Appendix G
HARVEST MANAGEMENT

Description of Fisheries that Impact Snohomish Chinook

Chinook salmon from Puget Sound are harvested throughout nearly their entire period of marine residency in a plethora of fisheries ranging geographically from Alaska to the ocean off the Washington coast and inside Puget Sound. For the past decade, fishing mortality on Snohomish natural-origin Chinook has been mainly incidental to fisheries targeting other stocks or species. Terminal area net fisheries directed at Snohomish Chinook were last opened in 1984; hook-and-line recreational fisheries have been reduced over the years, and directed take was closed in the mid-1990s. Even with the cessation of directed fishing, the cumulative effect of incidental harvest rates can be significant. The harvest management challenge has been to find ways to allow fishing on abundant stocks and species while minimizing the fishing-related mortality of key wild management units, such as Snohomish Chinook.

Because of the current lack of an indicator stock for Snohomish Chinook, it has been difficult to estimate the total exploitation rate or the distribution of fishing mortality for this unit. (While stock have been tagged, it will be several years before returns can be counted.) However, using the Pacific Salmon Commission's Chinook model, the Puget Sound Salmon Stock Review Group, appointed by the Pacific Fishery Management Council estimated that fisheries in Canada took 61% of the harvest of Snohomish Chinook in 1980, declining to 40% by 1990 (PSSSRG, 1997). Under Annex 4, Chapter 3, of the Pacific Salmon Treaty, adopted in 1999 (http://www.psc.org/pubs/treaty.pdf), Canadian interceptions of Snohomish Chinook have been reduced in absolute terms. However, due to the decline in fisheries impacts on both sides of the border, the Canadian portion of the overall harvest remains near the 1985-2001 average of 50% (average harvest fraction in Canadian fisheries from tables in PSC, 2003; current absolute exploitation rate in Canadian fisheries from comanagers' preseason FRAM run 1604).

From brood year 1977 through 1992, exploitation rates[1] on the Snohomish Chinook salmon management unit are estimated to have declined steadily from approximately 80% to approximately 55% (PSC, 1998). Since then, exploitation rates have declined further due to fisheries restrictions on both sides of the border (Table 1). The expected exploitation rate on Snohomish Chinook in 2004 was 29% (Table 1). This number is higher than the guideline of 24% due to recent increases in expected Canadian fishery impacts. Some uncertainties in these estimates of absolute exploitation rates notwithstanding, the trend is clear: despite a gauntlet of mixed-stock fisheries operating, in some cases, for several years on the same brood of Chinook, managers have been successful in achieving large harvest rate reductions.

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[1] This is a so-called "adult equivalent" exploitation rate, computed from the model used by the Pacific Salmon Commission's Chinook technical committee. It measures all sources of fishing-induced mortality (including both retention and non-retention mortality) as (R-E)/R, where R is the total number of fish that would have returned to spawn naturally in the absence of fishing and E is the estimated natural spawning escapement.

A number of restrictions implemented beginning in 1997 on the U.S. side of the border have contributed to the decline in overall exploitation rates. Retention of Chinook salmon is not currently allowed in any recreational fisheries in the Snohomish terminal area (including the river and nearby marine waters), except in specific locations and times when hatchery-produced fish can be targeted with minimal impact on wild Chinook salmon. In the Snohomish terminal area the net fishery directed at wild Chinook salmon has not been opened since 1984. Incidental harvest in net fisheries directed at other species or harvestable hatchery fish is carefully monitored and planned so that total impact rates will stay below guideline levels. In preterminal areas, retention of Chinook is not allowed in most recreational fisheries, and incidental impacts in net fisheries are carefully monitored and controlled. Recently, the state began an experimental mark-selective fishery in the Strait of Juan de Fuca to determine the effectiveness of mark-selective regulations.

Table 1.

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 1983-2000 (April 2003 revision of FRAM validation runs, personal communication, Andy Rankis, NWIFC, and Larrie LaVoy, WDFW) and from pre-season FRAM model predictions for 1999-2003[2]. The ceiling exploitation rate column is the maximum allowable annual AEQ exploitation rate from the management plan that was in effect for the year.

	AEQ ER		
Fishing Year	**Postseason**	**Preseason**	**Ceiling ER**
1983	73%		
1984	64%		
1985	55%		
1986	60%		
1987	48%		
1988	66%		
1989	52%		
1990	49%		
1991	52%		
1992	61%		
1993	62%		
1994	50%		
1995	65%		
1996	44%		
1997	29%		
1998	25%		
1999	31%	31%	38%
2000	26%	20%	35%
2001		21%	32%
2002		18%	32%
2003		19%	24%
2004		29%	24%

[2] FRAM runs 99NP, 00NP, 01NP, 02NP, 03NP, 1604.

The Washington Department of Fish and Wildlife opens two recreational fisheries in the terminal area, targeted at hatchery-produced Chinook. In the Skykomish River there is a mark-selective fishery in June and July targeting fish produced at the Wallace River Hatchery, nearly all of which are marked by removal of the adipose fin to indicate hatchery origin. This fishery is carefully monitored for compliance with mark-selective regulations and to determine the rate that unmarked fish are encountered. An allowance for hook-and-release mortality of unmarked fish in this fishery is included in preseason assessments of mortality to wild Snohomish Chinook in all fisheries. In Area 8D outside Tulalip Bay, there is a recreational fishery that targets fish produced at the Tulalip Hatchery. This fishery follows the time and area management strategy described below for the Tulalip bay net fishery so that the vast majority of fish harvested can be assumed to be from the hatchery. Wild stock impacts in this fishery are accounted for in preseason fishery planning.

The Tulalip Tribes authorizes a fishery in the vicinity of Tulalip Bay (Area 8D) to target Chinook produced at Tulalip Hatchery. Three strategies are used to minimize the harvest of non-target Chinook salmon in this fishery: 1) the fishery is conducted only during the time the hatchery fish return to Tulalip Bay, 2) the open area is restricted to the extreme terminal area to which the hatchery fish are returning, and 3) the fishery is open only part of the week to allow opportunity for non-local fish to pass through while local fish accumulate. This strategy has been evaluated by sampling the catch for otoliths since all Tulalip hatchery production has been thermally mass-marked since brood year 1993. Tulalip Hatchery Chinook comprised 95% of the catch in this fishery from 1997 through 2003 (Table 2). Some of the remaining 5% of the catch is wild Chinook, and these impacts are accounted for in preseason management models.

Table 2.
Estimated contribution of Tulalip Hatchery (TH) fish to Area 8D tribal net fishery from recoveries of marked otoliths, 1997-2003 (Rawson, Kraemer, and Volk, 2001 and unpublished data)

Year	8D Catch	TH %	TH No.
1997	8,295	96.8%	8,033
1998	7,101	92.1%	6,537
1999	15,076	97.7%	14,735
2000	7,605	89.9%	6,840
2001	4,692	93.8%	4,230
2002	5,023	91.9%	5,023
2003	8,903	94.5%	8,415
Total	56,695	94.9%	53,812

The terminal area management described above is required under the Pacific Salmon Treaty so that savings of wild fish realized by reductions in the ocean and preterminal mixed-stock fisheries will be passed through to spawning escapement. The net result all these measures has been that the harvest rate on wild Snohomish Chinook in the terminal fish area, greater than 50% in the early 1980s, has remained below 10% since 1992 (Figure 1). Since 1992, natural spawning escapement numbers for the Snohomish summer/fall Chinook management unit have been increasing (Figure 2), in part due to reductions in preterminal (including Canadian) harvest rates and the success of the pass-though management in the terminal areas.

Figure 1.

Terminal area harvest rates on Snohomish wild stock Chinook, 1978-2003. SOURCE: Tulalip tribes terminal area run reconstruction.

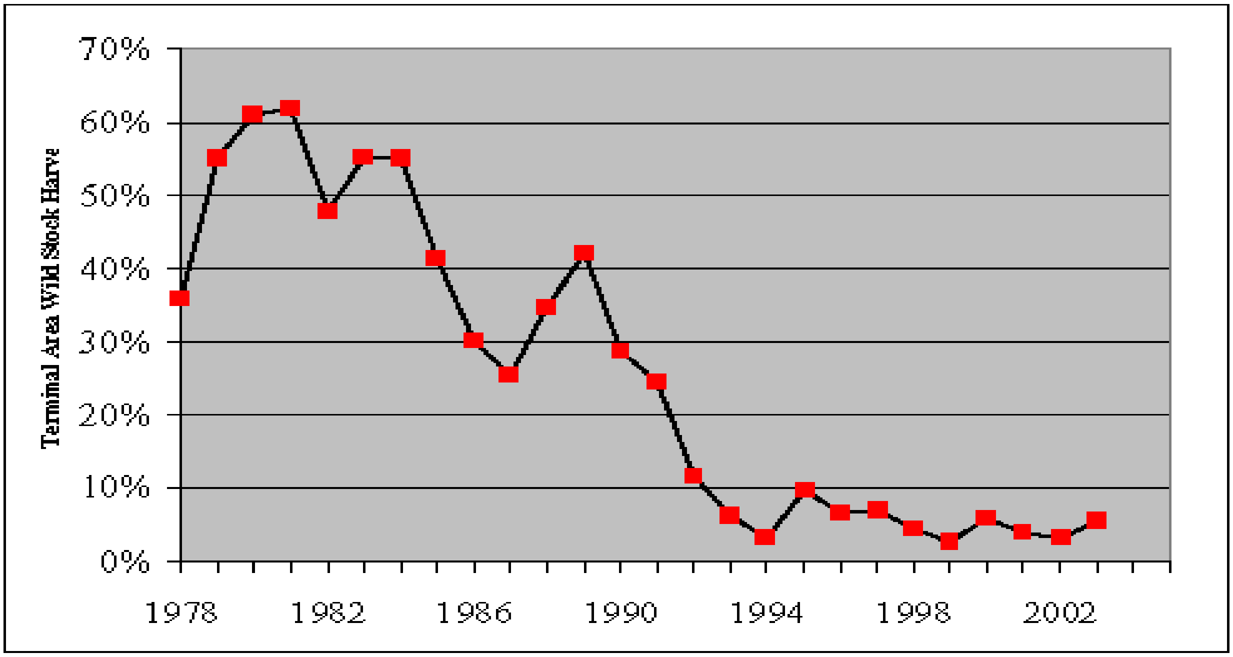
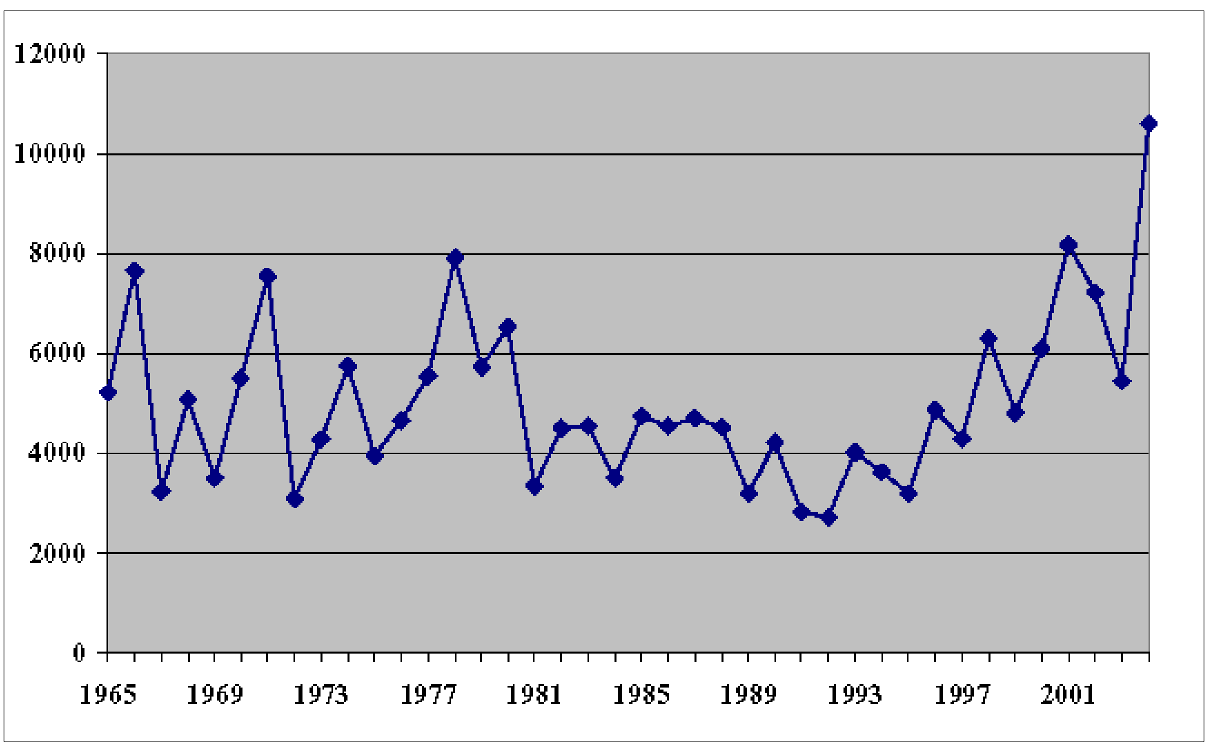


Figure 2.

Snohomish system natural spawning escapement, 1965-2004. SOURCE: Washington Department of Fish and Wildlife



Harvest Management Plan

As part of this recovery plan, harvest of Snohomish natural origin Chinook will be managed such that harvest will not impede achievement of the recovery goals for the Skykomish and Snoqualmie populations. Harvest management by itself cannot make recovery happen, but harvest impacts can be controlled so that habitat restoration and protection and hatchery reform measures will be effective in promoting recovery. The Comanagers' Puget Sound Chinook Harvest Management Plan (Puget Sound Indian Tribes and Washington Department of Fish and Wildlife, 2004), which will be in effect through the 2009 fishing season, has this as an overall objective and includes details of how the plan is designed to achieve this objective for specific management units, including Snohomish Chinook. Key elements of the plan and its derivation for Snohomish Chinook are described below. More detail can be found in the plan document and its appendices.

Management Objectives

Management objectives for Snohomish Chinook include an upper limit on total exploitation rate (Recovery Exploitation Rate: RER) to control the risk that harvest will impede the recovery of the component populations, 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%. These impacts include all mortalities related to fisheries, including direct take, incidental take, release mortality, and drop-off mortality in all fisheries.

Lacking direct information on the extent to which the current fisheries regime may differentially harvest the two populations, spawning escapements will be carefully monitored for indications of differential harvest impact. The observed distribution of escapements between the populations for 1965-2004 (Table 3) will be the benchmark for this assessment.

The Puget Sound Salmon Management Plan (PSSMP) (1985), adopted by the federal court as part of the United States vs. Washington litigation, sets out the procedures and guidelines for comanagement of the salmon resource. Although the PSSMP mandates that fisheries be managed to achieve maximum sustainable harvest (MSH) of primary natural management units, the Snohomish recovery exploitation rate is lower than the rate associated with MSH under current conditions of productivity. Thus, harvest management under the recovery plan is more conservative than under the PSSMP. Among other things, this should provide a buffer against the potential size and age selectivity of fisheries and the effects of that selectivity on reproductive potential, and uncertainty and error in management.

Under the current comanagers' plan there is no specific provision for directed harvest of Snohomish wild Chinook, even when such harvest would fit in under the RER threshold. Before the expiration of the current comanagers' plan (at the end of the 2009 fishing season), the comanagers will revisit this provision and may determine an upper abundance threshold above which limited directed harvest could be allowed consistent with population recovery objectives.

Table 3.

Estimated natural escapement for the Skykomish and Snoqualmie Chinook populations, 1965-2004 (SOURCE: WDFW) and estimated natural origin portion of that, 1965-2002, (K. Rawson unpublished analysis)

	Natural Escapement		Natural Origin Portion	
Year	Skykomish	Snoqualmie	Skykomish	Snoqualmie
1965	4693	525	3523	493
1966	6463	1188	4848	1114
1967	2899	321	2172	301
1968	4301	756	3218	709
1969	3066	424	2305	397
1970	4687	821	3535	770
1971	6756	785	5051	736
1972	2726	348	2028	326
1973	3621	656	2695	616
1974	4684	1061	3600	995
1975	3030	923	2324	866
1976	3223	1436	2302	1347
1977	4529	1013	3284	950
1978	5849	2056	4363	1929
1979	5277	449	4697	409
1980	5221	1305	3968	1227
1981	2408	922	1084	839
1982	3690	808	2878	768
1983	2813	1724	2391	1690
1984	2389	1095	1959	1029
1985	3580	1150	3222	1093
1986	3377	1157	2972	949
1987	3834	855	3412	812
1988	4004	509	3564	433
1989	2221	952	1666	819
1990	2932	1277	2551	1111
1991	2192	628	1951	496
1992	2002	706	1642	600
1993	1653	2366	942	2248
1994	2898	728	1478	561
1995	2791	385	1144	108
1996	3819	1032	1719	660
1997	2355	1937	1696	1821
1998	4412	1892	1500	1419
1999	3455	1344	1382	1048
2000	4665	1427	2099	1127
2001	4575	3589	1944	2817
2002	4325	2895	1916	2339
2003	3474	1972		
2004	7616	2990		

Low Abundance Threshold for Management

The low abundance threshold (LAT) for the Snohomish management unit (combined Skykomish and Snoqualmie populations) is 2,800 natural origin, naturally spawning fish. 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. Thus, further constraint depends on measures that reduce incidental take.

The LAT for the management unit was derived from critical escapement thresholds for each of the Snoqualmie and the Skykomish populations in a two-step process. Critical escapement thresholds are levels that should not be gone 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

Maximum Exploitation Rate Guideline (Rebuilding Exploitation Rate)

The rebuilding exploitation rate (RER) is the highest allowable ("ceiling") exploitation rate for a population 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 the harvest management plan only addresses harvest, we cannot directly evaluate the likelihood of the harvest plan's achieving its objective. Therefore, the RER is evaluated 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. Once the entire Snohomish River Basin Salmon Conservation Plan is implemented and it becomes clear that changes in habitat and hatchery management will have an effect, the harvest management plan will be reassessed and possibly revised using the new habitat and hatchery management conditions.

The RER is chosen such that the population is unlikely to fall below a critical threshold (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, if the productivity conditions for the population improve due to recovery actions, the RET will usually increase and the probability of exceeding the RET using the RER computed for current conditions will also increase over the probability computed under current conditions. Thus the RET serves as a proxy for the true goal of the plan, which can only be evaluated once information is available 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 will be less than the maximum sustainable harvest, the amount less being dependent on the likelihood of achieving the RET. The higher the likelihood of achieving the RET, the smaller actual fishing mortality will be. 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.

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

$$R = f(S, \mathbf{e}), \qquad [2]$$

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.

The viability and risk assessment procedure (VRAP, N J Sands, in prep.) was used for the projection

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[3] Equivalently, this could be termed "potential spawners" because it represents the number of fish that would return to spawn absent haravest-related mobillity.

phase. For each trial RER value, the population is repeatedly projected for 25 years. From the simulation results the fraction of years was computed 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 RET. Trial RERs for which the first fraction is less than 5% and the second fraction is greater than 80% are considered acceptable for use as ceiling exploitation rates for management under this plan.

Model Fitting Phase

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 Fishing 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. Two options were evaluated 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, it was 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" (Healy, 1991). Scale pattern analysis of Snohomish Chinook shows that a significant portion (approximately 25%, see, for example, TRT Abundance and productivity tables) of the return is stream type from both the Skykomish and Snoqualmie 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.

Option 1 was chosen because it was 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, scientists were able to address most of the concerns they had with Option 1. 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.

Stock composition was estimated of the Area 8D recreational and net harvest 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 return years from 1997 on (Table 2), 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.

Stock composition was estimated of the Area 8A net harvest 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 July 1 through September 30 are included in this analysis. Other Chinook harvested in Area 8A, for example in the winter blackmouth recreational fishery, 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. Jim Scott and Dell Simmons of the CTC completed this computation using coded-wire tag recoveries. 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. Two options for the maturation rates were also considered (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. It was decided that option 1 would be used because it is a more direct measure of the age structure of the spawners and relies on age specific data for the populations.

However, two potential concerns were identified 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, it was assumed all spawners were equally fecund regardless of their origin. This assumption resulted in a lower productivity assumption than any other assumption about hatchery effectiveness (Table 4), and thus a lower RER than if diminished effectiveness of hatchery-origin spawners had been assumed. This was therefore a conservative approach towards computing the RER, which was chosen because of a lack of knowledge regarding the effectiveness of hatchery spawners in natural areas.

Table 4.
Intrinsic productivity (MSY Exploitation Rate) by production function for the Skykomish Chinook population

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

Spawner-R ecruit 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 an index was used 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). Two indices were tried: 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:

$$(R = aSe^{-bs})(M^c e^{dF})$$ [Ricker] [3a]

$$(R = S/[bS+a])(M^c e^{dF})$$ [Beverton-Holt] [3b]

$$(R = min[aS,b])(M^c e^{dF})$$ [hockey stick] [3c]

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. The results of model fitting for various combinations of environmental correlates are summarized in the Appendix A of the comanagers' plan. Parameters were used from the fits using the NPS2 marine survival index and using both the marine and freshwater environmental correlates (Table 5).

Table 5.

Results of model fits for Skykomish Chinook using the generalized Ricker (Ric), Beverton-Holt (Bev), and hockey stick (Hoc) spawner-recruit models

	Results for the given model		
	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

Projection Phase

Performance of the Skykomish stock was projected 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. The average marine survival index for the low marine survival period was used 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, scientists 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 Appendix A of the comanagers' plan, and summarized results are in Table 6. 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, scientists used 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 6.

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

		#fish	%runs	%yrs	%runs	1st	LastYrs
Model	TgtER	Mort.	extnct	<LEL	end>UEL	Year	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 Thresholds

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.

The total system escapement required can then be computed such that each stock is expected 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 population came from the recent 12-year escapement breakout. Averaging the ratios of the two populations' estimated NOR escapements over the twelve years gives an average Snoqualmie fraction of 37.7% of the total.

The maximum of the management unit lower thresholds required to achieve the lower thresholds for the two populations is 2,800 (Table 7), 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.

Table 7.
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

Interpretation of the FRAM Model for Preseason Planning

Currently the comanagers use the Fishery Regulation Assessment Model (FRAM) for preseason planning of total fishery impacts (Table 1). Because a different set of exploitation rates (Table 8) 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 1 and 8 cannot be directly compared for a number of reasons. First, the A&P rates (Table 8) are brood year rates, while the FRAM rates (Table 1) 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.

Table 8.

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%

Second, FRAM more accurately represents Snohomish Chinook by modeling both the fingerling outmigrant or "ocean type" and yearling outmigrant or "stream type" (Healy, 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 annual fishing plans are implemented 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. 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 (Fig 2), 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, it is believed 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 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.)

Adaptive Management

The comanagers will review the basic parameters of this plan before the expiration of the current comanagers' plan (after the end of the 2009 fishing season). Basic parameters, including the RE R, lower escapement threshold, and an upper escapement threshold for directed fisheries and be recomputed using stock performance information, which is updated annually. In addition, the comanagers will review the relative impacts of the harvest management plan on the escapements of the two populations, trends in adults spawner size, adult spawner timing, spatial distribution of spawners, etc. Any plan modifications that are deemed to be necessary as a result of this review will be implemented beginning with the 2010 season.

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