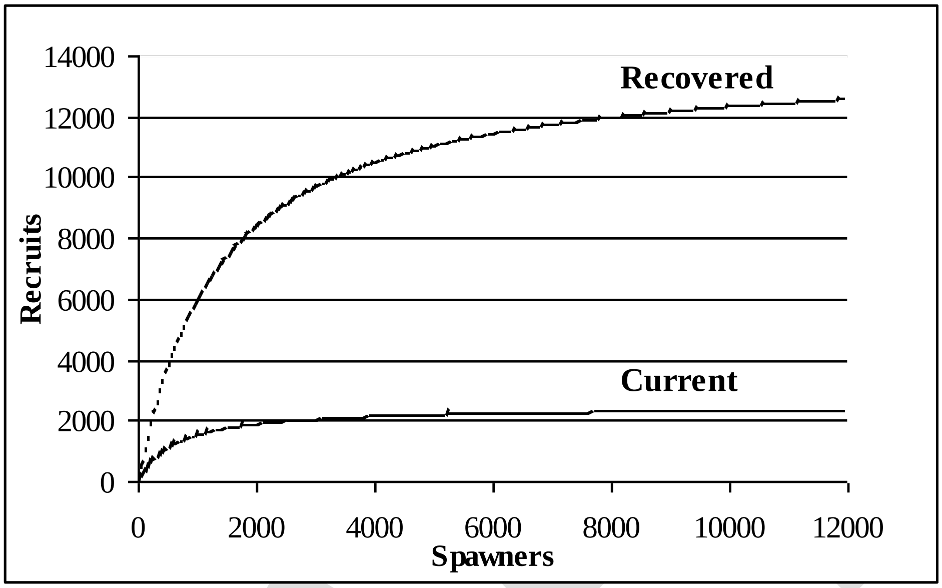

Figure 8. Natural and natural-origin spawner abundance in the North Fork Stillaguamish River.

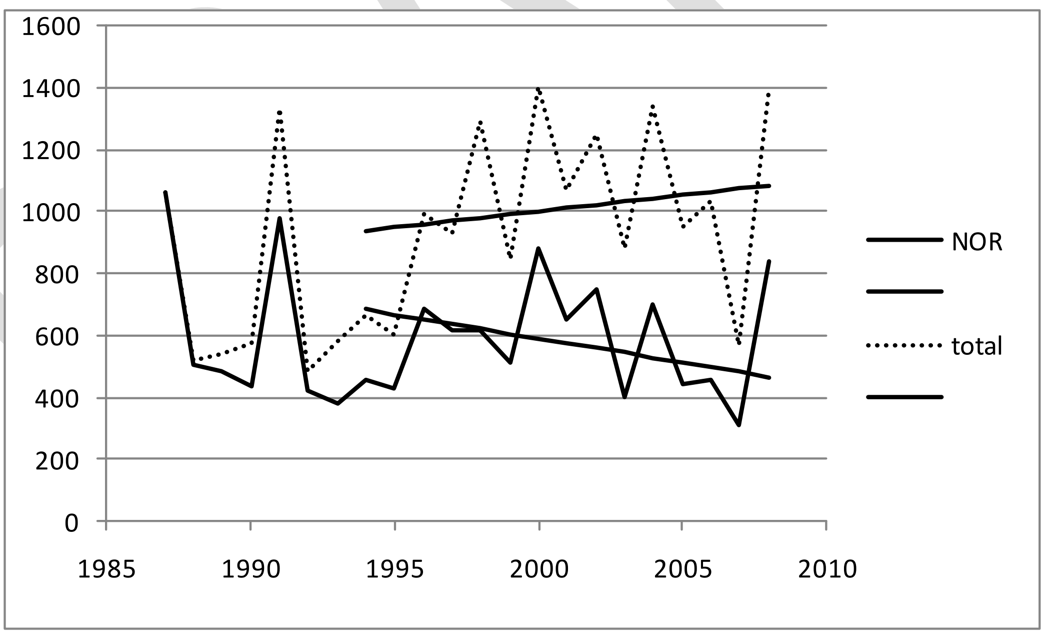

Figure 9. Productivity (adult recruits) of North Fork Stillaguamish summer Chinook under current and recovered habitat (PFC+) conditions. Beverton-Holt functions derived from habitat analysis using the EDT method.

The reduction of harvest pressure in SUS fisheries has helped to stabilize NOR escapement, and the listed hatchery recovery program will ensure persistence. Similar conclusions can be drawn from examination of current NOR escapement trends in the North Fork Nooksack, Skykomish, and Dungeness rivers. In these systems, NOR returns have remained at very low levels, while total natural escapement has increased where hatchery supplementation programs exist.

7.7 Protecting the Diversity of the ESU

The HMP protects all populations in the ESU. The Plan asserts that all extant populations are potentially valuable diversity elements of the ESU. It will allow some populations to reach their viable thresholds, hold others at stable abundance levels, well above their critical thresholds, and assure 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 core populations, essential to the integrity of the ESU

Management objectives for the Skagit, Stillaguamish, and Snohomish populations reflect low tolerance for risk of decline to critical status. 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 7.4) that applies to escapements between the LAT and the point of instability, so, on average, equilibrium pressure would force escapement to increase. The ER ceiling 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 not impeding rebuilding. Furthermore, annual target exploitation rates for these populations are expected to be 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, North and South Fork Stillaguamish, White, Green, Elwha, and Dungeness rivers. Non-indigenous populations persist, also supplemented by hatchery production, in the Puyallup, Nisqually, Skokomish, and Mid Hood Canal rivers.

The ecological and genetic risks associated with hatchery programs, as well as their benefits to ESU diversity and harvest opportunity, have been addressed and considered in the Puget Sound Chinook Hatchery Management Plan (2003). For most of these populations the benefits provided by hatcheries in maintaining higher levels of natural production and continued harvest opportunity may outweigh their ecological or genetic risks. Fishery constraints are expected to maintain the current status of most of these populations, well above their low abundance thresholds.

For the populations whose abundance has been at critical or near-critical levels in the recent past (i.e. in the North/Middle Fork and South Fork Nooksack, South Fork Stillaguamish, Mid Hood Canal, and Dungeness) harvest will continue to be constrained to reduce incidental harvest mortality. Hatchery recovery programs are operating in these systems to ensure persistence. Rebuilding of abundance for these populations will depend on alleviating habitat constraints.

The role of harvest management to enable recovery of the ESU is to ensure that spawning escapement is sufficient to optimize the productivity of populations, in the context of current habitat conditions. Harvest objectives and their implementation will compensate for the uncertainty in productivity and for management error. The constraints on harvest exerted by the HMP assure that the majority of any increase in abundance associated with favorable survival in the freshwater or the marine environment will accrue to escapement, in order to facilitate increased future production that benefits from the improved productivity conditions. Implementation of the HMP will, in general, allow 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 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 HMP provides a high degree of assurance that, for the next five years, the core indigenous populations in the Puget Sound ESU will continue to rebuild, and that all other populations will persist at, or above, their current abundance. A recovered ESU will necessarily include regional balance (i.e. geographic and diversity). The NMFS has not yet defined which of the extant populations are essential to a recovered ESU, so the qualifying language in the 4(d) rule, with respect to non-essential populations, does not provide a criterion for the adequacy of this plan. Clearly, systems where non-indigenous populations have been established through hatchery programs also comprise valuable elements of geographic and genetic diversity. But the ability of harvest management to preserve the existing diversity is limited. Despite the optimism created by the complex recovery planning effort now underway, the current diversity of the ESU may not persist unless habitat constraints are alleviated, thus allowing the natural productivity of Chinook population to increase.

7.8 Summary of Conservation Measures

1. Exploitation rates have been substantially reduced from past levels. 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 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 will assure meeting conservation needs of the least productive MUs will result in ERs below the ER ceilings for most 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. Exploitation rate objectives will be met for each MU, unless interceptions in Canadian and Alaskan fisheries increase to the extent that unacceptable further reductions in Washington fishing opportunity, on harvestable Chinook or other species, is necessary to achieve those objectives.

6. If annual abundance is forecast to result in escapement at or below the low abundance threshold, SUS fisheries exploitation rate will be further reduced to the CER ceiling. The low abundance thresholds are intentionally set at levels substantially higher than the actual point of biological instability, so that fisheries conservation measures are implemented to reduce the likelihood of abundance falling to that point.

7. High exploitation rates in the past may have selected against larger, older spawners, thereby changing the age composition or reducing the size of spawning Chinook. To the extent that this has occurred, the reduction in exploitation rates required under this plan will increase the proportion of larger, older spawners. The potential for size-, age-, and sex-selective effects of fisheries on spawning Chinook was reviewed in Appendix F of the 2004 Plan (PSIT and WDFW 2004).

8. The reduction in exploitation rates required under this plan will increase the number of Chinook carcasses on the spawning grounds. Any increase in productivity that results from this increase in carcasses will accelerate recovery beyond what was assumed when deriving the ceiling ER's (see Chapter 8).

9. Under all conditions of management unit status, whether critical or not, the co-managers maintain the prerogative to implement conservation measures that reduce fisheries-related mortality farther below any 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.

8. Monitoring and Assessment

The abundance (spawning escapement), hatchery- and natural-origin components of escapement, and age composition of Puget Sound Chinook populations will be monitored. This information is essential to assessing abundance trends and survival rates, and forecasting abundance for the purposes of harvest management. For some populations, smolt production will be estimated, to monitor freshwater survival. These data are also applicable to planning and monitoring the effectiveness of habitat restoration, and to hatchery management.

The performance of the fishery management regime will be evaluated annually, to assess whether management objectives were achieved, and identify the factors contributing to success or failure to achieve objectives.

8.1 Catch and Fishing Effort

Commercial, ceremonial, subsistence, and 'take-home' harvest in Washington catch areas 1 – 13, and associated subareas and freshwater areas, are recorded on sales receipts ('fish tickets'), and compiled in a jointly maintained database. Harvest of these types occurs primarily between May and October (with the exception of tribal winter troll harvest in the Strait of Juan de Fuca). Catch is monitored in-season for all fisheries, and a preliminary summary of catch and effort through October is available the following February.

The WDFW estimates recreational landed catch by analysis of a randomly selected subset of Catch Record Cards (CRC), which are required of all 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 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, Puget Sound areas 5 and 6, and certain freshwater Chinook fisheries including, in recent years, fisheries in the Skagit, Skykomish, Carbon, and Skokomish rivers. Creel sampling regimes have been developed to meet acceptable standards of variance for weekly catch.

Non-landed mortality of Chinook is significant for commercial troll, recreational hook-and-line fisheries, regulations for which may mandate release of sub-adult Chinook, or all Chinook, during certain periods. Studies are periodically undertaken to estimate encounter rates and hooking mortality for these fisheries. Findings from these studies are required to validate the encounter rates and release mortality rates used in fishery simulation models. Net fisheries also incur non-landed mortality, due to net-drop out. Chinook non-retention regulations govern certain non-Treaty seine fisheries; WDFW monitors Chinook encounters in these fisheries.

Sampling terminal-area fisheries to collect biological information about mature Chinook has been prioritized. Collection of scales, sex, and length data will characterize the age and size composition of the local population. Carcass and CWT sampling, and for some areas otolith analysis, will distinguish hatchery- and natural-origin fish.

8.2 Spawning Escapement

Chinook escapement is estimated annually for each population. A variety of sampling and computational methods are used to calculate escapement, including cumulative redd counts, peak counts of live adults, cumulative carcass counts, and integration under escapement curves drawn from a series of live fish or redd counts. General methods for estimating escapement were presented in the 2004 plan (PSIT and WDFW 2004). Updated description of methods used for Puget Sound systems will be included in annual performance reports (see below).

Escapement surveys and separate carcass sampling involve collection biological scales and morphometric data. Carcasses are examined for external marks (adipose or other fin clips), electronically scanned to detect coded-wire tags, or otoliths collected to determine hatchery origin.

8.3 Reconstructing Abundance and Estimating Exploitation Rates

Estimates of spawning escapement and its age composition, and of fishery exploitation rates enable reconstruction of cohort abundance. After adjustment to account for non-landed and natural mortality, these estimates of recruitment define the productivity of specific populations. The principal intent of the current Chinook harvest management regime is to set management unit objectives based on the current productivity of their component populations. These objectives will change over time, therefore, in response to change in productivity.

Indicator stocks, 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. These include Nooksack River early, Skagit River spring, Stillaguamish River summer, Green River fall, Nisqually River fall, Skokomish River fall, and Hoko River fall stocks. Additional indicator stocks are being developed for Skagit River summer and fall, and Snohomish summer stocks. To the extent possible, indicator stocks have the same genetic and life history characteristics as the wild stocks that they represent. Indicator stock programs are intended to release 200,000 tagged juveniles annually, so that tag recoveries will be sufficient for accurate estimation of harvest distribution and fishery exploitation rates.

Commercial and recreational catch in all marine fishing areas in Washington is sampled to recover coded-wire tagged Chinook. 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 / area stratum. These sampling objectives have been consistently achieved or exceeded in recent years (WFDW and PSIT 2008, WDFW and PSIT 2009)). Mass marking of hatchery-produced Chinook, by clipping the adipose fin, has necessitated electronic sampling of catch and escapement to detect coded-wire tags.

Coded-wire tag recovery data enables the calculation of total, age-specific fishing mortality in specific fisheries. These estimates of fishery mortality may be compared with those made by the fishery simulation model (FRAM) to check model accuracy. The FRAM may incorporate forecast or actual abundance and catch, which are scaled against base-year abundance and fisheries. It is recognized that the model cannot perfectly simulate the outcome of the coast-wide Chinook fishing regime, so, periodically, the bias in simulation modeling will be assessed. The migration routes of Chinook populations may vary annually, and the effect of changing fisheries regulations cannot be perfectly predicted in terms of landed or non-landed mortality.

Mark-selective fisheries, if implemented on a large scale, will exert significantly different landed and non-landed mortality rates on marked and unmarked Chinook populations. Accurate post-season assessment of age- and fishery-specific harvest mortality, through a gauntlet of non-selective and mark-selective fisheries, represents a daunting technical challenge, particularly due to the complex age structure of Chinook. 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 maintaining the objectives of the coast-wide CWT indicator stock programs. Analyses are in progress to assess if the accuracy of exploitation rates is significantly reduced.

8.4 Smolt Production and Survival

Smolt traps are operated in the Nooksack, Skagit, Stillaguamish, Skykomish, Snoqualmie, Puyallup, Nisqually, Skokomish, Dungeness, and Elwha rivers to estimate smolt production and survival. Methods and locations of smolt trapping studies are described in detail elsewhere (e.g. Seiler et al. 2002), but in general, traps are operated through the outmigration period of Chinook. By sampling a known proportion of the channel cross-section, with experimental determination of trapping efficiency, estimates of the total production of smolts are obtained. These estimates inform abundance forecasting, test the influence of environmental parameters on survival, and monitor the effectiveness of habitat restoration programs. Abundance forecasts may incorporate any indications of abnormal freshwater survival.

Survival of juvenile Chinook is highly dependent on conditions in the estuarine and near-shore marine zones. For many Puget Sound basins, degraded estuarine and near-shore marine habitat is believed to limit Chinook production. Studies are underway to describe estuarine and early marine life history, and to quantify survival through the critical transition period as smolts adapt to the marine environment.

8.5 Management Performance Assessment

The co-managers will assess the performance of Chinook fisheries management, in any annual report. Annual post-season review will enable remedial response in the pre-season planning process. A concise summary of previous year natural escapement and landed catch, compared to pre-season projections, will be available in March. . Escapement estimates from the previous fall, combined with terminal-area catch to estimate terminal runsize, are incorporated into abundance forecasts.. . The annual report will be completed in May, and include:

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

Tables will compare expected and observed catch for net and troll fisheries in coastal areas and Puget Sound, by region, for the preceding management year. Accompanying narrative will describe in-season management decisions, particularly those significant deviations from the pre-season schedule.

Recreational landed catch

Tables will compare projected and observed landed catch for the preceding management year, for areas where creel surveys have generated catch estimates. For the previous management year, tables will compare projected catch with preliminary CRC estimates. Analysis of some creel survey results will also require a one-year lag.

Non-landed mortality monitoring

Certain recreational (hook and line) and commercial troll fisheries operate under Chinook non-retention or other selective regulations. These fisheries are regularly or intermittently monitored to estimate encounters with unmarked or sub-legal Chinook, or compliance with regulations. Monitoring (interviews) occurs on board fishing vessels, at landing ports, or marinas and by remote observation (of some recreational fisheries). These studies and surveys are analyzed to validate assumptions that drive the FRAM projections of non-landed mortality. Analyses may be summarized or attached to the post-season report.

Spawning Escapement

Spawning escapement for all management units and populations will be compared to pre-season projections, and compared to UMTs and LATs established by this Plan. Each 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.

8.6 Retrospective Assessment

Harvest management performance will be periodically assessed by a retrospective analysis of accumulated data and information related to population abundance and productivity, harvest rates, sampling and monitoring objectives. Such an assessment will be completed so that it informs a subsequent revision of this Plan. These reports will include:

- Abundance and/or survival trend analysis for populations from time series of natural escapement or runsize, or smolt production.
- Recent harvest exploitation rates estimated by post-season FRAM runs, including a comparison with pre-season projections and relevant ER and CER ceilings.
- A discussion of significant and consistent deviations between pre-season projections and observed catch, escapement, or exploitation rates indicative of management error, and the likelihood of reducing such error by improving forecast methods or harvest modeling.
- A compilation of CWT sampling achievements, compared with sampling objectives.
- 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. Productivity re-assessment: updated recruitment functions derived from cohort reconstruction or other methods, applied to re-calibration of escapement thresholds and ER ceilings.
- Such re-assessment will occur, subject to data availability, and if there is evidence that survival has changed.
- Data gaps: The Plan and individual MU profiles in Appendix A inventory key data gaps that affect harvest management performance. The retrospective assessment will summarize gaps that have been addressed and update data requirements.

8.7 Marine-Derived Nutrients from Salmon

Adult salmon provide essential marine-derived nutrients to freshwater ecosystems, as a direct food source for juvenile or resident salmonids and invertebrates, and 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. 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.

Of relevance to harvest management is whether the management objectives stated in this Plan will result in spawning escapement levels likely to cause or exacerbate nutrient limitation, and thus negatively influence the growth and survival of juvenile Chinook, or otherwise constrain recovery of listed populations. Harvest management strategy will be informed by relevant information as it emerges, but currently available information does not suggest that nutrient limitation affects Puget Sound Chinook populations in this manner.

The role of adult Chinook must be examined in the context of escapement (i.e. nutrient potential) of all salmon species. In the large river systems that support Chinook, escapements of pink, coho, and chum salmon comprise a large majority of total nutrient input. Changing Chinook escapement, therefore, will not increase nutrient loading significantly

Natural escapements of Chinook, and of substantially more abundant pink and chum salmon, have varied widely without apparent correlation with survival of Chinook during their freshwater life history. Post-emergent survival of juvenile Chinook 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).

The fertilizing influence of salmon carcasses on Chinook depends on a complex array of factors, including their proximity to Chinook rearing areas, the influence of flow and channel structure on the length of time carcasses are retained, and Chinook life history.

The nutrient benefit of increased escapement affects, predominantly, smolt production from that brood year, especially for Chinook populations that outmigrate as sub-yearlings. Spawner – recruit analyses will reflect the potential effect of nutrient loading on productivity. Regular updating of the spawner – recruit function is mandated by this plan, and will detect changes in productivity that result from widely variable, and in some systems, increasing, nutrient loading associated with spawning escapement of all salmon.

Further study of the potential for nutrient limitation of Chinook growth and survival is warranted. Studies should be designed and implemented to test nutrient limitation hypotheses in several Chinook-bearing systems, and in smaller tributary systems that allow controlled experimental design. These studies should include monitoring secondary production of aquatic macroinvertebrates, fingerling condition, smolt abundance and survival to adulthood under controlled conditions to allows isolation of the effect of carcass nutrient loading. They will be difficult to design and implement, such that results are clear and unconfounded by the complexity of physical factors and trophic dynamics freshwater systems. Such studies may, ultimately, lead to quantifying nutrient loading thresholds where effects on Chinook growth and survival are evident, to guide harvest management.

Manipulating spawning escapement or supplementing nutrient loading with surplus hatchery returns will require resource management agencies to consider benefits and potential negative effects 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. Use of surplus carcasses from hatcheries also has serious potential implications for disease transmission. Public policy will, therefore, have to be carefully crafted to meet potentially conflicting mandates to protect water quality and restore salmon runs (Lackey 2003).

8.8 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 a certain extent related to the degree to which age at maturity and growth rate are genetically determined, subsequent generations may be composed of 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.. Available data suggest that the fecundity of mature Skagit River summer Chinook has not declined from 1973 to the present (Orrell 1976; Musselwhite and Kairis 2009). The age composition of Skagit summer / fall Chinook 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).

9. Amendment of the Harvest Management Plan

The Plan will continue to evolve. Management objectives will change in response to changes in the status and productivity of chinook populations. It is also likely that assessment tools will evolve to improve estimation of spawning escapement and cohort abundance, and additional data will become available to inform management objectives. As new information becomes available the co-managers will periodically reassess the Plan. The co-managers may change management objectives response to changes in the status and productivity of chinook populations. Estimates of spawning escapement, cohort abundance, and productivity will be updated as additional data becomes available, and assessed for potential relevance to adjusting management objectives. If the Plan is amended, changes will be submitted to NMFS for evaluation, well in advance of their implementation in preseason planning.

10. Glossary

Adult Equivalent (AEQ) - The adjustment of fishing mortality to account for the potential contribution of fish of a given age to the spawning escapement, in the absence of fishing. Because not all unharvested fish will survive to contribute to spawning escapement, a two-year-old Chinook has a lower probability of surviving to spawn, in the absence of fishing, than does a five-year-old.

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.

Critical Threshold - that level of abundance (i.e., spawning escapement) that incurs substantial risk of loss of genetic integrity, or exposes the population to depensatory mortality factors.

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, and comprise natural spawners or returns to a hatchery.

Exploitation Rate (ER) – The FRAM calculates the ER in a fishery or aggregate of fisheries as fishery mortality divided by the the sum of total fishing mortality plus escapement.

Extreme Terminal Fishery – A fishery in freshwater that is assumed to harvest fish from the local management unit.

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.

FRAM - The Fishery Regulation Assessment Model is a simulation model developed to estimate the impacts of Pacific Coast fisheries on Chinook and coho stocks.

Harvest Rate (HR) - Total fishing mortality for an area(s) and time period divided by the abundance in that area(s) at the start of the time period. Harvest can be stock or fishery specific.

Landed Catch – Harvested fish that are taken aboard vessels or shore and retained by fishers. [see also **Nonlanded Mortality**]

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. [see also **Management Unit**]

Management Unit - A stock or group of stocks that are aggregated for the purpose of achieving a management objective.

Maximum Sustainable Harvest (MSH) - The maximum number of fish of a management unit that can be harvested on a sustained basis, resulting in a spawning escapement level that optimizes productivity.

MSH Exploitation Rate – The maximum sustainable harvest (MSH) exploitation rate is the proportion of the stock abundance that could be harvested if long-term yield was to be maximized. The MSH exploitation rate is typically computed assuming stable stock productivity, although annual variability may occur.

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

Population – For the purposes of the Plan, equivalent to the stocks 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, quantified at some life stage (e.g. smolts or sub-adults) from a single parent brood year.

Run Size - The number of adult fish in an allocation unit, management unit, stock or any aggregation thereof that is subject to harvest in a given management year.

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) . This meaning differs from that used in some conservation literature, in which viability is associated with healthy, recovered population status (see McElhany et al. 2000).

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Appendix A: Management Unit Status Profiles

Nooksack River Management Unit Status Profile

Component Populations

North/Middle Fork Nooksack early Chinook

South Fork Nooksack early Chinook

Geographic description

The Nooksack River natural Chinook management unit is comprised of two early-returning, native Chinook populations that are genetically distinct, geographically separated, and exhibit slightly different migration and spawning timing from one another. They have been combined into a management unit because of their similar migration timing through the fishing areas in the Nooksack River, below the confluence with the South Fork, and Bellingham and Samish.

The North and Middle Forks drain high altitude, glacier-fed streams. Early-timed Chinook spawn in the North Fork and Middle Fork 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. Spawning also occurs in numerous tributaries including Deadhorse, Boyd, Glacier, Thompson, Cornell, Canyon, Boulder, Maple, Kendall, McDonald, Racehorse, and Canyon Lake creeks. The Middle Fork is a tributary to the North Fork. Spawning is currently concentrated in the North Fork, from RM 44 to RM 64, but may not represent the historical spawning distribution. The current distribution may be influenced by station and off-station release locations for Kendall hatchery origin North/Middle Fork Chinook.

The South Fork drains a lower-elevation watershed that is fed primarily by snowmelt and rainfall, but not by glaciers. Consequently, river discharges are relatively lower and temperatures relatively higher in the South Fork mainstem than the North and Middle forks during mid to late summer and early fall. The South Fork tributaries have temperature regimes more similar to those in the North and Middle Forks during the late summer and early fall. For both 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.

Early Chinook spawn in the South Fork from the confluence with the North Fork to the cascades at RM 30.8, and in Hutchinson, Skookum, Deer and Plumbago creeks. A partial passage barrier exists at Sylvesters Canyon at RM 25, and Chinook are not always recorded upstream of this barrier. In the South Fork spawning is currently concentrated between RM 8.5 and RM 25. Hutchinson Creek has had the majority of the tributary spawning in recent years, although discharge does not always permit use.

Life History Traits

Nooksack early Chinook are characterized by early entry into freshwater, a slow upstream migration, and lengthy holding period in the river prior to spawning (Barclay 1980, Barclay 1981). Early Chinook enter the lower Nooksack River from March through July, and on average migrate upstream over a 30 – 40 day period to holding areas. In the North / Middle Fork spawning occurs from mid-July through late September, peaking in the third week of August. South Fork spawning begins in August, and peak spawning occurs later than in the North / Middle Fork, in mid- to late-September.

Earlier analysis of scales collected from North Fork spawners showed that a large majority (91%) emigrated from freshwater at age-0 (WDFW 1995 cited in Myers et al.1998). In contrast, a larger and highly variable (as much as 69 percent) proportion of South Fork spawners emigrated as yearling smolts. A more thorough, fairly recent review by NMFS of the adult scale data collected from natural-origin spawners, for those years when at least 40 samples were analyzed, , determined that 29% and 38% of North/Middle and South Fork early Chinook, respectively, migrated from the river as yearlings. The number of naturally-produced fingerling and yearling smolts emigrating from the Nooksack system has not been quantified. These estimates are confounded by the complexity of contributing stocks.

Available information on the age composition of adults returning to the North/Middle forks and the South Fork (Table 1) indicates a predominance of age-4 returns. The North/Middle Fork age data were derived from natural origin adults sampled on the spawning grounds from 1993 through 2002. There is less confidence in South Fork population age structure. Low sample sizes, caused by difficulties in recovering carcasses on the spawning grounds, require caution in the interpretation of this data, particularly for the South Fork.

Table 1. Estimates of the age composition of returning adult natural origin early Chinook populations in the North / Middle Fork and South Fork of the Nooksack River.

	Age 2	Age 3	Age 4	Age 5	Age 6
North/Middle Fork NOR	<1%	19%	59%	22%	<1%
South Fork NOR	0%	12%	72%	16%	0%

Hatchery Recovery Programs

A recovery program for the North/Middle Fork 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 annually into the North Fork, or at various acclimation sites. The yearling release program was discontinued after the 1996 brood because returns showed that survival rates were lower than those of sub-yearling releases. In 2001, fingerling releases into the Middle Fork were started. Beginning in 1991 all release strategies in the North Middle Fork supplementation program were made identifiable by unique otolith marks in order to evaluate the success of the different release strategies.

The release strategy for the North/Middle Fork program was changed in 2001 to reduce the on-station release from Kendall Hatchery, which showed the highest stray rate into the South Fork. In 1998 approximately 900,000 fingerlings were released on-station, and afterwards a series of reductions took place to address straying concerns and habitat capacity. From 1999 through 2002, on-station releases ranged from about 630,000 to about 424,000; the on-station release goal was further reduced to 150,000 in 2003. That 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 to the North Fork or its tributaries) to 400,000 fingerlings in the North Fork (which constitute the double index tag program for this indicator stock), 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 total Kendall program release remains 750,000 sub-yearlings.

The North/Middle Fork Recovery program utilizes several release strategies from the Kendall Creek Hatchery. Otolith analysis enabled estimation of the contributions to the South Fork returns. While stray rates were low, they comprise a significant proportion of natural spawners in the South Fork. Beginning with the 2005 release, all Kendall origin Chinook have been adipose fin clipped except for 200,000 of the double index tag indicator stock release into the upper North Fork, to allow more accurate estimates of contributions to terminal area fisheries and spawning ground escapement.

A recovery program for the South Fork population operated at the Lummi Nation’s Skookum Creek Hatchery in brood years 1980 – 1993. The program was never large, and was discontinued because the returns to the hatchery ladder were low, and because capturing wild broodstock was not successful, and considered inappropriate at such low abundance. After the last returns from that program spawned, production of South Fork spring Chinook has been entirely wild.

A captive brood recovery program based at the Skookum Creek Hatchery in the South Fork was begun after microsatellite DNA analysis of recovered carcasses, using strengthened DNA baselines, allowed more accurate identification of natural origin spawners. The analysis of samples collected from the South Fork from 1999 to 2006 demonstrated that natural spawning involved the native South Fork stock, natural- and hatchery-origin strays from the North / Middle Fork population, and non-native fall Chinook. The South Fork Chinook population represented a much smaller proportion of the total early escapement to the South Fork than previously estimated.

Initial South Fork Chinook broodstock collection efforts targeted adults and included a temporary weir. These were largely unsuccessful, so the emphasis shifted to collecting juveniles. The natural-origin juveniles confirmed to be of native South Fork origin by DNA analysis are now the founding broodstock for the captive brood recovery program.

A small number of brood year 2006 juveniles and several hundred brood-year 2007 and 2008 juveniles are now being reared. Juvenile collections are anticipated to continue until there is good representation from of an entire brood cycle. An assessment of parentage for collections from BY2007 and BY 2008 shows that there is very good diversity being retaining in this effort.

The captive brood South Fork Chinook are being reared to adulthood in freshwater at Kendall Creek Hatchery and in salt water at the NMFS Manchester Research Station in Port Orchard. As these fish mature, they will be transferred back to Skookum Hatchery for spawning. Their offspring will be reared to sub-yearling stage at Skookum Hatchery, and released into the South Fork in late May. The ultimate objective is to release 200,000 fingerling smolts annually from Skookum Hatchery into the South Fork. Any additional smolts are likely to be released higher in the watershed in a strategy similar to that in the North/Middle Fork program to encourage more returning adults to utilize the existing spawning habitat. The first maturing adults from the captive brood program will likely mature in 2010.

The captive brood program is expected to end after the wild collections from a full brood cycle are reared to adulthood. Hatchery production will then transition to a conventional recovery program at Skookum Creek Hatchery, similar to WDFW's Kendall Hatchery program for North / Middle Fork Chinook. Over the next decade the South Fork population abundance is anticipated to increase dramatically, although production will be composite instead of entirely natural origin.

Population Status

The current status of the Nooksack early Chinook stocks is critical. Chronically low return of natural-origin Chinook to the North / Middle and South Forks are apparently due to poor freshwater survival. The SASSI review (WDF et al.1993 and WDFW 2002) and Nooksack recovery plan (WRIA 1 SRB 2005) reached the same conclusion. Table 2 shows the recent natural origin escapements to the two populations. Table 2 shows the recent natural origin escapements to the two populations. Estimates have been made on the basis of carcass CWTs and otolith marks in the North/Middle Fork populations available from 1995 and from DNA analyses in the South Fork available from 1999 on.

While still critically low, the number of natural origin North/Middle Fork population spawners has been gradually increasing. This may be partially attributable to the Kendall Creek Hatchery recovery program. Recruitment from higher combined hatchery origin and natural origin spawning escapement, comprised of a relatively large number of hatchery-origin spawners, has not increased substantially. This strongly suggests current habitat conditions and existing habitat capacity is constraining the population growth rate.

The Kendall Creek Hatchery program is considered essential to recovery of the North / Middle Fork population. In addition to the slowly increasing trend of natural-origin spawners, the proportion of natural origin fish on the spawning grounds relative to hatchery origin has also been increasing. This is likely due to the reduction in releases from the recovery program and to the slowly increasing natural origin abundances.

Table 2. Natural-origin escapement of North / Middle Forks and South Fork Chinook populations in the Nooksack River.

Year	North/Middle Fork	South Fork
1995	171	
1996	209	
1997	74	
1998	37	
1999	85	32
2000	160	111
2001	264	159
2002	224	135
2003	210	69
2004	314	29
2005	210	19
2006	275	61
2007	334	29
2008	307	83

South Fork population estimates (Table 2) represent the proportion of natural origin carcasses that were assigned to the South Fork population by microsatellite DNA analysis, applied to the estimated total natural origin early Chinook spawners. No clear trend is evident in the South Fork escapements from 1999 to 2008, although abundances are very low. These escapement estimates have appreciable uncertainty, for a number of reasons. There have been no adjustments in the estimates to account for years when flow conditions do not allow complete surveys, or for when suspended sediment reduces visibility and impedes identification of redds. Additionally, a low percentage of carcasses are sampled, particularly in the upper watershed where the proportion of South Fork native spawners is higher. These estimates of native South Fork abundance may be biased low. Genetic analysis of juveniles collected for broodstock indicates a significantly higher parental abundance than indicated by the escapement estimates for 2007 and 2008

Smolt releases from the South Fork recovery program are expected to begin in 2011, and increase rapidly over the next several years. Annual program releases may reach several hundred thousand Chinook sub-yearlings over the duration of this Plan. Consequently, adult return abundance is anticipated to increase appreciably over the next decade.

The early chinook spawning escapement in the North/Middle Forks is estimated from expanded carcass recoveries in the North Fork and tributaries. Each recovered carcass is expanded by 3.48. This relationship has been established between the carcass recoveries and total adults assuming 2.5 adults per redd during years when total redd counts were conducted when clear water allowed. In recent years the Middle Fork portion was estimated by counting total redds and expanding by 2.5 adults per redd.

The estimate of the early chinook spawning population in the South Fork (Table 3) has traditionally been based on the number of redds observed prior to the first of October expanded by 2.5 redds per spawner. Since 1999, this estimate has been further refined by separating hatchery origin strays (North / Middle Fork and summer fall Chinook) based on CWTs, otolith marks or adipose fin clips, and also by assigning the natural origin spawners to the South Fork, North / Middle Fork and summer fall Hatchery stocks. The latter step is based on the expansion of the microsatellite DNA stock assignment of carcasses collected through the first week of October to apply to the total estimated natural origin spawners.

Due to mixed stock composition, the total early Chinook estimates for the South Fork (Table 3) are significantly larger that the population escapement estimates derived by microsatellite DNA analysis (Table 4). The North/Middle Fork escapements clearly reflect the size of the Kendall releases. Release numbers increased appreciably in the late 1990's and were adjusted downward beginning in 2003. The peak escapement year was 2002, and the escapements have been stable at a lower level from 2006 through 2008.

Table 3. Total Spawners (hatchery- and natural-origin) in the North / Middle and South Forks of the Nooksack River through September 30, excluding hatchery turnbacks.

Year	North/Middle Fork	South Fork
1993	445	235
1994	45	118
1995	224	290
1996	537	203
1997	574	180
1998	370	157
1999	823	288
2000	1242	373
2001	2185	420
2002	3741	625
2003	2857	570
2004	1719	170
2005	2047	230
2006	1184	515
2007	1438	323
2008	1266	443

Table 4. Estimated stock composition of South Fork Chinook that spawned through Sept. 30.

	South Fk Native	North Fk NOR	Fall NOR	Kendall Cr Hatchery	Other Hatchery	Total Natural
1999	32	0	127	90	39	288
2000	111	42	132	74	15	373
2001	159	51	65	138	8	420
2002	135	55	98	289	47	625
2003	69	0	150	210	162	570
2004	29	29	88	14	12	170
2005	19	56	56	32	70	230
2006	61	104	192	84	90	515
2007	26	44	128	112	35	323
2008	80	106	126	109	23	443

Table 5 shows the annual escapement estimate for North / Middle Fork Chinook by origin. Recruits per natural spawner in the North / Middle Forks have consistently remained below one recruit per pair of spawners (Table 6), although a high percentage of the parentage are hatchery origin fish that are spawning naturally. A much lower percentage of spawners are natural-origin Chinook homing back to specific areas that successfully produced smolts. The lack of positive response in numbers of natural origin Chinook produced by the large parent year spawners from 2000 through 2005 strongly suggest habitat capacity limitations, and that harvest in the southern U.S. is not impeding the rebuilding of the abundance of natural origin spawners. The information for the South Fork population is not sufficient to draw any conclusion about its current productivity.

Table 5. Origin of Chinook spawners in the North/Middle Forks of the Nooksack River (Co-Manager unpublished data).

Return Year	Natural Origin	Cultured Origin	Total Escapement
1995	171	59	230
1996	209	326	535
1997	74	543	617
1998	37	333	370
1999	85	738	823
2000	160	1082	1242
2001	264	1921	2185
2002	224	3517	3741
2003	210	2647	2857
2004	314	1405	1719
2005	210	1837	2047
2006	275	909	1184
2007	334	1104	1438
2008	307	959	1266

Table 6. Natural origin return per natural spawner rates for early Chinook in the North/Middle Fork of the Nooksack River (Co-Manager unpublished data).

Brood year	Natural spawners	Total age 2 – 6 Returns	Return per Spawner
1992	493	184	0.37
1993	445	77	0.17
1994	45	25	0.55
1995	230	18	0.08
1996	535	248	0.46
1997	617	344	0.56
1998	370	120	0.32
1999	823	196	0.24
2000	1242	419	0.34
2001	2185	52	0.02
2002	3741	423	.11
2003	2857	147	.05

Habitat Status

The early Chinook populations have limited capacity under current conditions. The Ecosystem Diagnosis and Treatment (EDT) methodology has produced Habitat-based estimates of the productivity and abundance of the Nooksack early populations, under current, historical, and recovered (i.e. 'properly functioning' as identified by the NMFS in the FEMAT process) conditions habitat conditions.

The EDT results for the North/Middle Forks under current conditions estimate habitat capacity at 2,059 adults and a productivity of 1.6 adult recruits per spawner, without consideration of fisheries mortality. These results suggest higher productivity than the spawner –recruit relationship derived directly from natural origin escapements (Table 6), though most of the parent brood have been hatchery origin Chinook that spawned naturally. The EDT analysis indicates that productivity under recovered habitat conditions would be much greater (Figure 1).

A similar analysis of the current productivity in the South Fork (Figure 2) indicates adult capacity of 885 and a return of 1.1 recruits per spawner. Though data is not sufficient to estimate productivity under current conditions, the low level of returning adults of the South Fork population suggests that current productivity is significantly less than indicated by the EDT analysis. The status of the South Fork stock is more difficult to determine given uncertainty in recent abundances and the absence of a reliable return per spawner by age of return.

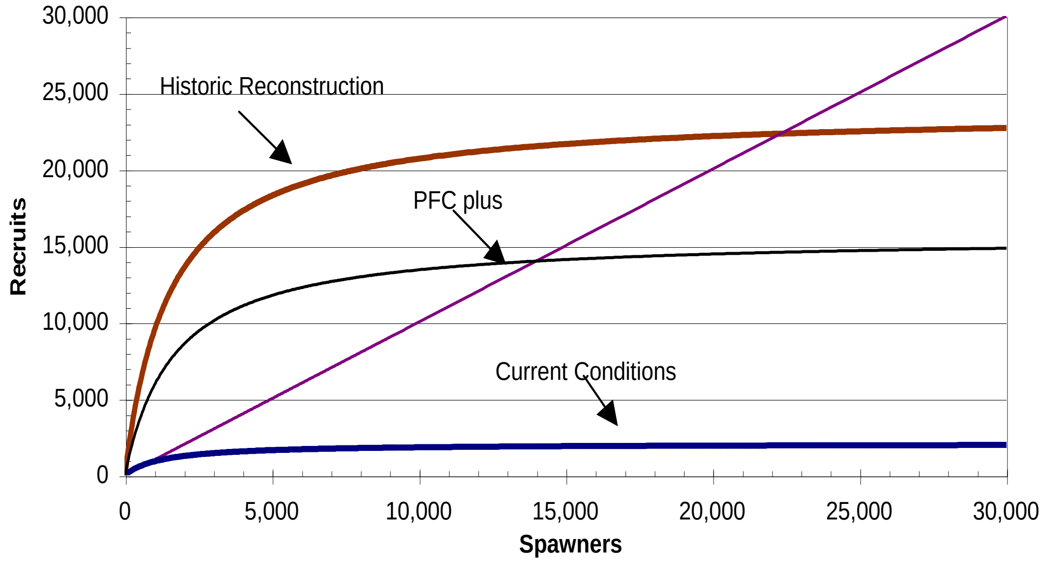


Figure 1. Spawner-recruit relationships under current, recovered, and historical habitat conditions in the North / Middle Fork of the Nooksack River, as estimated by EDT analysis.

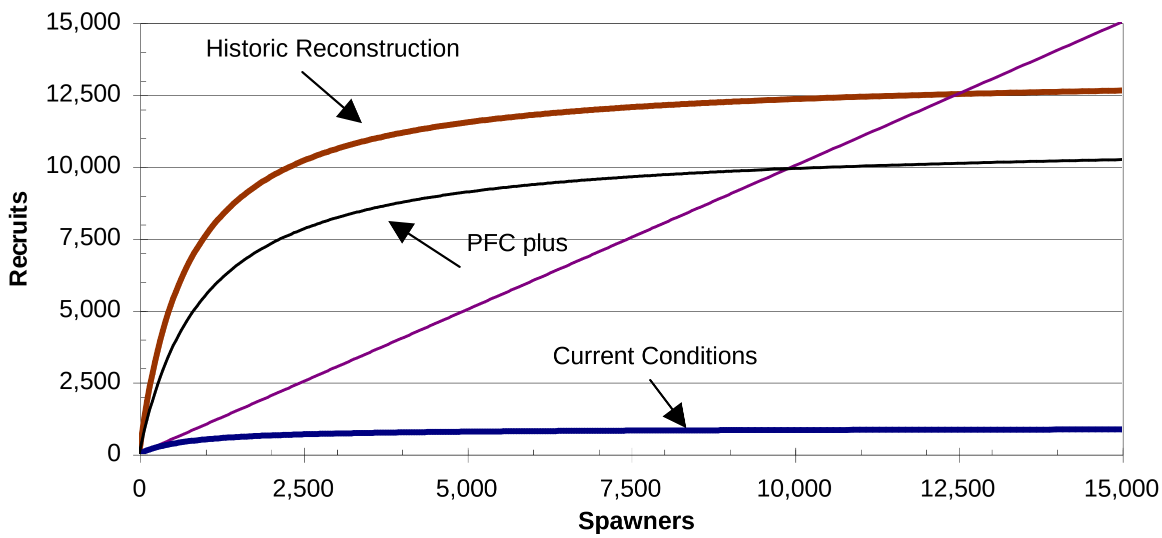


Figure 2. The spawner-recruit functions for South Fork Nooksack early Chinook under current, recovered, and historic habitat conditions, as estimated by the EDT method.

Current habitat conditions are degraded for both populations, but the specific factors most limiting population productivity and abundance differ between the North / Middle Forks, which are glacially influenced, and the South Fork which is not. The South Fork has lower discharge and higher temperatures than either the North or Middle Forks, and temperature impairments are acute in the South Fork. In 2007 a thermograph in the area of higher South Fork population spawning (river mile 20.7) recorded temperatures that exceeded water quality standards 92 days, or 94% of the days monitored (Coe and Cline 2009). Adult pre-spawn mortalities occasionally occur in the South Fork. Temperature, habitat diversity (reach habitat complexity and woody cover), and key habitat quality (including deep pools with cover and pool tailouts) are considered the most critical habitat deficiencies constraining abundance and productivity, and the sediment load of coarse and fine sediment are also important factors (WRIA 1 SRB 2005).

While the North and Middle Forks are glacially influenced, some tributaries also have temperature deficiencies that are limiting productivity and abundance (WRIA 1 SRB 2005). The habitat deficiency most affecting population abundance and productivity is channel stability. Channel migration and turnover in the North Fork are rapid, with some channels shifting multiple times each year, and only a few offering stable habitat for spawning, rearing, or flood refuge (Hyatt and Rabang 2003). The *Nooksack Chinook Spawning and Incubation Assessment* (Hyatt and Rabang 2003) found that redd failure rates in mainstems were nearly twice as high as in protected off-channel habitats, suggesting the loss of stable side channels is limiting North / Middle Chinook incubation and rearing survival. Figure 3 shows the natural origin recruits per brood year natural spawner (i.e. total escapement) regressed against the peak discharge event during the brood year incubation period. Scale analysis enables the age composition of non-otolith marked, natural-origin adults to be determined, and peak flow is derived at the USGS North Fork gage. While the relationship for the 1999- 2003 brood productivity is weaker than the relationship for the 1995-1998 broods, with fewer points, forty-three percent of the variability of survival to return is explained by the magnitude of the brood year incubation period high flow event. Clearly the combination of stochastic weather events and current habitat conditions are significantly affecting productivity of North / Middle Fork Chinook. The diversion dam blockage in the Middle Fork is also considered to be limiting population abundance (WRIA 1 SRB 2005).

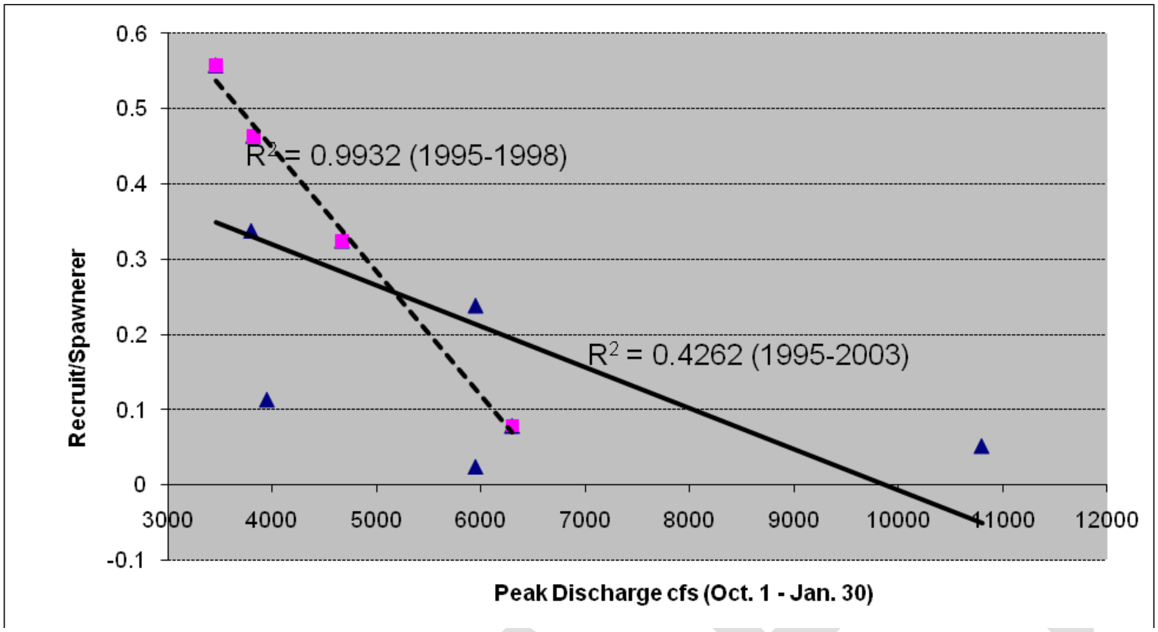


Figure 3. Natural origin recruits per natural spawner (ie total escapement) by brood year regressed against the peak discharge event during the brood year incubation period

Harvest distribution

Recoveries of coded-wire tagged North Fork early Chinook indicate that a majority of the historic harvest mortality occurs outside of Washington waters, primarily in British Columbia, with increasing rates along West Coast Vancouver Island, and lesser, but significant harvest in Georgia Strait and other net and recreational fisheries in British Columbia. Table 8 shows the recent relative harvest distributions for Nooksack early Chinook from 2001 through 2006 based on expanded coded wire tag recoveries of North / Middle Fork Chinook.

Table 8. 2001-2006 average distribution of fishery mortality, based on coded-wire tag recoveries of Kendall Creek Hatchery fingerlings. (CTC 2008).

	Alaska	B.C.	US troll	PS net	US sport
2001-2006	9.26%	80.35%	2.85%	2.22%	5.32%

Coded-wire tag recoveries indicate that in Washington waters, Nooksack early Chinook have been caught in the Strait of Juan de Fuca troll fishery, recreational fisheries in southern and northern Puget Sound, and net fisheries (primarily in Areas 7 and 7A, Bellingham Bay, and the Nooksack River) in northern Puget Sound. The Kendall Creek facility currently releases only fingerling early Chinook.

Exploitation rate trends

Table 9 shows two estimates of recent exploitation rates for Nooksack early Chinook. One is the FRAM post season validation model run, and the other is expansion of coded wire tags (CWT) from North / Middle Fork Chinook from the double index tag program at Kendall Creek Hatchery.

Table 9. Estimates of total exploitation rates for Nooksack early Chinook by calendar year (post-season FRAM validation estimates).

	Total	North	PT SUS	Term
2001	22%	17%	2%	2%
2002	19%	17%	2%	0%
2003	19%	16%	2%	2%
2004	20%	16%	2%	2%
2005	21%	17%	2%	2%
2006	20%	16%	2%	2%

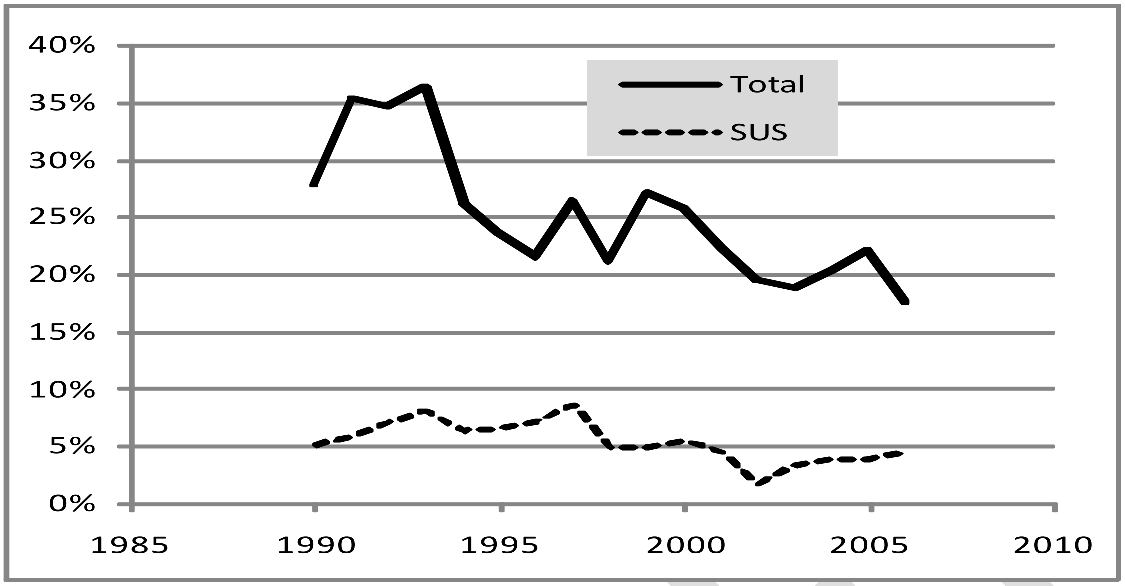


Figure 4. Total adult equivalent Exploitation rate of Nooksack early Chinook for management years 1990 – 2006, estimated by post-season FRAM runs.

Management Objectives

The management objective for Nooksack early Chinook is to minimize the impact on fishing related mortality under co-manager jurisdiction, while allowing for the exercise of treaty-reserved fishing rights and providing non-treaty fishing opportunity on harvestable salmon. Combined with the conservation actions adopted by the Pacific Salmon Commission to reduce the total Chinook fishing related mortality in northern U.S. and Canadian fisheries, this management objective is intended to ensure that harvest will not impede recovery of the North / Middle and South Fork populations, and to maintain supplementation production until the habitat capacity is restored to a level that will sustain viable populations.

The upper management threshold for each Nooksack early population is currently set at 2,000 natural origin spawners. The lower abundance threshold for each population is 1,000 natural origin spawners. For the foreseeable future the abundance of natural origin spawners of either of the Nooksack early Chinook populations is not expected to exceed the low abundance threshold. Under this circumstance, fisheries that impact the escapement of these populations will be shaped so the critical exploitation rate ceiling of 7% in southern US fisheries is not exceeded, except that once in five years the SUS ER ceiling may increase to 9%. These ceilings are not viewed as targets, but rather as ceilings when required to meet the minimum fisheries regime established by the tribes for full access to Ceremonial and Subsistence fisheries in the river, the international share of San Juan Islands and Point Roberts harvests, and the summer fall hatchery Chinook production in the terminal area.

With nearly 90% of the historic total harvest mortality occurring in Alaskan and Canadian fisheries (Table 8), further reduction fisheries impacts in Washington waters is limited. Net, troll, and recreational fisheries in Puget Sound are regulated to minimize incidental Chinook mortality while maintaining fishing opportunity on other species such as sockeye and summer/fall Chinook. The net fisheries directed at Fraser River sockeye, in catch areas 7 and 7A in late July and August, have resulted in very low impact on Nooksack early Chinook.

Conservation measures aimed at reducing spring Chinook harvest in the Strait of Juan de Fuca, northern Puget Sound and the Nooksack River have been in place since the late 1980's. There have been no directed commercial fisheries in Bellingham Bay and the Nooksack River since the late 1970's. Incidental harvest in fisheries directed at fall Chinook in Bellingham Bay and the lower Nooksack River was reduced in the late 1980's by severely reducing July fisheries. Since 1997, there have been very limited ceremonial and subsistence fisheries in the lower river in May and early July. Beginning in 2008, the July fishery was discontinued entirely, and a portion of the ceremonial and subsistence fishery was shifted to the lower North Fork as additional conservation measures to further limit the potential harvest of the South Fork early Chinook population. Commercial fisheries in Bellingham Bay that target fall Chinook have been delayed until August for tribal fishers, and mid-August for non-treaty fishers. Beginning in 1997, the release of summer/fall Chinook from the Kendall hatchery was moved down to the tidal portion of the river and then to the Maritime heritage center on the eastern shore of Bellingham Bay, and then eliminated entirely. The lower river release of summer was shifted into Bertrand Creek in 2007 to improve homing to non-early Chinook spawning areas, and in 2008 this Bertrand release was acclimated prior to release. All Nooksack Samish terminal area hatchery summer / fall Chinook releases have adipose fins removed and have a characteristic otolith mark to allow evaluation of release strategies on stray rates that might impede the recovery of the early chinook populations.

The limited ceremonial and subsistence harvest of Nooksack early Chinook in the Nooksack River is the highest priority in the tribal minimum fishing regime. This fishery will be limited to no more than 30 natural-origin spawners, and co-migrating cultured stock in excess of hatchery escapement requirements from mid March through Mid June, in the lower river and in the upriver area of the North Fork between the Highway 9 Bridge and the Mosquito Lake road bridge as determined during preseason modeling. The pattern of the fisheries is designed to avoid impact on the South Fork Population, identified by microsatellite DNA analysis only during the July ceremonial and subsistence fisheries in the lower river. 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 returns. Post season FRAM estimates of the exploitation rate associated with the ceremonial and subsistence have not exceeded 2% since 1995.

Fisheries in Bellingham Bay and the Nooksack River directed at fall Chinook will not open prior to August 1. Subsequent fishing in the Nooksack River occurs in progressively more upstream zones as early Chinook stocks clear these areas. Thus the area extending two miles downstream of the confluence of the North and South Forks will not open prior to September 16.

The co-managers are evaluating the productivity, abundance and diversity of the early Chinook runs that could be expected from the Nooksack watershed under properly functioning habitat conditions, as well as those that might have been expected to exist under historical conditions at Treaty time. The calculation of a normal exploitation rate has not be made but at the current escapement goal of

2000 natural origin spawners in each population, and an exploitation rate of 60%, a AEQ recruit abundance of 5,000 in each population would be anticipated.

An ambitious and long-term effort to restore and protect ecosystem functions required to sustain properly functioning chinook habitat, working in concert with appropriate hatchery production and harvest management regimes, is essential to recovery.

Data gaps

Many of the Data gaps outlined in the initial RMP remain because of the limited availability of resources. Following are the highest priority needs for technical information necessary to understand stock productivity and refine harvest management objectives:

1) Improve estimates of population specific total escapement to the Nooksack basin, with emphasis on North/Middle and South Fork populations, including estimates of natural-origin fish, and age composition for these fish.
    a) Secure resources to read backlog of otoliths collected at the Kendall Creek hatchery to provide a complete evaluation of the contribution of the different release strategies.
    b) The Microsatellite DNA stock baseline of spawning populations in the South Fork has been improved and analyses should be used to:
        i) Determination of the stock composition of the "early Chinook" in the South Fork.
        ii) The relative success of Chinook in the South Fork for each of the different spawning stocks as indicated by samples from the South Fork Smolt Trap.
        iii) The relative success of North Fork and South Fork natural production based on samples collected at the Hovander Smolt Trap.
    c) Develop alternative spawning ground population estimates that will allow:
        i) Evaluation of pre-spawning migration behavior through radio tags or DIDSON technology.
        ii) Improve estimates of the NOR age structure and stock composition (through increased recovery of carcasses on the spawning ground).
2) Investigate the effects of rearing conditions in the river, estuary and near shore areas to assist in the development of habitat restoration and protection actions.
3) Improve estimates of stock-specific, natural-origin early-timed smolt outmigration from the North/Middle and South Fork Chinook, and from late-timed Chinook.
4) Develop stock/recruit functions, or other estimates of freshwater survival data to monitor the productivity of the two early populations and late-timed Chinook.
5) Evaluate the success of the South Fork recovery program
6) Collect information to determine whether the current SUS fishing regime, or the hatchery supplementation program, are exerting deleterious selective effects on the size, sex, or age structure of spawners.
7) Improved estimates of the marine derived nutrients in the areas of importance to the productivity of Chinook in the Nooksack Basin.
8) Evaluation of acclimation and de-stressing release strategies in the North Fork Recovery Program.

9) Monitoring of ecosystem processes required to monitor changes in properly functioning Chinook habitat in the basin.
10) Re-establish the South Fork smolt trap.
11) Estimate the efficiency of the mainstem smolt trap in a manner that allows reasonable similarities between season-long and summed daily abundance estimates.
12) Investigate the sub-areas and duration of residence of Nooksack HORs and NORs in the estuarial and nearshore marine areas of Bellingham Bay and the Southern Straits of Georgia.

Skagit River Management Unit Status Profiles

Component Populations

Summer/fall Chinook management unit
- Lower Sauk River (summer)
- Upper Skagit River mainstem and tributaries (summer)
- Lower Skagit River mainstem and tributaries (fall)

Spring Chinook management unit
- Upper Sauk River
- Suiattle River
- Upper Cascade River

Geographic Description

There are two wild Chinook management units originating in the Skagit River system—summer/fall and spring Chinook. The co-managers (WDFW and WWIT 1994) identified three summer/fall and three spring timed populations. The Puget Sound Technical Review Team concurred with this delineation in their assessment historical population structure (Ruckelshaus et al. 2006).

Summer/fall Management Unit

The three populations tentatively identified within the summer/fall management unit are: Upper Skagit summers, Lower Sauk summers, and Lower Skagit falls. Upper Skagit summer Chinook 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 summer 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 mainstem fall stock spawns downstream of the mouth of the Sauk River and in the larger tributaries including Hansen, Alder, Grandy, Jackman, Jones, Nookachamps, O'Toole, Day, and Finney creeks.

Skagit summer/fall stocks are not currently supplemented to a significant extent by hatchery production. A Pacific Salmon Commission (PSC) indicator stock program collects summer broodstock (about 40 spawning pairs per year) from the upper river. Eggs and juveniles are reared at the Marblemount Hatchery. The objective of the program is to release 200,000 coded-wire tagged fingerlings for monitoring catch distribution and harvest exploitation rate. Summer Chinook fingerlings are acclimated in the County Line Ponds before they are released. Development of a lower river fall indicator stock program was initiated in 1999, with similar production objectives, and with releases occurring at the Baker River adult trapping facility. Production programs for fisheries enhancement of Skagit summer/fall Chinook, and plants of fall Chinook fingerlings into the Skagit system from the Samish Hatchery have been discontinued.

Spring Management Unit

The Skagit spring management unit includes stocks originating in the upper Sauk, the Suiattle, and upper Cascade rivers. The upper Sauk stock spawns in the mainstem to the forks, in the lower North Fork to the falls, and the South Fork to river mile 3.5., Included in this population are fish spawning in the Whitechuck River, and tributaries Camp, Pugh and Owl Creeks . The Suiattle stock spawns in several tributaries including Buck, Downey, Sulphur, Tenas, Lime, Circle, Straight, Milk and Big creeks. The Cascade spring 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 summer Chinook which use the lower 5 miles of the Cascade River. Spring Chinook originating from Suiattle River broodstock are released from Marblemount Hatchery. Annual releases averaged 112,000 yearlings for the period 1982–1991 (WDF *et al.* 1993). Since then, about 250,000 subyearlings have also been released each year. All spring Chinook releases are coded-wire tagged.

Life History Traits

The upper Skagit summer and lower Sauk River summer stocks spawn from early September through October. 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 mainstem, and reduced the impacts of high flood flows by storing runoff from the upper basin. The lower river fall stock enters the river and spawns later than the summer stocks; spawning peaks in mid October. Age of spawning is primarily 4 years, with significant Age-3 and Age-5 fish. Most summer/fall Chinook smolts emigrate from the river as subyearlings, 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 Chinook begin entering freshwater in April and spawn from late July through late September. Adult spring Chinook 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). Glacial turbidity from the Suiattle River and Whitechuck River limit egg survival in the lower Sauk River. Analysis of scales collected from adults on the spawning grounds indicates that the proportion of spawners that outmigrated as yearlings ranged from 20% to 85% in the Suiattle, 35% to 45% in the Upper Sauk, and 10% to 90% in the Upper Cascade system.

Status

Natural escapement for all three Skagit summer/fall Chinook populations has shown an increasing trend over the last 17 years (Table 1), and has greatly exceeded the low abundance threshold of 4,800 in every year since 1999. The geometric mean of the last five years' summer/fall escapement (2004–2008) was 16,865, an increase from previous 5-year geometric means of 7,804 (1994–1998) and 11,711 (1999–2003). Recent assessment of freshwater productivity for summer/fall Chinook suggests that long-term harvest would be maximized by using a preseason target of 14,500 as the Upper Management Threshold (*see Table 3 below*). Note that, due to variability and biases in management error, this Upper Management Threshold is higher than the calculated MSY escapement level (see Appendix XX).

Table 1. Spawning escapement of Skagit River Chinook, 1992-2008.

Year	Suiattle spring	Upper Sauk spring	Cascade spring	Total spring	Lower Sauk summer	Upper Skagit summer	Lower Skagit fall	Total summer/ fall
1992	201	580	205	986	469	5,548	1,331	7,348
1993	291	323	168	782	205	4,654	942	5,801
1994	167	130	173	470	112	4,565	884	5,561
1995	440	190	225	855	278	5,948	666	6,892
1996	435	408	208	1,051	1,103	7,989	1,521	10,613
1997	428	305	308	1,041	295	4,168	409	4,872
1998	473	290	323	1,086	460	11,761	2,388	14,609
1999	208	180	83	471	295	3,586	1,043	4,924
2000	360	388	273	1,021	576	13,092	3,262	16,930
2001	688	543	625	1,856	1,103	10,084	2,606	13,793
2002	265	460	340	1,065	910	13,815	4,866	19,591
2003	353	193	298	844	1,493	7,123	1,161	9,777
2004	495	700	380	1,575	443	20,040	3,070	23,553
2005	518	308	420	1,246	875	16,608	3,320	20,803
2006	375	1,043	478	1,896	1,095	16,215	3,508	20,818
2007	108	282	223	613	383	9,855	1,053	11,291
2008	203	983	284	1582	538	8,441	2,685	11,845

Spawning escapement for the spring Chinook unit has been consistently below 2,000, but has, been above the low abundance threshold of 576 every year since 1999. The geometric mean of escapement in 2004–2008 was 1,293, an increase from previous 5-year geometric means of 963 (1994–1998) and 957 (1999–2003).

Harvest Distribution

Coded-wire tag recovery data for PSC indicator stocks provide a description of the harvest distribution of Skagit Chinook, and contrast the differences between summer/fall and spring timed stocks. Yearling and fingerling releases from Marblemount Hatchery describe the distribution of spring Chinook. In the past, Samish hatchery fall fingerling releases were considered to be an accurate surrogate for the distribution of Skagit summer/fall Chinook. Local summer and fall indicator stocks are being developed for the Skagit using tagged releases of offspring from indigenous broodstock at the Marblemount Hatchery. Several years of data are now available for the summer indicator stock. For the period 2000–2005, approximately 88% of the mortality of summer Chinook has occurred in fisheries in British Columbia and Alaska (*i.e.* outside the jurisdiction of the Washington co-managers). Washington troll, net, and sport fisheries combined accounted for 12% of total summer Chinook fishing mortality (Table 2). The harvest distribution of yearling and fingerling spring Chinook differ, with about 62 and 81% of mortality occurring in northern fisheries, respectively. Puget Sound net fisheries account for 2% of fishery mortalities. Washington recreational fisheries account for 33% of yearling mortality, and 15% of fingerling mortality.

Table 2. Average distribution of fishery mortality for Skagit River Chinook for 2000–2006, expressed as percent fishery mortality (CTC 2008).

	Alaska %	Canada %	US Troll %	US Net %	US Sport %
Summer/Fall	6.2%	69.4%	2.0%	2.3%	20.2%
Spring fingerlings	6.3%	72.4%	2.0%	2.8%	16.6%
Spring yearlings	1.1%	58.3%	1.4%	2.7%	36.5%

Exploitation Rate Trend:

Annual (management year) exploitation rates for Skagit summer/falls, as estimated by post-season FRAM runs, have fallen drastically, from levels averaging nearly 70% 1983–1987, to an average of 44% from 2000-2006. Over the same period, exploitation rates for spring Chinook have decreased an even large amount, from similar historical levels to an average of 25% since 2000 (Figure 1).

According to the most recent FRAM validation runs, total exploitation rates for Skagit spring and summer/fall Chinook were below unit ERC's (38% and 50 % respectively) every year under the previous plan.

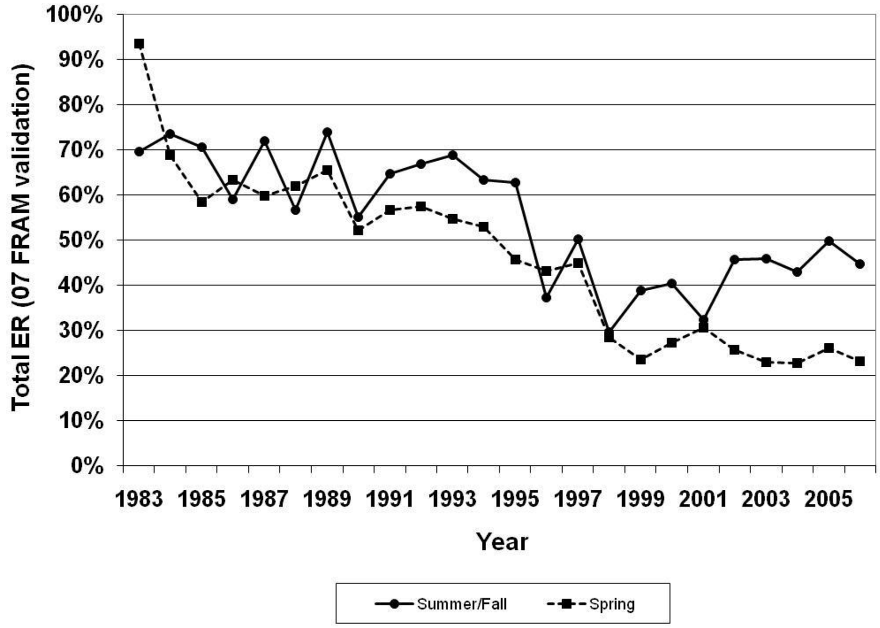


Figure 1. Total AEQ fisheries exploitation rate of Skagit summer/fall and spring Chinook, estimated from post-season FRAM runs for management years 1983–2006.

Management Objectives

Harvest management objectives in effect under the 2004 plan appear to have been successful, as positive trends in escapement have occurred for spring and summer units. In addition, recent analyses of the ERCs, which used recruitments generated from FRAM validation runs, indicated that the ERCs used in the 2004–2009 plan continue to satisfy jeopardy standards under the latest FRAM calibration (see following section, *Calculating Rebuilding Exploitation Rates (RERs) for Skagit Chinook Using FRAM Validation Run Recruitments*). Thus, the objectives from the previous plan, summarized in the table below (Table 3), will remain in effect for the duration of this plan. Details on the original derivation of these objectives are available in the Skagit management unit profile from the previous plan.

The co-managers have proposed to the Joint Chinook Technical Committee of the Pacific Salmon Commission (the CTC) that the Upper Management Thresholds and the ERCs in this plan be used to determine whether PSC management objectives have been achieved, pursuant to Paragraph 13 of the 2009-2018 PST Chinook Annex. If, however, the PSC adopts management objectives that are different from those in this plan, then, because adoption of PSC management objectives requires agreement of the federal government and NMFS' representatives on the CTC, as well as the State and Tribal co-managers, those PSC-adopted objectives will replace the UMTs and/or ERCs in this plan for purposes of evaluating whether this plan's escapement objectives have been achieved. In such a case, the UMTs and ERCs listed in this plan will still be the management objectives used preseason to set fisheries levels, but if the PSC-adopted management objectives are achieved post-season, whether the UMTs and ERCs listed in this plan were achieved or not, that will be deemed to be successful achievement of the escapement objectives in this plan.

Table 3. Harvest management objectives for Skagit River Chinook.

Management Unit	ERC	CERC	Upper Management Threshold	Low Abundance Threshold
Skagit Summer/Fall	50%	15% SUS even years; 17% SUS odd years	14,500	4,800
Upper Skagit Summer				2,200
Sauk summer				400
Lower Skagit Fall				900
Skagit Spring	38%	18% SUS	2,000	576
Upper Sauk				130
Cascade				170
Suiattle				170

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:

- Consistent release of coded-wire tagged fingerling summer and fall Chinook to enable direct assessment of harvest distribution, and estimation of harvest exploitation rates and marine survival rates.
- Update summer/fall Chinook productivity estimates once there are CWT indicator data available from a sufficient number of broods.
- Estimates of natural-origin smolt abundance from spring Chinook production areas.
- Estimates of estuarine and early-marine survival for fingerling and yearling smolts.
- Limiting factors on yearling Chinook abundance.

Calculating Rebuilding Exploitation Rates (RERs) for Skagit Chinook Using FRAM Validation Run Recruitments

by R. A. Hayman, Skagit River System Cooperative

I. INTRODUCTION

The exploitation rate ceilings (Rebuilding Exploitation Rates, or RERs) used to manage Skagit spring and summer/fall Chinook were initially calculated by deriving spawner-recruit parameters for each management unit, simulating recruitment, harvest, and escapement under variable conditions over a period of years, and varying the target exploitation rate until arriving at a target rate (the RER) that achieved Endangered Species Act (ESA) jeopardy standards (Hayman 1999; Hayman 2000; PSIT and WDFW 2004). Then, in any given year, in order to evaluate whether a particular fishing regime satisfied these RER ceilings, managers used the Chinook Fisheries Regulation Analysis Model (FRAM) to estimate projected impacts. FRAM originally expressed its exploitation rates as an index relative to a base period, but, to reduce confusion, these indexes were subsequently converted to absolute exploitation rates. It is these absolute exploitation rate numbers that are compared to the RERs, to evaluate whether a fishing regime does not exceed the RERs.

However, because of different assumptions about base-year escapement and recruitment of tagged Chinook, the base year exploitation rate numbers calculated in FRAM have not been the same as those that were used to calculate the RERs. In addition, each time FRAM was recalibrated, which was done when new stocks or fisheries (or data) were inserted into the model, the base year exploitation rate numbers changed slightly, which also changed the relation between the RERs and the exploitation rates calculated in FRAM. Thus, when the RERs were first calculated, and again each time FRAM has been recalibrated, it has been necessary to recalculate the RERs in FRAM-equivalent absolute numbers. This has sometimes been a controversial task.

In 2002, 2005, and 2007, FRAM was recalibrated, and validation runs were done. Validation runs are post-season runs that are intended to capture the fisheries, recruitments, and escapements *that actually occurred* each year (*preseason* FRAM runs represent only the fisheries, recruitments, and escapements that are *predicted*.). Since these are post-season runs, this means that the recruitments that are modeled are, in FRAM terms, estimates of the recruitments that actually occurred each year. If we could convert these fishing year recruitments to brood year recruitments, then we could do a spawner-recruit analysis *in terms of FRAM recruitment numbers* to derive spawner-recruit parameters, and use those parameters to recalculate the RERs. Because the spawner and recruit numbers used in these simulations would be derived from FRAM, the RERs that are derived from this analysis would be directly in FRAM terms, and would not need any readjustment. It is the purpose of this paper to generate the brood year recruitments of Skagit spring and summer/fall Chinook from the 2007 FRAM validation runs[1], calculate spawner-recruit parameters for each unit, and estimate the RER for each unit in FRAM-derived terms.

II. METHODS

Calculation of Brood Year Recruitments

The 2007 FRAM validation runs covered fishing years 1983-2006, a period of 24 years. Since FRAM models Chinook ages 2 through 5, this meant that recruitments could be calculated for brood years 1981 through 2001, or 21 brood years.

To generate the brood year recruitments, I ran FRAM validation runs for each fishing year, and output two reports from each run: the Population Statistics Report, which lists the FRAM-generated escapement[2] for each age, and the Mortality By Age Report, which lists the Adult Equivalent[3] (AEQ) total mortality by age, time step[4] (TS), and fishery. I then summed the age-specific AEQ mortality + escapement for each fishing year, to get the AEQ recruitment by age. The sum of the age-specific AEQ recruitments for each cohort was the brood year recruitment for that cohort.

For summer/fall Chinook, FRAM has both a fingerling and yearling stock, so both of those had to be summed for each brood year. Skagit Spring Chinook are represented only by a yearling stock. In order to subtract out the hatchery components of each management unit (the 1983-2002 FRAM runs do not explicitly break out hatchery fish by age), I multiplied the wild percent by age values from Hayman (2008), by the age-specific recruitment of each stock. The methods used to calculate the wild percent by age are described in Hayman (2007).

The resulting wild recruitments *could* be used for the spawner-recruit analysis, except that there is a problem – the FRAM validation runs were intended to mimic post-season observations as closely as possible, but they did not *eliminate* all differences. FRAM has a module, the Terminal Area Management Module (TAMM), that computes spawning escapements from the terminal harvest rates *that were actually used* (as opposed to the base period harvest rates, which is what

[1] Due to errors in the first sets of 2007 FRAM validation runs, they were re-run. The validation runs that were used for this analysis were those run on July 21, 2008.

[2] The FRAM-generated escapement is not the same as the observed escapement, because FRAM assumes a base period harvest rate in the terminal area. However, to calculate recruitment, which is catch + escapement, it doesn't matter whether the fish are counted as catch or escapement, as long as they are counted in one of those categories.

[3] The AEQ mortality is the calculated number of fish killed by a fishery, that would have survived to spawn if there had been no fisheries. The exploitation rate is calculated as AEQ mortality/AEQ recruitment.

[4] The FRAM time steps are: TS1 = Oct-April; TS2 = May-June; TS3 = July-Sept; TS4 = the next Oct-April. The total mortality for a given cohort in one year is the sum of mortalities that occur in TS2, TS3, and the next age's TS4 (because FRAM ages fish one year right after TS3).

FRAM uses for the Population Statistics Report), so the estimated escapements in TAMM should have been *close* to what was observed. However, they were *not the same*, and, for summer/falls, differed by as much as 2400 from the observed escapement. Thus, if we used the recruitments calculated by adding FRAM catch + escapement, and the *observed* spawning escapements to estimate exploitation rates, we got rates that were different from those estimated by FRAM. This left us with a question: which did we trust more – FRAM's estimates of recruitment, or FRAM's estimates of exploitation rates?

Since Chinook FRAM was originally designed to estimate exploitation rates, and since exploitation rates of hatchery indicator stocks can usually be estimated more accurately than escapements of wild stocks, I tended to side with the exploitation rate estimates. So I calculated an alternate set of recruitments that used the FRAM-generated *exploitation rates* (actually the complement of the exploitation rates), divided into the observed escapements, to estimate recruitment. To generate these recruitments, I calculated the percent age composition by year of the escapements listed in the Population Statistics Report, for each management unit, and multiplied those percentages by the *observed* escapement[5] that fishing year. This gave me the escapement-by-age of the observed escapement, assuming FRAM's age composition. For each cohort, I then summed the age-specific escapements *that resulted from* each brood year (e.g., for the 1981 brood year, I added together the 1983 age 2's, the 1984 age 3's, the 1985 age 4's, and the 1986 age 5's) to get the total escapement <u>that resulted from</u> each brood year.

I did a similar exercise to calculate the brood year exploitation rates: first, I took the same percent age composition of the escapements from the Population Statistics Report, and multiplied those percentages, by the *TAMM* escapement (not the observed escapement) that fishing year. This gave me the escapement-by-age of the TAMM escapement, and for each cohort, I then summed the age-specific escapements *that resulted from* each brood year, as described in the paragraph above, to get the total TAMM escapement that resulted from each brood year. For each brood year, I divided the TAMM escapement that resulted from that brood year by the brood year recruitment calculated by adding the FRAM catch + escapement, and the complement of that percentage was the brood year exploitation rate, as calculated by FRAM.

So I then had estimates of the *observed* escapement *that resulted from* each brood year (two paragraphs above), and brood year exploitation rates (one paragraph above). I divided the observed escapement that resulted from each brood year by the complement of that brood year's exploitation rate, and, voila! – I had an alternate estimate of brood year recruitment, which assumed that the FRAM-generated *exploitation rates* were accurate.

As it turned out, for summer/falls, the spawner-recruit parameters generated by assuming the FRAM recruitments were more accurate were almost the same as the parameters generated by

[5] Because the escapement estimation method for Skagit springs changed in 1992, there is concern about whether the estimates before 1992 are comparable to estimates made after the change. In this analysis, I ignored that concern.

assuming the FRAM exploitation rates were more accurate. So, much ado about nothing. For springs, however, there was more difference.

Estimation of Spawner-Recruit Parameters

Having calculated the spawners and recruits for each brood year, I then estimated the spawner-recruit parameters for a Ricker curve and for a Beverton-Holt curve. The equation that I used for the Ricker curve is:

$$R = S*\alpha*EXP(-\beta*S) + \varepsilon$$

where R is recruitment, S is the number of spawners, α and β are constants, EXP means to raise the base of the natural logarithm function to the power of the following argument, and ε is a random error term with mean of 0 and standard deviation of the prediction standard error at S (i.e., error is distributed symmetrically around the curve). The equation that I used for the Beverton-Holt curve is:

$$R = a*S/((a/b) + S) + \varepsilon$$

where a is the recruitment when S equals ∞, and b is the slope at the origin.

For each equation, I used Excel's Solver function to derive the parameter estimates that minimized the sum of squares of the residuals from the spawner-recruit curves. To calculate the standard errors of the parameters, I ran a regression of ln(R/S) against S, derived the coefficients of variation (C.V.) for each parameter, and multiplied the C.V. by the parameter estimate. That may not be the correct way to do it, but I didn't know how else to calculate the standard errors of separate parameters in a non-linear equation.

As we did in the previous RER analysis (PSIT and WDFW 2004), I made two further adjustments to the spawner-recruit curves, to try to account for depensatory recruitment at low escapement levels. The first adjustment was to establish a point of depensation (hereafter abbreviated "E_{crit}"), below which the average recruit/spawner value was 1.0 (i.e., for all escapements less than the point of depensation, recruitment averaged replacement only). This escapement value was calculated as 5% of the carrying capacity estimated from the spawner-recruit curve (Peterman 1977). The second adjustment was that for escapements less than all previously-observed values, but greater than E_{crit}, the average recruits/spawner value was equal to the recruits/spawner value at that lowest observed escapement (hereafter abbreviated "$E_{LowObsEsc}$"). I did this because, not having observed any escapements lower than the lowest observed level, it is unknown whether productivity increases at lower escapement levels, as theorized by both the Ricker and Beverton-Holt curves. This second adjustment also reduced the degree of knife-edge increase in escapement that occurs when escapement is one fish greater than E_{crit}.

Calculation of the RERs

The RERs are intended to achieve a recovery escapement level a high percentage of the time (see below). The recovery escapement is defined as follows:

Recovery Escapement (E_{recov}): The Puget Sound Chinook Technical Review Team (TRT), under policy direction from NMFS, defined the recovery escapement level (they called it the "viable" level) as the initial escapement from which, under current conditions, the probability that the run would go extinct at the end of 100 years is 5% (Ruckelshaus *et al.* 2002). I.e., the initial escapement for which

$$P(N_{100} < x_e) = 5\%$$

where P is probability, N_{100} is the number of fish in the escapement after the 100^{th} year, and x_e is an extinction level (I used 100 fish; 10 fish or 1 fish could also be considered an extinction level). Note that the recovery escapement varies with the assumed current exploitation rate.

The RER is defined as the maximum exploitation rate that would meet ESA jeopardy standards (i.e., not significantly impede progress to recovery) if it achieves the following:

1. The percentage of escapements less than the critical escapement (E_{crit}) increases by less than 5 percentage points relative to the baseline. Mathematically:

$$(\%E < E_{crit}) < ([\%E_{\text{under baseline}} < E_{crit}] + 5\%);$$

where %E is the percentage of escapements;

and either:

2a. Escapements at the end of 25 years exceed the recovery level at least 80% of the time. Mathematically:

$$(\%E_{25} > E_{recov}) \geq 80\%$$

where $\%E_{25}$ is the percentage of escapements after 25 years, and E_{recov} is the recovery escapement level.

Or:

2b. The percentage of escapements less than the recovery level at the end of 25 years differs from the baseline by less than 10 percentage points. Mathematically:

$$(\%E_{25} < E_{recov}) < ([\%E_{25\ under\ baseline} < E_{recov}] + 10\%)$$

I calculated the RERs by using methods described in Hayman (1999), Hayman (2000), and PSIT and WDFW (2004). In summary, I used a program that simulated recruitment, catches, and escapement of Skagit Chinook over a selected period of years. The simulations incorporated uncertainty, management error, and environmental variation. Stock-specific inputs to this model were the spawner-recruit parameters (with variability values for those parameter estimates), age composition values in the terminal area, and the distribution of management error (i.e., the percent difference between management targets and the harvest rates actually applied). The basic structure of the simulation consisted of starting with a brood escapement, generating a recruitment value, applying a *brood year* exploitation rate to that recruitment, breaking the resulting brood year escapement out by age, calculating the fishing year escapement, and repeating the process for the next year. I set the initial spawning escapement level, selected a target exploitation rate, and ran the program for a chosen number of years (100 years for E_{recov} runs, and 25 years for RER runs). At the end of each run, the program generated a new set of underlying spawner-recruit parameters (using the uncertainty in the parameter estimates) and ran the simulation again for the chosen number of years. This process repeated for a user-selected number of runs. After all the runs were completed for a given target exploitation rate, the program output the target exploitation rate, the mean recruitment, the mean catch, the mean escapement number, the number of times escapement fell below the critical escapement, the number of runs that ended with an escapement below the recovery escapement, and the number of runs that ended with extinction. This process was then repeated for a different target exploitation rate.

I did make some programming changes from the previous analyses (PSIT and WDFW 2004). The changes were:

- I did not use QuickBasic to run the program – instead, I converted the program into an Excel spreadsheet (CKBUFFER in Excel 608.xls).

- The previous version used a constant percent age composition for the recruitments; in this analysis, the age composition of the recruitment varied between brood years – the program randomly chose a brood year age composition from among the BY 1981 to 2001 age compositions that were calculated from the FRAM validation runs.

- Instead of using flow in cfs as the freshwater survival factor, I used a relation between flood recurrence interval and survival (E. Beamer, Skagit River System Cooperative, *pers. comm.*), and randomly chose a survival index value (mean survival = 1.0) from a list of index values that ran from 1972 to 2006. Because the survival index was relative to the mean, there was no coefficient for this term in the spawner-recruit relation.

- To vary marine survival, I used the same sine function that was used in Hayman (1999); however, at that time, because there was a huge El Nino event in 1996-97, I started the simulations at an offset of $3\pi/2$ (the lowest point) on the marine survival cycle. Because it is now about a half-cycle later, I started the simulations in this analysis at an offset of $\pi/2$ (the highest point) on the marine survival cycle.

- I updated the initial escapements (which started the run) to the escapements observed in 2003-2007.

- To simulate management error, rather than randomly selecting an actual error value observed in the past, I instead calculated the range of management errors observed in the past (by comparing FRAM validation ERs to the preseason forecast ERs), and randomly chose a whole percentage value within that range.

- I limited the allowed percentage deviation from the spawner-recruit curve to a rounded maximum or minimum of the observed percentage deviations.

Effects of Habitat Restoration Actions

I also modeled the effects of habitat restoration actions on the calculated RERs. Since NOAA has adopted the Puget Sound Salmon Recovery Plan (Ruckelshaus *et al.* 2005) as the species recovery plan under the ESA for Puget Sound Chinook, it is assumed that NOAA will insure that the actions called for in that plan, including the habitat restoration actions, will be implemented. In the Skagit chapter of that plan (Beamer *et al.* 2005: pg 285), it was calculated that implementation of all the proposed habitat restoration actions would result in a 23% increase in Skagit Chinook capacity, and a 22% to 65% increase in productivity, depending on the relative level of ocean survival. Since CKBUFFER models the entire range of ocean survival, I used the midpoint, 44%, as the estimate of the increase in productivity that will result from the habitat restoration actions. The actions would be implemented over a 20-yr period, and, while actions to increase capacity would take effect within a year or two after completion of a project, actions to increase productivity would likely require more time to take effect. Thus, in modeling the effects of restoration actions, I assumed no effect for the first 10 years, that capacity increases would take full effect by year 20, and that productivity increases would be fully implemented by year 30. In order to model these increases, I increased the capacity parameters (the Ricker β – actually, to increase capacity, I decreased this parameter – and the Beverton-Holt a) by an additional 2.3% each year from year 11 to year 20, and I increased the productivity parameters (the Ricker α and the Beverton-Holt b) by an additional 2.2% each year from year 11 to year 30. Thus, I was also assuming that the increases in capacity and productivity were linear from year 11 until they were fully effective.

III. RESULTS

Spawner-Recruit Parameters

For the RER analysis, I chose to use the recruitment numbers that were generated by using the FRAM exploitation rates. This made little difference for Skagit summer/falls (Table 1), but there was more of a difference for Skagit springs (Table 2). For Skagit summer/falls, the best-fit spawner-recruit parameters for these data were:

Skagit Summer/Fall Chinook

	Ricker	Beverton-Holt
α or a	6.854	35815
β or b	8.16E-05	14.18
MSY Escapement	8632	6986
Replacement	23575	33288
Std dev of α or a	1.207	12903
Std dev of β or b	2.94E-05	2.50
Root Mean Square Error	14710	14904
Maximum Deviation Ratio	2.53	2.66
Minimum Deviation Ratio	0.23	0.24

In comparison, if I had used the recruitments calculated by summing the FRAM AEQ mortalities and escapements, the Ricker α would have been 6.888, and β would have been 8.16E-05 (i.e., the same value).

For Skagit springs, the best-fit spawner-recruit parameters were:

Skagit Spring Chinook

	Ricker	Beverton-Holt
α or a	4.843	3182
β or b	5.85E-04	16.65
MSY Escapement	1055	589
Replacement	2696	2991
Std dev of α or a	1.009	1368
Std dev of β or b	2.52E-04	3.47
Root Mean Square Error	1689	1649
Maximum Deviation Ratio	2.71	2.72
Minimum Deviation Ratio	0.37	0.39

In comparison, if I had used the recruitments calculated by summing the FRAM AEQ mortalities and escapements, there would have been more of a difference than was the case for summer/falls – for springs, the Ricker α would have been 5.668, and β would have been 6.91E-04.

For both Skagit summer/falls and springs, there was considerable scatter around the spawner-recruit curves (Fig. 1). Because of this scatter, the standard deviations of the spawner-recruit parameters (particularly the Ricker β and the Beverton-Holt a) were relatively wide, and, in generating the underlying spawner-recruit parameters to be used for each run, could have given *really* improbable spawner-recruit curves if allowed to vary without constraint. Thus, I limited the allowed variation in the Ricker β and Beverton-Holt a parameters such that the replacement levels could not go outside a range of about 7,500 to 75,000 for summer/fall Chinook, and a range of about 700 to 10,000 for Skagit springs.

Brood Year Age Composition

For the simulations, I combined the FRAM age 2 escapements with the age 3 escapements. While there was considerable variability in age composition between brood years, the age composition of the summer/fall escapements (Table 3) were generally more weighted toward age 2+3 (and less toward age 5) than the spring Chinook escapements (Table 4).

Point of Depensation (E_{crit})

For Skagit summer/fall Chinook, the Ricker relation gave a carrying capacity (i.e., replacement) estimate of 23,575, and the Beverton-Holt carrying capacity was 33,288. Assuming that the point of depensation is 5% of the carrying capacity (Peterman 1977), the E_{crit} I used for the Ricker simulations was **1179**; for the Beverton-Holt simulations, E_{crit} was **1664**.

For Skagit spring Chinook, the Ricker relation gave a carrying capacity estimate of 2696, and the Beverton-Holt carrying capacity was 2991. Thus, E_{crit} for the Ricker simulations was **135**; for the Beverton-Holt simulations, E_{crit} was **150**.

Recovery Escapement Level (E_{recov})

In 1999, when I first calculated summer/fall Chinook recovery escapement levels, the simulations showed that an initial escapement level of 4700 met the criteria for recovery escapement (i.e., initial escapement from which there is less than 5% probability[6] of going extinct in 100 years) (Hayman 1999). This escapement level, 4700, was about midway between the critical escapement (1165 in that calculation), and the MSY escapement (between 8,000 and 10,000). In this year's

[6] Actually, in the 1999 calculation, the criterion I used was a 1% probability of going extinct in 100 years. If I had used a 5% probability, the recovery escapement would have been lower.

analysis, however, for reasons I don't have time to figure out, the simulations indicated that the recovery escapement criterion was satisfied by any value above the critical escapement. And, unlike in the 1999 analysis, it was a knife-edged breakpoint: for all initial escapements below the critical level, about 99% of the runs ended with extinction; for all escapements above the critical level, almost none did. This indicates that, under the assumptions modeled, Skagit Chinook may be highly robust to extinction risk at surprisingly low escapement levels, but, for purposes of deriving an RER, this was not particularly informative, because it didn't make sense for the critical threshold to be the same as the viable threshold. The escapement level that, in actual biological fact, satisfies the E_{recov} criteria might indeed be close to E_{crit}, but it is highly unlikely that the threshold for oblivion is the same as the threshold for viability. As a result, for the recovery escapement level in these simulations, I used a much higher value – the calculated MSY escapement. This is not unprecedented – we used the calculated MSY escapement as the recovery escapement level in the 2004 plan (PSIT and WDFW 2004) to set the RER for Skagit spring Chinook, and NMFS used the MSY escapement as the recovery escapement level for RER calculations it did for other Puget Sound units (NMFS 2005). Note, however, – and let's get all the disclaimers out of the way – just what it is that we are using the MSY escapement for: the calculated MSY escapement is being used in this exercise *solely* for the purpose of deriving an RER; it is not any kind of a management target or minimum threshold. If our objective was only to maintain a low probability of extinction, the simulations indicate that a considerably lower escapement target would be justified; if our objective was to maximize long-term harvest, prior analyses (PSIT and WDFW 2004, Appendix A, Skagit chapter, Derivation of Upper Management Thresholds) have indicated that, due to variability and biases in the data, the escapement target would have to be considerably higher than the calculated MSY escapement. In this analysis, the calculated MSY escapement is being used solely to determine the ceiling exploitation rate (RER) that provides more than an 80% probability after 25 years of exceeding the escapement level from which there is less than a 5% probability of going extinct after 100 years. Note also that the MSY escapement *is a conservative value for this task*, because the simulations in this analysis indicated that escapements considerably *below* the MSY escapement level *also satisfy* the criterion of less than a 5% probability of extinction after 100 years. So, if a run ends with an escapement slightly below the MSY escapement, *it's not the end of the world*. For purposes of estimating an RER, that run would count as a failure to exceed the chosen threshold, but it does not mean that extinction is inevitable.

Got all that? Good. What this means is that, for Skagit summer/fall Chinook, I used a recovery escapement level of **8632** for simulations that used the Ricker equation, and **6986** for simulations that used Beverton-Holt. For Skagit spring Chinook, the Ricker relation yielded an MSY escapement estimate of 1055, and the Beverton-Holt relation gave an MSY escapement of 589. While we have had spring Chinook escapements below 589, and those escapements did produce relatively good recruitments (Table 2), I just could not bring myself to use a number as low as 589 as an MSY level for spring Chinook. Consequently, in the RER simulations for spring Chinook, I used **1055** as the recovery escapement level for both the Ricker and the Beverton-Holt simulations. Note that this puts added conservatism in the Beverton-Holt simulations.

RER Calculation

In analyzing the RER simulations (Tables 5-12), the first thing to realize is that I never figured out how to generate a repeating random number sequence in Excel; consequently, there was some slop in the results (e.g., a slightly higher ER might result in a slightly *higher* modeled mean escapement in one simulation run), and, if I ran the exact same simulation again, I may not get exactly the same results. That said, the results are repeatable to within $\pm$ 1 percentage point, and this random variation did not change the overall conclusions of this analysis. This variation also means that, because the RERs are only repeatable to within $\pm$ 1 percentage point, there is no biological justification for managing for 6-decimal place precision in the RERs.

For all simulations, the calculated RERs were higher than the RERs used for current management (50% for summer/falls; 38% for springs). For the Ricker model runs, there were more critical escapements and runs ending below E_{recov} at the lower exploitation rates than for the Beverton-Holt model runs at the lower exploitation rates (compare, for example, Table 5 vs. Table 6). This was because the Ricker curve has a descending limb at high abundances; thus, when the freshwater and marine survival factors were both high, and combined to produce very high escapements, the resulting recruitments were very low. This did not occur for the Beverton-Holt simulations, because the Beverton-Holt curve does not decline at high escapements. Nonetheless, there was little difference between the two spawner-recruit models in their estimates of RER – for summer/falls, the estimates of RER varied from **60% to 64%** (Tables 5, 6, 9, and 10), depending on the model used and the assumptions about variation in the spawner-recruit parameters (see next paragraph); for spring Chinook, the RER estimates ranged from **48% to 55%** (Tables 7, 8, 11, and 12).

Because I was unsure whether it is valid to vary the underlying spawner-recruit parameters before each 25-year run, or whether that double-counts the variability, I also ran the simulations with the underlying spawner-recruit parameters held constant throughout all the runs (Tables 9 through 12). In these simulations, recruitments did vary around the spawner-recruit curve, but the spawner-recruit curve itself did not change each run. The RERs calculated from these runs were higher than in the runs where the underlying spawner-recruit parameters varied before each run – the differences ranged from one percentage point for summer/fall Chinook modeled with a Ricker curve (compare Table 5 vs. Table 9), to six percentage points for spring Chinook modeled with a Beverton-Holt curve (compare Table 8 vs. Table 12).

At the current RERs (50% for summer/falls, and 38% for springs), the probability that the escapement after 25 years would exceed E_{recov} ranged from 88% to 98% for summer/falls, and from 88% to 95% for springs (Tables 5 through 12).

Effects of Habitat Restoration Actions

When it was assumed that all the habitat restoration actions in the Skagit Chinook Recovery Plan (Beamer *et al.*, 2005) were implemented, the RERs ranged from **65% to 67%** for summer/falls, and from **57% to 60%** for Skagit springs (Tables 13 through 20). These RERs were all higher than in the corresponding simulations run under assumed current habitat. For Skagit summer/falls, the increase in RER attributable to habitat restoration ranged from 3 percentage points (compare Table 18 to Table 10) to 7 percentage points (compare Table 13 to Table 5). For Skagit springs, the increase in RER ranged from 5 percentage points (compare Table 20 to Table 12) to 10 percentage points (compare Table 15 to Table 7).

At the current RERs, assuming the habitat restoration actions are carried out, the probability that the escapement after 25 years would exceed E_{recov} ranged from 95% to 99% for summer/falls, and from 93% to 98% for springs (Tables 13 through 20). These probabilities were two to seven percentage points higher than under current habitat conditions.

The RERs calculated from each of these simulations are summarized in Table 21.

IV. DISCUSSION

The current RERs, in the 2004-2009 Comprehensive Chinook Management Plan, are 50% for Skagit summer/fall Chinook and 38% for Skagit spring Chinook (PSIT and WDFW 2004). This plan expires in 2009, and will need to be extended. The analysis described in this paper indicates that, under the most-recently calibrated version of FRAM, if these exploitation rates are retained as the RERs in the plan extension, **they would meet jeopardy standards**.

It would also not be necessary to "FRAMize" these rates, because they were developed using FRAM-generated exploitation rates. However, this does not solve all "FRAMization" problems, because, while there would be no need to convert FRAM-output exploitation rates to a different scale for *preseason* planning, there is still the problem of determining *post-season*, from coded-wire tag (CWT) recoveries, whether the exploitation rate objectives were met. That is, are FRAM-generated exploitation rates equivalent to CWT-generated exploitation rates? This may or may not be the case. If we compare FRAM brood year exploitation rates to CWT AEQ brood year exploitation rates, for recent-year Skagit summer/fall and spring Chinook, we get the following (data sources are FRAM validation runs, and RMIS CWT recovery database):

	Skagit Summer/Falls		Skagit Spring Chinook	CWT AEQ ER	
BY	FRAM BY ER	CWT AEQ ER	FRAM BY ER	Fingerlings	Yearlings
1993			49%	22.1%	39.4%
1994	33%	30.5%	41%	17.3%	31.4%
1995	36%	20.6%	25%	28.7%	28.6%
1996	37%	21.0%	20%	12.5%	14.9%
1997	42%	30.2%	21%	20.6%	40.8%
1998	34%	29.4%	41%	18.2%	19.5%
1999	49%	36.4%	27%	31.7%	33.4%
2000	36%	20.0%			
2001	46%	21.3%			

Before jumping to too many conclusions, note that the CWT ERs do not include non-landed mortalities, which can be a big part of the exploitation rate (the CWT recoveries are just those listed on RMIS). Thus, it is not possible, just from these data, to determine whether there is a bias in the FRAM exploitation rates, compared to CWT exploitation rates. But this is something that will need to be addressed in more detail when evaluating both FRAM and the performance of the Comprehensive Chinook plan.

The modeled effects of habitat restoration (Tables 13 through 20) indicate that higher exploitation rates would be allowable if habitat is restored. The degree of change may seem small for summer/falls (RERs would only increase by 3 to 7 percentage points), but Upper Skagit summers are also the Puget Sound wild Chinook population that is closest to achieving its recovery goals (WDFW 2002); thus, the habitat doesn't need quite as much improvement as it does for other Chinook stocks. For Skagit springs, which are farther from achieving recovery, the effect of habitat restoration on the RER is greater – 5 to 10 percentage points. For stocks with much more trashed habitat, like Stillaguamish, the effect of habitat restoration would likely be much greater – the current RER for Stillaguamish is 25%; under restored conditions, the Stillaguamish should have approximately the same productivity as the Skagit (Ruckelshaus *et al*. 2005, Vol. I, pg 137); thus, approximately the same RER. Since the RERs calculated for the Skagit, with all the habitat restoration actions taken, are in the 60% to 70% range (Table 21), this means that, with habitat restoration, the Stillaguamish RER could increase by 35 to 40 percentage points! This would obviously be a substantial change, and highlights the oft-repeated mantra that harvest management can only do so much – in Puget Sound, habitat is the key to Chinook salmon recovery.

Table 1. Escapement and recruitment estimates for Skagit summer/fall Chinook. Recruitments were calculated two different ways: by expanding the observed escapements by the *exploitation rates* generated from the FRAM validation runs (column titled "From FRAM ER"); and by summing together the *AEQ mortalities plus escapements* from the FRAM validation runs (column titled "From FRAM R"). For the analyses in this report, the values from the "From FRAM ER" column were used.

		Wild Recruitment	
Brood Yr	Spawners	From FRAM ER	From FRAM R
1981	8283	72966	77244
1982	9910	57647	54248
1983	8723	22067	23395
1984	12628	38534	38979
1985	16002	21312	22013
1986	17908	35515	36647
1987	9409	20780	20384
1988	11468	19532	18675
1989	6684	18309	20334
1990	16792	13059	12519
1991	5824	21152	19966
1992	7348	18858	19262
1993	5801	18068	18799
1994	5655	21562	19599
1995	6985	6345	6468
1996	10706	25932	26891
1997	4951	27544	27128
1998	14700	22413	18635
1999	5035	28044	28416
2000	17126	36771	38644
2001	13945	40198	41325

Table 2. Escapement and recruitment estimates for Skagit spring Chinook. Recruitments were calculated two different ways: by expanding the observed escapements by the *exploitation rates* generated from the FRAM validation runs (column titled "From FRAM ER"); and by summing together the *AEQ mortalities plus escapements* from the FRAM validation runs (column titled "From FRAM R"). For the analyses in this report, the values from the "From FRAM ER" column were used.

		Wild Recruitment	
Brood Yr	Spawners	From FRAM ER	From FRAM R
1981	1361	5257	4706
1982	965	7212	6667
1983	710	4124	4167
1984	755	4948	5646
1985	3248	3438	3333
1986	1977	4742	5308
1987	1981	2830	2314
1988	2064	2911	2905
1989	1516	1949	1046
1990	1592	1120	764
1991	1442	1463	2469
1992	986	2112	3601
1993	782	1611	1534
1994	470	1966	1569
1995	855	1057	487
1996	1051	1114	1161
1997	1041	1881	3072
1998	1086	1860	1330
1999	471	1277	1449
2000	1021	1840	2619
2001	1856	1969	1368

Table 3. Age composition of the *escapement* of each brood year of Skagit summer/fall Chinook, calculated from the 2007 FRAM validation runs. Note that the age composition of the escapement is different from the age composition of the *recruitment*, which has a bigger contribution of age 2 and age 3 fish.

SKAGIT SUMMER/FALL CHINOOK

Brood Year	Age 2+3	Age 4	Age 5
1981	25.1%	65.7%	9.2%
1982	26.1%	67.8%	6.1%
1983	18.7%	70.7%	10.6%
1984	20.5%	72.2%	7.3%
1985	17.7%	68.6%	13.7%
1986	18.5%	74.7%	6.8%
1987	38.9%	55.8%	5.4%
1988	14.6%	79.7%	5.7%
1989	27.0%	64.3%	8.7%
1990	21.1%	71.9%	7.0%
1991	35.0%	60.3%	4.7%
1992	27.5%	69.4%	3.1%
1993	47.5%	40.7%	11.8%
1994	10.0%	83.9%	6.1%
1995	20.8%	67.2%	12.0%
1996	9.3%	82.9%	7.8%
1997	23.0%	64.5%	12.5%
1998	12.5%	81.9%	5.5%
1999	34.0%	45.7%	20.3%
2000	16.0%	57.1%	26.9%
2001	30.6%	55.6%	13.9%

Table 4. Age composition of the *escapement* of each brood year of Skagit spring Chinook, calculated from the 2007 FRAM validation runs. Note that the age composition of the escapement is different from the age composition of the *recruitment*, which has a bigger contribution of age 2 and age 3 fish.

SKAGIT SPRING CHINOOK

Brood Year	Age 2+3	Age 4	Age 5
1981	5.8%	86.9%	7.2%
1982	21.6%	64.8%	13.6%
1983	9.3%	66.9%	23.8%
1984	14.4%	69.8%	15.8%
1985	7.8%	76.5%	15.8%
1986	26.3%	60.0%	13.8%
1987	3.0%	82.3%	14.7%
1988	22.9%	52.1%	25.0%
1989	3.3%	72.6%	24.0%
1990	15.8%	42.3%	41.9%
1991	9.4%	66.8%	23.8%
1992	14.5%	77.6%	7.9%
1993	3.1%	66.2%	30.7%
1994	8.2%	64.2%	27.6%
1995	7.3%	51.5%	41.2%
1996	0.5%	33.4%	66.1%
1997	2.2%	73.6%	24.2%
1998	14.8%	46.0%	39.2%
1999	7.2%	83.7%	9.2%
2000	3.9%	88.7%	7.4%
2001	12.2%	61.4%	26.4%

Table 5. Simulated results of modeling Skagit summer/fall Chinook recruitments, catches, and escapements at different target exploitation rates (ER), over a 25-yr period, 2,000 times for each target ER, using a Ricker spawner-recruit relation, in which the underlying spawner-recruit parameters vary for each 25-yr run. The highest ER that achieves jeopardy standards is underlined and bolded.

Skagit Summer/Fall Chinook with Ricker Spawner-Recruit Parameters that Vary for Each 25-Yr Run

Years/Run:	25	Runs/ER:	2000		
SR Model:	Ricker	Ecrit:	1179	Marine Surv Cycle (yrs):	24
Erecov:	8632	ELowObs	6000	Starting Offset to cycle:	$\pi/2$

Target ER	Mean Recruits	Mean Catch	Mean Esc	# < Ecrit	# End < Erecov	# End Extinct	% < Ecrit	% End < Erecov	% End Extinct
0%	30425	0	30425	98	192	0	0.2%	9.6%	0.0%
5%	32348	4852	27496	26	176	0	0.1%	8.8%	0.0%
10%	31859	4779	27080	34	190	0	0.1%	9.5%	0.0%
15%	31870	5197	26673	41	168	0	0.1%	8.4%	0.0%
20%	33771	6878	26893	22	180	0	0.0%	9.0%	0.0%
25%	33830	8586	25243	15	181	0	0.0%	9.1%	0.0%
30%	34365	10465	23901	11	187	0	0.0%	9.4%	0.0%
35%	35860	12744	23116	21	204	0	0.0%	10.2%	0.0%
40%	36074	14652	21422	11	152	0	0.0%	7.6%	0.0%
45%	36540	16681	19858	14	193	0	0.0%	9.7%	0.0%
50%	36837	18733	18104	37	232	1	0.1%	11.6%	0.1%
55%	36405	20333	16071	84	259	1	0.2%	13.0%	0.1%
<u>60%</u>	36460	22180	14280	269	363	0	0.5%	18.2%	0.0%
61%	36078	22364	13714	387	446	2	0.8%	22.3%	0.1%
62%	36056	22658	13397	424	491	1	0.8%	24.6%	0.1%
63%	35284	22518	12766	588	515	4	1.2%	25.8%	0.2%
64%	34330	22333	11997	863	621	7	1.7%	31.1%	0.4%
65%	34184	22531	11653	1137	643	6	2.3%	32.2%	0.3%
70%	31195	22155	9040	4151	1158	93	8.3%	57.9%	4.7%
75%	25387	19226	6161	11651	1611	463	23.3%	80.6%	23.2%
80%	22707	18128	4579	18567	1832	976	37.1%	91.6%	48.8%

Table 6. Simulated results of modeling Skagit summer/fall Chinook recruitments, catches, and escapements at different target exploitation rates (ER), over a 25-yr period, 2,000 times for each target ER, using a Beverton-Holt spawner-recruit relation, in which the underlying spawner-recruit parameters vary for each 25-yr run. The highest ER that achieves jeopardy standards is <u>underlined and bolded</u>.

Skagit Summer/Fall Chinook with Beverton-Holt Spawner-Recruit Parameters that Vary for Each 25-Yr Run

Years/Run:	25	Runs/ER:	2000		
SR Model:	Bev-Holt	Ecrit:	1664	Marine Surv Cycle (yrs):	24
Erecov:	6986	ELowObs	6000	Starting Offset to cycle:	π/2

Target ER	Mean Recruits	Mean Catch	Mean Esc	# < Ecrit	# End < Erecov	# End Extinct	% < Ecrit	% End < Erecov	% End Extinct
0%	39907	0	39907	3	10	0	0.0%	0.5%	0.0%
5%	39887	5983	33904	7	11	0	0.0%	0.6%	0.0%
10%	39181	5877	33304	2	19	0	0.0%	1.0%	0.0%
15%	39593	6464	33129	8	16	0	0.0%	0.8%	0.0%
20%	39260	7984	31276	16	16	0	0.0%	0.8%	0.0%
25%	38729	9819	28910	27	24	0	0.1%	1.2%	0.0%
30%	38090	11613	26476	21	33	0	0.0%	1.7%	0.0%
35%	38278	13605	24673	28	50	0	0.1%	2.5%	0.0%
40%	38447	15602	22846	36	24	0	0.1%	1.2%	0.0%
45%	37496	17102	20394	79	64	0	0.2%	3.2%	0.0%
50%	37414	18979	18435	201	94	1	0.4%	4.7%	0.1%
55%	35824	19997	15827	560	155	3	1.1%	7.8%	0.2%
60%	34083	20769	13315	1089	257	7	2.2%	12.9%	0.4%
61%	33811	20938	12873	1377	310	16	2.8%	15.5%	0.8%
<u>**62%**</u>	32804	20631	12174	1703	376	10	3.4%	18.8%	0.5%
63%	33291	21288	12003	1819	406	17	3.6%	20.3%	0.9%
64%	32771	21252	11519	2324	521	23	4.6%	26.1%	1.2%
65%	31929	21066	10863	3111	611	41	6.2%	30.6%	2.1%
70%	27806	19792	8015	7980	1107	188	16.0%	55.4%	9.4%
75%	23054	17484	5570	16498	1628	676	33.0%	81.4%	33.8%
80%	19325	15457	3868	23579	1891	1200	47.2%	94.6%	60.0%

Table 7. Simulated results of modeling Skagit spring Chinook recruitments, catches, and escapements at different target exploitation rates (ER), over a 25-yr period, 2,000 times for each target ER, using a Ricker spawner-recruit relation, in which the underlying spawner-recruit parameters vary for each 25-yr run. The highest ER that achieves jeopardy standards is underlined and bolded.

Skagit Spring Chinook with Ricker Spawner-Recruit Parameters that Vary for Each 25-Yr Run

Years/Run:	25	Runs/ER:	2000		
SR Model:	Ricker	Ecrit:	135	Marine Surv Cycle (yrs):	24
Erecov:	1055	ELowObs	470	Starting Offset to cycle:	π/2

Target ER	Mean Recruits	Mean Catch	Mean Esc	# < Ecrit	# End < Erecov	# End Extinct	% < Ecrit	% End < Erecov	% End Extinct
0%	3560	0	3560	31	138	0	0.1%	6.9%	0.0%
5%	3733	210	3523	28	126	0	0.1%	6.3%	0.0%
10%	3696	369	3327	27	140	0	0.1%	7.0%	0.0%
15%	3687	554	3133	16	143	0	0.0%	7.2%	0.0%
20%	3737	749	2988	9	137	0	0.0%	6.9%	0.0%
25%	3866	966	2900	17	144	0	0.0%	7.2%	0.0%
30%	3843	1149	2694	23	174	0	0.0%	8.7%	0.0%
35%	3848	1341	2506	43	215	0	0.1%	10.8%	0.0%
40%	3849	1535	2315	42	239	0	0.1%	12.0%	0.0%
45%	3844	1733	2111	139	322	0	0.3%	16.1%	0.0%
46%	3783	1739	2043	156	344	1	0.3%	17.2%	0.1%
47%	3732	1758	1973	193	357	2	0.4%	17.9%	0.1%
48%	3733	1791	1942	240	395	3	0.5%	19.8%	0.2%
49%	3772	1849	1922	297	405	7	0.6%	20.3%	0.4%
50%	3833	1914	1919	266	460	5	0.5%	23.0%	0.3%
55%	3617	1979	1638	782	619	18	1.6%	31.0%	0.9%
60%	3523	2116	1407	2136	891	93	4.3%	44.6%	4.7%
65%	3143	2043	1099	5524	1236	317	11.0%	61.8%	15.9%
70%	2683	1861	822	10613	1538	663	21.2%	76.9%	33.2%
75%	2330	1695	635	15814	1757	1097	31.6%	87.9%	54.9%
80%	2127	1616	511	20018	1869	1374	40.0%	93.5%	68.7%

Table 8. Simulated results of modeling Skagit spring Chinook recruitments, catches, and escapements at different target exploitation rates (ER), over a 25-yr period, 2,000 times for each target ER, using a Beverton-Holt spawner-recruit relation, in which the underlying spawner-recruit parameters vary for each 25-yr run. The highest ER that achieves jeopardy standards is underlined and bolded.

Skagit Spring Chinook with Beverton-Holt Spawner-Recruit Parameters that Vary for Each 25-Yr Run

Years/Run:	25	Runs/ER:	2000		
SR Model:	Bev-Holt	Ecrit:	150	Marine Surv Cycle (yrs):	24
Erecov:	1055	ELowObs	470	Starting Offset to cycle:	π/2

Target ER	Mean Recruits	Mean Catch	Mean Esc	# < Ecrit	# End < Erecov	# End Extinct	% < Ecrit	% End < Erecov	% End Extinct
0%	3671	0	3671	6	73	0	0.0%	3.7%	0.0%
5%	3548	199	3349	19	85	0	0.0%	4.3%	0.0%
10%	3569	357	3212	25	82	0	0.1%	4.1%	0.0%
15%	3527	529	2998	19	103	0	0.0%	5.2%	0.0%
20%	3473	695	2778	47	131	0	0.1%	6.6%	0.0%
25%	3469	866	2603	67	169	0	0.1%	8.5%	0.0%
30%	3511	1050	2460	68	184	1	0.1%	9.2%	0.1%
35%	3480	1217	2263	104	213	0	0.2%	10.7%	0.0%
40%	3444	1378	2066	156	253	3	0.3%	12.7%	0.2%
45%	3351	1505	1846	340	328	2	0.7%	16.4%	0.1%
46%	3394	1566	1829	375	333	8	0.8%	16.7%	0.4%
47%	3365	1583	1782	299	343	5	0.6%	17.2%	0.3%
48%	3385	1625	1760	398	361	11	0.8%	18.1%	0.6%
49%	3376	1658	1718	339	376	4	0.7%	18.8%	0.2%
50%	3382	1687	1695	481	401	9	1.0%	20.1%	0.5%
55%	3288	1808	1480	824	531	22	1.6%	26.6%	1.1%
60%	3112	1867	1245	2088	768	75	4.2%	38.4%	3.8%
65%	2811	1824	987	5327	1122	233	10.7%	56.1%	11.7%
70%	2507	1733	774	10059	1447	549	20.1%	72.4%	27.5%
75%	2290	1666	624	14728	1679	892	29.5%	84.0%	44.6%
80%	2019	1533	486	19186	1840	1218	38.4%	92.0%	60.9%

Table 9. Simulated results of modeling Skagit summer/fall Chinook recruitments, catches, and escapements at different target exploitation rates (ER), over a 25-yr period, 2,000 times for each target ER, using a Ricker spawner-recruit relation, in which the underlying spawner-recruit parameters remain constant for each 25-yr run. The highest ER that achieves jeopardy standards is underlined and bolded.

Skagit Summer/Fall Chinook with Ricker Spawner-Recruit Parameters Constant for Each 25-Yr Run

Years/Run:	25	Runs/ER:	2000		
SR Model:	Ricker	Ecrit:	1179	Marine Surv Cycle (yrs):	24
Erecov:	8632	ELowObs	6000	Starting Offset to cycle:	$\pi/2$

Target ER	Mean Recruits	Mean Catch	Mean Esc	# < Ecrit	# End < Erecov	# End Extinct	% < Ecrit	% End < Erecov	% End Extinct
0%	26220	0	26220	54	200	0	0.1%	10.0%	0.0%
5%	27841	4176	23665	10	166	0	0.0%	8.3%	0.0%
10%	27914	4187	23727	13	174	0	0.0%	8.7%	0.0%
15%	27847	4542	23305	8	164	0	0.0%	8.2%	0.0%
20%	28427	5780	22647	9	166	0	0.0%	8.3%	0.0%
25%	28981	7341	21639	4	133	0	0.0%	6.7%	0.0%
30%	29498	8974	20524	1	144	0	0.0%	7.2%	0.0%
35%	30155	10706	19449	2	151	0	0.0%	7.6%	0.0%
40%	30639	12465	18173	3	134	0	0.0%	6.7%	0.0%
45%	31183	14243	16940	0	150	0	0.0%	7.5%	0.0%
50%	31529	16031	15498	4	162	0	0.0%	8.1%	0.0%
55%	31322	17499	13823	26	198	0	0.1%	9.9%	0.0%
60%	30612	18591	12021	127	343	0	0.3%	17.2%	0.0%
61%	30400	18827	11572	153	376	0	0.3%	18.8%	0.0%
62%	30144	18975	11169	213	425	0	0.4%	21.3%	0.0%
63%	29830	19133	10697	384	479	0	0.8%	24.0%	0.0%
64%	29474	19140	10334	520	555	2	1.0%	27.8%	0.1%
65%	29054	19174	9880	691	662	4	1.4%	33.1%	0.2%
70%	25717	18267	7450	3690	1215	71	7.4%	60.8%	3.6%
75%	21355	16157	5197	11353	1725	443	22.7%	86.3%	22.2%
80%	17895	14304	3591	19565	1926	1064	39.1%	96.3%	53.2%

Table 10. Simulated results of modeling Skagit summer/fall Chinook recruitments, catches, and escapements at different target exploitation rates (ER), over a 25-yr period, 2,000 times for each target ER, using a Beverton-Holt spawner-recruit relation, in which the underlying spawner-recruit parameters <u>remain constant</u> for each 25-yr run. The highest ER that achieves jeopardy standards is <u>underlined and bolded</u>.

Skagit Summer/Fall Chinook with Beverton-Holt Spawner-Recruit Parameters Constant for Each 25-Yr Run

Years/Run:	25	Runs/ER:	2000		
SR Model:	Bev-Holt	Ecrit:	1664	Marine Surv Cycle (yrs):	24
Erecov:	6986	ELowObs	6000	Starting Offset to cycle:	$\pi/2$

Target ER	Mean Recruits	Mean Catch	Mean Esc	# < Ecrit	# End < Erecov	# End Extinct	% < Ecrit	% End < Erecov	% End Extinct
0%	39890	0	39890	0	0	0	0.0%	0.0%	0.0%
5%	39342	5901	33441	0	1	0	0.0%	0.1%	0.0%
10%	39334	5900	33434	0	3	0	0.0%	0.2%	0.0%
15%	39395	6426	32969	0	3	0	0.0%	0.2%	0.0%
20%	39135	7951	31184	0	2	0	0.0%	0.1%	0.0%
25%	38821	9853	28969	0	5	0	0.0%	0.3%	0.0%
30%	38595	11746	26849	0	5	0	0.0%	0.3%	0.0%
35%	38345	13644	24702	0	1	0	0.0%	0.1%	0.0%
40%	37607	15278	22330	0	8	0	0.0%	0.4%	0.0%
45%	37224	17001	20224	1	18	0	0.0%	0.9%	0.0%
50%	36470	18489	17981	12	38	0	0.0%	1.9%	0.0%
55%	35459	19795	15664	60	61	0	0.1%	3.1%	0.0%
60%	34297	20884	13413	328	152	0	0.7%	7.6%	0.0%
61%	33622	20816	12806	489	203	1	1.0%	10.2%	0.1%
62%	33319	20975	12344	645	265	1	1.3%	13.3%	0.1%
63%	32499	20800	11699	875	307	0	1.8%	15.4%	0.0%
<u>**64%**</u>	31819	20641	11179	1379	389	3	2.8%	19.5%	0.2%
65%	31487	20780	10707	1715	516	12	3.4%	25.8%	0.6%
70%	27548	19579	7969	6230	1098	104	12.5%	54.9%	5.2%
75%	22470	17064	5406	15649	1665	610	31.3%	83.3%	30.5%
80%	19089	15216	3873	23062	1903	1188	46.1%	95.2%	59.4%

Table 11. Simulated results of modeling Skagit spring Chinook recruitments, catches, and escapements at different target exploitation rates (ER), over a 25-yr period, 2,000 times for each target ER, using a Ricker spawner-recruit relation, in which the underlying spawner-recruit parameters remain constant for each 25-yr run. The highest ER that achieves jeopardy standards is underlined and bolded.

Skagit Spring Chinook with Ricker Spawner-Recruit Parameters Constant for Each 25-Yr Run

Years/Run:	25	Runs/ER:	2000		
SR Model:	Ricker	Ecrit:	135	Marine Surv Cycle (yrs):	24
Erecov:	1055	ELowObs	470	Starting Offset to cycle:	π/2

Target ER	Mean Recruits	Mean Catch	Mean Esc	# < Ecrit	# End < Erecov	# End Extinct	% < Ecrit	% End < Erecov	% End Extinct
0%	2944	0	2944	7	95	0	0.0%	4.8%	0.0%
5%	2979	149	2830	4	108	0	0.0%	5.4%	0.0%
10%	3024	303	2721	4	105	0	0.0%	5.3%	0.0%
15%	3073	461	2612	3	92	0	0.0%	4.6%	0.0%
20%	3108	621	2486	3	103	0	0.0%	5.2%	0.0%
25%	3135	786	2350	1	101	0	0.0%	5.1%	0.0%
30%	3144	945	2200	6	107	0	0.0%	5.4%	0.0%
35%	3169	1109	2060	12	136	0	0.0%	6.8%	0.0%
40%	3183	1273	1910	13	152	0	0.0%	7.6%	0.0%
45%	3163	1421	1742	25	247	0	0.1%	12.4%	0.0%
50%	3080	1535	1545	101	364	2	0.2%	18.2%	0.1%
51%	3077	1570	1507	126	354	3	0.3%	17.7%	0.2%
52%	3043	1580	1462	133	440	1	0.3%	22.0%	0.1%
53%	3028	1605	1424	200	478	2	0.4%	23.9%	0.1%
54%	3005	1619	1386	259	506	3	0.5%	25.3%	0.2%
55%	2975	1636	1339	392	575	8	0.8%	28.8%	0.4%
60%	2777	1670	1107	1489	945	50	3.0%	47.3%	2.5%
65%	2487	1616	870	5100	1363	271	10.2%	68.2%	13.6%
70%	2205	1528	678	10194	1665	685	20.4%	83.3%	34.3%
75%	1952	1424	529	15840	1848	1125	31.7%	92.4%	56.3%
80%	1772	1350	422	20783	1933	1465	41.6%	96.7%	73.3%

Table 12. Simulated results of modeling Skagit summer/fall Chinook recruitments, catches, and escapements at different target exploitation rates (ER), over a 25-yr period, 2,000 times for each target ER, using a Beverton-Holt spawner-recruit relation, in which the underlying spawner-recruit parameters remain constant for each 25-yr run. The highest ER that achieves jeopardy standards is underlined and bolded.

Skagit Spring Chinook with Beverton-Holt Spawner-Recruit Parameters Constant for Each 25-Yr Run

Years/Run:	25	Runs/ER:	2000		
SR Model:	Bev-Holt	Ecrit:	150	Marine Surv Cycle (yrs):	24
Erecov:	1055	ELowObs	470	Starting Offset to cycle:	π/2

Target ER	Mean Recruits	Mean Catch	Mean Esc	# < Ecrit	# End < Erecov	# End Extinct	% < Ecrit	% End < Erecov	% End Extinct
0%	3570	0	3570	0	12	0	0.0%	0.6%	0.0%
5%	3555	177	3377	0	17	0	0.0%	0.9%	0.0%
10%	3546	355	3191	0	20	0	0.0%	1.0%	0.0%
15%	3537	531	3005	0	24	0	0.0%	1.2%	0.0%
20%	3542	709	2833	0	35	0	0.0%	1.8%	0.0%
25%	3491	873	2617	0	48	0	0.0%	2.4%	0.0%
30%	3499	1050	2449	0	56	0	0.0%	2.8%	0.0%
35%	3445	1205	2240	0	72	0	0.0%	3.6%	0.0%
40%	3403	1363	2040	2	110	0	0.0%	5.5%	0.0%
45%	3366	1514	1852	7	167	0	0.0%	8.4%	0.0%
50%	3309	1651	1658	44	237	0	0.1%	11.9%	0.0%
55%	3217	1768	1449	199	365	0	0.4%	18.3%	0.0%
56%	3185	1788	1397	203	457	2	0.4%	22.9%	0.1%
57%	3168	1809	1358	339	502	2	0.7%	25.1%	0.1%
58%	3169	1838	1331	400	565	5	0.8%	28.3%	0.3%
59%	3089	1826	1263	527	612	7	1.1%	30.6%	0.4%
60%	3068	1841	1227	860	691	14	1.7%	34.6%	0.7%
65%	2774	1797	977	3649	1063	141	7.3%	53.2%	7.1%
70%	2515	1738	777	7925	1407	421	15.9%	70.4%	21.1%
75%	2223	1623	599	13440	1691	853	26.9%	84.6%	42.7%
80%	1996	1520	476	18375	1862	1232	36.8%	93.1%	61.6%

Table 13. Skagit summer/fall Chinook modeled recruitments, catches, and escapements that would be projected under different exploitation rates (ER), with Ricker spawner-recruit parameters varied after each 25-year run, and assuming that the habitat restoration actions described in the Skagit Chinook Recovery Plan are carried out. The highest ER that achieves jeopardy standards is underlined and bolded.

Habitat Restoration Runs: Skagit Summer/Fall Chinook w/ Ricker Parameters Varied

Years/Run:	25	Runs/ER:	2000			
SR Model:	Ricker	Ecrit:	1179	Marine Surv Cycle (yrs):	24	
Erecov:	8632	ELowObs	6000	Starting Offset to cycle:	π/2	

Target ER	Mean Recruits	Mean Catch	Mean Esc	# < Ecrit	# End < Erecov	# End Extinct	% < Ecrit	% End < Erecov	% End Extinct
0%	36915	0	36915	78	173	1	0.2%	8.7%	0.1%
5%	37107	1883	35224	66	202	0	0.1%	10.1%	0.0%
10%	38449	3904	34546	45	176	0	0.1%	8.8%	0.0%
15%	39314	6422	32891	46	141	0	0.1%	7.1%	0.0%
20%	38914	7913	31001	30	140	0	0.1%	7.0%	0.0%
25%	40261	10189	30071	11	143	0	0.0%	7.2%	0.0%
30%	41439	12605	28834	17	119	0	0.0%	6.0%	0.0%
35%	42283	15003	27280	9	123	0	0.0%	6.2%	0.0%
40%	43989	17875	26115	14	90	0	0.0%	4.5%	0.0%
45%	44365	20266	24100	13	104	0	0.0%	5.2%	0.0%
50%	45854	23259	22596	45	93	0	0.1%	4.7%	0.0%
55%	44922	25079	19843	46	97	0	0.1%	4.9%	0.0%
60%	44597	27125	17472	177	132	1	0.4%	6.6%	0.1%
65%	42447	27995	14452	724	269	9	1.4%	13.5%	0.5%
66%	42212	28270	13942	918	318	11	1.8%	15.9%	0.6%
67%	40843	27805	13038	1319	388	22	2.6%	19.4%	1.1%
68%	40580	27996	12584	1751	482	25	3.5%	24.1%	1.3%
69%	38835	27198	11637	2636	561	60	5.3%	28.1%	3.0%
70%	38141	27149	10992	3029	671	74	6.1%	33.6%	3.7%
75%	30968	23497	7471	9490	1267	341	19.0%	63.4%	17.1%
80%	25226	20138	5088	16773	1671	853	33.5%	83.6%	42.7%

Table 14. Skagit summer/fall Chinook modeled recruitments, catches, and escapements that would be projected under different exploitation rates (ER), with Beverton-Holt spawner-recruit parameters varied after each 25-year run, and assuming that the habitat restoration actions described in the Skagit Chinook Recovery Plan are carried out. The highest ER that achieves jeopardy standards is underlined and bolded.

Habitat Restoration Runs: Skagit Summer/Fall Chinook w/ Beverton-Holt Parameters Varied

Years/Run:	25	Runs/ER:	2000		
SR Model:	Bev-Holt	Ecrit:	1664	Marine Surv Cycle (yrs):	24
Erecov:	6986	ELowObs	6000	Starting Offset to cycle:	π/2

Target ER	Mean Recruits	Mean Catch	Mean Esc	# < Ecrit	# End < Erecov	# End Extinct	% < Ecrit	% End < Erecov	% End Extinct
0%	44120	0	44120	0	3	0	0.0%	0.2%	0.0%
5%	44160	2239	41921	2	3	0	0.0%	0.2%	0.0%
10%	44239	4491	39747	9	6	0	0.0%	0.3%	0.0%
15%	44199	7216	36983	3	9	0	0.0%	0.5%	0.0%
20%	44387	9021	35367	4	7	0	0.0%	0.4%	0.0%
25%	44044	11183	32861	6	5	0	0.0%	0.3%	0.0%
30%	43478	13250	30227	14	10	0	0.0%	0.5%	0.0%
35%	42624	15110	27514	12	18	0	0.0%	0.9%	0.0%
40%	42544	17318	25226	82	24	0	0.2%	1.2%	0.0%
45%	42282	19317	22964	80	32	0	0.2%	1.6%	0.0%
50%	42084	21347	20737	116	54	0	0.2%	2.7%	0.0%
55%	40810	22738	18072	291	77	3	0.6%	3.9%	0.2%
60%	38952	23661	15291	846	132	4	1.7%	6.6%	0.2%
65%	35730	23610	12120	2389	340	31	4.8%	17.0%	1.6%
66%	36098	24172	11926	2644	385	29	5.3%	19.3%	1.5%
67%	34995	23814	11181	3116	417	46	6.2%	20.9%	2.3%
68%	34290	23672	10618	3956	521	70	7.9%	26.1%	3.5%
69%	32708	22898	9810	5208	666	101	10.4%	33.3%	5.1%
70%	31778	22563	9216	6524	753	160	13.0%	37.7%	8.0%
75%	25275	19191	6084	14842	1415	570	29.7%	70.8%	28.5%
80%	20986	16732	4254	21901	1772	1103	43.8%	88.6%	55.2%

Table 15. Skagit spring Chinook modeled recruitments, catches, and escapements that would be projected under different exploitation rates (ER), with Ricker spawner-recruit parameters varied after each 25-year run, and <u>assuming that the habitat restoration actions described in the Skagit Chinook Recovery Plan are carried out</u>. The highest ER that achieves jeopardy standards is <u>underlined and bolded</u>.

Habitat Restoration Runs: Skagit Spring Chinook w/ Ricker Parameters Varied

Years/Run:	25	Runs/ER:	2000		
SR Model:	Ricker	Ecrit:	135	Marine Surv Cycle (yrs):	24
Erecov:	1055	ELowObs	470	Starting Offset to cycle:	$\pi/2$

Target ER	Mean Recruits	Mean Catch	Mean Esc	# < Ecrit	# End < Erecov	# End Extinct	% < Ecrit	% End < Erecov	% End Extinct
0%	4351	0	4351	36	93	0	0.1%	4.7%	0.0%
5%	4499	226	4273	25	83	0	0.1%	4.2%	0.0%
10%	4435	445	3991	29	79	0	0.1%	4.0%	0.0%
15%	4469	672	3797	13	78	0	0.0%	3.9%	0.0%
20%	4566	915	3651	19	75	0	0.0%	3.8%	0.0%
25%	4667	1173	3493	16	70	0	0.0%	3.5%	0.0%
30%	4758	1423	3336	6	69	0	0.0%	3.5%	0.0%
35%	4772	1673	3099	13	93	0	0.0%	4.7%	0.0%
40%	4717	1882	2836	26	87	0	0.1%	4.4%	0.0%
45%	4817	2169	2648	63	132	0	0.1%	6.6%	0.0%
50%	4627	2312	2315	187	162	1	0.4%	8.1%	0.1%
55%	4362	2402	1960	501	259	8	1.0%	13.0%	0.4%
56%	4375	2444	1931	722	316	16	1.4%	15.8%	0.8%
57%	4361	2495	1866	716	360	17	1.4%	18.0%	0.9%
<u>**58%**</u>	4264	2469	1795	943	383	24	1.9%	19.2%	1.2%
59%	4331	2557	1773	1285	429	44	2.6%	21.5%	2.2%
60%	4016	2410	1605	1607	510	51	3.2%	25.5%	2.6%
65%	3673	2392	1282	4828	897	222	9.7%	44.9%	11.1%
70%	3067	2137	931	9708	1281	563	19.4%	64.1%	28.2%
75%	2691	1954	737	14418	1573	922	28.8%	78.7%	46.1%
80%	2325	1772	554	18448	1781	1212	36.9%	89.1%	60.6%

Table 16. Skagit spring Chinook modeled recruitments, catches, and escapements that would be projected under different exploitation rates (ER), with Beverton-Holt spawner-recruit parameters varied after each 25-year run, and assuming that the habitat restoration actions described in the Skagit Chinook Recovery Plan are carried out. The highest ER that achieves jeopardy standards is underlined and bolded.

Habitat Restoration Runs: Skagit Spring Chinook w/ Beverton-Holt Parameters Varied

Years/Run:	25	Runs/ER:	2000		
SR Model:	Bev-Holt	Ecrit:	150	Marine Surv Cycle (yrs):	24
Erecov:	1055	ELowObs	470	Starting Offset to cycle:	π/2

Target ER	Mean Recruits	Mean Catch	Mean Esc	# < Ecrit	# End < Erecov	# End Extinct	% < Ecrit	% End < Erecov	% End Extinct
0%	4026	0	4026	7	40	0	0.0%	2.0%	0.0%
5%	4008	200	3808	9	54	0	0.0%	2.7%	0.0%
10%	3970	397	3573	22	59	0	0.0%	3.0%	0.0%
15%	3995	599	3395	17	61	0	0.0%	3.1%	0.0%
20%	3954	790	3164	30	80	0	0.1%	4.0%	0.0%
25%	3892	975	2917	44	102	0	0.1%	5.1%	0.0%
30%	3921	1174	2747	41	88	0	0.1%	4.4%	0.0%
35%	3973	1390	2583	71	122	0	0.1%	6.1%	0.0%
40%	3787	1509	2278	113	150	2	0.2%	7.5%	0.1%
45%	3868	1744	2124	169	182	0	0.3%	9.1%	0.0%
50%	3790	1900	1890	342	255	3	0.7%	12.8%	0.2%
55%	3708	2040	1668	822	350	18	1.6%	17.5%	0.9%
56%	3688	2062	1625	656	345	9	1.3%	17.3%	0.5%
57%	3708	2115	1593	932	351	22	1.9%	17.6%	1.1%
58%	3535	2042	1493	1228	469	29	2.5%	23.5%	1.5%
59%	3572	2110	1463	1409	459	38	2.8%	23.0%	1.9%
60%	3546	2132	1414	1618	504	36	3.2%	25.2%	1.8%
65%	3278	2125	1153	4392	854	179	8.8%	42.7%	9.0%
70%	2891	2006	885	8365	1187	408	16.7%	59.4%	20.4%
75%	2556	1863	692	13037	1461	715	26.1%	73.1%	35.8%
80%	2298	1748	550	17389	1692	1039	34.8%	84.6%	52.0%

Table 17. Skagit summer/fall Chinook modeled recruitments, catches, and escapements that would be projected under different exploitation rates (ER), with Ricker spawner-recruit parameters held constant after each 25-year run, and assuming that the habitat restoration actions described in the Skagit Chinook Recovery Plan are carried out. The highest ER that achieves jeopardy standards is underlined and bolded.

Habitat Restoration Runs: Skagit Summer/Fall Chinook w/ Ricker Parameters Held Constant

Years/Run:	25	Runs/ER:	2000		
SR Model:	Ricker	Ecrit:	1179	Marine Surv Cycle (yrs):	24
Erecov:	8632	ELowObs	6000	Starting Offset to cycle:	π/2

Target ER	Mean Recruits	Mean Catch	Mean Esc	# < Ecrit	# End < Erecov	# End Extinct	% < Ecrit	% End < Erecov	% End Extinct
0%	31575	0	31575	38	191	0	0.1%	9.6%	0.0%
5%	32136	1631	30505	21	168	0	0.0%	8.4%	0.0%
10%	32805	3332	29473	14	137	0	0.0%	6.9%	0.0%
15%	33634	5486	28147	12	145	0	0.0%	7.3%	0.0%
20%	34198	6955	27243	14	127	0	0.0%	6.4%	0.0%
25%	34999	8877	26122	7	142	0	0.0%	7.1%	0.0%
30%	35925	10944	24981	3	105	0	0.0%	5.3%	0.0%
35%	36299	12895	23404	0	100	0	0.0%	5.0%	0.0%
40%	37411	15192	22219	7	59	0	0.0%	3.0%	0.0%
45%	37785	17265	20520	1	74	0	0.0%	3.7%	0.0%
50%	38671	19653	19018	3	74	0	0.0%	3.7%	0.0%
55%	38608	21567	17041	7	64	0	0.0%	3.2%	0.0%
60%	38033	23160	14873	50	79	0	0.1%	4.0%	0.0%
65%	35760	23561	12199	360	230	2	0.7%	11.5%	0.1%
66%	35265	23614	11652	664	271	6	1.3%	13.6%	0.3%
67%	34486	23418	11068	818	329	11	1.6%	16.5%	0.6%
68%	33422	23036	10385	1207	438	16	2.4%	21.9%	0.8%
69%	32297	22652	9645	1614	575	26	3.2%	28.8%	1.3%
70%	31580	22410	9170	2302	663	34	4.6%	33.2%	1.7%
75%	24598	18640	5957	9696	1377	353	19.4%	68.9%	17.7%
80%	20071	16011	4059	17237	1795	868	34.5%	89.8%	43.4%

Table 18. Skagit summer/fall Chinook modeled recruitments, catches, and escapements that would be projected under different exploitation rates (ER), with Beverton-Holt spawner-recruit parameters held constant after each 25-year run, and assuming that the habitat restoration actions described in the Skagit Chinook Recovery Plan are carried out. The highest ER that achieves jeopardy standards is underlined and bolded.

Habitat Restoration Runs: Skagit Summer/Fall Chinook w/ Beverton-Holt Parameters Held Constant

Years/Run:	25	Runs/ER:	2000		
SR Model:	Bev-Holt	Ecrit:	1664	Marine Surv Cycle (yrs):	24
Erecov:	6986	ELowObs	6000	Starting Offset to cycle:	π/2

Target ER	Mean Recruits	Mean Catch	Mean Esc	# < Ecrit	# End < Erecov	# End Extinct	% < Ecrit	% End < Erecov	% End Extinct
0%	44639	0	44639	0	0	0	0.0%	0.0%	0.0%
5%	44558	2259	42299	0	0	0	0.0%	0.0%	0.0%
10%	44264	4496	39768	0	0	0	0.0%	0.0%	0.0%
15%	44111	7193	36919	0	0	0	0.0%	0.0%	0.0%
20%	44000	8943	35056	0	0	0	0.0%	0.0%	0.0%
25%	43752	11112	32640	0	0	0	0.0%	0.0%	0.0%
30%	43263	13190	30073	0	3	0	0.0%	0.2%	0.0%
35%	43192	15369	27823	0	0	0	0.0%	0.0%	0.0%
40%	42390	17206	25183	0	4	0	0.0%	0.2%	0.0%
45%	42113	19261	22851	0	5	0	0.0%	0.3%	0.0%
50%	41229	20928	20301	5	9	0	0.0%	0.5%	0.0%
55%	40441	22606	17835	37	27	0	0.1%	1.4%	0.0%
60%	38914	23712	15202	174	50	0	0.3%	2.5%	0.0%
65%	36146	23875	12271	1056	216	5	2.1%	10.8%	0.3%
66%	34986	23469	11517	1587	261	18	3.2%	13.1%	0.9%
67%	34289	23323	10966	2071	349	14	4.1%	17.5%	0.7%
68%	33395	23050	10345	2853	443	35	5.7%	22.2%	1.8%
69%	32755	22949	9806	3664	542	49	7.3%	27.1%	2.5%
70%	31335	22301	9034	4973	670	89	9.9%	33.5%	4.5%
75%	25190	19099	6091	13394	1414	487	26.8%	70.7%	24.4%
80%	20157	16112	4044	22115	1800	1121	44.2%	90.0%	56.1%

Table 19. Skagit summer/fall Chinook modeled recruitments, catches, and escapements that would be projected under different exploitation rates (ER), with Ricker spawner-recruit parameters <u>held constant</u> after each 25-year run, and <u>assuming that the habitat restoration actions described in the Skagit Chinook Recovery Plan are carried out</u>. The highest ER that achieves jeopardy standards is <u>underlined and bolded</u>.

Habitat Restoration Runs: Skagit Spring Chinook w/ Ricker Parameters Held Constant

Years/Run:	25	Runs/ER:	2000		
SR Model:	Ricker	Ecrit:	135	Marine Surv Cycle (yrs):	24
Erecov	1055	ELowObs	470	Starting Offset to cycle:	π/2

Target ER	Mean Recruits	Mean Catch	Mean Esc	# < Ecrit	# End < Erecov	# End Extinct	% < Ecrit	% End < Erecov	% End Extinct
0%	3560	0	3560	17	66	0	0.0%	3.3%	0.0%
5%	3622	181	3441	10	65	0	0.0%	3.3%	0.0%
10%	3674	367	3307	8	49	0	0.0%	2.5%	0.0%
15%	3724	559	3165	6	52	0	0.0%	2.6%	0.0%
20%	3785	758	3028	5	54	0	0.0%	2.7%	0.0%
25%	3818	956	2862	6	37	0	0.0%	1.9%	0.0%
30%	3857	1162	2695	2	35	0	0.0%	1.8%	0.0%
35%	3898	1362	2536	0	45	0	0.0%	2.3%	0.0%
40%	3903	1560	2342	3	59	0	0.0%	3.0%	0.0%
45%	3889	1746	2143	7	62	0	0.0%	3.1%	0.0%
50%	3838	1921	1917	53	95	0	0.1%	4.8%	0.0%
55%	3660	2007	1653	145	181	0	0.3%	9.1%	0.0%
56%	3603	2018	1584	235	209	5	0.5%	10.5%	0.3%
57%	3568	2031	1537	300	239	2	0.6%	12.0%	0.1%
58%	3512	2041	1471	458	284	7	0.9%	14.2%	0.4%
<u>**59%**</u>	3456	2049	1407	637	376	15	1.3%	18.8%	0.8%
60%	3382	2031	1351	820	411	14	1.6%	20.6%	0.7%
65%	2968	1927	1041	3752	891	162	7.5%	44.6%	8.1%
70%	2525	1754	770	8987	1376	500	18.0%	68.8%	25.0%
75%	2188	1601	587	14191	1665	927	28.4%	83.3%	46.4%
80%	1925	1460	465	19151	1837	1282	38.3%	91.9%	64.1%

Table 20. Skagit spring Chinook modeled recruitments, catches, and escapements that would be projected under different exploitation rates (ER), with Beverton-Holt spawner-recruit parameters held constant after each 25-year run, and assuming that the habitat restoration actions described in the Skagit Chinook Recovery Plan are carried out. The highest ER that achieves jeopardy standards is underlined and bolded.

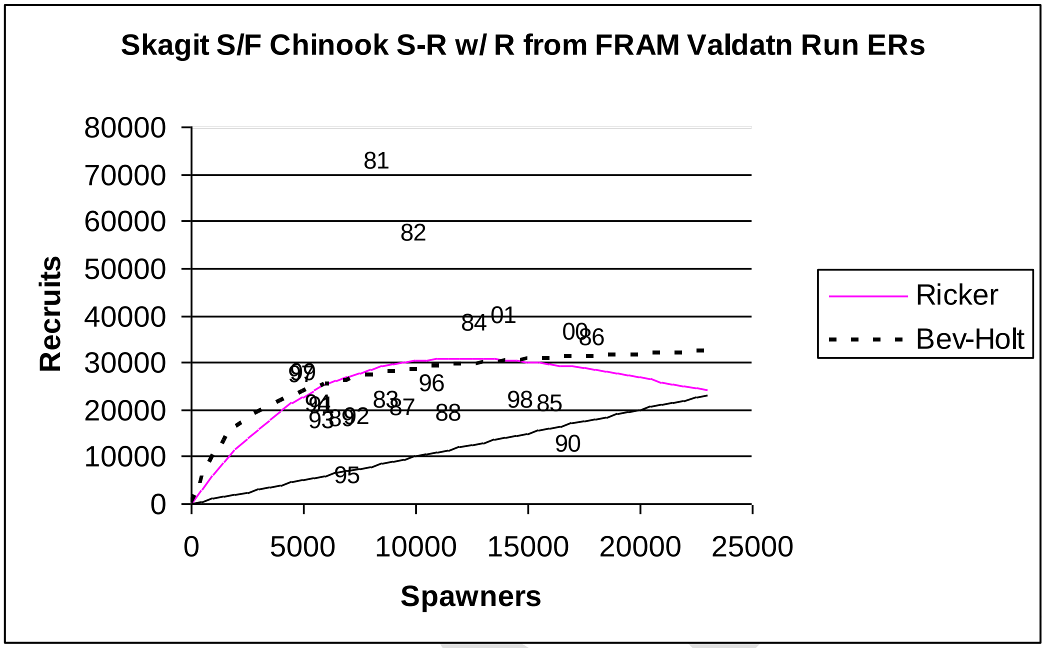
Habitat Restoration Runs: Skagit Spring Chinook w/ Beverton-Holt Parameters Held Constant

Years/Run:	25	Runs/ER:	2000		
SR Model:	Bev-Holt	Ecrit:	150	Marine Surv Cycle (yrs):	24
Erecov	1055	ELowObs	470	Starting Offset to cycle:	π/2

Target ER	Mean Recruits	Mean Catch	Mean Esc	# < Ecrit	# End < Erecov	# End Extinct	% < Ecrit	% End < Erecov	% End Extinct
0%	3985	0	3985	0	5	0	0.0%	0.3%	0.0%
5%	3962	198	3764	0	9	0	0.0%	0.5%	0.0%
10%	3962	396	3566	0	10	0	0.0%	0.5%	0.0%
15%	3942	590	3352	0	10	0	0.0%	0.5%	0.0%
20%	3927	787	3140	0	14	0	0.0%	0.7%	0.0%
25%	3918	983	2936	0	18	0	0.0%	0.9%	0.0%
30%	3885	1166	2719	0	16	0	0.0%	0.8%	0.0%
35%	3862	1353	2509	0	36	0	0.0%	1.8%	0.0%
40%	3835	1533	2302	0	51	0	0.0%	2.6%	0.0%
45%	3789	1709	2080	5	90	0	0.0%	4.5%	0.0%
50%	3729	1862	1867	17	109	0	0.0%	5.5%	0.0%
55%	3655	2011	1644	86	188	0	0.2%	9.4%	0.0%
60%	3485	2085	1399	478	351	4	1.0%	17.6%	0.2%
61%	3431	2094	1337	808	427	14	1.6%	21.4%	0.7%
62%	3409	2119	1290	1000	497	11	2.0%	24.9%	0.6%
63%	3352	2111	1241	1423	564	31	2.8%	28.2%	1.6%
64%	3274	2099	1175	2003	677	60	4.0%	33.9%	3.0%
65%	3194	2080	1114	2722	711	69	5.4%	35.6%	3.5%
70%	2838	1970	868	6822	1140	302	13.6%	57.0%	15.1%
75%	2448	1785	664	12357	1512	682	24.7%	75.6%	34.1%
80%	2191	1670	521	16685	1704	1013	33.4%	85.2%	50.7%

Table 21. Summary of the RERs derived from each type of simulation, for Skagit summer/fall and spring Chinook (from Tables 5 through 20). The rightmost column lists the probability that escapement will exceed E_{recov} at the current RER (50% for Skagit summer/falls, and 38% for Skagit spring Chinook).

	Spawner-Recruit	Spawner-Recruit	Habitat Restoration		P(>E_{recov}) @ Current
Summer/Fall	Ricker	Vary Each Run	Current Habitat	60%	88%
Summer/Fall	Beverton-Holt	Vary Each Run	Current Habitat	62%	95%
Spring	Ricker	Vary Each Run	Current Habitat	48%	88%
Spring	Beverton-Holt	Vary Each Run	Current Habitat	49%	88%
Summer/Fall	Ricker	Constant	Current Habitat	61%	92%
Summer/Fall	Beverton-Holt	Constant	Current Habitat	64%	98%
Spring	Ricker	Constant	Current Habitat	51%	93%
Spring	Beverton-Holt	Constant	Current Habitat	55%	95%
Summer/Fall	Ricker	Vary Each Run	Restored Habitat	67%	95%
Summer/Fall	Beverton-Holt	Vary Each Run	Restored Habitat	65%	97%
Spring	Ricker	Vary Each Run	Restored Habitat	58%	95%
Spring	Beverton-Holt	Vary Each Run	Restored Habitat	57%	93%
Summer/Fall	Ricker	Constant	Restored Habitat	67%	96%
Summer/Fall	Beverton-Holt	Constant	Restored Habitat	67%	99%
Spring	Ricker	Constant	Restored Habitat	59%	97%
Spring	Beverton-Holt	Constant	Restored Habitat	60%	98%



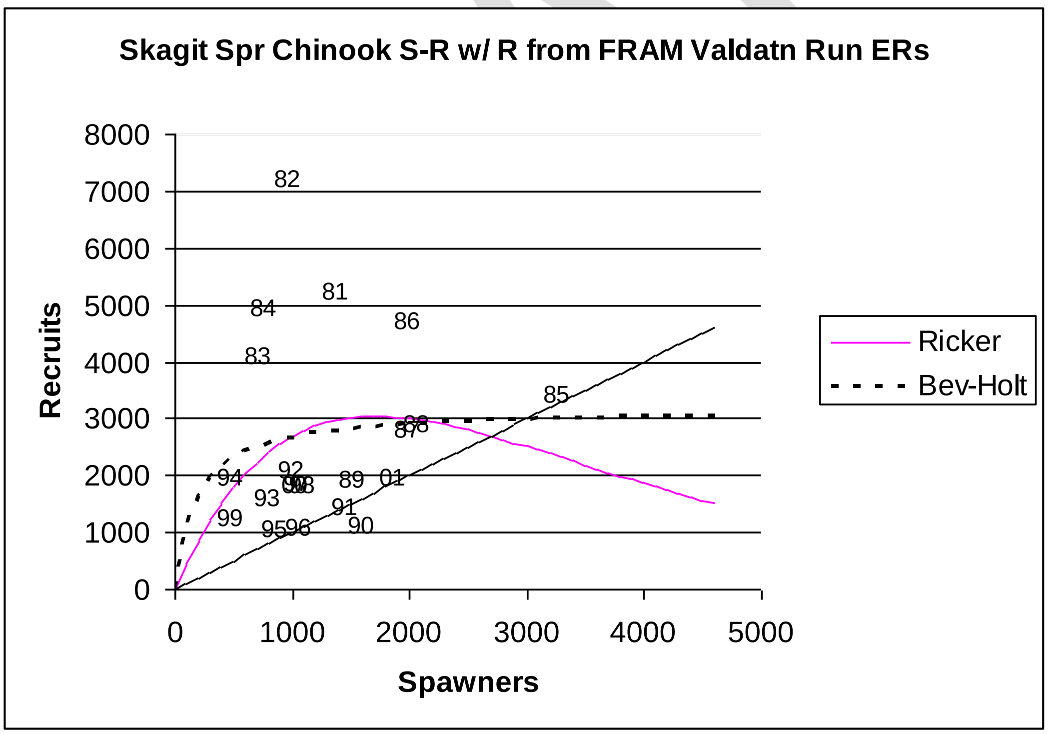


Figure 1. Spawner-recruit curves for Skagit summer/fall Chinook (top) and spring Chinook (bottom). Recruitments were generated by expanding the observed escapements by the exploitation rates calculated from the FRAM validation runs. Two-digit numbers shown are the brood years.

Stillaguamish River Management Unit Status Profile

Component Populations

Stillaguamish summer Chinook
Stillaguamish fall Chinook

Geographic description

The Stillaguamish River management unit includes summer and fall stocks which are distinguished by differences in their spawning distribution, migration and spawning timing, and genetic characteristics. The summer stock, a composite of natural and hatchery-origin supplemental production, spawns in the North Fork, as far upstream as RM 34.4 but primarily between RM 14.3 and 30.0, and in the lower Boulder River and Squire Creek. Spawning also occurs in French, Deer, and Grant creeks, particularly when flows are high. The fall stock, which is not enhanced or supplemented by hatchery production, spawns throughout the South Fork and the mainstem of the Stillaguamish River (WDF et al.1993), and in Jim Creek, Pilchuck Creek, and lower Canyon Creek. Despite the small overlap in spawning distribution, it is likely that the two stocks are genetically distinct.

Allozyme analysis of the summer stock shows it to be most closely related to spring and summer Chinook stocks from North Puget Sound, and the Skagit River summer stocks in particular. The fall stocks align most closely with South Sound MAL, which includes Green River falls and Snohomish River summer and falls.

Life History Traits

Summer run adult enter the river from May through August. Spawning begins in late August, peaks in mid-September, and continues past mid-October. Fall Chinook enter the river much later – in August and September. The peak of spawning of the fall stock occurs in early to mid-October, about three weeks later than the peak for the summer stock. The age composition of mature Stillaguamish River summer Chinook, based on scales collected from 1985 – 1991 was as follows: 4.9% age-2, 31.9% age-3, 54.7% age-4, and 8.5% age-6 (WDF 1993 cited in HGMP). Juvenile summer Chinook produced in the Stillaguamish River primarily (95%) emigrate as sub-yearlings (WDF 1993 cited in HGMP).

Status

WDF et al. (1993) classified both the summer and fall stocks as depressed, due to chronically low escapement. Degraded spawning and rearing habitat currently limit the productivity of Chinook in the Stillaguamish River system (PFMC 1997). After analyzing the trends in spawning escapement through 1996, the PSC Chinook Technical Committee concluded that the stock was not rebuilding toward its escapement objective (CTC 1999).

Aggregate spawning escapement for Stillaguamish summer/fall Chinook has averaged 999 (geometric mean) for the period 2003-2007, down from a mean of 1,429 for 1998-2002. The 15-year trend in total natural escapement to the North Fork is positive, and natural-origin escapement is apparently stable. The trend in escapement to the South Fork is negative, with escapement falling below 200 in three of the last seven years. South Fork escapement is assumed to comprise natural-origin, indigenous Chinook, but the stray rate from the North Fork has not been quantified.

Table 1. Spawning escapement of Stillaguamish summer/fall Chinook, 1986-2008.

	North Fork		South Fk &
Year	NOR	Total	Mainstem
1986	980	980	297
1987	1,065	1,065	256
1988	506	516	201
1989	483	537	274
1990	434	575	267
1991	978	1,331	301
1992	422	486	294
1993	380	583	345
1994	456	667	287
1995	431	599	223
1996	684	993	251
1997	613	930	226
1998	615	1,292	248
1999	514	845	253
2000	884	1,403	243
2001	653	1,066	283
2002	748	1,253	335
2003	401	884	106
2004	701	1,340	169
2005	444	947	89
2006	457	1,035	219
2007	311	569	40
2008	839	554	278

The summer Chinook supplementation program, which collects broodstock from the North Fork return, was initiated in 1986 as a Pacific salmon Treaty indicator stock program, and its current objective is to release 200,000 tagged fingerling smolts per year. Most releases are into the North Fork, via acclimation sites; relatively small numbers of smolts have been released into the South Fork. This supplementation program is considered essential to the recovery of the stock, so these fish are included in the listed ESU. The program contributes substantially to spawning escapement in the North Fork.

As a response to low spawning escapements in the South Fork Stillaguamish River, the Stillaguamish Tribe initiated a program in 2007 to supplement the fall-timed Chinook stock with fry releases from broodstock captured from the South Fork. The intent was to implement a strategy similar to the one successfully employed on the North Fork. While broodstock collection on the North Fork is dependent on concentrations of adult Chinook in pre-spawning holding areas, such areas do not exist on the South Fork. The limited spawning population means that concentrations of adult fish may be defined as only 5 or 6. Broodstock collection efforts are further hindered due to lack of visibility resulting from high turbidities typical of the South Fork in the fall. And while North Fork broodstock collections occur prior to pink salmon arrival in odd years, South Fork activities directly overlaps the pink run. From a practical perspective, South Fork broodstock collection needs to be delayed until the majority of the pink salmon run has cleared. In 2007 & 2008 the program captured non-Stillaguamish Chinook, or single males, or single females, but to date no Stillaguamish-origin breeding pairs have been collected.

Other actions are being undertaken to collect Chinook for the South Fork program, including:

- Investigation of potential fall Chinook holding in deeper/cooler pools in the mainstem and the North Fork, where they could be captured, and screened using DNA analysis to determine their origin and suitability for the program

- Beach seine collection of outmigrants for use in a captive brood program similar to the program used on the Nooksack. There are currently 20 juvenile Chinook that were collected early in 2009 behind held at the Harvey Creek Hatchery.

- An adult trap has been installed at the Army Corps of Engineers flow augmentation dam downstream of I-5 on the mainstem Stillaguamish. The trap began fishing in August 2009, and has been very successful in the capture of coho and pink salmon. The mortality of capture and transfer to the hatchery are being evaluated using coho salmon.

Harvest distribution

Recoveries of coded-wire tagged North Fork Stillaguamish summer Chinook have provided an accurate description of harvest distribution in the past, although recent estimates are not available due because releases were not adipose clipped for several years, precluding their recovery in fisheries that were not electronically sampled. Northern fisheries in Alaska and British Columbia accounted 68 percent of total harvest mortality (Table 2). Washington ocean fisheries accounted for less than 1 percent. Washington sport fisheries accounted for 29 percent of total fisheries mortality.

Table 2. Average distribution of fishery mortality of Stillaguamish River fall Chinook, expressed as the proportion of fishery mortality, 2000-2006 (CTC 2008).

Year	AK%	CN%	US tr %	US net%	US spt %
1996	2.0%	47.6%	0.0%	0.4%	50.0%
1997	20.5%	40.6%	0.0%	3.7%	35.2%
1998	48.9%	31.4%	0.0%	7.4%	12.2%
1999	27.8%	58.1%	0.0%	1.1%	13.0%
2000	27.5%	55.4%	2.7%	0.5%	14.0%
2001	5.6%	43.9%	0.9%	3.8%	45.9%
2006	10.6%	56.6%	3.4%	9.8%	19.6%
Average	20.4%	46.2%	0.6%	2.8%	28.4%

Exploitation rate trends

Post-season FRAM runs, incorporating actual catch in all fisheries and actual abundance, indicate that total fishery-related, adult equivalent, exploitation rates for Stillaguamish Chinook have fallen from an average of 55% for 1983 – 1997, to an average of 23% from 2000-2008 (Figure 1). Southern U.S. rates have fallen even more dramatically, decreasing from an average of 40% in the 1980's, to less than 12% since 2001.

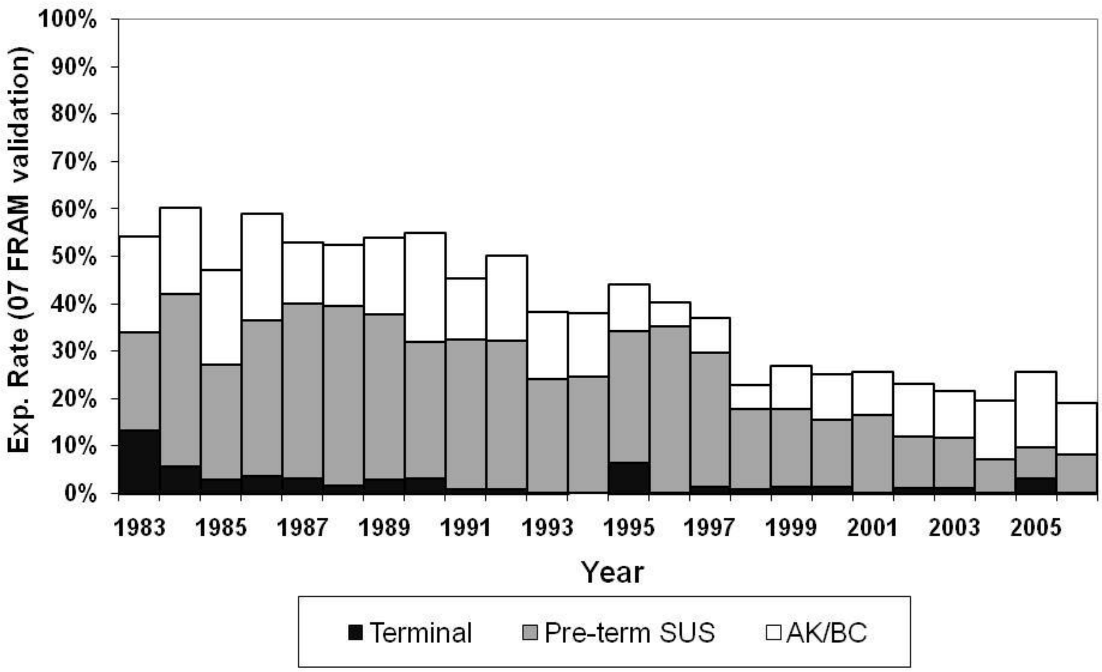


Figure 1. Adult equivalent fishery exploitation rates of Stillaguamish Chinook in Alaska/BC, preterminal Southern United States, and terminal fisheries from 1983-2006, as estimated by post-season FRAM runs.

Management Objectives

The management guidelines for Stillaguamish Chinook include an exploitation rate objective and a low abundance escapement threshold. The exploitation rate objective is the maximum fraction of the production from any brood year that is allowed to be removed by all sources of fishery-related mortality, including direct take, incidental take, and non-landed mortality. The exploitation rate is expressed as an adult equivalent rate, in which the mortality of immature Chinook is discounted relative to their potential survival to maturity.

Analysis specific to Stillaguamish summer Chinook was completed to develop the exploitation rate objective to reflect, to the extent possible, the current productivity of the stock. Brood year recruitment (i.e., number of recruits per spawner) was estimated, for brood years 1986 through 1993, by reconstructing the total abundance of natural origin Chinook that were harvested or otherwise killed by fisheries, or escaped to spawn. The resulting brood year recruitment rates were partitioned into freshwater and marine survival rates. The future abundance (i.e. catch and escapement) of the stock was simulated for 25 years, using a simple population dynamics model, under total fishery exploitation rates that ranged from 5 percent to 60 percent. In the model, production from each year's escapement was subjected to randomly selected levels of freshwater and marine survival, and randomly selected levels of management error. Each model run (i.e. for each level of exploitation rate) was replicated one thousand times, and the set of projected population abundances analyzed to determine the probability of achieving the management objectives. The simulation for Stillaguamish summer Chinook, across a range of exploitation rates (Table 3), indicated that total exploitation rates below 0.35 met the recovery criteria.

The fishery management objective for the 2000 management year was to realize an exploitation rate that, if imposed consistently over a future time interval

- would not increase the probability that the stock abundance would fall below the critical escapement threshold, after 25 years, by more than five percentage points higher than were no fishing mortality to occur; and

- would result in at least an 80 percent of greater probability of the stock recovering (i.e. escapement exceeding the current level) after 25 years.

Stock recovery, for this analysis, was defined as the average spawning escapement for the final three years in the simulation period exceeding the average for the first three years in the simulation period (Rawson 2000).

Table 3. Summary of results of 1,000 runs of the simulation model at each exploitation rate.

Exploitation	Probability of	Probability	Median	Median
0.00	1%	96%	2.75	3,597
0.05	1%	96%	2.81	3,377
0.10	1%	96%	2.76	3,165
0.15	2%	95%	2.66	2,964
0.20	2%	95%	2.56	2,758
0.25	3%	93%	2.57	2,418
0.30	4%	92%	2.48	2,210
0.35	6%	92%	2.46	1,920
0.40	7%	91%	2.29	1,686
0.45	11%	87%	2.14	1,444
0.50	17%	80%	1.92	1,180
0.60	41%	52%	1.04	648
0.70	73%	12%	0.27	259
0.80	94%	0%	0.02	55

At the present time, there is very little information concerning the productivity of the Stillaguamish fall stock other than the fact that the average abundance of this stock has been approximately 50% of the Stillaguamish summer stock based on relative escapement. Incorporating this lower estimate of abundance, and assuming the same productivity (i.e. recruitment rates), the simulation model predicted that exploitation rates below 35% met the first management objective. The probability of rebuilding at this exploitation rate was 96%. This analysis indicates that a target exploitation rate of 0.35 would also be appropriate for the Stillaguamish fall stock.

The Washington co-managers have set an exploitation rate guideline of 0.25, as estimated by the FRAM simulation model, for the Stillaguamish Chinook management unit. According to the simulation model this level of exploitation results in a 4 percent risk of the stocks falling below the critical escapement threshold of 500, and affords a 92 percent probability of recovery (i.e., that spawning escapement will exceed the current average level).

The low abundance threshold for North Fork Stillaguamish Chinook is 500 natural-origin spawners. Reconstruction of the total brood abundance of adult Stillaguamish Chinook suggests that escapements of 500 (+/- 50) can result in recruitment rates ranging from two to five adults per spawner (Rawson 2000). The genetic integrity of the stock may be at risk and depensatory mortality factors may affect the stock when annual escapement falls below this threshold to 200 (NMFS BO 2000). The critical threshold for South Fork Stillaguamish Chinook is undetermined pending further analysis of data. The low abundance threshold for the Stillaguamish management unit is based on the 1996-2002 average fraction of the natural escapement for the years 1996-2002 that was in the North Fork. This average was .813 (range: .770 - .852). Thus a management unit escapement of

500/.813 = 615 would, on average, include 500 North Fork fish. The range of management unit escapement thresholds computed this way is 586 to 649. Based on this, we have selected a low abundance threshold of 650 for the Stillaguamish management unit. Whenever spawning escapement is projected to be below this level, fisheries will be managed to either achieve the critical exploitation rate ceiling, or exceed the low abundance threshold.

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:

- Spawning escapement estimates that include variance for summer and fall stocks
- Estimates of natural-origin smolt production (freshwater survival to the estuary)

Snohomish River Management Unit Status Profile

Component Populations

The stock structure of summer/fall Chinook in the Snohomish basin is based on the report of the Puget Sound TRT (Ruckelshaus et al. 2006) suggesting that there are two populations of summer/fall Chinook in the Snohomish basin. The comanagers have reviewed this report along with additional information, and have concluded that the former four-stock structure of Snohomish Chinook (WDF et al. 1993) should be revised to conform to the TRT's population structure.

Summer/fall Chinook management unit

Skykomish
Snoqualmie

Geographic description

Skykomish Chinook spawn in the mainstem of the Skykomish River, and its tributaries including the Wallace and Sultan Rivers, in Bridal Veil Creek, the South Fork of the Skykomish between RM 49.6 and RM 51.1 and above Sunset Falls (fish have been transported around the falls since 1958), and the North Fork 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 (Snohomish Basin Salmonid Recovery Technical Committee (SBSRTC) 1999). There is some indication that spawning in the North Fork has declined over the last twenty years (Snohomish Basin Salmonid Recovery Technical Committee (SBSRTC) 1999). Fish spawning in Snohomish mainstem and the Pilchuck River are currently considered to be part of the Skykomish stock pending further collection and analysis of genetic stock identification data.

Snoqualmie Chinook spawn in the Snoqualmie River and its tributaries, including the Tolt River, Raging River, and Tokul Creek.

There is some uncertainty whether a spring Chinook stock once existed in the Snohomish system. Suitable habitat may still exist in the upper North Fork, above Bear Creek Falls.

Life History Traits

Summer Chinook enter freshwater from May through July, and spawn, primarily, in September, while fall Chinook spawn from late September through October. However, fall Chinook spawning in the Snoqualmie River continues through November. The peak of spawning in Bridal Veil creek is in 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 (WDF et al. 1993).

The age composition of returning Snoqualmie River fall Chinook showed a relatively strong age-5 component (28 percent), relative to other Puget Sound fall stocks. Age-3 and age-4 fish comprised 20 and 46 percent, respectively, of returns in 1993 – 1994 (Myers et al. 1998).

Most Snohomish summer and fall Chinook smolts emigrate as subyearlings, but, based on scale data, an annually variable, but relatively large, proportion of smolts are yearlings. Of the summer Chinook smolts sampled in 1993 and 1994, 33 percent were yearlings (Myers et al. 1998). Based on scale data, 25 to 30 percent of returning fall Chinook also showed a stream-type life history (Snohomish Basin Salmonid Recovery Technical Committee (SBSRTC) 1999). No other summer or fall Chinook stocks in Puget Sound produce this high a proportion of yearling smolts. Rearing habitat to support yearling smolt life history is vitally important to the recovery of these stocks.

Management Unit / Stock Status

Total natural spawning escapement of Snohomish summer/fall stocks has ranged between 2,700 and 10,600 since 1990 (Table 1). Escapement has shown a positive trend, averaging 4,080 through the 1990’s, and increasing to an average of 6,956 since 2000.

Table 1. Natural escapement to the Snohomish basin, 1990-2008.

Year	Skykomish	Snohomish	Total	Natural origin
1990	2,932	1,277	4,209	
1991	2,192	628	2,820	
1992	2,002	706	2,708	2,242
1993	1,653	2,366	4,019	3,190
1994	2,898	728	3,626	2,039
1995	2,791	385	3,176	1,252
1996	3,819	1,032	4,851	2,379
1997	2,355	1,937	4,292	3,516
1998	4,412	1,892	6,304	2,919
1999	3,455	1,344	4,799	2,430
2000	4,665	1,427	6,092	3,227
2001	4,575	3,589	8,164	4,762
2002	4,325	2,895	7,220	4,255
2003	3,474	1,972	5,446	
2004	7,616	2,990	10,606	7,909
2005	3,203	1,281	4,484	
2006	5,693	2,612	8,305	6,896
2007	2,295	1,687	3,982	2,684
2008	5,745	2,560	8,308	6,970

A portion of the natural-spawning fish are the survivors of releases from the Wallace River and Bernie Kai-Kai Gobin (Tulalip) facilities. Since 1997 it has been possible to estimate the natural origin portion of the natural escapement because all Chinook production at the Bernie Kai-Kai

Gobin and Wallace River hatcheries has been thermally or adipose mass-marked, and there has been comprehensive sampling of adult Chinook in natural spawning areas. In most years the natural origin component of the natural escapement is significantly smaller than the total natural escapement estimate, although in many recent years the natural origin portion alone of the natural escapement has been higher than the total natural escapement between 1980 and 1999 (Table 1 and state/tribal Chinook escapement database).

Harvest distribution and exploitation rate trends:

Assessment of exploitation rate trends for Snohomish summer/fall Chinook is difficult because there has been no coded-wire tagged indicator stock representing the management unit. Post-season runs of the FRAM model show a clearly declining trend in annual fishing year exploitation rate from 1983-2000, and fairly stable rates since 2000 (Figure 1, Table 2). These validation runs use the same projection model used in preseason planning, but use post-season estimates of spawning escapement and fishery harvest and non-catch mortality instead of preseason abundance and fishing level predictions. Thus, these runs adjust for observed abundances and fishing levels, but they assume the stock composition of fisheries is the same as the base period stock composition used in the FRAM model.

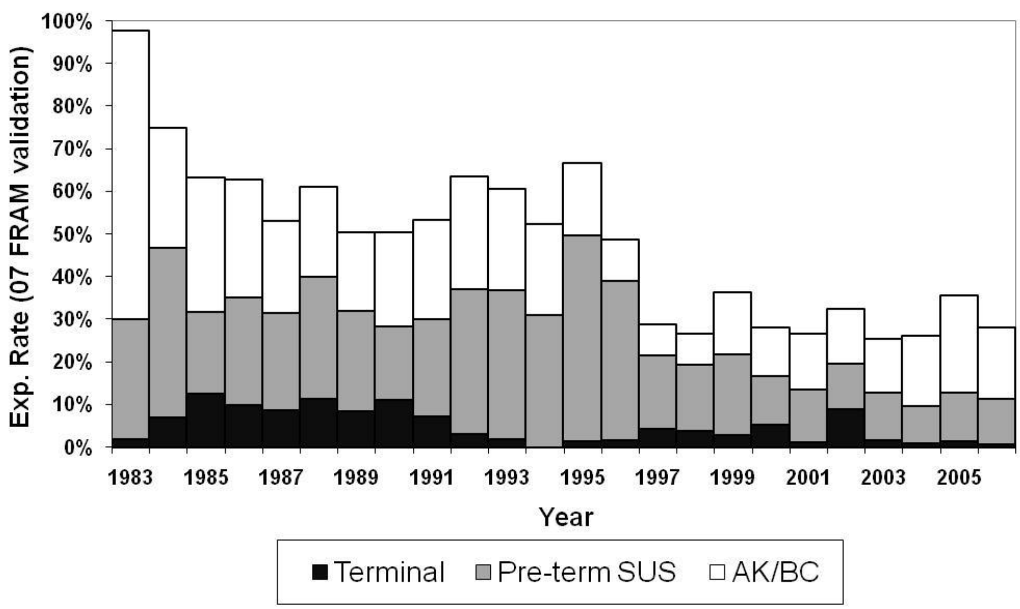


Figure 1. Adult equivalent fishery exploitation rates of Snohomish Chinook in Alaska/BC, preterminal Southern United States, and terminal fisheries from 1983-2006, as estimated by post-season FRAM runs.

Post-season FRAM (validation) estimates of the total ER for Snohomish Chinook have been higher than pre-season estimates in six of eight years since 2001, with an average over-prediction of 3%. This difference is largely because post-season rates for northern fisheries (AK/BC) have been, on average higher, than the pre-season estimates. Pre-season projections of the SUS fishery ER have, on average, been similar to post-season estimates. The SUS ER was lower than the CERC of 15% in all years under the previous plan (2004-2006).

Table 2. Adult equivalent (AEQ) exploitation rates (ER) by fishing year for the Snohomish summer/fall Chinook management unit from post-season runs of the FRAM model for 1983-2006 (2009 revision of FRAM validation runs) and from pre-season FRAM model predictions for 1999-2006.

	Post-season			Pre-season		
Year	Alaska/BC	SUS	Total	Alaska/BC	SUS	Total
1983	28%	45%	73%			
1984	32%	45%	78%			
1985	29%	35%	64%			
1986	27%	36%	63%			
1987	21%	31%	52%			
1988	20%	40%	60%			
1989	19%	32%	51%			
1990	20%	29%	49%			
1991	25%	29%	54%			
1992	25%	38%	62%			
1993	25%	40%	65%			
1994	20%	33%	53%			
1995	15%	54%	70%			
1996	10%	39%	49%			
1997	7%	22%	29%			39%
1998	7%	21%	28%			47%
1999	17%	24%	41%			33%
2000	12%	17%	29%			26%
2001	13%	17%	30%	8%	15%	23%
2002	13%	20%	33%	5%	14%	19%
2003	13%	13%	26%	6%	14%	20%
2004	16%	9%	25%	16%	13%	29%
2005	24%	12%	36%	18%	15%	33%
2006	16%	11%	27%	18%	15%	33%

Table 3. Brood year exploitation rates reported in the Puget Sound Technical Recovery Team's Abundance and Productivity tables for the Skykomish and Snoqualmie Chinook populations.

Brood Year	Skykomish	Snoqualmie
1980	86%	86%
1981	88%	87%
1982	84%	77%
1983	68%	67%
1984	82%	83%
1985	75%	74%
1986	76%	74%
1987	70%	69%
1988	76%	78%
1989	74%	75%
1990	67%	59%
1991	54%	39%
1992	56%	61%
1993	61%	64%
1994	54%	54%
1995	46%	38%
1996	51%	44%
1997	46%	43%
1998	48%	46%

Management Objectives

Management objectives for Snohomish summer/fall Chinook 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, associated with all salmon fisheries, not to exceed 24 percent. These impacts include all mortalities related to fisheries, including direct take, incidental take, release mortality, and drop-off mortality.

Lacking direct information on the extent to which the current fisheries regime may disproportionately harvest any single stock, 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[1] 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.

LOW ABUNDANCE THRESHOLD FOR MANAGEMENT

A low abundance threshold of 2,800 spawners (natural origin, naturally spawning fish) for the Snohomish management unit is established (see estimation procedure below) 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 for each of the Snoqualmie, and Skykomish populations in a two-step process. Critical escapement thresholds are levels that we don't 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:

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

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

$E_{crit,p}$ is the critical threshold for population ***p;***

$R/S_{low,p}$ is the average of recruits/spawner for population ***p*** under low survival conditions; and

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

The following describes the $\boldsymbol{E_{man,p}}$ for the Snoqualmie and Skykomish stocks within the Snohomish management unit. The following analysis is based on estimates of natural spawning escapement to the Snohomish system, by population, for the most recent twelve years (Table 1) .

[1] A primary management unit is one for which fisheries are directly managed to achieve a particular escapement goal or exploitation rate.

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 threshhold[2] (CT) and likely to grow to or above a rebuilding escapement threshold (RET). The CT is chosen as the smallest previously-observed escapement from which there was a greater than 1:1 return per spawner, while 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 (MSH escapement does not increase in the Hockey stick model if productivity and capacity increase together as in eq. 5) 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.

[2] Note that, there are other provisions of this plan that call for further reduction of the exploitation rate ceiling should the abundance be observed or expected to be near the lower threshold. This will provide additional protection against falling below the lower threshold that is not considered in this section, which address only the conditions under which the RER would apply.

There are two phases to the process of determining an RER for a population. The first, or model fitting phase, involves using recent data from the target population itself, or a representative indicator population, to fit a spawner-recruit relationship representing the performance of the population under current conditions. Population performance is modeled as

$$R = f(S, \mathbf{e}),$$

where S is the number of fish spawning in a single return year, R is the number of adult equivalent recruits[3], and **e** is a vector of environmental, density-independent correlates of annual survival. The purpose of this phase is to be able to predict the recruits from spawners and environmental covariates into the future. What is important here is to simulate a pattern of returns into the future, not predict returns for specific years.

Several data sources are necessary for this analysis: a time series of natural spawning escapement, a time series of total recruitment (obtained from run reconstruction based on harvest and escapement data), age distributions for both of these, and time series for the environmental correlates of survival. In addition, one must assume a functional form for f, the spawner-recruit relationship; in our case three different forms were examined. Given the data, one can numerically estimate the parameters of the assumed spawner-recruit relationship to complete the model fitting phase.

The second, or projection phase, of the analysis involves using the fitted model in a Monte Carlo simulation to predict the probability distribution of the near-term future performance of the population assuming that current conditions of productivity continue. Besides the fitted values of the parameters of the spawner-recruit relationships, one needs estimates of the probability distributions of the variables driving the population dynamics, including the process error (including first order autocorrelation) of the spawner-recruit relationship itself and each of the environmental correlates. Also, since fishing-related mortality is modeled in the projection phase, one must estimate the distribution of the deviation of actual fishing-related mortality from the intended ceiling. This is termed “management error” and its distribution, as well as the others are estimated from available recent data.

We used the viability and risk assessment procedure (VRAP, N J Sands, in prep.) for the projection phase. For each trial RER value, the population is repeatedly projected for 25 years. From the simulation results we computed the fraction of years in all runs where the escapement is less than the LAT and the fraction of runs for which the final year’s escapement (average of last 3 years) is greater than the UAT. Trial RERs for which the first fraction is less than 5% and the second fraction

[3] Equivalently, this could be termed “potential spawners” because it represents the number of fish that would return to spawn absent harvest-related mortality.

is greater than 80% are considered acceptable for use as ceiling exploitation rates for management under this plan.

MODEL FITTING PHASE

General

The model used to estimate the spawner recruit parameters uses fishing rate and maturation rate estimates along with the spawning estimates to determine the time series of total recruitment needed.

Preterminal Fishery Rates

Fishery rates were based on an aggregate of Puget Sound summer/fall Chinook hatchery indicator stock populations (Stillaguamish, Green, Grovers, George Adams, Nisqually, Samish). Although a new indicator stock tagging program has been implemented to represent Skykomish wild Chinook, there is currently no coded-wire-tag (CWT) recovery data available that is directly representative of the Snohomish populations and no direct measure of fishery exploitation on the wild populations. We evaluated two options for estimating fishery rates on the Snohomish populations: 1) an aggregate of Puget Sound summer/fall Chinook hatchery coded-wire-tag (CWT) indicator stocks using the Pacific Salmon Commission Chinook Technical Committee (CTC) exploitation rate indicator stock analysis (CTC 1999 for method, Dell Simmons pers. Comm. for most recent data); and 2) estimates from the CTC Chinook model (CTC 1999).

Option 1 relies on CWT recoveries from individual years to reconstruct the fishery rates for that year, but is dependent on a consistently high rate of catch and escapement sampling to make precise estimates. After further evaluation, we determined that catch and escapement sampling for most of the populations within the aggregate meet or exceed their target sampling rates in most years. Snohomish populations may not have the same distribution as the populations within the aggregate. Puget Sound summer/fall Chinook populations show some similarity in the general trend over time of exploitation in preterminal fisheries. Although it is logical to assume that Snohomish summer/fall populations follow a similar trend with respect to the change over time in the rate of preterminal exploitation, concern remains that the aggregate Puget Sound indicator stocks may not accurately reflect the true exploitation rates of Snohomish populations. Also, the indicator stocks that comprise the aggregate are not likely to represent harvest patterns of yearling outmigrant or “stream type” (Healey 1991). Scale pattern analysis of Snohomish Chinook shows that a significant portion of the return is stream type from both fingerling and yearling populations.

Under Option 2, the CTC model uses CWT recoveries from the Stillaguamish indicator stock during the 1979-1982 base period to estimate fishery exploitation on the Snohomish population in subsequent years so estimates are less subject to year-year variability in sampling rates. The CTC model appears to best reflect the pattern of reduced overall exploitation they expected to see in the early 1990's in response to more restrictive fishing regimes. Again, it is possible that the distribution and exploitation of the Stillaguamish and Snohomish populations are different.

We chose Option 1 because we determined that, for the purposes of deriving an RER, year specific fishery rates would be better than estimates derived from a base period based on a limited number of Stillaguamish CWT recoveries. Option 1, by using an aggregate set of populations, maximizes the use of the available data and smoothes differences in any one year associated with a particular population. Also, we were able to address most of the concerns we had with Option 1. In addition, Therefore, the aggregate was used as a surrogate to represent the Snohomish populations in preterminal fisheries. Fishery rates were derived from the CTC CWT exploitation rate analysis for each population in the aggregate and averaged across all populations for each year for which data were available.

The average CTC CWT exploitation rate analysis for fall indicator stocks by age was used for brood year 1979 to 1994, ages 2-4 for brood year 1995 and ages 2-3 for brood year 1996. The 1995 age 5+ fishery rate was based on an average of the 1993-94 rates. The 1996 ages 4-5+ were based on an average of the 1994-1995 rates because the current CTC CWT exploitation rate analysis is not complete for these ages for these brood years. However, available data for ages 2 and 3 indicate fishery rates were similar in 1994-1996. Fishery rates will continue to be updated as data become available.

Terminal Fishery Rates

Terminal area fisheries include mature Chinook harvested in net fisheries throughout Puget Sound and in recreational fisheries in the Snohomish River system and Area 8D. The in-river recreational fishery harvest is partitioned into natural and hatchery-produced components based on the relative magnitudes of the escapement to natural areas and to the Wallace River Hatchery.

The stock composition of the Area 8D recreational and net harvest is estimated using results of recoveries of thermally-marked otoliths from Tulalip hatchery. The otolith recoveries are used to estimate the Tulalip hatchery contribution to this fishery for the brood years from 1997 on (Rawson et al. 2001), which is subtracted from the total catch. The remaining catch is partitioned into components based upon the relative run strengths of the Stillaguamish and Snohomish Chinook returns to their rivers. In particular, the Snohomish natural fraction is estimated as the Snohomish natural escapement plus the Snohomish natural portion of the in-river recreational harvest divided by the sum of the escapements to the Stillaguamish and Snohomish Rivers and the in-river harvests of Chinook in those rivers. For years before 1997 the procedure is the same, except that the proportional contribution of Tulalip hatchery fish to Area 8D is assumed to be the average of the values measured for 1997-2001.

The stock composition of the Area 8A net harvest is estimated using the relative proportions of all the Stillaguamish/Snohomish stocks passing through Area 8A. Only Chinook harvested during the so-called “adult accounting period” of July1 through September 30 are included in this analysis. Other Chinook harvested in Area 8A are part of the preterminal fishing rate. In particular, the Snohomish natural fraction is the sum of the Snohomish natural escapement, the Snohomish natural fraction of the in-river harvest, and the Snohomish natural fraction of the 8D harvest, divided by the sum of the total escapement and harvest in both rivers plus the Area 8D harvest and escapement to Tulalip hatchery.

To the three harvest components computed above (in-river, 8D, and 8A) the harvest of mature Snohomish natural Chinook in Puget Sound net fisheries outside of Area 8A must be added. This computation was completed using coded-wire tag recoveries by Jim Scott and Dell Simmons of the CTC. The terminal, or mature fishery, fishing rate is then the sum of the harvest in the four components divided by the numerator plus the Snohomish natural escapement.

Maturation Rates

We also considered two options for the maturation rates (the fraction of each cohort that leaves the ocean to return to spawn during the year): 1) maturation rates derived from age data collected from scales and otoliths from the spawning grounds combined with the age-specific fishing rates described above; 2) estimates derived from the CTC model for the Snohomish model population. In general, fish matured at older ages under option 1 than option 2, and no fish matured as two year olds. We decided to use option 1 because it is a more direct measure of the age structure of the spawners and relies on age specific data for the populations.

However, we identified two potential concerns that should be taken into account when using the data: 1) age 2 fish are generally underrepresented in spawning ground samples for several reasons: e.g., carcasses decay faster, the smaller body size makes them more susceptible to being washed downstream, they are less visible to samplers; and 2) only one year, 1989, had a sufficient number of samples to use. The age structure for other years was extrapolated from 1989 by using the 1989 age composition to reconstruct brood year and calendar year escapements by age. The age structure is then adjusted to minimize the difference between the estimated calendar year escapements and the observed calendar year escapements for each year for which data are not available.

Hatchery Effectiveness

No adjustments were made for the relative fecundity of naturally-spawning hatchery-produced fish as compared with natural-origin fish, since there is no available data for the effectiveness of hatchery spawners in the wild when compared with their natural origin counterparts for Puget Sound Chinook. For the RER analysis, we assumed all spawners were equally fecund regardless of their origin. This is a conservative assumption since it would tend to underestimate productivity (assuming hatchery fish are less effective) and, therefore, the resulting RER, minimizing the possibility of adopting a harvest objective that was too high (Table 4.)

Table 4. Intrinsic Productivity (MSY Exploitation Rate) by Production Function for the Skykomish Chinook population.

Hatchery Effectiveness	Ricker	Beverton-Holt	Hockey Stick
Not Effective	7.58 (49%)	14.14 (65%)	8.07 (77%)
Half as Effective	6.26 (52%)	8.34 (65%)	4.55 (63%)
Equal Effectiveness	5.49 (47%)	6.51 (53%)	3.66 (51%)

Spawner-recruit Models

The data were fitted using three different models for the spawner recruit relationship: the Ricker (Ricker 1975), Beverton-Holt (Ricker 1975), and hockey stick (Barrowman and Myers 2000). The simple forms of these models were augmented by the inclusion of environmental variables correlated with brood year survival. For marine survival we used an index based on the common signal from a several Chinook coded-wire tag groups released from Puget Sound hatcheries (J Scott, Washington Department of Fish and Wildlife, personal communication). We tried two indices: one (PS6) used tag groups from throughout Puget Sound; the other (NPS2) used coded wire tags from North Puget Sound hatcheries only. The other environmental correlate, associated with survival during the period of freshwater residency, was the September-March peak daily mean stream flow during the fall and winter of spawning and incubation.

Equations for the three models are as follows:

$(\mathbf{R} = \mathbf{aS}e^{-\mathbf{bS}})(\mathbf{M}^{\mathbf{c}}e^{\mathbf{dF}})$ [Ricker]

$(\mathbf{R} = \mathbf{S}/[\mathbf{bS} + \mathbf{a}])(\mathbf{M}^{\mathbf{c}}e^{\mathbf{dF}})$ [Beverton-Holt]

$(\mathbf{R} = min[\mathbf{aS},\mathbf{b}])(\mathbf{M}^{\mathbf{c}}e^{\mathbf{dF}})$ [hockey stick]

In the above, a is the density independent parameter, b is the density dependent parameter, c is the parameter for marine survival, d is the parameter for the freshwater covariate, M is the index of marine survival, and F is the freshwater correlate, peak Sep-Mar mean daily flow in this case.

Data used for the Skykomish Population

The Skykomish RER was based on analyses of the 1979-1996 brood years. Uncertainty about accuracy of escapement data and completeness of catch data precluded use of data before 1979. The 1996 brood year was the last year for which data were available to conduct a complete cohort reconstruction. There was no evidence of depensation or of a time trend in the data after adjustment for environmental variables.

Results

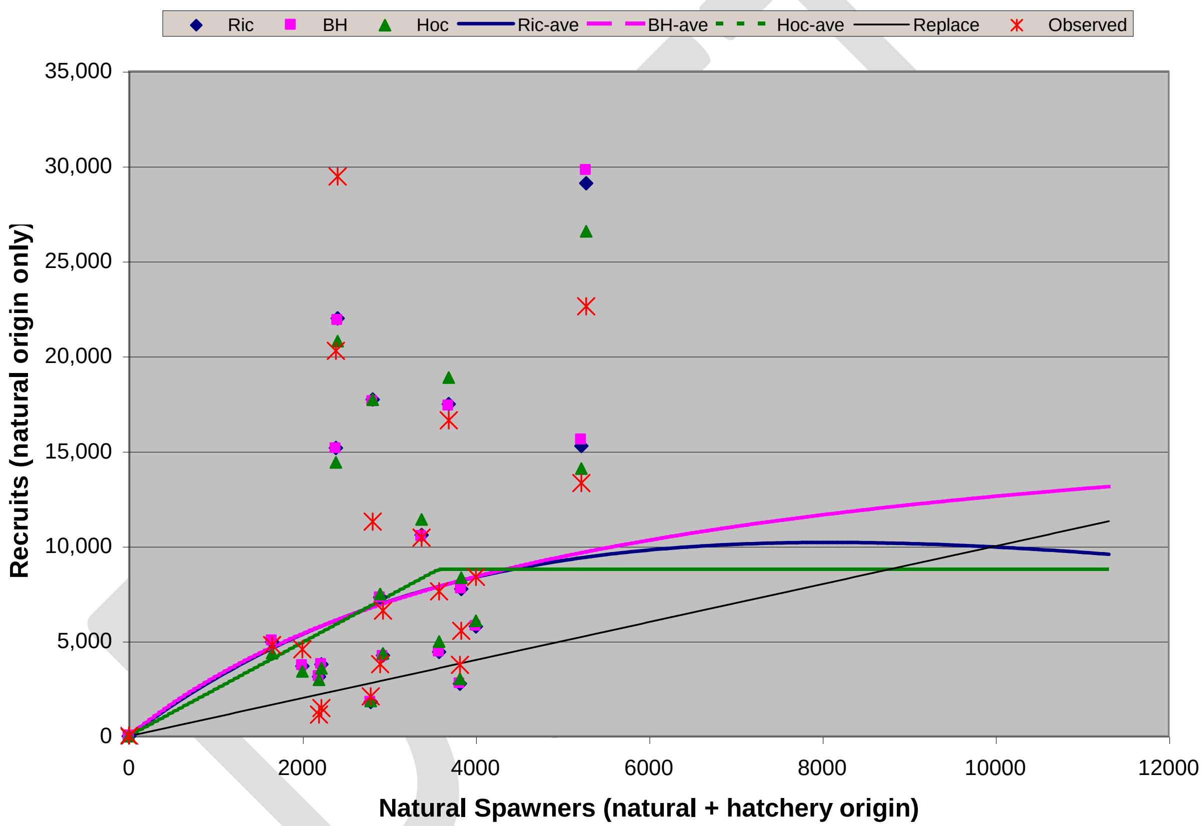


Figure 1. Comparison of observed and predicted recruitment numbers for the Skykomish Chinook population, brood years 1979 – 1996, under three different models of the spawner-recruit relationship (see text for further details).

The results of model fitting for various combinations of environmental correlates are summarized in Table 7 and graphed in Figure 1. We used the parameters from the fits using the NPS2 marine survival index and using both the marine and freshwater environmental correlates (upper right corner of Table 7).

PROJECTION PHASE

We projected the performance of the Skykomish stock at exploitation rates in the range of 0 to .30 at intervals of .01 using the fitted values of a, b, c, and d for the three spawner-recruit models. All projections were made assuming low marine survival using the average and variance of the marine survival indices observed for the most recent 10-year period. The freshwater environmental correlate (peak winter flow) was projected using the average and variance observed for the entire period used in the model fitting phase. Projections were run for target exploitation rates varying from 0 to .50, in increments of .01. The lower abundance threshold (LAT) was 1,745, derived as described above. The upper abundance threshold was the MSH escapement level (also described above). This biological reference point varies with the assumed marine survival and also with the particular form of the spawner-recruit relationship. We used the average marine survival index for the low marine survival period to obtain the RET for each spawner-recruit function. These values were: 3,500 – Ricker, 3,600 – Beverton-Holt, and 3,600 – hockey stick.

For each combination of spawner-recruit relationship and exploitation rate we ran 1000 25-year projections. Estimated probabilities of exceeding the RET were based on the number of simulations for which the final spawning escapement exceeded the RET. Estimated probabilities of falling below the LAT were based on the number of years (out of the total of 25,000 individual years projected for each combination) that the spawning escapement fell below the LAT. For each spawner-recruit relationship the sequence of Monte Carlo projection running through the exploitation rate range from 0 to .30 started with the same random number seed so that the results for the different spawner-recruit models would be comparable.

Detailed results of these projections are in Table 8, and summarized results are in Table 5. Indicated target exploitation rates are 0.25 – Ricker, 0.27 – Beverton-Holt, and 0.22 – hockey stick. Since there is no basis to choose one of these models over the other, we propose to use the average of these values as the target exploitation rate. This average is 0.24, rounding down to the nearest whole percentage exploitation rate.

Table 5. Results of the VRAP projections of the Skykomish Chinook stock under current conditions showing the indicated target exploitation rate for each form of the spawner-recruit relationship.

Model	TgtER	#fish Mort.	%runs extnct	%yrs <LEL	%runs end>UEL	1st Year	LastYrs Ave.
Ricker	0.25	1671	0	4.0	80.0	2123	5711
Bev-Holt	0.27	1889	0	4.5	80.3	2084	6149
H-Stick	0.22	1427	0	3.0	81.3	2172	5747

MANAGEMENT UNIT REBUILDING EXPLOITATION RATE AND LOWER ESCAPEMENT THRESHHOLDS

The management unit maximum exploitation rate was set at 0.24, which is the average of the maximum allowable rates computed for the Skykomish stock using the three different spawner-recruit relationships. This is assumed to provide the appropriate protection to both populations. It was not possible to obtain a fit of the Snoqualmie data to any of the spawner-recruit models, with or without the use of environmental correlates. It is believed that this is due to the fact that some of the escapement estimates for the Snoqualmie are unreliable, and biased low, due to poor visibility in some years.

The lower abundance threshold for management was set starting with critical escapement levels, expands these per population management thresholds, and expands again to a management unit threshold based on the average contribution of each population to the management unit's escapement.

The second step in deriving the management unit lower threshold was to expand each stock's lower management threshold by dividing the percentage of the total escapement that the stock is expected to comprise.

We can then compute the total system escapement required such that we expect each stock to achieve its lower escapement management threshold by dividing the percentage of the total escapement the stock is expected to comprise. The expected percentages of each stock came from the recent 12-year escapement breakout by stock (Table 1). Averaging the ratios of the two stocks' estimated NOR escapements over the twelve years gives an average Snoqualmie fraction of 37.7% of the total.

Table 6. Derivation of the lower management threshold for each Snohomish Chinook population and the management unit escapement necessary to achieve this level for each population.

	Snoqualmie	Skykomish
Critical level	400	942
Low R/S	1.01	0.71
Exp. rate	.24	.24
Low threshold	521	1745
Implied MU LT	1,381	2,802

The maximum of the management unit lower thresholds required to achieve the lower thresholds for the two stocks is 2,800 (Table 6), which was chosen as the management unit lower threshold for management planning purposes. Because this is so much higher than the indicated management threshold for protection of Snoqualmie escapement, this plan is providing extra protection to the Snoqualmie stock pending acquisition of better escapement data.

INTERPRETATION OF FRAM MODEL FOR PRESEASON PLANNING

Currently the comanagers use the Fishery Regulation Assessment Model (FRAM) for preseason planning of total fishery impacts (Table 2). Because a different set of exploitation rates (Table 3) was used in the model fitting phase for Snohomish Chinook, it is important to assess whether preseason exploitation rates from FRAM are directly comparable with the RER derived in the projection phase described above.

The exploitation rates in Tables 2 and 3 cannot be directly compared for a number of reasons. First, the A&P rates (Table 3) are brood year rates, while the FRAM rates (Table 2) are calendar or fishing year rates. FRAM is based on applying current year abundances and fishery exploitation levels to average fishery-specific exploitation rates observed form coded-wire tag recoveries in a base period (Larrie Lavoy, WDFW, personal communication). In contrast the preterminal rates in the A&P tables use current year coded-wire tag recoveries from indicator groups.

Second, FRAM more accurately represents Snohomish Chinook by modeling both the fingerling outmigrant or “ocean type” and yearling outmigrant or “stream type” (Healey 1991) components of the Snohomish run. Comparison of coded-wire tag recoveries from hatchery groups released as age-0 fingerlings as compared with groups released as age-1 yearlings consistently shows differences in patterns of fishery exploitation. FRAM utilizes CWT recovery information from Wallace River (Skykomish) yearling production releases as well as fingerling CWT data to accurately reflect Snohomish Chinook distributions (Larrie LaVoy, WDFW, personal communication). Because yearling recovery data are not incorporated into the A&P tables, these rates may not be an accurate reflection of the true rates for Snohomish Chinook.

Finally, the two models use different set of indicator coded-wire tag groups to represent the Snohomish management unit. This is more difficulty for the Snohomish than for other management units because there is no local indicator coded-wire tag stock available for Snohomish ocean type Chinook, although a program of double-index tagging at Wallace River hatchery began in 2000 with hopes of developing an appropriate indicator group.

In summary, information available at this time indicates that there is some management risk to using FRAM as we implement annual fishing plans with the intention of achieving our management plan objectives. However, given the uncertainties in estimates associated with estimates of exploitation rates in both the A&P tables and with FRAM, it is not clear that one is more accurate in representing true Snohomish Chinook exploitation rates. Therefore, some additional, precaution is called for in using FRAM to assess whether a given package of proposed fisheries will result in an exploitation rate below the RER guideline of 0.24 for the Snohomish. Therefore, the comanagers will initially use a guideline of 0.21 for the Snohomish instead of the 0.24 derived in the projection phase of this analysis. This guideline was the highest preseason projected exploitation rate for Snohomish since the 2000 application of the comanagers’ plan (Table 2). The range of preseason exploitation rates primarily reflects variation in abundance of other Chinook stocks and changes in the pattern or level of fisheries outside the comanagers’ jurisdiction. Given the procedures in place for annual implementation of the plan, particularly with respect to our intention of not increasing fisheries and our record of managing fisheries to levels that are below exploitation rate ceilings, our expectation is for preseason Snohomish Chinook exploitation rates less than 0.21. Since observed spawning escapements have been increasing during this period (Table 1), consistently above the comanagers' former goal of 5,250 (Ames and Phinney 1977), and generally the largest observed since the beginning of the database in 1965, we feel that recent management has met this plan's objective of reducing fishery impacts so that the population can recover if other factors improve.

In addition, as part of our commitment to evaluate performance of the plan and modify it as necessary to ensure objectives are achieved, the comanagers intend to l review in detail the implications of the differences between the A&P and FRAM exploitation rates. This may result in the need to recompute RER estimates, compute a quantitative adjustment for FRAM projections.

Data gaps

Priorities for filling data gaps to improve understanding of stock / recruit functions, harvest exploitation rate, and marine survival:

- Annual implementation of a double-index coded-wire tagging program using fingerling summer Chinook from Wallace River Hatchery to enable direct assessment of harvest distribution, and estimation of harvest exploitation rates and marine survival rates. (Initiated beginning with the 2000 brood year).

- Estimates of natural-origin smolt abundance from Chinook production areas. (Outmigrant trapping began in the Skykomish in 2000 in the Snoqualmie in 2001).

- Estimates of estuarine and early-marine survival for fingerling and yearling smolts.

- Quantification of the contribution of hatchery-origin adults to natural spawning for each stock. (Research is underway. Estimates of hatchery contribution to natural spawning populations is available for the 1997 through 2001 return years.)

Table 7. Results of model fits for different combinations of environmental correlates.

PS(6) for marine, FW

	Ric	Bev	Hoc
a - productivity	4.1658	0.2400	4.1658
b - Spawners	0.000000	0.000000	42,216
c – Marine	0.8330	0.8330	0.8330
d - Freshwater	-0.000011	-0.000011	-0.000011
SSE	2.414	2.414	2.414
MSE (esc)	0.268	0.268	0.268
autocorrelation in error	0.199	0.199	0.199
R	0.680	0.680	0.680
F	2.579	2.579	2.579
PROBABLITIY	0.1184	0.1184	0.1184
MSE (reruits)	0.564	0.564	0.564
autocorrelation in error	-0.390	-0.390	-0.390
Ave.Pred. Error	7237	7237	7237

NPS(2) for marine, FW

	Ric	Bev	Hoc
a - productivity	5.1234	0.1782	3.6572
b - Spawners	0.000124	0.000035	13,092
c – Marine	0.6418	0.6394	0.6313
d - Freshwater	-0.000014	-0.000014	-0.000014
SSE	0.343	0.345	0.347
MSE (esc)	0.038	0.038	0.039
autocorrelation in error	-0.366	-0.358	-0.449
R	0.895	0.891	0.891
F	12.096	11.569	11.568
PROBABLITIY	0.0016	0.0019	0.0019
MSE (reruits)	0.276	0.278	0.255
autocorrelation in error	-0.133	-0.126	-0.147
Ave.Pred. Error	3994	4092	3999

No Freshwater, PS(6)

	Ric	Bev	Hoc
a - productivity	2.8789	0.3474	2.8789
b - Spawners	0.000000	0.000000	42,216
c – Marine	0.8398	0.8398	0.8398
d - Freshwater	0.000000	0.000000	0.000000
SSE	2.897	2.897	2.897
MSE (esc)	0.290	0.290	0.290
autocorrelation in error	0.203	0.203	0.203
R	0.617	0.617	0.617
F	3.066	3.066	3.066
PROBABLITIY	0.0915	0.0915	0.0915
MSE (reruits)	0.447	0.447	0.447
autocorrelation in error	-0.372	-0.372	-0.372
Ave.Pred. Error	7773	7773	7773

No Freshwater, NPS(2)

	Ric	Bev	Hoc
a - productivity	4.6677	0.0761	3.9737
b - Spawners	0.000254	0.000132	6,238
c – Marine	0.6986	0.7042	0.7341
d - Freshwater	0.000000	0.000000	0.000000
SSE	1.056	1.057	1.065
MSE (esc)	0.106	0.106	0.106
autocorrelation in error	0.175	0.141	0.116
R	0.862	0.855	0.877
F	14.505	13.605	16.739
PROBABLITIY	0.0011	0.0014	0.0006
MSE (reruits)	0.298	0.304	0.316
autocorrelation in error	-0.071	-0.088	-0.069
Ave.Pred. Error	4310	4437	4089

No Marine

	Ric	Bev	Hoc
a - productivity	3.7071	0.2697	3.7071
b - Spawners	0.000000	0.000000	19,851
c – Marine	1.0062	1.0000	1.0000
d - Freshwater	-0.000010	-0.000010	-0.000010
SSE	3.463	3.463	3.463
MSE (esc)	0.346	0.346	0.346
autocorrelation in error	0.086	0.086	0.086
R	0.435	0.435	0.435
F	1.164	1.164	1.164
PROBABLITIY	0.3512	0.3512	0.3512
MSE (reruits)	0.768	0.768	0.768
autocorrelation in error	-0.324	-0.324	-0.324
Ave.Pred. Error	7838	7838	7838

No Marine or Freshwater

	Ric	Bev	Hoc
a - productivity	2.7118	0.3688	2.7118
b - Spawners	0.000000	0.000000	66,517
c – Marine	0.5000	0.5000	0.5000
d - Freshwater	-0.000001	-0.000001	-0.000001
SSE	3.758	3.758	3.758
MSE (esc)	0.342	0.342	0.342
autocorrelation in error	-0.017	-0.017	-0.017
R	0.299	0.299	0.299
F	1.076	1.076	1.076
PROBABLITIY	0.3219	0.3219	0.3219
MSE (reruits)	0.789	0.789	0.789
autocorrelation in error	-0.369	-0.369	-0.369
Ave.Pred. Error	7938	7938	7938

Table 8. Summary of projections of the Skykomish population at different target exploitation rates for three different forms of the spawner-recruit relationship.

	Pr(final esc > UAT) %			Pr(ann. Esc. < LAT) %		
Target ER	**B-H**	**Ricker**	**Hockey-St**	**B-H**	**Ricker**	**Hockey-St**
0.00	99.20	96.60	96.30	0.30	0.50	0.50
0.01	99.40	97.80	96.50	0.40	0.70	0.60
0.02	99.00	96.40	95.80	0.50	0.70	0.60
0.03	98.70	95.80	95.60	0.40	0.60	0.50
0.04	98.10	95.60	94.70	0.40	0.70	0.60
0.05	98.40	96.40	95.80	0.50	0.70	0.70
0.06	97.80	95.10	94.30	0.60	0.90	0.80
0.07	97.40	94.70	93.20	0.60	0.90	0.80
0.08	97.80	94.90	94.00	0.60	0.90	0.80
0.09	97.50	94.80	93.70	0.70	1.00	1.00
0.10	97.40	94.20	92.70	0.70	1.00	1.00
0.11	96.90	94.10	92.20	0.90	1.20	1.10
0.12	95.70	92.10	90.50	0.80	1.20	1.20
0.13	96.50	93.40	90.70	1.20	1.60	1.60
0.14	96.00	92.10	90.30	1.10	1.40	1.40
0.15	95.60	90.40	89.30	1.20	1.50	1.60
0.16	93.60	90.90	88.20	1.60	2.00	2.00
0.17	93.70	89.80	87.00	1.50	1.80	2.00
0.18	91.40	87.90	84.60	1.60	1.90	2.10
0.19	91.10	87.70	83.80	2.10	2.50	2.80
0.20	91.00	86.90	83.90	1.90	2.30	2.60
0.21	91.00	87.90	84.40	2.10	2.40	2.80
0.22	90.70	87.30	**82.50**	2.30	2.70	3.00
0.23	86.40	82.70	78.70	2.80	3.20	3.70
0.24	86.40	82.30	77.10	3.40	3.70	4.40
0.25	84.30	**80.00**	75.30	3.50	4.00	4.80
0.26	85.80	82.40	76.90	3.30	3.90	**4.70**
0.27	**80.30**	77.10	71.50	4.50	**4.90**	6.10
0.28	77.90	73.90	68.70	**4.50**	5.00	6.30
0.29	78.40	73.90	65.80	5.10	5.60	7.20
0.30	75.20	72.00	65.60	5.20	5.60	7.50

Lake Washington Management Unit Status Profile

Component Populations

Cedar River Fall
Sammamish River Fall

Geographic distribution

Fall Chinook primarily spawn in two sub-basins in the Lake Washington watershed: the Cedar River sub-basin located at the south end of Lake Washington and the Sammamish River sub-basin which drains into the north end of Lake Washington.

Cedar River Chinook

Before construction of the City of Seattle's Landsburg Dam in 1901, Chinook spawning access in the Cedar River extended to Cedar Falls at RM 34.5. From 1901 until 2003, spawning access was restricted to the Cedar River below the dam at RM 22.6. In 2003, fish passage facilities were completed at the dam. The vast majority of spawning occurs in the mainstem Cedar River upstream of RM 5.0. Reaches surveyed for Cedar River Chinook spawners are RM 22.6 to RM 0.0 and from RM 34.5 to RM 22.6.

Sammamish River Chinook

Most Sammamish River Chinook spawn in Bear and Issaquah creeks, the two largest tributary streams within the sub-basin. No Chinook spawning occurs within the Sammamish River mainstem.

Approximately 10 of the 12.4 miles of Bear Creek are accessible to Chinook, although most spawning occurs between RM 4.25 and 8.75. A tributary to Bear Creek, Cottage Lake Creek is three miles long and is also utilized. Spawning in Issaquah Creek occurs predominately in the reach between RM 1.0 and the Issaquah Hatchery at RM 3.2.

Sammamish River spawning surveys are conducted in the following reaches: RM 1.3 – 8.8 in Bear Creek, RM 0.0 – 3.0 in Cottage Lake Creek and RM 0.0 to RM 3.2 in Issaquah Creek.

Life History Traits

Juvenile trapping in the Cedar River indicates that the outmigration is bimodal with most of the fish entering the lake prior to April as fry. A smaller percentage of these fish rear in the river to smolt size and outmigrate between May and July. On average, 75% of the migrants are fry. These fry rear along the lakeshore, grow quickly, and leave the lake as zero-age smolts. Juvenile trapping in Bear Creek indicates that most Chinook migrants leave the creek as zero-age smolts.

Smolt outmigration through the Chittenden Locks begins in mid-May and continues until at least September. Recent PIT tagging of Cedar River Chinook suggests that the Cedar River fish migrate out later in the season than basin hatchery Chinook. Lake Washington Chinook stocks have a protracted smolt outmigration, with a large percentage of the run outmigrating after July 1.

Adult Chinook enter the Lake Washington basin from late May through September, and enter tributaries from mid-August through early November. Spawning is usually complete by mid-November.

Hatchery Contribution

Hatchery production in the Lake Washington basin currently occurs at the Issaquah Creek Hatchery (Chinook and coho), the University of Washington (UW) Hatchery (Chinook and coho), and the Cedar River Interim Sockeye Facility (sockeye). The Issaquah Hatchery, in operation since 1936, releases approximately two million sub-yearling Chinook smolts annually. The UW hatchery, which began roughly a decade later, releases about 200,000 sub-yearling Chinook annually.

The first recorded plants of juvenile Chinook into the Lake Washington basin occurred in 1901, and intermittent plants continued for decades. 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. It is noteworthy that the hatchery stocks at Issaquah Creek Hatchery and the UW Hatchery were both principally derived originally from Green River hatchery stock. Since 1994, the Issaquah hatchery has used local broodstock from Issaquah Creek exclusively.

Freshwater run reconstruction has shown that approximately 85% of adult Chinook returning to the Lake Washington basin are hatchery origin fish. All age classes of returning hatchery adults since 2004 were from hatchery releases that were almost entirely marked with adipose-clipped fins. Because of this, recent Lake Washington basin spawning surveys have been able to detect most hatchery fish spawning naturally. The percentage of hatchery fish on the spawning grounds varies across the basin. Results are shown in Table 1.

Estimates of hatchery and natural contribution for Issaquah Creek are derived from sampling at the hatchery rack. An assumption that the hatchery contribution at the rack is the same as the contribution in Issaquah Creek was confirmed in 2007 by extensive carcass sampling in the creek. These estimates are conservative since juvenile hatchery Chinook mark rates are less than 100%. The estimates for mark rate in Bear Creek assume that the natural production from Issaquah Creek contributes unmarked spawners to Bear Creek in the same proportion as that in Issaquah Creek.

Table 1. Hatchery mark rates (ad-clips) in hatchery and natural spawners in the Lake Washington Basin. (Note: 5 yr-old returns were not marked in 2003).

Location	Return year					
	2003	2004	2005	2006	2007	2008
Issaquah Creek		90.5%	92.4%	94.2%	94.2%	
Bear Creek	54.0%	63.0%	78.9%	77.7%	75.0%	
Cedar River	24.1%	35.6%	31.5%	20.3%	14.8%	10.0%

Genetic Information

A comprehensive review of the available genetic data from naturally-spawning and hatchery Chinook in the Lake Washington watershed by WDFW 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. This does not prove that they are a single genetic population; only that there are not sufficient data to show otherwise (Warheit and Bettles, 2005).

The TRT concluded that the spatial separation provided moderate support for the designation of separate independent populations in the Sammamish and Cedar sub-basins. This qualified conclusion was based on the view that genetic differentiation between the two sub-basins is most likely influenced by extensive use of Green River-origin hatchery fish in the Sammamish River (Ruckelshaus et al., 2006).

Status

Standardization of Cedar River Escapement Goal

In the past, harvest management plans for Lake Washington Chinook were formulated with consideration of a fixed spawning escapement goal for Cedar River Chinook. The updated management objectives that are set forth in this document provide for a more appropriate escapement objective in light of new information and uncertainties that exist about optimal production levels, while still incorporating aspects of the former objective.

An interim escapement goal for the Cedar River was set in 1993 at 1,200 Chinook for an index reach based on average escapements observed in years 1965-1969. Estimates of spawner abundance in the reach were based on fish counts applying the area-under-the-curve (AUC) method.

In more recent years, estimates of spawner abundance have also been made using redd counts (e.g., Burton et al. 2006) performed over the entirety of the spawning area downstream of Landsburg Dam. These data have been used to convert previous estimates of escapement within the index reach to estimates of spawner abundance (as would be derived through redd counts) for the entirety of the river (below the dam) using simple linear regression. Using this regression, the goal of 1,200 fish in the index reach can be converted to 1,680 Chinook for the entirety of the river downstream of the dam. This number (1680) reflects a redd-based escapement value consistent with the interim escapement goal derived using AUC methodology.

In 2003, a new fish ladder allowed Chinook to pass above Landsburg Dam, complicating consideration of an appropriate escapement goal for the entire sub-basin.

While a spawning level of 1,680 fish for the river provides a useful benchmark, insufficient data exist to more appropriately define the production characteristics of the river. The escapement goal is an interim value based on the Cedar River as it existed in the late 1960s. Since that time, the habitat below Landsburg Dam has degraded from development, while passage above the dam has been created. Benefits afforded by recent habitat restoration need to be quantified. Both the productivity and capacity of the Cedar need to be re-evaluated in light of these changes.

Abundance Trends

The status of Chinook stocks in the 2002 Salmonid Stock Inventory was reported as “Depressed” for the Cedar population and “Healthy” for the Sammamish population components. Estimated abundance at various points within the Lake Washington beginning in 2000 is shown in Table 2. Patterns of abundance of the Cedar River Chinook population show an upward trend in recent years (Figure 1). The estimated total number of spawners in the Cedar River was relatively at a high level in the 1970s and 1980s, then dropped to much lower levels in the mid 1990s, but has recently been trending upward.

Numbers of natural spawners (hatchery origin plus natural origin spawners) estimated in the Sammamish River sub-basin are shown in Table 2. Inter-annual variation is quite high in the data sets. The estimates shown for total Sammamish natural spawners consist of the Bear and Issaquah creek spawning escapements for the reaches described above.

It is noteworthy that the numbers of spawners estimated in Bear Creek show no statistical relationship to the size of the Sammamish River run (Figure 2). Most of the spawners (>75% in recent years) in Bear Creek are hatchery strays. Mechanisms influencing the number of spawners that move into this tributary may be related to inter-annual variation in one or more environmental factors, such as temperature and flow. Further investigation is needed to understand the factors that regulate spawner abundance within Bear Creek.

<u>Uncertain Historical Presence of Sammamish Population</u>

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 they have acknowledged that there is uncertainty about this (e.g., RITT 2008). There is apparently no clear documentation that Chinook were consistently produced in the Sammamish sub-basin prior to the advent of hatcheries. The TRT's conclusion was given as:

> *"Although the current Sammamish River population is largely supported by naturally spawning hatchery fish, the basin area suggests it had the capacity to support a self-sustaining, independent population. The cumulative catchment area of tributaries draining into the Sammamish River and from Swamp, North, Bear, Little Bear, and Issaquah creeks is more than 60,000 ha, which is larger than the smallest watershed containing an independent population in the TRT's analyses (the South Fork Nooksack River)."* (Ruckelshaus et al. 2006)

If a population did exist historically in the Sammamish sub-basin, that population is now considered to be extinct. The TRT stated that:

> *"The history of hatchery releases in the Sammamish River raises two key uncertainties. First, although the TRT identified an historical population associated with this river, the Chinook salmon that currently use the watershed likely do not represent the historical population. This population is believed to be genetically extinct because of many factors for decline, including an extensive history of introductions of Green River-origin hatchery fish."* (Ruckelshaus et al. 2006)

Table 2. Co-manager's estimated Chinook abundance at various points in the Lake Washington basin beginning in 2000

	Natural Spawning Escapement		Hatchery Escapement		Total Run Size Entering Sammamish R.
Return Year	Cedar Total (1)	Samm R. Total (2)	UW Hatch (3)	Iss Hatch (4)	Samm sub-basin spawning ground and hatchery escapement plus Lake Samm harvest (5)
2000	133	642	476	3,676	4,318
2001	975	1,689	654	10,451	14,835
2002	673	1,478	1,101	5,620	7,098
2003	798	650	1,564	5,742	6,596
2004	1225	1,012	2,520	12,771	13,783
2005	828	866	2,511	6,852	7,718
2006	1,465	2,214	2,080	8,934	11,931
2007	2,148	1,300	2,196	13,431	21,831

1. Estimated total spawner abundance for the Cedar R population based on redd counts.
2. Total naturally spawning Chinook in the Sammamish sub-basin
3. Number returning to the UW hatchery facility.
4. Number taken into the Issaquah Cr hatchery facility; including fish later passed upstream of the rack.
5. Estimate of run size returning to the Sammamish River sub-basin. This value includes Sammamish natural spawners, Issaquah Hatchery fish, and L. Sammamish Treaty harvest.

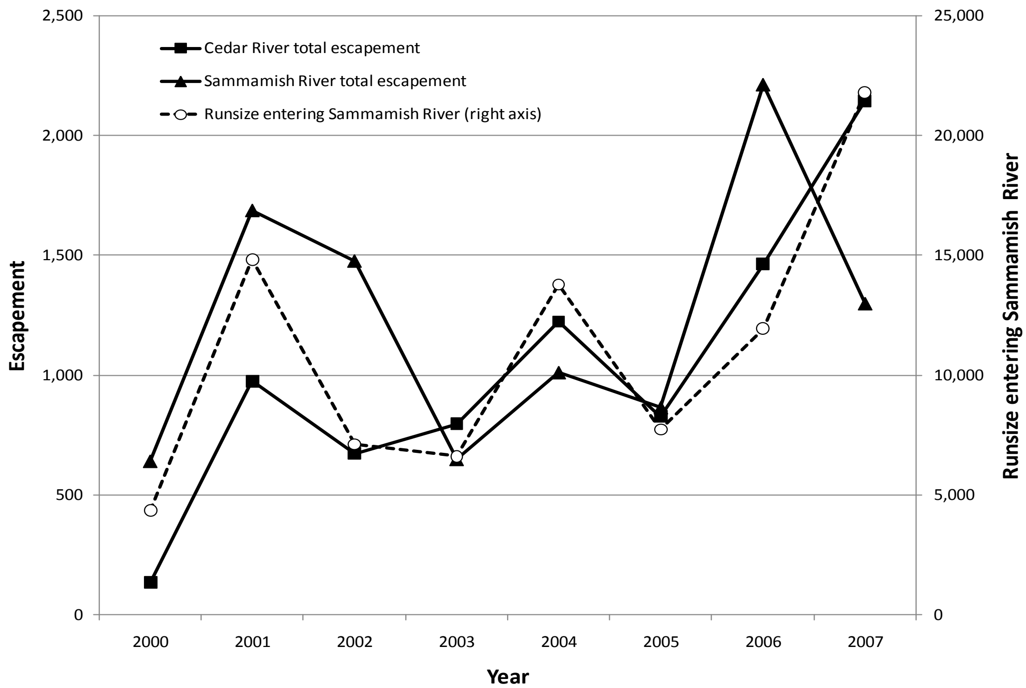


Figure 1. Estimated Cedar River Chinook escapement, Sammamish River Chinook escapement, and runsize of Chinook entering the Sammamish River. Note that the run size to the Sammamish River is on a different axis than the natural escapements.

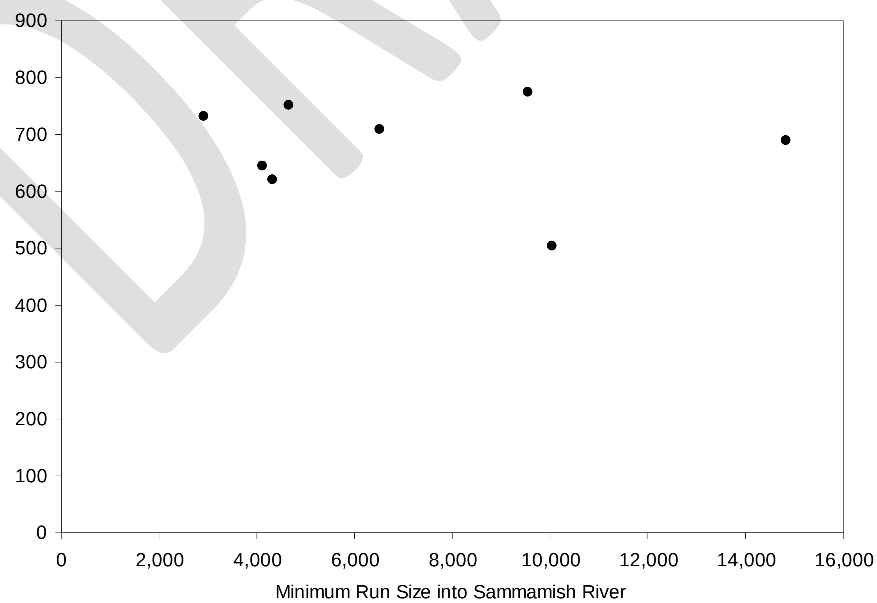


Figure 2. The relationship between the number of Chinook spawning naturally in Bear Creek and the total Sammamish River run size (estimated return to the sub-basin).

Harvest Distribution

The harvest distribution of Lake Washington Chinook has not been directly assessed because representative coded-wire tagged hatchery releases are only available for a few brood years from the Issaquah Hatchery in the late 1980s and the University of Washington hatchery in the late 1990s. However, because of their similar life history and genetic heritage, tagged fingerling releases from other Central Puget Sound hatchery facilities (Soos Creek and Grovers Creek) likely provide a good representation of pre-terminal harvest distribution (see, e.g., the Green River profile).

The harvest distribution of Lake Washington Chinook has been estimated using post-season FRAM model runs (Figure 3). Results of modeling show that harvest distribution has changed dramatically between the mid 1980s (the first five years with modeling analysis available) and the most recent five year period with modeling results available. A much larger proportion of the impacts now occur in northern fisheries (Alaskan and Canadian combined) compared to the mid 1980s. In contrast, a sharp reduction in harvest has occurred in the terminal areas, where only about 14% of the total impacts occurred in recent years.

Terminal harvests of Lake Washington Chinook have been severely restricted since 1994 by eliminating directed harvest and limiting impacts to incidental catches in Shilshole Bay, the Ship Canal, and in Lake Washington when targeting sockeye and coho. In an effort to utilize Issaquah Hatchery Chinook fisheries have been promulgated in Lake Sammamish in recent years.

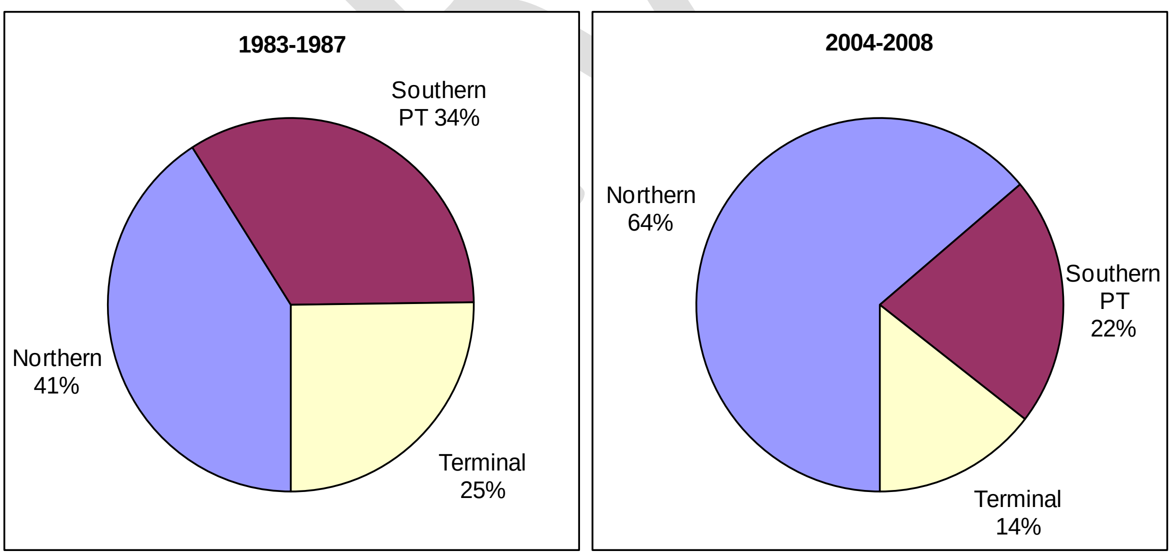


Figure 3. Estimated distribution of LW Chinook harvest during two 5-year periods (1983-1987, 2002-2006) derived from post-season FRAM validation runs. Geographic areas are lumped into Northern (Alaska, Canada), Southern (US pre-terminal) and terminal (Shilshole Bay, Lake WA basin)

Exploitation Rate Trends

Based on post-season FRAM model runs, average total annual exploitation rates for Lake Washington Chinook fell from a high of about 89% in 1988 to a low of 16% in 1998. Since 1998, exploitation rates have risen to between approximately 35-40% (Figure 4). The estimated annual exploitation rates have averaged approximately 3% in the terminal area from 1997-2006, by far the least of the impacts associated with any of the fishery groupings.

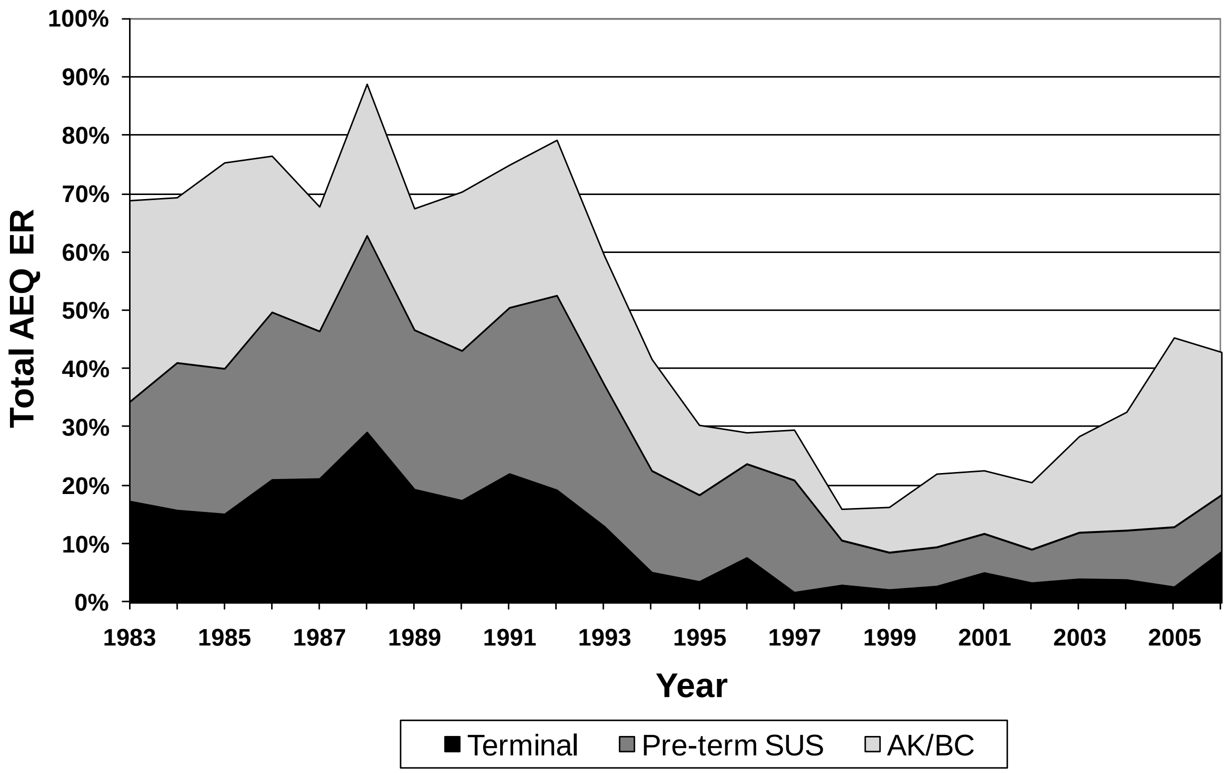


Figure 4. Annual adult equivalent exploitation rates of Lake Washington Chinook for all fisheries combined, in Alaska and British Columbia combined, in southern U.S. pre-terminal areas, and in the Lake Washington terminal areas. Estimates are based on post-season FRAM runs for management years 1983 – 2006.

Management Objectives

Management objectives for Lake Washington Chinook reflect current information on population status. Achieving these objectives will contribute to continued movement toward recovery of Chinook, while also providing opportunity for harvesting available hatchery fish. Management of Lake Washington Chinook is based on protection of Cedar River Chinook. These Lake Washington

Chinook management objectives include a limit on the exploitation rate for all Southern U.S. fisheries, procedures to manage terminal area fisheries based on in-season estimates of terminal area abundance, and provisions for Chinook-directed fisheries when spawning escapement is projected to be greater than the upper management threshold (UMT). This management regime assures that harvest of Lake Washington Chinook will not impede recovery of the ESU.

- The Southern U.S. fisheries will be limited by a ceiling of 20% (SUS ER) with the exception that if Cedar River Chinook spawning escapement is projected to be greater than the UMT as determined in-season, Chinook-directed fisheries may be implemented in terminal areas by agreement of the Co-Managers that increase the total SUS ER over 20%.

- A low abundance management threshold (LAT) of 200 Cedar River Chinook will be used to identify critical status of Lake Washington Chinook. If critical status of Lake Washington Chinook is identified, then pre-terminal Southern U.S. fisheries will be restricted by a ceiling exploitation rate no greater than 10%.

- During the adult migration period (June-September) fisheries management in the terminal area is to be based on an inseason update of the Lake Washington run size using fish counts made at the Chittenden Locks. The update will allow for estimating both the total run size and the Cedar River run size entering freshwater. The inseason update method and terminal area fisheries that are based on this update will be agreed to by the Co-Managers prior to implementation. The terminal area includes Shilshole Bay, the Ship Canal, Lake Union, Lake Washington and Lake Sammamish. Terminal area fisheries will be managed as follows:

    - If escapement is estimated to be at or below the LAT, then Chinook impacts will be limited to the number of Cedar River Chinook caught incidentally during fisheries for other species. Extraordinary measures will be taken in terminal area fisheries for other species to minimize incidental impacts on Cedar River Chinook.

    - If escapement is estimated to be above the LAT and below the upper management threshold (UMT) of 1680 Cedar River Chinook, harvest that has an impact on Cedar River Chinook will be restricted to fisheries for other species and/or ceremonial and subsistence fisheries.

    - At abundances of Cedar River Chinook above the UMT, Chinook-directed fisheries may be implemented by agreement between the Co-Managers.

- Stock composition will be estimated by relative run strength of component sub-stocks as forecasted. Where data is available, such as the marked to unmarked ratio at the Chittenden locks or other terminal area data, sub-area stock composition may be revised for fishery modeling. Harvest in Lake Sammamish will be managed to target surplus abundance of Issaquah Hatchery Chinook.

- Total spawning escapement into the Cedar River is expected to include a contribution of hatchery-origin Chinook similar to that observed in years 2003-2008. All naturally spawning Chinook in the Cedar River will be used when evaluating upper and lower abundance thresholds.

- The aforementioned management objectives provide protection for the Sammamish River population, as well as the Cedar River population. Harvest management objectives defined by this RMP will continue to provide sufficient protection for Sammamish River Chinook. The co-managers believe the Sammamish River population is not essential to recovery of the Puget Sound ESU. Additional constraints to harvest are not warranted.

- The allowable impacts as defined by the harvest management regime will be divided between the non-treaty and treaty fisheries by co-manager agreement in a manner allowing each party to make its own wise-use decisions consistent with the unique characteristics and constraints of its fisheries.

- Adaptive management will be employed in the event of extreme variation from observed environmental or population dynamics.

Data Gaps/ Information Needs

Lake Washington is a complex and unique environment for Chinook salmon. Additional research is needed to better understand life history and survival (Table 3). Subject to funding availability, the highest priority will be placed on data collection to quantify the productivity of Lake Washington stocks. This information will help assess the success of recovery actions whether these involve harvest, habitat restoration, or hatchery supplementation.

Table 3. Data gaps related to harvest management, and projects required to address those data needs

Data gap	Research needed
Estimates of return per spawner and egg to outmigrant productivity	Estimate hatchery contribution on the spawning grounds for run reconstruction. Juvenile migrant trapping in Cedar R at Renton and at/near Landsburg, in Bear Cr. and in Issaquah Cr.
Variability in AUC escapement estimates and correlation w/ redd counts	Continued redd counts and spawner surveys
Adult migration routes and behavior in Lake Washington and Ship Canal	Multi-year ultrasonic tag study to assess temporal and spatial separation of stocks, bottlenecks in migration
Updated escapement goal for Cedar population, including habitat area above Landsburg	Develop model using habitat measures and productivity estimates. Juvenile migrant trap effort at or near Landsburg
Updated escapement estimates for Sammamish population	Spawner surveys and stream life estimates in Issaquah Creek, and assessment of fall back rate from fish passed above the Issaquah Hatchery weir
Terminal area gear-induced mortality	Studies to assess delayed mortality from hook and release, hook drop-off and net drop-out
Uncertainty in run size estimates at the Chittenden Locks relative to spawning ground surveys	Mark/recapture study, independent assessment of Chinook abundance and migration through large lock chamber
Net change in habitat quantity and quality over time	Comprehensive analysis of habitat conditions given restoration efforts and continued land development and other constraints (flood control, LWD restriction)
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
Relative survival of different components of the Cedar River juvenile outmigration	Is survival from emergent fry to smolt and from fry to adult correlated with early life history strategy? (i.e. – what are the relative survival rates of fry outmigrants compared to smolt outmigrants?) Is survival different in the upper basin than it is in the
Water management during high flow events in the Cedar	How is scour of redds related to the magnitude and duration of peak flow events and the position of redds
Outmigration survival by stock	Estimate avian predation and other mortality factors

Green River Management Unit Status Profile

Component Populations

Green River Fall Chinook

Geographic distribution

Fall Chinook spawing 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 26.7 to RM 61. Spawning migration is blocked by the City of Tacoma's diversion dam at RM 61, and at RM 64 by Howard Hanson Dam. Spawning occurs in the lower 10 miles of Newaukum 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. The majority of spawning in Soos Creek occurs in the lower six miles. Reaches surveyed for Green River Chinook spawners are from Highway 167 to the Tacoma Headworks Dam (RM 23.8 to RM 61.0. Newaukum Creek is surveyed from the mouth (RM 0.0) to 400th Street (RM 4.5).

Life History Traits

Fall Chinook begin entering the Green River in July, and spawn from mid-September through early November. Ninety nine percent of smolts outmigrate in their first year (WDFW 1995 cited in Myers et al.1998), with a large but variable proportion migrating downstream as fry. The long-term average age composition of adult returns indicates the predominance of age-4 fish (62 percent), with age-3 and age-5 fish comprising 26 percent and 11 percent, respectively (WDF et al.1993, WDFW 1995 cited in Myers et al.1998).

Hatchery Contribution

Returns from hatchery production contribute substantially to natural spawning in the Green River and tributaries. Analysis of coded wire tags recovered from the spawning grounds and the in-river fishery has yielded highly variable results. Collection of data from mass-marked Chinook began in 2003 and has produced estimates of hatchery contribution ranging from 53% to 65% for years 2004-2007. Estimates of the abundance and productivity of the naturally spawning stock are compromised by these conditions and viability of the naturally spawning stock, absent the hatchery contribution, is uncertain. (Myers et al.1998).

Genetic Information

Chinook hatchery programs currently exist at Soos Creek and Icy Creek. Broodstock has always been collected from local returns since the hatchery began operations in 1903. Spawners in Soos Creek are presumed to be predominantly of hatchery origin. Allozyme analysis has shown no significant difference between Newaukum Creek natural spawners and Soos Creek Hatchery Chinook. (Marshall et al.1995). There is a significant amount of genetic interchange between natural- and hatchery-origin Chinook in the hatchery broodstock and between hatchery adults and natural origin fish on the spawning grounds (WDFWD et al. 2002).

Status

The SASSI review (WDFW et al. 2002) classified Green River Chinook as healthy. Spawning escapement has consistently met the objective of 5,800 since 1997 with the exception of 2005 (Table 1).

Table 1. Spawning escapement of Green River Fall Chinook, 1997-2007

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Esc	9967	7300	9100	6170	7975	13950	10406	13991	4089	10157	7186

The nominal escapement goal is based on approximate estimates of escapement in the 1970s, and may not reflect the productivity constraints associated with current degraded habitat, but will be used to guide fisheries management until natural capacity is better quantified. Escapement estimation methods are under co-manager review. Surveys were expanded in recent years to calibrate assumptions regarding the relationship between index area counts and total escapement. Three years of mark/recapture research by WDFW suggested escapements two to three times higher than those derived from redd-based methods. Spawning ground surveyors expressed doubt that they could be missing half or more of the redds. An additional WDFW study was conducted to determine if redd superimposition was occurring. Results were negative. Further research is planned to provide an independent estimate for comparison.

Harvest Distribution

Coded-wire tagged fingerling releases from the Green River (and Grovers Creek) describe harvest distribution in recent years. The PSC Chinook Technical Committee analysis cited below expands CWT recoveries for sampling rate and adjusts for adult equivalence. Fisheries in British Columbia and Alaska account for 41 percent of total fishing mortality. Washington troll, net and recreational and Puget Sound net fisheries account for 12%, 24% and 24%, respectively (Table 2).

Table 2. Average distribution of fishery mortality of South Sound fingerling Chinook derived from CWT analysis (CTC 2008).

Alaska	B.C.	US Troll	US net	US sport
0.9%	39.3%	11.9%	24.2%	23.7%

Exploitation Rate Trends

Post-season FRAM runs, incorporating actual catch and stock abundance indicate that total annual exploitation rates have increased since 2001 with most of the increase in northern fisheries. Some reduction is expected in northern fishery impacts as a result of the 2008 PST agreement. ER's in pre-terminal southern fisheries have remained fairly constant. Terminal area ER's have varied. Green River Chinook are managed to meet or exceed the escapement goal. This objective was not achieved in one year of the past eleven (Table 1). In 2005 terminal area management actions identified lower abundance than forecasted, resulting in closure mid-season as reflected by the terminal ER being 9%, about half of the recent year average as may be seen in Table 3 below.

Table 3. Green River Chinook Exploitation Rates 2001 – 2006.

	Pre-season FRAM				FRAM validation			
	Total	North	PT SUS	Term SUS	Total	North	PT SUS	Term SUS
2001	49%	10%	12%	27%	33%	11%	7%	16%
2002	55%	7%	10%	38%	46%	11%	6%	29%
2003	50%	10%	10%	30%	44%	16%	8%	20%
2004	62%	25%	10%	27%	51%	20%	8%	22%
2005	61%	18%	10%	33%	52%	32%	10%	9%
2006	50%	22%	10%	17%	51%	24%	10%	17%

Management Objectives

The co-managers manage fisheries to meet or exceed the spawning escapement goal of 5,800 Green River Chinook. This goal has been met or exceeded in all but one (2005) of the past eleven years. The co-managers expect that the goal will continue to be met or exceeded as a result of this management approach.

Management objectives for Green River Chinook include an exploitation rate objective for pre-terminal Southern U. S. fisheries and a procedure to manage terminal-area fisheries that is based on inseason abundance thresholds (triggers) designed to assure that the escapement goal will be achieved**.** This management regime assures that harvest related impacts on Green River Chinook will not impede recovery of the ESU.

Washington preterminal fisheries impacts on Green River Chinook are managed to not exceed a 15 percent 'SUS' exploitation rate, as estimated by the FRAM model. Pre-terminal fisheries include the coastal troll and recreational fisheries managed under the Pacific Fishery Management Council, and commercial net and recreational fisheries in Puget Sound outside of Elliott Bay.

Terminal area abundance is estimated annually utilizing a test fishery conducted since 1989. Using this data, planned terminal area fisheries directed at Chinook are conditional to meeting criteria defined for two inseason triggers. For the first in-season trigger, a catch value less than 100 Chinook in the test fishery would cause cancellation of subsequent commercial and sport fisheries. For the second in-season trigger, a catch less than 1,000 Chinook for the first commercial opening would cause cancellation of any further Chinook-directed fishing. These criteria were defined to correspond with a total run of about 15,000 Chinook (hatchery and natural origin combined).

In-season abundance thresholds were met in 2000-2007. Terminal area Chinook-directed treaty net and sport fisheries were implemented as scheduled with the exception of the 2005 season. Although the threshold criteria were achieved for that season, the co-managers canceled further fishing. Natural escapements for 1997-2007 are provided in Table 1. The preliminary estimate for 2008 escapement is more than 5,900 spawners.

A low abundance threshold of 1,800 natural spawners is established for the Green River management unit on the basis of the lowest observed escapement resulting in a higher escapement four years later. If natural escapement is projected to fall below this threshold during pre-season planning, then additional management measures will be implemented to minimize fishery-related mortalities of Green River Chinook in accordance with procedures described in section 5.3 (Response to Critical Status).

Data Gaps/ Information Needs

Several aspects of the productivity of Green River Chinook are potentially affected by hatchery-origin fish spawning naturally. The abundance, timing, spawning distribution, and age structure of natural-origin Chinook may be masked by the presence of hatchery-origin fish. The viability of the natural origin population cannot be accurately assessed without determining the effects of hatchery straying, so the need for this information will prioritize research. Table 4 gives descriptions of the data needs and how they are being addressed.

Table 4. Data gaps in Green River Chinook stock assessment and harvest management, and projects required to address those gaps.

Data need	Related project	Update
Quantification of the proportion of natural escapement that is comprised of hatchery strays.	1. Completion of a CWT data set for refinement of current CWT-based estimates. (work in progress) 2. Mass marking of hatchery production. (Brood years since 1999 marked	1 and 2 are complete Surveys for marked fish have resulted in better estimates of hatchery contribution
Re-evaluation of escapement estimation methodology	1. Expanded surveys to calibrate expansion of index area data to total. (begun in 1998 – work continues.) 2. Mark/recapture study to independently calibrate total escapement estimate in association with expanded survey effort. (done in 2000-2002, report in progress)	1 and 2 are complete Results of mark/recapture study gave unrealistic escapement estimates. Redd superimposition study did not resolve questions. New study proposed to obtain independent estimate.
Estimation of the number of Chinook fry and smolts that emigrate annually from the mainstem Green and Newaukum Creek.	Trap placement in the mainstem Green 1999-2002)	A trap has been operated annually since 1999. Funding has been obtained for near term future operation
Gear induced incidental mortality	A literature review and preliminary study design should be done.	No progress

White River Management Unit Status Profile

Component Populations

White River Spring Chinook

Geographic distribution

White River Chinook are trapped at the Lake Tapps diversion dam in Buckley (RM 23.4) and are transported above Mud Mountain Dam (RM 29.6). Chinook spawning above Mud Mountain Dam occurs in the White River and several tributaries, notably the West Fork White, Clearwater, and Greenwater rivers, and Huckleberry Creek. Chinook also spawn below the Lake Tapps diversion dam in the White River, Boise Creek and Salmon Creek.

Spawning ground surveys are conducted in the Clearwater and Greenwater rivers and in Huckleberry Creek above Mud Mountain Dam, and in the White River mainstem, Boise Creek and Salmon Creek below the diversion dam. Visibility in the White River mainstem is often impaired by glacial sediment, affecting estimates of spawner abundance.

Tagged White River Spring Chinook have been recovered in the Puyallup River and its other tributaries indicating some degree of within-system straying.

The White River population is the only spring stock still present in southern Puget Sound and is genetically distinct from other Chinook stocks in Puget Sound. The White River Hatchery and the Minter Hupp Complex are used to supplement production. The supplementation program is considered essential to recovery and hatchery production is included in the listed ESU.

Life History Traits

Spring Chinook enter the Puyallup River from May through mid-September, and spawn from mid-September through October. Fry emerge from the gravel in late winter and early spring. In contrast to other spring stocks in Puget Sound, White River Chinook smolts emigrate primarily (80 percent) as subyearlings (WDFW et al., 1996), after a short rearing period of three to eight weeks. Adults mature primarily at age-3 or age-4.

Hatchery Contribution

A portion of the spring Chinook juveniles produced at the White River Hatchery and the Hupp/Minter complex are reared in upper White River watershed acclimation ponds. Since the 1999 brood year, acclimation pond fish have been ventral fin clipped to differentiate them from natural returns and on-station hatchery releases. Since 2003, between 17% and 61% of the adult Chinook returns sampled at the Buckley Trap were acclimation pond returns. From 2006 through 2009, returning adult hatchery Chinook surplus to the White River Hatchery needs have been trucked upstream. This number has ranged from 85 to 426 per year.

Genetic Information

A comprehensive review of the available genetic data from natural spawning and hatchery Chinook was conducted by Shaklee and Young (2003). This study was cited in the Puget Sound TRT's analysis of the genetics of White River Chinook (Ruckelshaus, et al., 2006). Genetic data support the independence of Puyallup basin Chinook from its nearest neighbors (Green and Nisqually river populations) and strongly support independence between the Puyallup and White River populations. Within the White, the early run hatchery and wild genetic samples are very similar, reflecting the effects of the broodstock program that began in the 1970s.

The origins of late-returning Chinook salmon in the White River are uncertain. Genetic evidence indicates that the extant population is characteristic of Green River-origin Chinook salmon and genetically distinct from the early returning White River population (Shaklee and Young, 2003). According to the TRT, these fish may represent:

- a life history form that was a distinct historical population,
- a late-returning form that was once part of the historical White River population but was replaced by nonnative Chinook salmon,
- a part of the historical late-returning Puyallup population that used the lower White River, or
- recent establishment of the life history in the White River from introductions of Green River-origin hatchery fish.

Status

The status of White River spring Chinook has been considered critical although abundance has improved in recent years. Escapement exceeded 5,000 Chinook in the early 1940s, but the effects of dams and other habitat degradation reduced abundance to tens of fish by the late 1970s. An emergency egg bank was begun in 1977 at the Minter Creek and Hupp Springs hatcheries.

A settlement between Puget Sound Energy (PSE) and the Muckleshoot Tribe in the mid 1980s resulted in higher flows below the diversion dam and construction of the White River Hatchery, since used to rebuild native spring Chinook. Several acclimation ponds have been established in the upper basin in cooperation with the Puyallup Tribe. Juvenile passage improvements were constructed at Mud Mountain Dam and in the Lake Tapps diversion canal in the late 1990s. PSE ceased hydroelectric operations in 2004, restoring a more natural flow regime below the diversion.

The U.S. Army Corps of Engineers operates the Buckley fish trap on the south bank of the Lake Tapps diversion dam, and records daily adult returns and fish haul counts. Buckley haul counts from 1942 through 2008 are shown in Figure . Data gathered at the trap provides the most accurate enumeration available for Chinook transported to the upper basin. The White River Hatchery is located on the north bank of the river at the diversion dam and includes a fish trap that attracts mostly hatchery returns. Chinook transported from the Buckley trap to the upper White River watershed, and hatchery returns to the White River Hatchery are shown in Table 1.

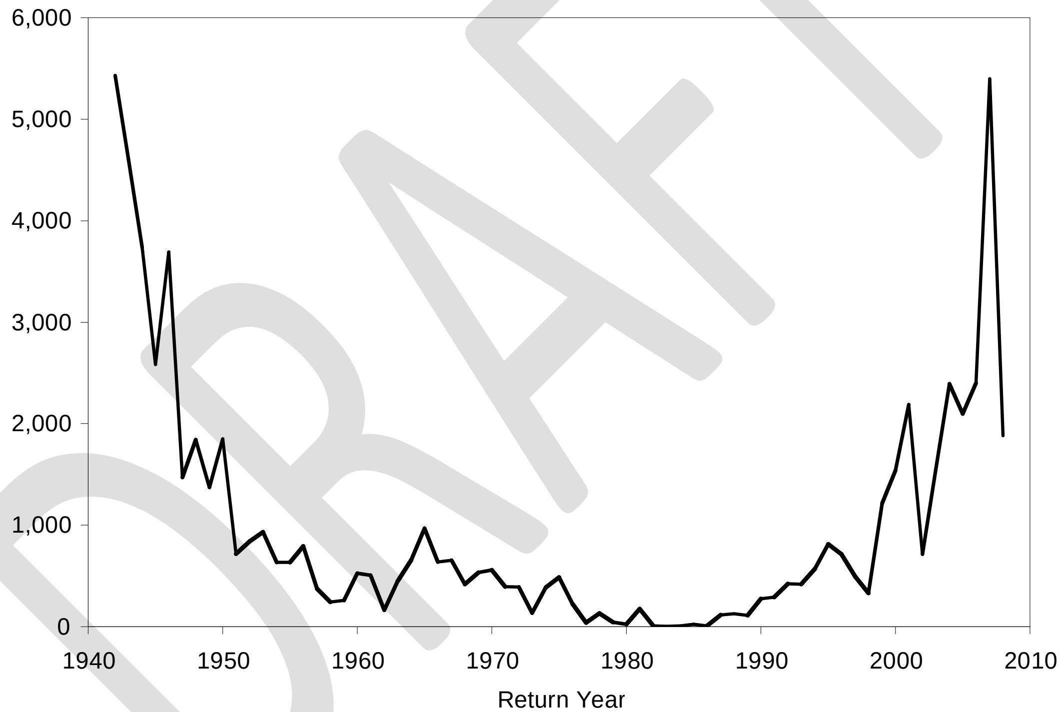


Figure 1. Adult White River Chinook Transported above Mud Mountain Dam

Early and late-timed Chinook overlap considerably in their timing of arrival at the two traps, and therefore separation between them is not precise. As conditions allow, adipose-bearing Chinook without detectable CWTs are sorted and transported upstream. These include both natural-origin fish (NOR) and supplemental production from upper basin acclimation ponds. Adipose-clipped Chinook are identified as strays and returned to the river below the dam. In recent years, some NOR Chinook have been taken to the hatchery for broodstock integration, while some surplus hatchery returns have been transported to the upper basin.

Marking of acclimated Chinook has improved identification of NOR returns, however, the ability to distinguish between NOR spring, spring/fall hybrid and fall Chinook on either the spawning grounds or at the Buckley trap is limited. Trap capacity is overwhelmed during periods of high salmon abundance including large coho and pink salmon returns, impeding the ability to sort and count Chinook. New trap construction is currently scheduled for 2012 -2016 as part of an Army Corps of Engineers' diversion dam replacement project. The new trap facilities are expected to improve sorting and sampling capability.

The total number of Chinook based on surveys upstream of Mud Mountain Dam from 1999 to 2006 averaged 550 (live count) and 590 (adjusted by multiplying redd counts by 2.5 Chinook per redd). The average number of Chinook transported upstream for the same period averaged 1,460, indicating that only about 40 percent of the trap count is accounted for in spawning surveys. Poor visibility in the glacial White River mainstem likely prevents a full accounting of Chinook. It is also possible that some Chinook fall back down through Mud Mountain Dam.

The South Sound Spring Chinook Technical Committee is currently re-evaluating escapement and recovery goals for the stock. The Committee has determined that, for purposes of management, no distinction can be made between early and late timed Chinook at the fish traps or on the spawning grounds. The number of fish transported upstream will continue to be used as an index for stock goals and annual assessment of stock status. The hatchery program will continue to use as broodstock only those Chinook that meet genetic screening for spring, or early-timed Chinook.

Table 1. Escapement of White River Spring Chinook, 1998-2008.

Return Year	CWT Chinook to White River Hatchery	Chinook Transported above Mud Mt. Dam	Total
1998	1,277	244	1,521
1999	2,058	923	2,981
2000	785	810	1,595
2001	1,349	692	2,041
2002	696	665	1,361
2003	1,425	1,010	2,435
2004	1,479	985	2,464
2005	1,759	1,603	3,362
2006	2,133	1,584	3,632
2007	4,919	1,733	6,226
2008	1,873	971	2,466

Harvest Distribution

From 1983 – 2006, approximately 71% of the White River Chinook harvest (range 39% - 92%) occurred in the pre-terminal Southern U.S. fishery (FRAM validation runs, 2007 calibration, July 21, 2008). Alaska and British Columbia fisheries together accounted for 15% of the harvest (range 0%-36%), and terminal harvests averaged 11% (range 2% - 47%). Over this period there has been a gradual increase in the proportion of the catch represented by terminal fisheries, and a decrease in pre-terminal fisheries. Average distribution of annual mortality across west coast fisheries for recent years is shown in Table 2.

Table 2. Recent average distribution of annual harvest mortality.

Years	Alaska	Canada	WA ocean	Pre terminal net & troll	PS sport	Terminal net	Escapement
2000-2006	0.000	0.028	0.005	0.005	0.076	0.042	0.816

Exploitation Rate Trends

White River Chinook have been represented in the Fishery Regulation Assessment Model (FRAM) by two distinct tag groups. From 1990 through 1999, these fish were modeled using yearling tag groups released from Minter/Hupp hatchery facilities. Because natural production from the White River migrates primary as sub-yearlings, when fingerling tag data from the White River Hatchery releases became available they were employed in FRAM. The estimated ER impact on fingerling production may be seen in Figure , below. Based on coded-wire tagged fingerlings releases and recovered during 2000-2006, total exploitation of White River spring Chinook has averaged 18%.

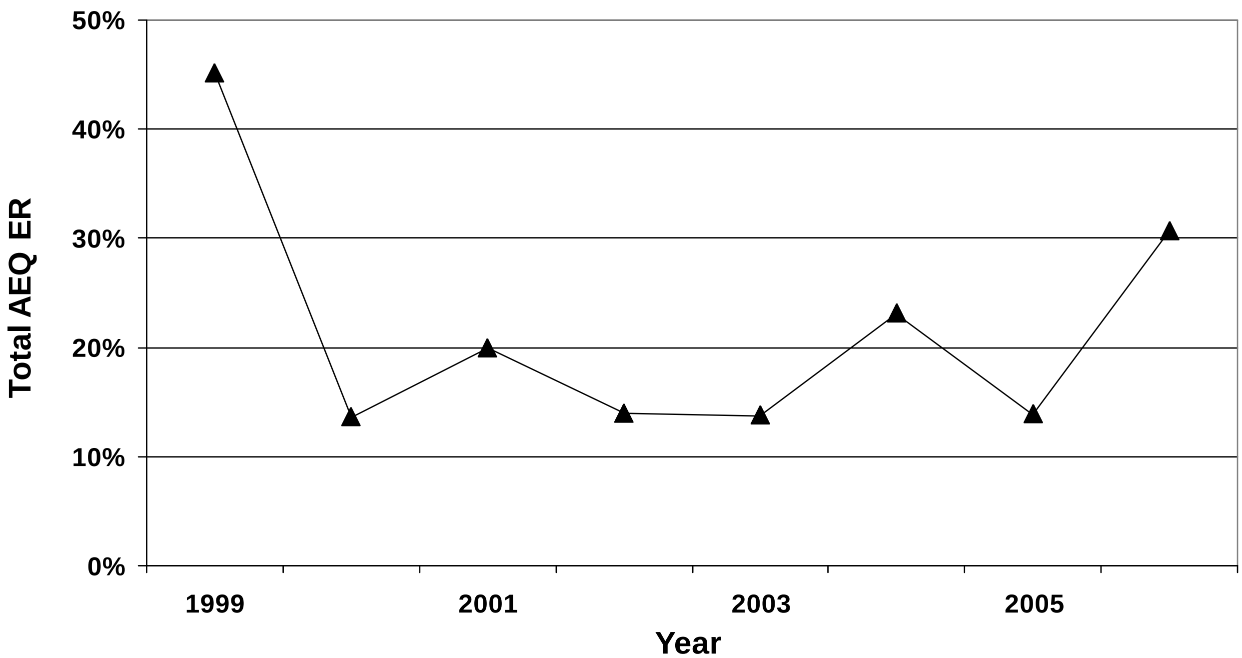


Figure 2. White River Chinook total AEQ exploitation rate in all fisheries, 1999 – 2006.

The spike in exploitation rate (ER) shown in 2006 in the figure above is driven by a high incidence of age 2 recoveries and is not representative of the adult ER in 2006 (personal communication, Larrie Lavoy).

Management Objectives

The management objective in effect during 2000-2009 has been a total exploitation rate of 20%. This was recognized as a conservative objective that would provide spawning escapements well in excess of the low abundance critical threshold of 200 spawners. Under this regime, escapements have increased, averaging 1,460 during the period 1999-2006. During this same period returns to the hatchery increased from an average of 820 (1999-2003) to 1,375 (2004-2008).

Fisheries in Washington will be managed to achieve a total exploitation rate, including fisheries in British Columbia, no greater than 20 percent. This exploitation rate ceiling, which is three points higher than the ceiling in the 2001 Harvest Management Plan, reflects changes in coded wire tag and historical catch data incorporated in the most recent calibration of FRAM (L. LaVoy, WDFW, memorandum to co-manager technical staff, February 12, 2002). Achievement of this rate requires continued constraint of Puget Sound net and recreational fisheries, and allows minimal tribal fisheries in the river. Tag recovery and escapement data are insufficient, at present, to support direct assessment of the productivity of the stock.

Data Gaps/ Information Needs

A number or uncertainties exist concerning Chinook productivity and stock origins in the White River. Table 3 lists several of the key uncertainties. The highest priority for future research will focus on improving understanding of the productivity of naturally spawning Chinook and the stock origins of late returning Chinook.

Table 3. Data gaps in White River Chinook stock assessment and harvest management, and projects required to address those gaps.

Data Gap	Research Needed
Uncertainty in stock origin/composition of spawners above and below Mud Mountain Dam	Additional genetic sampling at the trap and on the lower river spawning grounds using larger sample sizes over the full run timing. Quantification of hatchery- and natural-origin adults on the spawning grounds.
Timing of river entry of early and late timed Chinook	Radio or ultrasonic tracking study
Estimation of natural smolt production	Investigate feasibility of outmigrant trapping above and below 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

Puyallup River Fall Chinook Management Unit Status Profile

Component Populations

Puyallup River fall

Spawning Distribution

Fall Chinook spawn in South Prairie Creek (a tributary of the Carbon River) up to RM 15, the Puyallup mainstem up to Electron Dam at RM 41.7, to a limited extent in the mainstem and tributaries of the upper Puyallup above Electron Dam, the lower Carbon River up to RM 8.5, Voight Creek, Fennel Creek, Canyon Falls Creek, Clarks Creek, Clear Creek, Kapowsin Creek, the lower White River, Salmon Creek, and Boise Creek.

Life History Traits

Puyallup River fall Chinook are genetically similar to Green River Chinook, reflecting extensive use of this stock to initiate local hatchery programs. Genetic analysis suggests a low degree of independence from the Green populations; the current existence of native fall genotypes is uncertain (Ruckelshaus et al.2006). Fall Chinook returning to the Puyallup and to the White River are, however, more strongly genetically independent and distinct from the White River spring population.

Freshwater entry into the Puyallup River occurs from mid-June through October, and spawning occurs from mid-September through mid-November. Scales collected from South Prairie Creek between 1992 and 2007 indicate that average annual age composition is: 1.8% age-2, 16.7% age-3, 67.3% age-4, 12.0% age-5 and 0.1% age-6 fish (WDFW, unpublished data).

Habitat Limiting Factors

The Puyallup watershed has been altered by timber harvest, hydroelectric facilities, and floodplain modification. The lower river has been channelized and constricted by levees, degrading spawning habitat and eliminating virtually all off-channel rearing habitat. The estuarine delta and Commencement Bay have been developed for industrial purposes, leading to degradation and loss of habitat crucial to juvenile Chinook.

Adult access to the upper Puyallup watershed is still inhibited by the Electron diversion dam; the fish ladder constructed in 2001 is not functional at high flow. Natural Chinook smolt production from the upper watershed is subjected to entrainment in the Electron diversion. A trap intended to collect smolts in the forebay above the powerhouse is inefficient, and allows the majority of smolts to be killed by passage through the turbines.

Pierce County (2008) identified and prioritized habitat actions for salmon recovery in the Puyallup watershed. For fall Chinook, priority projects included the improvement of smolt screening on the

Electron diversion, levee setback and flood-plain re-connection projects upstream of RM 2.6, and increases in estuarine off-channel habitat below RM 2.6. Due to the complexity and cost of the high-priority projects, they are unlikely to be completed during the span of this plan.

Hatchery Production

Hatchery production of fingerling 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. Storm damage to the Voight Creek facility precluded Chinook production for brood year 2008. Production objectives were subsequently reduced from 1.6 million to 400,000. Production objectives for the Clarks Creek facility, which began in brood year 2004, were increased from 400,000 to 1.6 million. The Tribe will release 100,000 Clarks Creek fingerlings into the Cowskull acclimation ponds in the upper Puyallup watershed.

Escapement

Spawning escapement to the Puyallup system is based on surveys of the South Prairie – Wilkeson Creek basin, Fennel, Canyon, Kapowsin, and Clarks creeks. A substantial number of fall Chinook also spawn in the White River below the Buckley trap. Spawning occurs in the mainstem White River, Boise Creek, and Salmon Creek. The mainstem and Carbon Rivers are not consistently surveyable due to glacial turbidity and/or high flow, 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 system in recent years has further confounded Chinook escapement estimates; when large numbers of pink salmon concurrently spawn in South Prairie Creek, Chinook counts are unreliable.

Escapement to South Prairie Creek, and the estimate of system total escapement, declined from 2001 – 2005, but the 15-year trend is stable (i.e. the negative slope is not biologically significant, Geiger and Zhang 2002). The 2004 – 2008 geometric mean total natural escapement (1449) was lower than the 1999-2003 geometric mean (1533). Mean South Prairie Creek escapements for these periods were 752 and 935, respectively. Escapement to South Prairie Creek has consistently exceeded the escapement goal (500) since 1994. Achieving escapement of at least 500 in South Prairie Creek, in former versions of this Plan, was considered to represent adequate seeding of spawning area in the Puyallup watershed.

The changes in hatchery production will affect the distribution, and possibly the magnitude, of natural escapement. Lower production at Voight Creek is expected to reduce the number of hatchery-origin Chinook spawning in South Prairie Creek. More intensive escapement survey effort and carcass sampling may be needed to describe the contribution of Clarks Creek-origin Chinook to natural escapement.

Table 1. Fall Chinook escapement to the South Prairie Creek index reach, and estimated total natural escapement to the Puyallup River.

Year	Puyallup basin natural escapement	South Prairie - Wilkeson Index escapement
1992	3,034	
1993	1,999	
1994	1,363	798
1995	2,405	1,408
1996	2,166	1,268
1997	1,139	667
1998	1,756	1,028
1999	1,988	1,430
2000	1,193	695
2001	1,915	1,154
2002	1,590	840
2003	1,173	740
2004	1,065	573
2005	725	389
2006	1,599	978
2007	2,626	1,194
2008	1,967	925

The estimated proportion of hatchery-origin fish in the South Prairie Creek index has varied in recent years, ranging from 18% to 46%.

Harvest distribution and exploitation rate trends:

The harvest distribution of Puyallup fall Chinook has not been directly assessed. Fishery recoveries of CWT'd and marked releases from Voight Creek, beginning with brood year 2002 will provide relevant information. Distribution in pre-terminal fisheries is likely similar to that of the South Sound fingerling indicator stock, which is composed of tagged releases from the Green River (Soos Creek) and Grovers Creek hatcheries (see the Green River MU profile). For 2001-2006, an average of 39% of the fishery recoveries of that indicator stock were in British Columbia, 12% were in SUS troll fisheries, 24% in Puget Sound net fisheries, and 24% in Washington recreational fisheries (CTC 2008b).

Post-season FRAM validation runs indicate that the total annual adult-equivalent exploitation rates for Puyallup fall Chinook have averaged 66% since 2001. The ER associated with northern fisheries increased since 2001, and ranged from 11% to 33% since 2003 (Table 2). SUS fishery ERs have fallen, from 62% in 2001 to 27% in 2006, due to reduction in terminal (in-river) fishery impacts; pre-terminal SUS ERs have been stable in the range of 6% to 10%. Preseason modeling has been adjusted to more accurately predict terminal harvest impacts, which have declined substantially in recent years.

Pre-season and post-season harvest impact estimates are affected by the uncertainty in estimating spawning escapement and total runsize. The co-managers intend to review methods for Puyallup fall Chinook runsize estimation with the intention of improving accuracy of these harvest impact estimates.

Table 2. Annual, adult equivalent exploitations rates for Puyallup fall Chinook derived from post-season FRAM runs.

	Total	Northern	PT SUS	Term
2001	72%	11%	7%	55%
2002	69%	11%	6%	51%
2003	63%	16%	8%	39%
2004	72%	20%	8%	43%
2005	69%	33%	10%	26%
2006	51%	24%	10%	17%

Management Objectives

The harvest management strategy for Puyallup fall Chinook assumes the indigenous late-timed Chinook population has been extirpated, so recovery will involve local adaptation of the extant Green River-origin stock. The suitability of this stock to achieve recovery objectives is not certain. The hatchery program, in recent years, has utilized only locally-collected broodstock, to promote adaptation.

Harvest strategy reflects the requirement for meaningful exercise of the tribes' treaty-reserved right to harvest Chinook, and WDFW's intent to enable recreational fishing opportunity. The tribes' objective is to conduct commercial and C&S fisheries in the Chinook management period in the Puyallup River, and to fully harvest surplus coho and pink salmon. Recreational opportunity will be provided to harvest Chinook, pink, and coho in the Puyallup mainstem and the Carbon River.

Harvest objectives reflect the managers' intent to maintain stable natural spawning escapement to the Puyallup system. Optimum escapement (i.e., MSY) and habitat capacity have not been quantified, due to constraints on measuring total system escapement and recruitment. Escapement has, however, been more consistently and accurately estimated in the South Prairie Creek – Wilkeson drainage. Voight Creek hatchery returns have comprised a significant proportion of natural spawners in South Prairie Creek in recent years. Recent changes in hatchery production will affect the distribution of hatchery-origin spawners, and will likely reduce their number in South Prairie Creek. Escapement surveys over the next five years will necessarily continue to focus on clear-water tributaries, but surveys and sampling may change to better quantify the distribution and contribution of Voight Creek and Clark Creek-origin adults to natural spawning.

The objective for pre-season harvest planning will be to constrain SUS fisheries, so that the total ER does not exceed 50%. Recent year post-season FRAM estimates have exceeded this ceiling, but the underlying objective to ensure natural escapement of at least 500 to South Prairie Creek has been consistently achieved. The UMT is set at this level, as an aggregate of natural- and hatchery-origin adults, for the purposes of post-season performance assessment.

Habitat-based assessment of current productivity, using the Ecosystem Diagnosis and Treatment model, provides estimates of Chinook productivity for the Puyallup River, excluding the White River basin (Mobrand Biometrics 2003). EDT models indicate that current natural productivity is very low. It estimates MSY escapement at 522, and equilibrium escapement at 1,137. EDT models suggest that life history trajectories associated with South Prairie Creek are relatively more productive; MSY escapement is estimated at 230, and equilibrium escapement at 667. Recent-year estimates of the number of natural-origin adults spawning in South Prairie Creek range from 328 to 688, exceeding the EDT estimate of MSY for this tributary system. While EDT models do not precisely estimate the parameters defining freshwater production potential (Steel et al.2009), these analyses support the conclusion that recent escapement have achieved or exceeded the level associated with optimum productivity.

If the pre-season FRAM projection of natural escapement to the Puyallup system falls to or below the LAT of 500, pre-terminal SUS fisheries will be constrained so the associated ER does not exceed 12%. Terminal-area fisheries will also be further constrained by restricting recreational fisheries and tribal net fisheries to maintain fishing opportunity on harvestable hatchery Chinook, pink, coho, and chum salmon, and ensuring tribal C&S fishing opportunity.

Data gaps

- Determine the changes in natural spawning escapement and spawning distribution that result from the changes in hatchery production.
- Validate standardized methods for estimating total spawning escapement based on South Prairie – Wilkeson and index reaches. Estimate the number of fall Chinook spawning in the White River and its tributaries.
- Review methods for forecasting abundance, estimating index-reach and total natural escapement, and natural- and hatchery-origin components.
- Analyze new information on harvest distribution from recovery of CWT group releases from Voight Creek Hatchery.

Nisqually River Chinook Management Unit Status Profile

Component Populations

Nisqually fall

Geographic description

Adult Chinook ascend the mainstem of the Nisqually River to river mile 40, where further access is blocked by the La Grande and Alder dams, facilities that were constructed for hydroelectric power generation by the City of Tacoma's public utility in the early 1900's. Due to the identification of a substantial fish passage barrier, it is unlikely that Chinook utilized higher reaches in the system prior to their construction. 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 largely undeveloped Fort Lewis military reservation. At river mile 26, a portion of the flow is diverted into the Yelm Power Canal, which carries the water 14 miles downstream to a powerhouse, where the flow returns to the mainstem at river mile 12. A fish ladder provides passage over the diversion. Both Tacoma's and Centralia's FERC license requires minimum flows in the mainstem Nisqually.

Fall Chinook spawn in the mainstem above river mile 3, in numerous side channels, as well as in the lower reaches of Yelm Creek, Ohop Creek, the Mashel River and several smaller tributaries. Production is augmented by production at the Kalama Creek and Clear Creek hatcheries, operated by the Nisqually Indian Tribe.

Life History Traits

Adult fall Chinook enter the Nisqually River system from July through September, and spawning activity continues through November. After emerging from the gravel, juveniles typically spend two to six months in freshwater before beginning their seaward migration. Residence time in their natal streams may be quite short, as the fry usually move downstream into higher order tributaries or the mainstem to rear. Extended freshwater rearing for a year or more, that typifies some Puget Sound summer/fall Chinook stocks, has not been observed in the Nisqually system.

Returning adults mature primarily at age-3 and age-4, comprising 45 and 31 percent, respectively (WDF et al.1993, WDFW 1995 cited in Myers et al.1998).

Stock Status

It is generally agreed that native spring and fall Chinook stocks have been extirpated from the Nisqually River system, primarily as a result of blocked passage at the Centralia diversion, de-watering of mainstem spawning areas by hydroelectric operations, a toxic copper ore spill associated with a railroad trestle failure, historically high harvest rates in the preterminal fisheries, non-stock specific hatchery practices, and other freshwater and marine habitat degradation (Barr, 1999). Studies are underway to determine whether any genetic evidence suggests persistence of the native stock. Initial results indicate that the existing naturally-spawning and hatchery stocks are indistinguishable, and were derived from hatchery production that utilized, principally, Puyallup River and Green River fall Chinook.

Escapement estimates for the Nisqually system are calculated based on a method developed by Herrington-Tweit and Newman (1986), which expands peak counts in the mainstem index (RM 21.6-26.2) and Mashel River index (RM 0.5-3.2) to estimate total basin escapement. Spawner counts in the mainstem Nisqually are difficult because of the glacial nature of the river, and are highly variable due to the poor viewing conditions. The 1986 expansion methodology was intended to account for this issue, but it was developed using data collected prior to the construction of the Clear Creek Hatchery. Because hatchery strays make large contributions to natural escapement, the distribution of spawning in the watershed has likely changed, meaning that the 1986 methodology may no longer be an accurate estimator of the naturally spawning population.

Natural spawning escapement has ranged from 340 to 2,788 over the past 15 years (Table 1). Natural escapement exhibits a significantly increasing trend over that timeframe, and escapement has exceeded the nominal escapement goal in five of the last seven years. The marked increase in escapement in years since 2004 is attributable to a management shift to emphasize a natural escapement objective, increased survey frequency in the index reaches in the Mashel River and the mainstem, and an increase in the return of hatchery produced Chinook. Estimates derived from redd and spawner surveys have been validated by change-in-ratio (CIR) estimates (M. Alexandersdottir, NWIFC, pers comm 2006) for 2002 – 2005. Survey-based estimates fall within the confidence bounds of the CIR estimates.

The natural escapement goal has been consistently achieved despite relatively high harvest rates, due in part to the contribution of hatchery-origin Chinook to natural spawning. A significant portion of this natural spawning escapement is comprised of hatchery origin strays. Hatchery returns have increased over the past 15 years, from a low of 1,370 in 1993, to a high of 15,497 in 2007. Terminal net harvest has shown a similar trend, increasing from 4,024 in 1993, to a high of 22,933 in 2007.

Estimates of hatchery-origin and natural-origin contributions to spawning escapement have been made since 2004, but the precision and accuracy of these estimates are poor due to relatively low mark rates on hatchery fish (85-92% in recent years), and difficulty in sampling adequate numbers of carcasses in all of the spawning areas. When adjusted for mark rates and stratified by sampling areas, hatchery-origin spawners have been estimated to account for an average of 75% of the natural spawners from 2004-2007 (range of 74%-76%).

Table 1. Annual abundances of fall Chinook returning to the Nisqually River system.

Year	Terminal Net Harvest	Escapement Hatchery	Escapement Natural	Escapement Total
1993	4,024	1,370	1,655	3,025
1994	6,183	2,104	1,730	3,834
1995	7,171	3,623	817	4,440
1996	5,365	2,701	606	3,307
1997	4,309	3,251	340	3,591
1998	7,990	4,067	834	4,901
1999	14,614	13,481	1,399	14,880
2000	6,836	4,918	1,253	6,171
2001	14,098	7,612	1,079	8,691
2002	11,703	9,341	1,542	10,883
2003	14,425	7,697	627	8,324
2004	13,834	8,225	2,788	11,013
2005	11,088	12,470	2,159	14,629
2006	21,568	10,535	2,179	12,714
2007	22,933	15,497	1,743	17,240

Harvest distribution and exploitation rate trend

The harvest distribution of Nisqually Chinook has been described by analysis of coded-wire tagged fingerling Chinook released from Clear Creek and Kalama Creek hatcheries (Table 2). In recent years 17 percent of the total harvest mortality has occurred in British Columbia and Alaska, primarily in the WCVI troll fishery. Washington troll fisheries have accounted for 7 percent of total fishery mortality. Recreational (ocean and Puget Sound) and net fisheries in Puget Sound, have accounted for 29 and 47 percent of total mortality, respectively.

Table 2. Harvest distribution of Nisqually Chinook, as expressed as the proportion of fishery mortality, 2000-2006.

Year	AK%	CN%	US tr %	US net%	US spt %
2000	0.0%	20.8%	1.9%	42.3%	34.9%
2001	0.5%	10.4%	7.0%	41.2%	41.0%
2002	0.0%	16.7%	5.2%	55.5%	22.6%
2003	0.1%	13.2%	6.3%	57.3%	23.0%
2004	0.3%	14.2%	12.2%	50.3%	23.0%
2005	0.0%	24.5%	9.6%	24.5%	41.4%
2006	0.2%	13.5%	8.9%	60.0%	17.4%
Average	0.2%	16.2%	7.3%	47.3%	29.1%

The total annual exploitation rate for Nisqually Chinook, as described by post-season FRAM runs, has declined slightly since the early 1990's (Figure 1), but still averaged 77% from 2000-2006. FRAM rates are assumed to accurately index the recent trend in exploitation rate, but may not accurately quantify annual exploitation rates, because of the lack of CWT data in the model base period. Exploitation rates in northern fisheries have increased since the late 1990's, averaging 7% from 1995-2002, and 20% from 2003-2006. Pre-terminal SUS exploitation rates have remained fairly constant, averaging less than 20% from 1998-2006. Terminal rates have been more variable, and have averaged 45% over the same period.

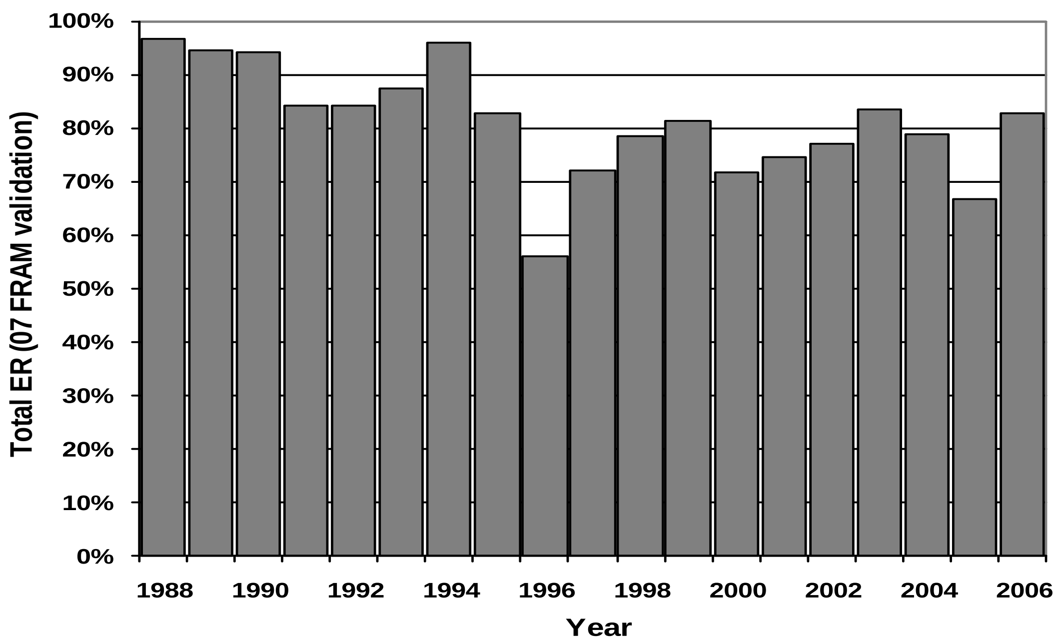


Figure 1. Total annual, adult equivalent fisheries exploitation rate of Nisqually fall Chinook, from 1988 – 2006, estimated by 2007 FRAM validation run.

Overall approach to recovery

A key long-term goal of the Nisqually Chinook Recovery Plan (NCRT 2001) is to establish a self-sustaining, naturally spawning Chinook population in the basin. The plan acknowledges that a number of habitat, hatchery, and harvest actions must take place if that goal is to be reached. Significant progress has been made on the habitat portion of the recovery plan. For example, nearly 72% of the main-stem Nisqually is in protected stewardship, restoration of the Mashel River is nearly complete, and the estuary restoration will be fully complete by late 2009, with the total creation of over 900 acres and 21.5 miles of side-channel habitat.

The harvest management objective for Nisqually Chinook under the previous harvest plan was a fixed escapement goal, met with a combination of natural and hatchery-origin spawners. The fixed goal was adjusted over time, to reflect the improvements to habitat conditions, with the most recent goal being 1,200 spawners. It is generally accepted that natural production of Nisqually Chinook under current conditions cannot support recent exploitation rates (average of 77% since 2000), and that hatchery strays are currently sustaining the natural population. This means that harvest rates and hatchery-origin contribution to natural spawning must be addressed if the goal of a self-sustaining population is to be reached.

A new tool for management of spawner composition in the Nisqually, a floating live-capture weir, is scheduled for construction in the summer of 2010. While details on the operation of the weir are still under development, the weir will be managed to achieve the desired hatchery/natural-origin spawner ratio on the spawning grounds. The intent is to drastically reduce the percentage hatchery-origin spawners (pHOS) in the river over time, while maintaining escapement levels above the current goal of 1,200. This reduction in pHOS is expected to improve the productivity of the population, as it should readapt to natural conditions in the watershed.

Attaining natural-origin escapements of the desired magnitude will require reduction in exploitation rates on natural-origin Chinook, although the extent of the required reductions is difficult to assess, due to data limitations. Assessments of productivity and capacity for Nisqually Chinook are complicated by uncertainty in stock assessment data. Escapement estimates are problematic, due to the glacial nature of the mainstem, and the lack of verification of the 1986 escapement methodology. Hatchery and natural-origin composition of spawning escapement are only available for returns since 2004. While acknowledging these and other data issues, analysis completed by the Nisqually Stock Assessment Workgroup using the All-H Analyzer (AHA) model estimated that under current habitat conditions and assumptions of stock fitness, the MSY harvest rate for the natural spawning Nisqually Chinook is 47%. If productivity and capacity improved as expected over the next 10-15 years, the MSY harvest rate could increase to 52%.

Harvest management objectives

The harvest management objective for Nisqually Chinook under this plan is to transition to a total exploitation rate ceiling of 47% for the naturally spawning component, equal to the best current estimate of MSY. The transition to the lower rate will happen in two-year intervals, beginning in 2010. In 2010 and 2011, fisheries will be planned to not exceed a total exploitation rate of 65% on Nisqually Chinook. In 2012 and 2013, the exploitation rate ceiling will be reduced to 56%. Finally, in 2014 the rate will be reduced to 47%, and will remain there for the duration of the plan unless otherwise agreed to by the co-managers. The Nisqually Indian Tribe has an objective for a minimum terminal area fishery equivalent to a 20 % harvest rate on the returning runsize.

This stepped reduction in exploitation rate will provide immediate reduction in exploitation rates on natural-origin Chinook, and will quickly transition to the current estimate of MSY. This transition period will allow time for habitat and hatchery actions to continue, including refinement of the use of the weir as a tool for data collection and reduction of pHOS. New methods for selective harvest of hatchery-origin Chinook will be investigated during this period, to insure that returning hatchery fish are utilized, while impacts on natural-origin Chinook are reduced.

As the operational plan for the weir and new hatchery/natural-origin spawner composition objectives are refined, further reductions in exploitation rates may be needed to meet those objectives. The use of the weir to reduce pHOS will lead to an immediate reduction in total spawning abundance in the Nisqually, and there is uncertainty about the response of the population to this change in the short term. There is also uncertainty regarding the existing fitness level of the natural stock and the timing and magnitude of changes over time. The new, higher quality data collected through operation of the weir will allow improved analysis of the fitness**,** capacity and productivity of the population, and refinement of the exploitation rate ceiling. Should new data and analysis identify a more appropriate exploitation rate for the population, management objectives may be adjusted during the term of this plan. The changes to hatchery proportions on the spawning grounds and the continued improvements to habitat should lead to increases on productivity of Nisqually Chinook over time, meaning that management objectives will need to be reevaluated frequently.

Data gaps

- Improve total natural escapement estimates
- Use data collected at the new weir, along with continue data collection through spawner surveys, to recalibrate past natural escapement estimates
- Continue age-specific estimates of both natural and hatchery-origin recruits, including the possibility of complete parentage studies
- Develop stock-recruit analysis and quantify the current natural productivity of the system as improved data are collected, and as habitat and hatchery changes lead to future changes in productivity

Skokomish River Management Unit Status Profile

Harvest management objectives for Skokomish Chinook reflect a new strategy for recovering Chinook salmon with historical life history patterns, suited to environmental conditions in a restored Skokomish watershed. Historically, early-returning Chinook were produced in the upper North and South Fork reaches of the Skokomish River. The recent settlement agreement between the Skokomish Tribe, the City of Tacoma, State and Federal Resource agencies regarding operation of the Cushman hydroelectric project and associated mitigation supports restoration of early (spring) Chinook, initially in the North Fork, and subsequently in the South Fork. Details of this strategy are being developed as part of the Skokomish River Chinook Salmon Recovery Plan (SRCSRP), to achieve the Co-managers' objective of recovering a self-sustaining, naturally-produced Chinook population in the Skokomish watershed.

Upon completion of the SRCSRP and its formal incorporation into the Puget Sound Chinook Recovery Plan, the Co-managers will propose modifications to the Puget Sound Chinook Harvest Management Plan that reflect the intent of the SRCSRP.

The co-managers' will continue to monitor natural escapement, age composition, and spawning distribution of fall Chinook, about which recent information is summarized below, to inform subsequent recovery planning decisions.

Geographic description

Two hydroelectric dams block passage to the upper North Fork Skokomish watershed. The reservoirs inundate 18 miles of river habitat that was formerly suitable to Chinook production.

Chinook 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 RM 5.0 including Vance Creek. In the North Fork spawning occurs upstream to Cushman Dam at RM 17.0. However, a majority of the spawning in the North Fork has historically occurred below RM 13.0 due to low flow releases from the hydroelectric facility limiting access higher in the system (WDF et al. 1993).

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, but flushing flows will have short-term negative impacts. Under the new restoration strategy, spring Chinook 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 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 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 habitat in the North Fork caused by construction and operation of the Cushman hydroelectric project.

Chinook escapements to George Adams Hatchery have increased since the mid-1990's and have ranged from about 4,000 to 16,000 fish since 2000 (Table 2).

Table 16. Chinook spawning escapement in the Skokomish watershed (Skokomish Chinook technical workgroup 2006).

Year	Natural Escapement	Hatchery Escapement
1988	2666	4,930
1989	1204	2,556
1990	642	2,186
1991	1719	3,068
1992	825	294
1993	960	612
1994	657	495
1995	1398	5,196
1996	995	3,100
1997	452	1,885
1998	1177	5,584
1999	1692	8,227
2000	962	4,033
2001	1913	8,816
2002	1479	8,834
2003	1125	10,034
2004	2398	12,278
2005	2032	16,018
2006	1209	12,356
2007	531	13,720
2008	1134	13,695

There is significant uncertainty in estimates of natural escapement for some years in this time series. Estimates of the proportions of hatchery-origin and natural-origin fish among natural spawners are uncertain and perhaps biased in years prior to 2008 due to relatively low sampling rates, few recoveries of coded-wire tagged or marked Chinook, and uncertainty about expanding marked recoveries to fully account the hatchery proportion. Estimates of hatchery origin-fish in the natural escapement have averaged approximately 56% (range of 7% to 95%) from 1998-2007.

Harvest distribution and exploitation rate trends

The harvest distribution of Skokomish Chinook is described by coded-wire tag recoveries of fingerlings released from George Adams Hatchery. The standard analysis conducted by the PSC Chinook Technical Committee involves expansion of estimated recoveries from fisheries to account for non-landed mortality. The average of 2001-2006 recoveries indicates that 60% percent of CWT recoveries were from Washington fisheries (Table 2).

Table 17. Average distribution of fishery mortality of George Adams Hatchery fingerling Chinook, from analysis of CWT recoveries (CTC 2008).

AK	BC	WA troll	WA net	WA sport
1.7%	40.2%	10.7%	16.5%	30.9%

The total annual (i.e., management year) exploitation rate, computed by post-season FRAM runs has been relatively stable since 2001, when the first Puget Sound Chinook Harvest Plan was implemented. 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 for management years 2001- 2006, estimated by post-season FRAM validation runs.

Year	North	PT SUS	Term	Total
2001	14%	10%	32%	57%
2002	15%	9%	27%	51%
2003	18%	7%	35%	61%
2004	21%	10%	23%	55%
2005	30%	7%	19%	57%
2006	19%	8%	28%	55%

Management Objectives

The management objectives for the extant fall population are 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%.
- For the purposes of pre-season harvest planning, the Upper Management Threshold will be 3650 (the aggregate of 1650 natural spawners and 2000 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 1200 in most years.

There is substantial evidence that the productivity of the extant fall stock is very low, due, in part, to the constraints imposed by current habitat condition, Domestication of hatchery-origin Chinook has occurred as result of their early life history in the hatchery environment, and due to hatchery cultural practices. As a result of reduced fitness, survival of hatchery-origin adults that return and spawn naturally may also be reduced. This loss of fitness, which has only been theoretically quantified, has occurred over many generations of artificial production. Advanced freshwater entry, spawning and emergence timing may also be significantly affecting productivity. These factors suggest that long-term recovery objectives may not be achieved by the extant stock.

If the early-timed stock re-introduction proceeds as now planned, with release of sub-yearling smolts as early as the spring of 2012, the first adults from this initial broods will return starting in 2014. We cannot predict the level or distribution of fishing mortality these Chinook will experience. The Recovery Plan will specify the elements of the monitoring program necessary to estimate catch distribution and fishing mortality, and develop harvest objectives and conservation measures.

The ongoing Chinook recovery effort will continue to address habitat constraints in the Mainstem and lower reaches of the North and South Fork. High flows into the lower North Fork will be implemented to restore structure and function to the channel. Hydro project operations will result in normative hydrology, as specified by the Cushman settlement. Aggradation in the lower South Fork and Mainstem will be addressed as the ACOE General Investigation concludes, possibly by large-scale removal of accumulated material. Engineered logjams will be installed and the riparian area re-vegetated to restore structure and function to lower South Fork channel. Rearing habitat in the delta will be increased and improved by removing dikes and re-connecting side channels. Some of these habitat restoration efforts will have short-term negative effects on Chinook production, but initial focus on re-introduction of early Chinook into North Fork and upper South Fork can proceed while habitat restoration proceeds in the lower basin.

The potential for Chinook recovery will not be known until the effectiveness of habitat restoration is realized.

Monitoring

- Continue spawning survey regime and re-evaluate the current methodology used to estimate natural spawning escapement.
- Monitor the effects of flushing flows, and resulting channel changes in the North Fork on spawning distribution.
- Sample terminal catch and spawning grounds to determine age composition and hatchery / natural origin.
- Operate smolt trap(s) to estimate production from the South and (after early-stock reintroduction) North Fork.

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 RM 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 RM 7, and to the upper Dosewallips River at RM 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 river mainstems provide nearly the entire production potential.

Life History Traits

Genetic characterization of the Mid-Hood Canal Management Unit (MU) has, to date, been limited to comparison of adults returning to the Hamma Hamma River in 1999 with other Hood Canal and Puget Sound populations. These studies, although not conclusive, suggest that returns to the Hamma Hamma River are not genetically distinct from the Skokomish River returns, or recent George Adams and Hoodsport hatchery broodstock (A. Marshall, WDFW unpublished data). The reasons for this similarity are unclear, but straying of Chinook that originate from streams (including large on-station hatchery releases) further south in Hood Canal, and hatchery stocking in the rivers of the Mid-Hood Canal MU in past years, could be contributing causes.

Status

The Mid-Hood Canal MU is comprised of Chinook local sub-populations in the Dosewallips, Duckabush and Hamma Hamma watersheds. These sub-populations are at low abundance (Table 1). Prior to 1986 no reliable abundance estimates are available because all escapement for these rivers was estimated by extrapolation of estimates for Skokomish River Chinook. Escapement survey areas and survey effort have changed recently 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 even include some ‘dip-ins’ that ultimately spawn elsewhere in Hood Canal. Nonetheless, it is apparent that the population is currently in critical status. 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 recently been mass-marked. In the

Hamma River, where a Chinook supplementation program is ongoing that includes fish releases sourced from the Skokomish River hatchery, preliminary estimates based on mass marked hatchery production show that spawning escapement was comprised of 53%-62% hatchery-origin Chinook in 2008 (WDFW and PSIT 2009).

Table 1. Natural spawning escapement of Mid-Hood Canal fall Chinook salmon, 1990-2008.

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	54	762
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

Chinook salmon from the three Mid-Hood Canal rivers have been designated as a single population, although the NMFS Technical Recovery Team (TRT) concluded that the historical existence of a self-sustaining population is not certain (Ruckelshaus et al. 2006). The proximity to the Mid-Hood Canal Chinook population to the Skokomish River population suggests there could have been genetic exchange between fish originating in the watersheds. The TRT considered alternative population structure scenarios for Hood Canal Chinook including the possibility that one or more self-sustaining population of Chinook (e.g., fall and/or spring) occurred in the Skokomish River and that the Dosewallips, Duckabush, and Hamma Hamma rivers had Chinook spawners whose numbers were largely supported by the Skokomish Chinook "source" population. However, the TRT did identify Mid-Hood Canal and Skokomish as the two historical independent populations of Hood Canal

The historical presence of a natural population notwithstanding, current habitat conditions may not be suitable to sustain natural Chinook production. Although historical spawner abundance estimates suggest that abundance has previously rebounded from levels as low as those in recent years, the increase in escapements during 1998-2001 and in 2008, however, is likely primarily due to the returns of Chinook adults from the ongoing supplementation program on the Hamma Hamma River.

Harvest distribution and exploitation rate trends:

The harvest distribution and recent fishery exploitation rates of Mid-Hood Canal Chinook, cannot be directly estimated because until recently none of the component sub-populations have been coded-wire tagged. Releases from the supplementation program on the Hamma Hamma River have been coded-wire tagged beginning with BY 2004 and initial results will soon be available. However, it is reasonable to assume that, given their similar life history, tagged fingerling Chinook released from the George Adams Hatchery on the Skokomish River follow a similar migratory pathway and experience mortality in a similar set of pre-terminal fisheries in British Columbia and Washington. A summary of recent analyses of the Skokomish River data is shown in that profile.

The FRAM model is used to provide both pre-season and post-season estimates of exploitation rates for the Mid-Hood Canal Chinook. Post-season FRAM estimates of the total annual exploitation rate for Mid-Hood Canal Chinook show a dramatic decrease in the average rate of 63% for the period of 1983 – 1997, to an average of 27% for the period of 1998 – 2006 (Figure 1). The exploitation rate on Hood Canal Chinook in northern fisheries (Alaska and Canada) has not shown this same dramatic decrease, with the recent year average (17% since 1998) only 4% less than the average for the earlier period (21% for 1983 – 1997). Southern U.S. exploitation rates declined from an average rate of 41% for the period 1983 – 1997, to just 10% for the period 1998 – 2006. Terminal area exploitation rates are estimated to be near zero for the recent period. Estimates of fishing impacts on Mid-Hood Canal Chinook rely on assumptions about how well hatchery tagged fish represent wild production. The co-managers are currently re-examining those assumptions for Mid-Hood Canal Chinook in Hood Canal and other Puget Sound fisheries.

Management Objectives

The management objective for the Mid-Hood Canal MU is to maintain and restore sustainable, locally adapted, natural-origin Chinook sub-populations. The purpose of harvest management actions taken specifically for Mid-Hood Canal Chinook is to remove harvest as a significant factor impeding recovery of the ESU.

When the escapement goal (currently 750 spawners) is not expected to be met, fisheries in southern U.S. areas (SUS) will be managed to achieve a preterminal (PT) AEQ exploitation rate of less than 15%, as estimated by the FRAM model. In this case, preterminal fisheries include the coastal troll and recreational fisheries managed under the Pacific Fisheries Management Council, and the marine commercial and recreational fisheries in Puget Sound. The migratory pathway and harvest distribution of Mid-Hood Canal Chinook is presumed to be identical to the pattern of Skokomish River Chinook in preterminal fisheries. The extreme terminal areas for this management unit include the freshwater areas in each river.

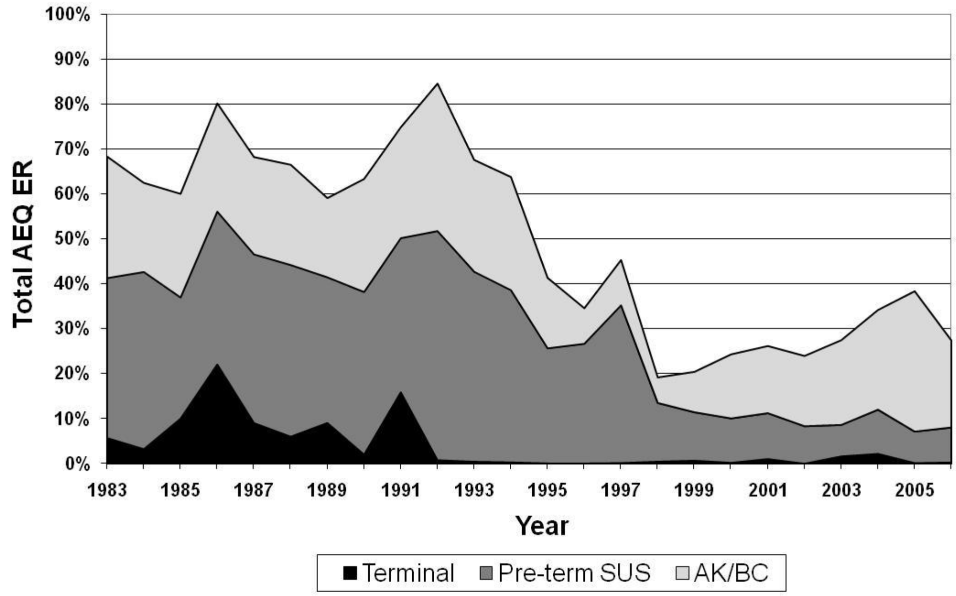


Figure 1. Total annual, adult equivalent fisheries exploitation rate of Mid-Hood Canal Chinook, from 1983 – 2006, estimated by FRAM validation run.

Terminal-area fisheries at the far southern end of Hood Canal, near the mouth of or in the Skokomish River, are assumed to have an insignificant impact on adults returning to the mid-Hood Canal rivers of origin. Recent coded-wire tagging of Hamma Hamma Chinook and recoveries in fisheries may provide a basis for testing this assumption in the near future.

If the escapement goal is not expected to be met, all extreme terminal (freshwater) fisheries that are likely to impact adult spawners of these sub-populations will be closed.

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, further conservation measures will be implemented in preterminal and terminal fisheries to reduce mortality and ensure that the projected preterminal Southern U.S. (PTSUS) AEQ exploitation rate does not exceed 12.0%. Spawning escapement has been below the low abundance threshold each year since 2000 and critical status for this management unit is expected to continue in the near future. 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.

Data gaps

- Continue to improve escapement estimates
- Test the accuracy of the pre-season forecasts
- Develop means to assess the origin composition of adults in the escapement
- For each sub-population, and the MU, reassess spawner requirements and quantify the current productivity (in terms of recruits per spawner) and capacity (in terms of adults and juvenile migrants).
- Monitor and evaluate coded-wire tag returns from the Hamma Hamma supplementation program to fisheries and escapement, and to review current assumptions about effects of fisheries within Hood Canal upon Mid-Hood Canal Chinook.

Dungeness Management Unit Status Profile

Component Populations

Dungeness River Chinook

Distribution and Life History Characteristics

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 two-thirds of the redds located downstream of RM 10.8. Chinook also spawn in the Gray Wolf River (confluence with Dungeness at RM 15.8) up to RM 5.1.

The entry timing of mature Chinook into the Dungeness River is not described precisely, because of chronically low returns of adults. It may occur from spring through September. Adult weir operations in 1997 and 2001 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). Ocean- and stream-type life histories have been observed among juvenile Chinook in the system, with extended freshwater rearing more typical of the earlier-timed segment (Williams et al.1975). Hirschi and Reed (1998) found that a significant number of Chinook juveniles overwinter in the Dungeness River.

Smolts from the Dungeness River exhibit primarily an ocean-type life history, with age-0 emigrants comprising 95 to 98 percent of the total (WDF et al.1993, Smith and Sele 1995, and WDFW 1995 cited in Myers et al.1998). Adults mature primarily at age four (63%), with age 3 and age 5 adults comprising 10% and 25%, of the annual returns, respectively (PNPTC 1995 and WDFW 1995 cited in Myers et al.1998).

Stock Status

The SASSI report (WDF et al.1993) classified the Dungeness spring/summer as critical due to a chronically low spawning escapement to levels, such that the viability of the stock was in doubt and the risk of extinction was considered to be high. Dungeness Chinook continued to be classified as critical in the SaSI report (WDFW 2003) because of continuing chronically low spawning escapements.

The nominal escapement goal for the Dungeness River is 925 spawners, based on historical escapements observed in the 1970's and estimated production capacity re-assessed in the 1990's (Smith and Sele 1994). From 1986 through 2000, the average escapement was only 153 (Table 1). Escapements increased from 2000 through 2006, averaging 893. It should be noted however that the increase in escapements was largely attributable to the captive brood supplementation program, as 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 escapements have shown corresponding decreases in the 2007 and 2008 return years.

Table 1. Spawning escapement, broodstock collection, and hatchery/natural-origin composition of Dungeness River Chinook 1986 - 2008.

Return year	Estimated number of natural spawning Chinook	Number of Chinook collected for broodstock plus pre-spawned mortalities	Total adult Chinook return	Number and percent of HOR Chinook in natural spawning population **(NS)** a/	Number and percent of NOR Chinook in natural spawning population **(NS)** a/
1986	238	0	238	Unknown	238
1987	100	0	100	Unknown	100
1988	335	0	335	Unknown	335
1989	88	0	88	Unknown	88
1990	310	0	310	Unknown	310
1991	163	0	163	Unknown	163
1992	153	0	153	Unknown	153
1993	43	0	43	Unknown	43
1994	65	0	65	Unknown	65
1995	163	0	163	Unknown	163
1996	183	0	183	Unknown	183
1997	50	0	50	Unknown	50
1998	110	0	110	Unknown	110
1999	75	0	75	Unknown	75
2000	218	0	218	Unknown	218
2001	453	0	453	436 (96.3%)	17 (3.6%)
2002	633	0	633	518 (81.8%)	115 (18.2%)
2003	640	0	640	517 (80.8%)	123 (19.2%)
2004	953	61	1,014	815 (80.9%)	193 (19.1%)
2005	955	122	1,077	651 (68.2%)	304 (31.8%)
2006	1,405	138	1,543	1,112 (79.2%)	293 (20.8%)
2007	305	98	403	159 (52.0%)	146 (48.0%)
2008	140	89	229	54 (38.6%)	86 (61.4%)

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.

WDFW has operated screw traps in the lower Dungeness each year since 2005, to estimate the number of juvenile salmon produced in the basin. Estimates for Chinook production (Table 2) ranged from a high of 136,571 in 2007 to a low of 14,239 smolts in 2008 (Data are available in WDFW juvenile monitoring annual report series, including Topping et al.(2008)). Estimated egg to smolt survival has averaged around 4% over that period. 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 above, and of the general low productivity of the population.

Table 2. Dungeness Chinook adult escapement (natural-spawning), potential egg deposition, Chinook smolts produced, and estimated egg to smolt survival for 2004-2008 broods.

Brood year	Outmigrant year	Adults	Females	Potential egg deposition	Smolts	Egg to smolt survival
2004	2005	953	381	1,906,000	69,392	4%
2005	2006	955	382	1,910,000	124,928	7%
2006	2007	1405	562	2,810,000	136,571	5%
2007	2008	305	122	610,000	14,239	2%
2008	2009	140	56	280,000		

The co-managers, in cooperation with federal agencies and private-sector conservation groups, implemented a captive brood stock program 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 have been collected and spawned, with the goal of releasing 100,000 zeros and 100,000 yearlings each year.

In addition to the broodstock program, the local watershed council (Dungeness River Management Team) and a work group of state, tribal, county and federal biologists have been working on several habitat restoration efforts. Based on the 1997 report, “Recommended Restoration Projects for the Dungeness River” by the Dungeness River Restoration Work Group, local cooperators have installed several engineered log jams, and acquired small riparian refugia properties. Other projects including larger scale riparian land acquisition, dike setback, bridge lengthening and setback, as well as estuary restoration are in the planning, analysis and proposal phases.

Management Objectives

The management objective for Dungeness Chinook is to stabilize escapement and recruitment, as well as to restore the natural-origin recruit population through supplementation and fishery restrictions. Pre-terminal incidental harvest is constrained to a ceiling AEQ exploitation rate of 10.0% in southern U.S. waters. Directed terminal commercial and recreational harvests have not occurred in recent years, and incidental harvest in fisheries directed at coho and pink salmon have been regulated to limit Chinook mortality.

Direct quantification of the productivity of Dungeness Chinook will require either the accumulation of sufficient coded-wire tag recoveries to reconstruct cohort abundance, or an alternate method of measuring freshwater (egg-to-smolt) and marine survival. Releases from the supplementation program are represented by coded-wire tagged groups, adipose fin marked groups, otoliths-marked groups and blank-wire tag groups. Recoveries of these tags, otoliths, and marks will enable cohort reconstruction. However, given the degraded condition of spawning and rearing habitat in the lower mainstem, it must be assumed that current natural productivity is critically low.

The lack of stock specific historical tag information has necessitated the interim use of a neighboring representative stock in fishery simulation modeling of Dungeness Chinook salmon. Tagged Elwha Hatchery fingerlings are used by the FRAM to estimate the harvest distribution and exploitation rates for the Elwha and Dungeness management units. (See Elwha Profile, below). Also, for units with very low abundance, such as the Dungeness, the FRAM model's accuracy may be limited. 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.

The low abundance escapement threshold for the Dungeness River is 500 natural spawners, which is approximately 50% of the escapement goal. Whenever natural spawning escapement for this stock is projected to be below this threshold, SUS fisheries will be managed to further reduce incidental mortality to incidental AEQ impacts of less than 6.0%.

Data gaps

- Describe freshwater entry timing
- Continue to collect scale or otolith samples to describe the age composition of the terminal run.
- Describe the fishery contribution and estimate fishery-specific exploitation rates from CWT recoveries.
- Estimate marine survival.
- Continue annual estimates of smolt production, and corresponding estimates of freshwater survival

Elwha River Management Unit Status Profile

Component Populations

Elwha River Chinook

Geographic Distribution and Life History Characteristics

Summer Chinook spawn naturally in the portions of the lower 4.9 miles of the Elwha River, below the lower Elwha dam, though most of the suitable spawning habitat is below the City of Port Angeles' water diversion dam at RM 3.4. Their productive capacity is very low, because of extremely restricted suitable habitat. Their productivity is also very low due to severely altered and degraded spawning and rearing habitat, and high water temperatures during the adult entry and spawning season, which contribute to pre-spawning mortality (see Table 2, below).

Entry into the Elwha River begins in early June and continues through early September. Spawning begins in late August, and peaks in late September and early October (WDF et al.1993). Elwha Chinook mature primarily at age 4 (57%), with age 3 and age 5 fish comprising 13% and 29%, of annual returns, respectively (WDF et al.1993, WDFW 1995, PNPTC 1995 cited in Myers et al.1998).

Naturally produced smolts emigrate primarily as subyearlings. Roni (1992) reported that 45 to 83% of Elwha River smolts emigrated as yearlings, and 17 to 55 percent as subyearlings, but this study did not differentiate naturally produced smolts from hatchery releases of yearlings.

Status

Elwha River Chinook were originally designated as "healthy" in the SASSI document (WDF et al.1993), which considered productivity in the context of the currently available habitat for natural production. Because of chronically low levels of spawner escapement during the last decade, the SaSI report (WDFW 2003) reclassified the Elwha Management Unit as "depressed."

The stock is a composite of natural and hatchery production. In the Elwha River, Chinook production is limited by two hydroelectric dams which block access to upstream spawning and rearing habitat. Recovery of the stock is dependent on removal of the two dams, and restoration of access to high quality habitat in the upper Elwha basin and certain tributaries. Chinook produced by the hatchery mitigation program in the Elwha system are considered essential to the recovery, and are included in the listed ESU.

Preparations are underway for the removal of the Elwha and Glines Canyon dams, with the physical removal of the dams scheduled to begin in 2011. The removal of the dams will lead to periods of high sediment loads in the lower river, and may make that area unsuitable for spawning. During this time, the hatchery program will focus on maintaining the integrity of the gene pool of the existing population. The Elwha River Fish Restoration Plan (Ward et al.2008) provides details on the approaches being used for restoring Chinook and other species in the basin. Multiple strategies ranging from the transport of adult spawners upstream of the construction areas, the outplanting of smolts and pre-smolts in a variety of areas throughout the watershed, and maintaining a separate broodstock source in nearby Morse Creek will minimize the risk of losing this critical stock of Chinook in the Strait of Juan de Fuca region.

Over the last decade or more, Elwha hatchery egg-take goals have largely remained static, producing between 3 and 4 million subyearling Chinook. Survival rates to adult spawner of these releases have been highly variable for return years 1999-2008, ranging from 0.02% to 0.14% and averaging 0.07% returning to the Elwha River. Yearling releases of approximately 500,000 smolts weres discontinued in 1995 due to high costs and poor survival rates associated with this release strategy (approximately 0.2% smolt to adult survival in most years; Figure 1). Yearling production of 200,000 to 400,000 smolts was restarted in BY2002; initial returns indicate a further decrease of smolt to adult survival rates of less than 0.05%. Poor ocean conditions in recent years may account for some of these results, but managers are evaluating the efficacy of this production strategy for Elwha River Chinook.

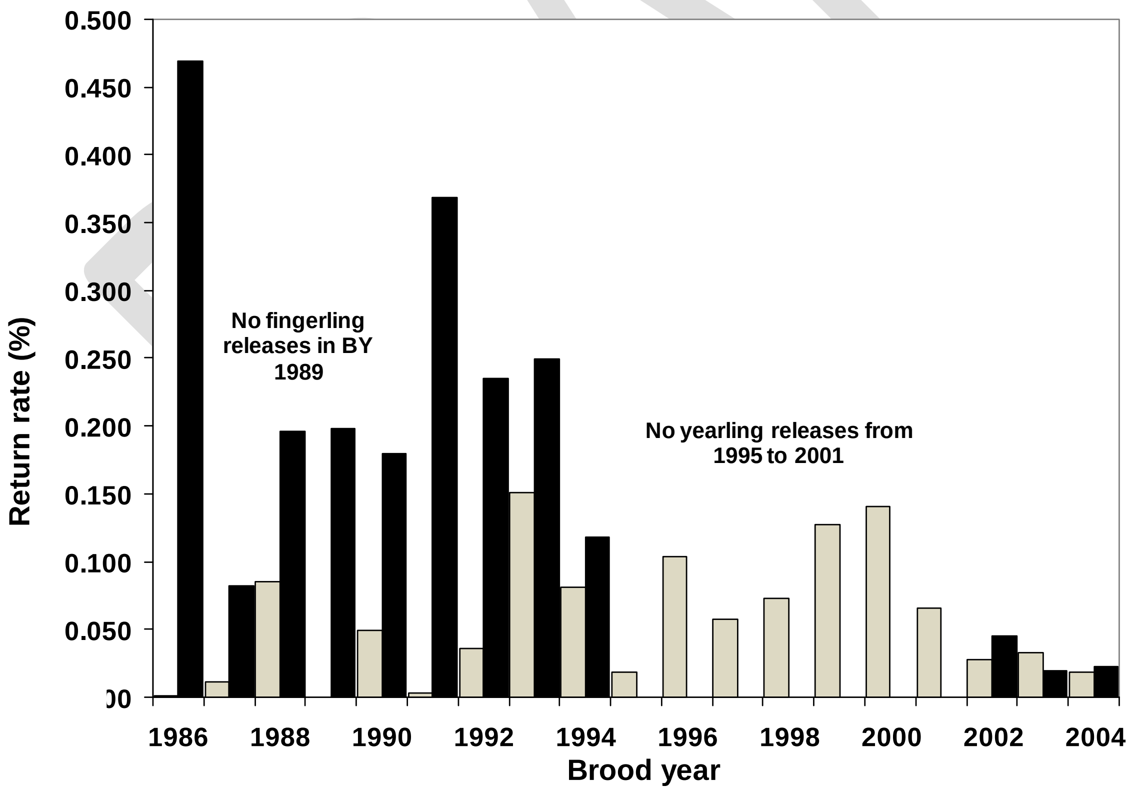


Figure 1. Fingerling and yearling return rates for Elwha River hatchery Chinook releases, Brood Years 1986 to 2004 (R. Cooper, WDFW, unpublished data).

The nominal spawning escapement goal of 2,900 for Elwha River Chinook has been achieved only once since the 1980s (Table 1), even though SUS harvest has been drastically reduced, and in-river fishery impacts have been absent for over 10 years. The average number of spawners over the last five years (2004-2008) has been 1,947, around 100 fewer than the average of 2,053 for the preceding five years (1999-2003).

Table 1. Total spawning escapement of Elwha River Chinook, 1986-2008.

Year	Escapement	Year	Escapement
1986	2,269	1998	2,358
1987	3,631	1999	1,602
1988	7,395	2000	1,851
1989	4,927	2001	2,208
1990	2,956	2002	2,376
1991	3,361	2003	2,227
1992	1,222	2004	3,404
1993	1,562	2005	2,119
1994	1,216	2006	1,913
1995	1,150	2007	1,146
1996	1,608	2008	1,153
1997	2,517		

Pre-spawning mortality has been a significant factor affecting natural and hatchery production in the Elwha system. High water temperature during the period of freshwater entry and spawning is exacerbated by impoundment of the river behind the two upstream dams. It contributes directly to prespawning mortality, and in some years, promotes the infestation of adult Chinook by *Dermocystidium*. Pre-spawning mortality has ranged up to 68% of the extreme terminal abundance (Table 2), largely due to parasitic infestation. Presumably dam removal will help to alleviate pre-spawning mortality problems.

Table 2. Prespawning mortality of Elwha River Chinook.

Return Year	Hatchery Voluntary	In-River Gross	Gaff-Seine	Hatchery Prespawn	In-River Prespawn	Total Prespawn Mortality
1986	1,285	1,842	505	376	482	27.4%
1987	1,283	4,610	1,138	432	1,830	38.4%
1988	2,089	5,784	506	428	50	6.1%
1989	1,135	4,352	905	148	412	10.2%
1990	586	2,594	886	160	64	7.0%
1991	970	2,499	857	108	N/A	3.1%
1992	97	3,762	672	26	2,611	68.3%
1993	165	1,404	771	7	0	0.5%
1994	365	1,181	749	61	269	21.3%
1995	145	1,667	518	37	625	36.5%
1996	214	1,661	1,177	147	120	14.2%
1997	318	2,209	624	3	7	0.4%
1998	138	2,271	1,551	51	0	2.1%
1999	113	1,512	609	23	0	1.4%
2000	177	1,736	1,021	62	0	3.2%
2001	195	2,051	1,396	38	0	1.7%
2002	473	1,943	1,080	40	0	1.7%

Harvest Distribution and Exploitation Rate Trend

Based on recoveries in 1993 – 1997 of tagged fingerlings released from the local hatchery, Elwha River Chinook are a far-north migrating stock, as evidenced by 16% and 59% of total fishing mortality occurring in Alaskan and British Columbian fisheries, respectively (Table 3). Net fisheries in Puget Sound account for only 1% of total fishing mortality, and Washington troll and sport fisheries account for 11%, and 22%, respectively.

Table 3. The average distribution of fishing mortality for Elwha River Chinook, expressed as a proportion of total, annual adult equivalent exploitation (CTC 2003)

Years	Alaska	B.C.	Wash. Troll	Puget Sound Net	Washington sport
1993 – 97	16.2%	58.8%	1.9%	0.8%	22.3%

Post-season FRAM simulations indicate that the total exploitation rate of Elwha River Chinook decreased in the late 1990's, averaging 54% prior to 1998, and dropping to 21% from 1998 to 2001 (Figure 2). From 2002 through 2006, rates climbed slightly, averaging 35% over that period. This increase is attributed to northern fisheries, as exploitation rates in SUS fisheries remained at levels less than 5% during this time (Table 4). These post-season FRAM estimates represent aggregates of JDF units, but are believed to correctly represent the trend in ER for the Elwha unit.

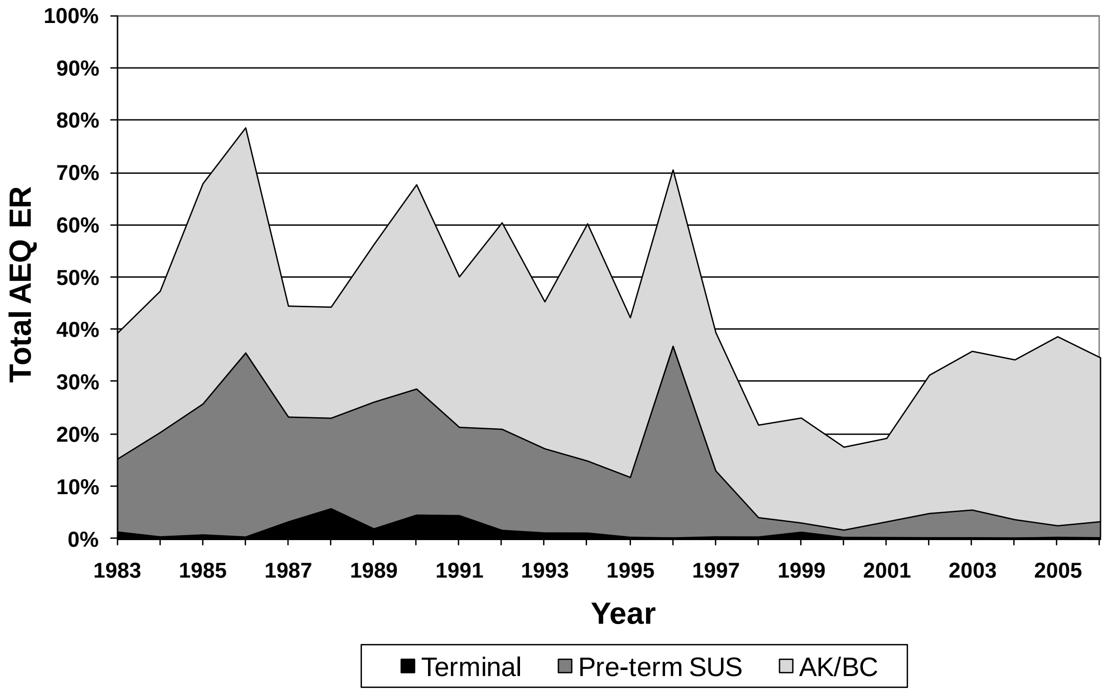


Figure 2. Adult equivalent fishery exploitation rates of Elwha Chinook in Alaska/BC, preterminal Southern United States, and terminal fisheries from 1983-2006, as estimated by post-season FRAM runs (2007 validation).

Table 4. Fishery-related adult equivalent exploitation rates of Elwha River Chinook for management years 2000-2006, estimated by post-season FRAM validation runs.

Year	Total	Alaska/BC	Southern US
2000	18%	16%	2%
2001	19%	16%	3%
2002	31%	26%	5%
2003	36%	30%	6%
2004	34%	30%	4%
2005	39%	36%	3%
2006	34%	31%	3%

Management Objectives

Fisheries in Washington waters, including those under jurisdiction of the Pacific Fisheries Management Council, when the escapement goal is not projected to be met, will be managed so as not to exceed a "Southern U.S." incidental AEQ exploitation rate of 10.0% on Elwha Chinook. Harvest at this level will assist recovery by providing adequate escapement returns to the river to perpetuate natural spawning in the limited habitat available, and provide broodstock for the supplementation program. It represents a significant decline in harvest pressure from levels seen in the 1980s and early 1990s in southern U.S. fisheries. The SUS exploitation rate on the Strait of Juan de Fuca management unit aggregate averaged 24% for return years 1983 – 1996. Since 1997, actual SUS AEQ exploitation rates averaged less than 4%.

The low abundance threshold for the Elwha River is 1,000 spawners, which represents a composite of 500 natural and 500 hatchery spawners. Whenever spawning escapement for this stock is projected to be below these levels, SUS fisheries will be managed to further reduce incidental AEQ mortality to less than 6.0%.

Data Gaps

- Estimates of total and natural smolt production from the Elwha River.
- Estimates of the age composition and description of life history of smolts.
- Monitor changes to spatial structure, genetic structure and life history diversity of the population during and after dam removal.
- Reassess management objectives as the watershed recovers from removal of dams.

Western Strait of Juan de Fuca Management Unit Status Profile

Component Populations

Hoko River fall Chinook

Geographic description

Fall Chinook spawn primarily in the mainstem of the Hoko River, from above intertidal zone to RM 22, but primarily between RM 3.5 (the confluence of the Little Hoko River) to the falls at RM 10. 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(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 counted small numbers of Chinook. Their origin is unknown, but they are assumed to be strays from the Hoko system.

Currently, Chinook from the Hoko Hatchery are being outplanted into the upper Hoko mainstem and tributaries of the upper and lower portions of the watershed, to seed high quality habitat, which has not been utilized consistently for spawning or rearing. Re-introduction to the Sekiu River, and other western Strait streams that once supported Chinook, is also being planned, after the Hoko River consistently achieves its escapement goals.

Life History Traits

Based on scales collected from natural spawners and broodstock from 1989 through 2008, returning Hoko River adults are predominately age 4 (46%) and age 5 (34%) , with age 3 and age 6 adults comprising 15% and 2%, respectively, of the mean annual return. The available data suggest that most smolts produced in the Hoko system emigrate as subyearlings (Williams et al.cited in Myer et al.1998).

Status

The established escapement goal for Hoko River Chinook is 850 natural spawners. This goal, first presented in WDF *Technical Report 29* (Ames and Phinney 1977), 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 752 spawners from 2000-2008.

Numbers of natural Chinook spawners have increased since the inception of the supplementation program in 1982, from counts of less than 200, before hatchery supplementation was initiated, to the recent year average of 610 spawners. Abundance of Hoko Chinook has been highly variable over the past 20 years, but shows no long-term positive or negative trend. Well over half the Hoko River natural spawners in most years may be attributed to the supplementation program; since 2000, an average of 67% of the total escapement to the Hoko has been over supplementation origin (H. Leon, pers. Comm..). The goal of 850 natural spawners has only been achieved in six of the last 21 years (1988 to 2008; Table 1).

Table 1. Natural spawning escapement of Chinook and hatchery broodstock removals from the Hoko River, 1988 – 2008.

Return Year	Natural Spawners	Hatchery Brood Stock	Total Escapement
1988	686	90	776
1989	775	67	842
1990	378	115	493
1991	894	112	1,006
1992	642	98	740
1993	775	119	894
1994	332	96	428
1995	750	155	905
1996	1,227	38	1,265
1997	768	126	894
1998	1,618	104	1,722
1999	1,497	191	1,688
2000	612	119	731
2001	768	178	946
2002	449	237	686
2003	863	235	1,098
2004	866	220	1,086
2005	203	81	284
2006	845	50	895
2007	462	106	568
2008	431	52	483
2000-2008 Avg	610	142	752
Goal:	850	200	1,050

Although the escapement goals set in Technical Report 29 have been commonly accepted over the past two decades, 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 stock-recruitment relationship for Hoko Chinook, which may lead to revision in the escapement goal. Makah Fisheries Management 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.

Harvest Distribution and Exploitation Rate Trends

The migration pathway, and harvest distribution, of Hoko River Chinook has been described from recoveries of coded-wire tagged fish released from the Hoko Hatchery. The tag data suggest that Hoko Chinook are harvested primarily by coastal fisheries in Southeast Alaska and British Columbia (Table 2). Total exploitation rates on Hoko Chinook, as estimated by CWT data, have declined from an average of 33.5% between 1989 and 1999, to an average of 24.6% between 2000 and 2007 (Makah Tribe, unpublished data).

Table 2. Average distribution of fishery mortality of Hoko fall Chinook, expressed as the proportion of fishery mortality, 2000-2006 (CTC 2008).

Year	AK%	CN%	SUS tr %	SUS net%	SUS spt %
2000	80.5%	12.4%	7.1%	0.0%	0.0%
2001	80.7%	15.2%	0.0%	0.0%	4.1%
2002	58.5%	38.4%	0.0%	0.0%	3.1%
2003	75.3%	24.7%	0.0%	0.0%	0.0%
2004	46.1%	50.7%	0.0%	0.0%	3.3%
2005	35.3%	59.7%	2.1%	0.0%	2.9%
2006	54.7%	41.4%	1.9%	0.0%	1.9%
Average	61.6%	34.6%	1.6%	0.0%	2.2%

Prior to 2006, the Hoko stock was aggregated with the other Strait of Juan de Fuca stocks for FRAM modeling purposes. Beginning in 2006, Hoko was separated from the other stocks using historic tag data, so FRAM-based post-season estimates of exploitation rates specific to Hoko are available for 2006 – 2008 (Table 3). Like the CWT data, FRAM suggests that Hoko Chinook are primarily harvested in northern fisheries.

Table 3. Exploitation rate on Hoko Chinook as estimated by post-season FRAM (2007 validation) 2006-2008.

Area	2006	2007*	2008*
Northern (AK/BC)	25.8%	32.9%	22.6%
SUS - Preterminal	3.7%	3.3%	3.7%
SUS - Terminal	0.0%	0.0%	0.0%
Total	29.5%	36.2%	26.4%
*2007 and 2008 data are preliminary			

Cohort-reconstruction estimates of recruits shows that for most brood years since the mid-1980's, the number of natural-origin recruits (the sum of landed catch, spawning escapement, plus natural and non-landed mortality) has been fewer than the number of spawners that produced them. This indicates that the problem with producing natural-origin recruits is habitat-related, very likely caused by degraded freshwater habitat, including recurrent flooding and erosion, possibly combined with poor marine survival. Almost the entire watershed (98%) has been clearcut, and 60% of the watershed has been clearcut within the last 25 years. There are 350 miles of roads in the 72 square mile watershed.

Management objectives

Management guidelines include a recovery exploitation rate objective for the Western Strait of Juan de Fuca management unit and a low abundance escapement threshold. The recovery exploitation rate objective is a maximum of ten percent in southern U.S. fisheries. The critical escapement 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 fisheries to achieve a lower rate than the 10% ceiling SUS exploitation rate.

Data gaps

- Derive a spawner/recruit relationship for Hoko Chinook. Traditional spawner recruit/models may not be appropriate for the Hoko, given the habitat degradation and resulting low productivity of the population discussed above.

Appendix B: Tribal Minimum Fisheries Regime

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.
- 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:

- Ceremonial fishery in late May limited to 10 natural-origin early Chinook. Subsistence fishery July 1-4 limited to 20 natural-origin early Chinook. Ceremonial and subsistence harvest to be taken in the lower river, and between the confluence of the South Fork and the confluence of the Middle Fork.
- 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,
- 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:

- Net fishery Chinook impacts incidental to fisheries directed at pink, coho, chum, and steelhead.
- Pink fishery schedule limited to maintain Chinook impacts at or below the modeled rate.

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.
- No Chinook directed commercial fishery in the Ship Canal or Lake Washington.
- Limited Chinook test fisheries to acquire data
- 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 (September 15th) 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.
- No Chinook directed commercial fishery.
- Net fishery impacts incidental to fisheries directed at coho. Coho opening delayed until first week of September.

Duwamish/Green River Fisheries:

- Chinook test fishery to re-evaluate forecasted abundance.
- No Chinook directed commercial fishery.
- Net fishery impacts incidental to fisheries directed at coho. Coho opening delayed until the second week of September and restricted to waters below the 16th Ave Bridge. Coho

opening above the 16th Ave Bridge to the Boeing Street Bridge (upstream of the turning basin) delayed until September 22nd. 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.
- Chinook test fisheries to acquire data.

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:

- Net fisheries closed from beginning of February to beginning of August.
- Chinook net fisheries limited to 1 day/week. August 7th –September 10th.
- Muckleshoot on-reservation fisheries on White River limited to hook and line C & S fishing for seniors, with a limit of 25 Chinook.
- Puyallup tribal C&S fishery for spring Chinook in the Puyallup mainstem
- Tribal C&S fisheries for fall Chinook in the Puyallup mainstem and White River.
- Commercial net fishery Chinook impacts incidental to fisheries directed at coho, pink, and chum.

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).