3.3 Fish

3.3.1 Threatened and Endangered Species

This section describes the status of salmonid species with particular reference to chinook salmon, the species most likely to be affected by the Proposed Action and its alternatives. All five species of Pacific salmon (genus *Oncorhynchus*) chinook, coho, chum, sockeye and pink – are present in the affected environment and are subject to harvest impacts. Two Evolutionarily Significant Units (ESUs) of Pacific salmon indigenous to the affected environment are listed as threatened under the Endangered Species Act (ESA): the Puget Sound Chinook ESU and the Hood Canal summer chum ESU. Chinook and coho salmon from other ESUs, some of which are listed, are infrequently encountered in fisheries covered under the Resource Management Plan (see Subsection 3.3.1.3). Bull trout (*Salvelinus confluentus*) are present in streams and lakes in the affected environment, and possibly in the marine area as well. Puget Sound and Washington coastal bull trout were listed as threatened in 1999 (see Subsection 3.3.1.4.)

General Salmonid Life History

Pacific salmon and steelhead trout belong to the genus *Oncorhynchus* within the family *Salmonidae* that includes anadromous salmon, trout, char, whitefish, and grayling. Except in limited cases where geologic or anthropomorphic events have blocked migration to salt water, all five species of Pacific salmon, – chinook, sockeye, coho, chum, and pink – exhibit an anadromous life cycle, meaning they spawn in fresh water, mature in the marine environment, and return to fresh water to reproduce and die. Though Pacific salmon species share many general traits, individual populations have adapted to local environmental conditions, and life history strategies are diverse. A general overview of salmonid life history is given here. The reader is referred to Groot and Margolis (1991) for a more in-depth review.

Mature salmon spawn in fresh water, constructing nests called *redds* in stream gravels where fertilized eggs are buried to incubate. All five species of salmon die after spawning. Generally, the young of all salmon species emerge from the gravel in the spring. Newly-emerged salmon are called *fry*. Embryo development rate, the timing of fry emergence, and the subsequent patterns of freshwater rearing and seaward migration are determined primarily by water temperature; thus, hydrologic characteristics play an important role in shaping salmonid populations. Specific timing and location of freshwater residence and subsequent migration patterns of each of the five species and populations within species varies markedly. Actively-feeding riverine juveniles are known as *fingerlings* until they are physiologically ready to migrate to salt water, at which time they are called *smolts*. This transitional life stage is referred to as *smolting*, and may occur in the river or estuary. The term *yearlings* refers to juveniles that

remain in their natal stream (*overwinter*) until the following spring before migrating seaward. Juveniles that migrate as fingerlings are often referred to as *sub-yearlings*.

Both pink and chum salmon migrate seaward almost immediately after emerging from the gravel, and thus are less dependent on freshwater habitat than are sockeye, chinook and coho. Sockeye and coho may spend one or two years in fresh water before migrating to the ocean. The freshwater rearing habits of fingerlings among and within individual chinook populations may vary considerably.

Once at sea, salmon migrate over routes that vary markedly among species and populations. Seaward migration of immature salmon tends to be over a broader temporal and geographic range than streamward migration routes that are generally quite predictable for species and populations.

Table 3.3-1 summarizes differences in key characteristics of the five species, including rearing time in freshwater, early rearing habitats, time spent at sea, age at maturity and size.

Table 3.3-1. Summary of key characteristics of Pacific salmon species.

Characteristic	Chinook	Chum	Coho	Pink	Sockeye
Time rearing in fresh water	1 month to 1 year	Hours to days	Most 1 to 2 years	Hours to days	1 to 2 years
Primary early rearing habitats	Stream, estuary	Estuary	Stream	Estuary	Lake
Years spent at sea	1.5 to 4.5	2.5 to 4.5	0.5 to 1.5	1.5	1.5 to 3.5
Age in years at maturity	2 to 8	2 to 7	2 to 4	2	3 to 8
Average length and weight at maturity	35 inches 35 pounds	26 inches 12 pounds	22 inches 10 pounds	18 inches 4 pounds	26 inches 5 pounds

Source: Canadian Department of Fisheries and Oceans September 2001.

3.3.1.1 Puget Sound Chinook

General Life History and Abundance

The Puget Sound Chinook ESU includes runs of chinook salmon from the North Fork Nooksack River in northeast Puget Sound to watersheds in South Puget Sound, Hood Canal and the Dungeness and Elwha Rivers on the Strait of Juan de Fuca (see Figure 3.2-4 in Subsection 3.2). It occupies a central geographic position in the historical range of chinook salmon, which extended from the Ventura River, California to Point Hope, Alaska in North America and in northeastern Asia from Hokkaido, Japan to the Anadyr River in Russia (Healey 1991).

Maturing adults from the Puget Sound Chinook ESU return to their natal streams from early spring to mid-fall, spawning from August though November. The majority of populations in the Puget Sound Chinook ESU migrate to the ocean within their first year following emergence, but important exceptions exist and are noted below. Many Puget Sound chinook rear within Puget Sound marine waters for several months.

Fisheries catch data show the ocean migration range of Puget Sound chinook extends as far north as northern British Columbia and Alaska for some populations. Some apparently rear their entire life within Puget Sound, but most migrate to the ocean and north along the Canadian coast. The majority are caught inside the Strait of Juan de Fuca, the Strait of Georgia, Puget Sound, and off the west coast of Vancouver Island. Less than one percent is caught off the west coasts of Washington and Oregon (Washington Department of Fish and Wildlife et al. 1997). Puget Sound populations show different tendencies to migrate along the west coast of Vancouver Island or through Johnstone Strait and the Strait of Georgia. Catch distribution is discussed in more detail below in the descriptions of individual populations.

Myers et al. (1998) estimated an approximate run size of 690,000 chinook in Puget Sound at the beginning of the 20th century[i] when hatchery production was negligible, compared to a recent average run size of approximately 240,000, the majority of which is from hatchery production. Cramer et al. (1999) notes the total numbers of chinook produced in Puget Sound dropped in the 1990s to about half the production sustained in the previous two decades. Because of the decrease in total run sizes, managers regulated fisheries to reduce harvests, thereby maintaining spawning escapements at close to their previous levels.

Recent studies (Hare et al. 1999) suggest marine survival of salmon species fluctuates in roughly 20- to 30-year periods that correspond to broad-scale climate changes. In this century, shifts in the ocean-climate regime occurred in 1925 – to a warm/dry climate; in 1947 – to a cold/wet climate; and in 1977 – to a warm/dry climate. Following the ocean regime shift in 1977, marine survival of Puget Sound hatchery chinook dropped sharply beginning with the 1979 brood, and has remained at less than 50 percent of the early 1970s value until 2000. In 2001, following improved oceanographic conditions, there was a notable increase in escapement within many runs.

[i] This estimate, as with other historical estimates, should be viewed with caution. Puget Sound cannery pack probably included a portion of fish landed at Puget Sound ports but originating in Canada and other areas outside Puget Sound, and the estimates of exploitation rates used in run-size expansions are not based on precise data (Myers et al. 1998).

Description of Individual Puget Sound Populations

Populations are described here in terms of:

General spawning range	– River or river section
Origin	– Native (to basin)
	– Mixed (native with influence from outside basin, usually from past hatchery transfers
Status	– Healthy, depressed, critical, or unknown
Run timing	– Spring, summer, summer-fall, or fall

Run timing refers to the seasonal period during which mature adults return to rivers, and is generally descriptive of a suite of life-history characteristics that, as a whole, contribute to the diversity of populations. Puget Sound spring-run populations return to natal rivers from early spring to mid-summer, and spawn from late summer to early fall in colder, higher-elevation areas of watersheds where eggs and fry develop more slowly. Puget Sound fall-run populations return to natal streams from late summer to fall and spawn until late fall. Spring-run juveniles tend to reside longer in natal streams before their ocean migration, and to have different ocean migration patterns than do fall runs. As the term implies, spawn-timing characteristics of summer-fall runs are intermediate to spring and fall runs.

In evaluating the effect of the Proposed Action on listed salmonids, the National Marine Fisheries Service (NMFS) uses an approach consistent with concepts developed by the National Oceanic and Atmospheric Administration (NOAA), Northwest Fisheries Science Center, for defining the conservation status of populations and ESUs. These concepts are described in detail in McElhany et al. 2000, incorporated here by reference. These viable salmonid population guidelines describe the importance of abundance levels, productivity, spatial structure, and diversity as indicators of population status. In assessing the affect of an action, these guidelines help to stratify the ESU adequately to represent its unique population characteristics (National Marine Fisheries Service 2000).

The most direct biological effect of the Proposed Action or its alternatives is expected to be changes in the abundance (spawning escapement) of certain populations within the ESU. Consequently, measures of abundance and description of the geographic and temporal distribution of populations – which determine their vulnerability to fisheries – are key in NMFS' evaluation and are emphasized in this discussion. Habitat characteristics, though important over the long term in shaping life history characteristics, are expected to be minimally affected or unaffected by the Proposed Action of fishing regime management. Therefore, habitat characteristics are treated briefly here, and described in more detail in Appendix C. Appendix C also includes further detail on life history characteristics of each of the populations.

In accord with the viable salmonid population guidelines, NMFS considers the effect an action may have on both the *critical threshold level* of abundance and the *viable population abundance level*. The critical threshold represents a boundary below which the risk of extinction increases substantially. The viable population threshold is a higher abundance level that would generally indicate recovery or a point beyond which ESA protection is no longer required (McElhany et al. 2000; and NMFS 2000). Because NMFS and the co-managers most commonly use measures of spawning escapement (i.e., the number of sexually-mature adults returning to spawning grounds) to express abundance, these threshold levels are referred to as the *Critical Escapement Threshold* (CET), and *Viable Escapement Threshold* (VET) as determined under current environmental conditions. NMFS has quantified specific critical escapement thresholds for 14 of the populations, and specific viable escapement thresholds for 10 of the populations described here (Table 3.3.2). It should be noted that specific viable escapement thresholds are estimates based on current habitat conditions, and do not necessarily reflect a level beyond which ESA protection is no longer warranted. In other cases, NMFS relies on general guidelines developed by the Northwest Fisheries Science Center (McElhany et al. 2000), and escapement goals developed by the co-managers to define acceptable levels of spawner abundance.

The metric for evaluating salmon fishery impacts for chinook populations originating within the Puget Sound Action Area is *exploitation rate* – i.e., fisheries-related mortality expressed as the estimated proportion of the total population(s) taken in various fisheries. For chinook salmon, this is more specifically defined as the proportion of the total abundance of all age classes of fish from a given population or management unit present before fishing began in a given management year. For other species, exploitation rate is more simply calculated as catch or fishing mortality divided by catch plus escapement. In evaluating impacts of fisheries on the ESU, NMFS uses the concept of *rebuilding exploitation rates* developed consistent with the concepts of the Viable Salmonid Population guidelines. In general terms, a rebuilding exploitation rate (RER) is the level of exploitation that would result in a low probability that the proposed harvest action will endanger the population, and a relatively high probability that it will not impede recovery (McElhany et al. 2000; and NMFS 2000).

Table 3.3-2. Critical escapement thresholds, viable escapement thresholds, and rebuilding exploitation rates determined by NMFS for Puget Sound chinook populations.

	Critical Escapement Threshold	Viable Escapement Threshold	Rebuilding Exploitation Rate
Nooksack River Spring			0.12
North Fork	400	700	
South Fork			
Skagit River Summer-Fall			
Lower Skagit	251	2,182	0.49
Lower Sauk	200	681	0.51
Upper Skagit	967	7,454	0.60
Skagit River Spring			
Upper Cascade	170		
Upper Sauk	130	330	0.38
Suiattle	170	400	0.41
Stillaguamish River Summer-Fall			
North Fork	300	552	0.32
South Fork	200	300	0.24
Snohomish River Summer-Fall			
Skykomish	1,650	3,500	0.18
Snoqualmie	400		
Green-Duwamish River	835	5,523	0.53

Source: NMFS 2000 and NMFS 2003.

The Fishery Regulation Assessment Model (FRAM) provides estimates of total or fishery-specific exploitation rates for chinook management units, Chinook Validation File, for December 2002 provided by the Northwest Indian Fisheries Commission (Fishery Regulation Assessment Model, December 2002). This model is briefly described in Appendix C. The exploitation rates include the number of fish actually harvested and an estimated number of fish that die as a result of being captured and released, or sustain some other form of injury from fishing gear (see *incidental catch* in the glossary and Appendix C).

The distribution of fishery impacts among the major fisheries is also described for populations. These estimates are based on information from the coded-wire tag database. In this system, a portion of salmon reared in hatcheries throughout the affected environment are implanted with minute tags

bearing relevant information about their origin. A portion of these tags are recovered through monitoring programs in the fisheries, at hatcheries, and on spawning grounds. Impacts of fisheries on naturally-spawning fish (that for the most part are not tagged) are estimated based on impacts of hatchery-tagged *indicator populations* released in areas frequented by the natural runs. Unless otherwise noted, estimates of harvest impacts reported in this section are from *The Pacific Salmon Commission Joint Chinook Technical Committee Report Annual Exploitation Rate and Model Calibration Report, TC-Chinook 02-3* (Pacific Salmon Commission, October 2002). The status of populations is qualitatively described as *critical*, *depressed* or *healthy* – taking into account many life history and habitat factors, but particularly trends in spawning escapement – a convention used by the co-managers.

Included in the Puget Sound Chinook ESU are 22 populations (Puget Sound Technical Recovery Team, April 8, 2002) grouped by the co-managers into 15 management units, corresponding to watersheds throughout the ESU. The co-managers have classed the populations as Category 1, 2 or 3 on the basis of the history of salmon in the area, the current characteristics of the population, and the influence of hatchery production. Category 1 populations are genetically unique and indigenous to watersheds of Puget Sound. Category 2 populations are located in watersheds where indigenous populations may no longer exist, but where sustainable populations existed in the past and where the habitat can still support self-sustaining, natural populations). Category 3 populations are generally found in small tributaries that may now have some natural spawning, but historically never had independent, self-sustaining populations of chinook salmon.

Management decisions embodied in the Proposed Action consider Category 1 and 2 populations because those have been identified as areas that have or historically had independent self-sustaining, natural chinook populations. The status of these populations varies from healthy to critical. The population delineation proposed by the Puget Sound Technical Recovery Team and incorporated by NMFS in this document contains only Category 1 and 2 populations.

Chinook salmon populations have been grouped into four regions of the Puget Sound Action Area: North Puget Sound, South Puget Sound, Hood Canal, and the Strait of Juan de Fuca (see Figure 3.2-1 in Subsection 3.2).

North Puget Sound

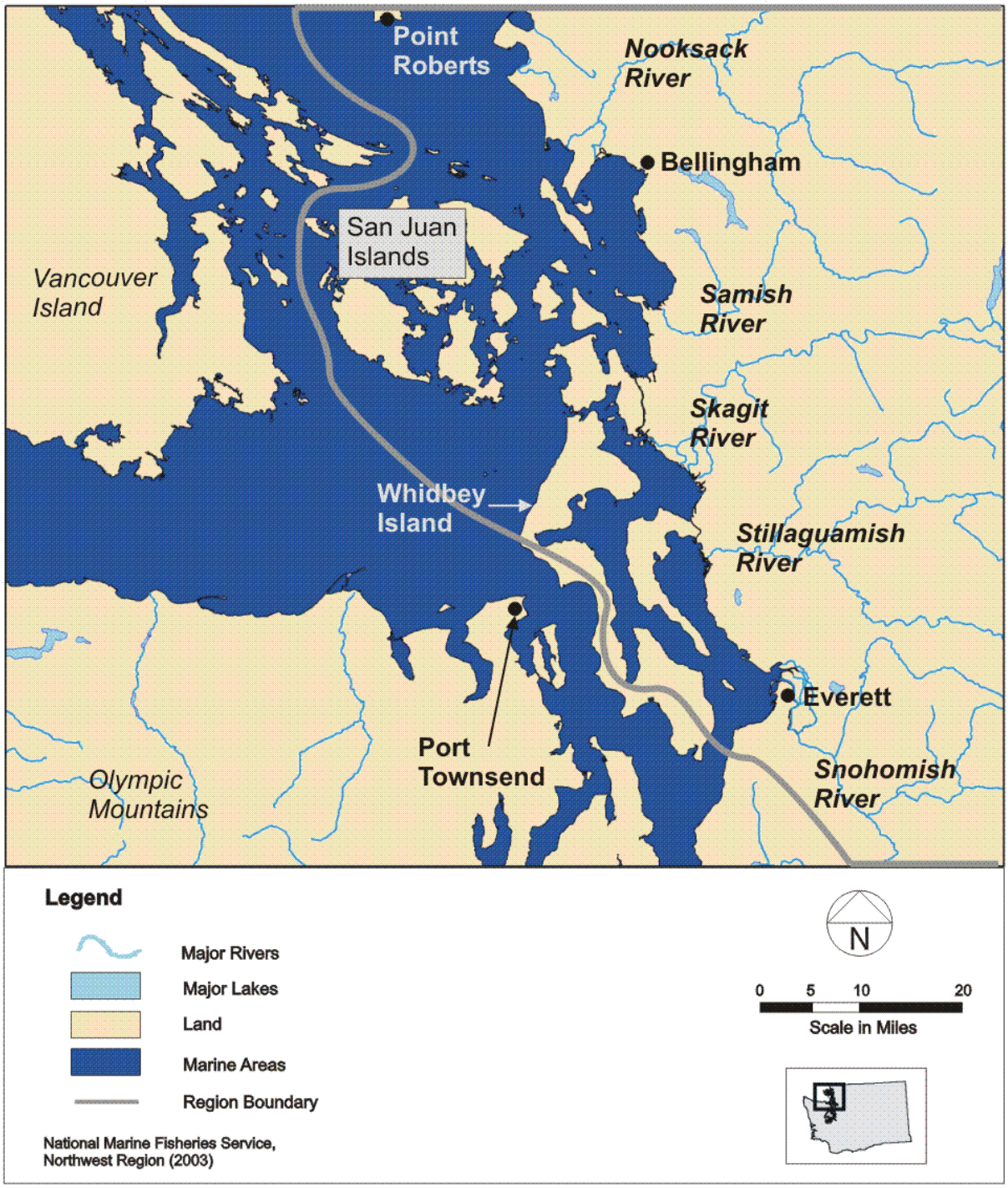
River systems in the North Puget Sound region include the Nooksack, Samish, Skagit, Stillaguamish and Snohomish (see Figure 3.3-1). These four watersheds contain 12 distinct chinook populations

(Puget Sound Technical Recovery Team 2001). These drainages are hydrologically diverse, and support populations with diverse run timing and life history strategies, including five of Puget Sound's seven spring chinook runs and three of its five summer-run populations.

Nooksack River. The Nooksack River enters northern Puget Sound just north of the City of Bellingham, and drains approximately an 800-square-mile area of the Cascade and Puget Lowland ecoregions. Its main tributaries are the North Fork, Middle Fork and South Fork.

The North Fork, a turbid, glacial stream, is somewhat colder than the South Fork, which is generally low and clear at the time of spawning migrations. These tributaries have developed genetically distinct, Category 1, spring-run populations. Both populations spawn in the upper reaches and tributaries of their respective streams (the North Fork population also spawns in the Middle Fork. The North Fork population spawns from mid-July through September in roughly 50 miles of spawning area, and the South Fork population spawns from the end of July through the first week of October over approximately 40 miles of spawning territory (Myers et al. 1998; and Cramer et al. 1999).

Figure 3.3-1. North Puget Sound Region.



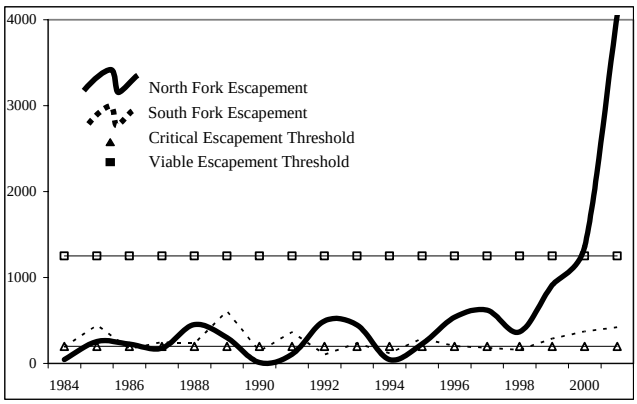
The status of the Nooksack early chinook populations is considered critical, due to chronically low returns and poor freshwater survival. The critical escapement threshold is 400 spawning adults, and the viable escapement threshold 700 spawning adults for the combined populations (Puget Sound Technical Recovery Team, July 22, 2003). The North Fork population is more abundant than that in the South Fork, and benefits from the hatchery supplementation program, but the natural productivity of both populations is critically depressed (Puget Sound Indian Tribes and Washington Department of Fish and Wildlife 2003). Escapement to the North Fork was below 500 fish in all but two years from 1984 through 1998. Spawning escapement was 911 fish in 1999, 1,357 in 2000, and 4,057 in 2001. The marked increase in 2001 was partly due to the diversion of a large number of male chinook that returned to the hatchery (personal communication with Susan Bishop, NMFS Sustainable Fisheries Division, January 13, 2003). The annual spawning escapement to the South Fork varied from 103 to 606 fish between 1984 and 2001, and the overall trend in escapement during this period has remained flat. Escapement from 1998 through 2001 averaged 310 fish (Figure 3.3-2) (Puget Sound Technical Recovery Team, *in preparation*). Terminal harvest rates have declined, but the recruits per natural-origin spawner for both populations have consistently remained below one recruit per pair of spawners (NMFS 2003b).

NMFS determined the rebuilding exploitation rate to be 12 percent for both populations (Nooksack Rebuilding Exploitation Rate Working Group 2003). The total fisheries exploitation rate on both populations averaged 36 percent from 1983 through 1996, and 18 percent from 1996 through 2000. Because the Nooksack River is located relatively close to the border between the United States and Canada, and Nooksack early-run chinook tend to migrate northward, the majority of harvest mortality occurs within British Columbia, which accounted for 73 percent of fishery mortality from 1997 through 2000 (Fishery Regulation Assessment Model, December 2002). Southern U.S. fisheries accounted for 26 percent of mortality during this period, and Alaska fisheries 1 percent. Puget Sound fisheries that impact this population are commercial net fisheries in northeastern Puget Sound (Marine Catch Areas 7 and 7A), Bellingham Bay and the Nooksack River (3 percent), and Puget Sound sport fisheries (18 percent) (Figure 3.3-2) (Pacific Salmon Commission, October 2002).

Figure 3.3-2. Spawning escapement, fishing exploitation rate, and geographic distribution of fishing mortality for Nooksack River spring chinook.

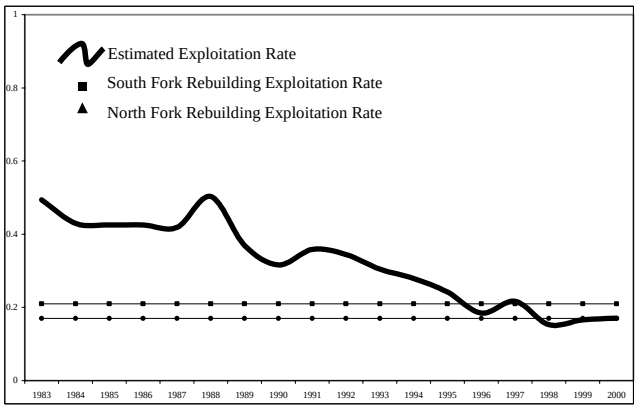
Spawning Escapement and Escapement Goal for Nooksack River Spring Chinook

Estimated escapement of naturally-spawning adults compared to NMFS' Critical and Viable Escapement



Estimated Fishing Exploitation Rate on Nooksack River Spring Chinook

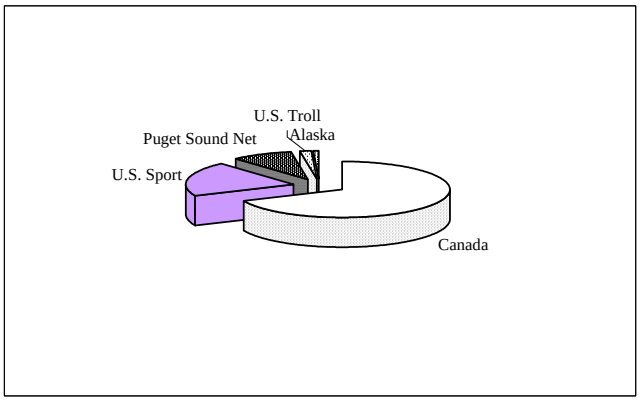
Estimated exploitation rate based on Fishery Regulations Assessment Model compared to NMFS' Recovery



Geographic Distribution of Fishing Mortality on Nooksack River Spring Chinook

Distribution of fishing mortality based on coded-wire tag recoveries of Nooksack spring chinook indicator

Alaska	1%
Canada	73%
Puget Sound Net	3%
U.S. Sport	18%
U.S. Troll	1%



Sources: Puget Sound Technical Recovery Team (in progress), Northwest Indian Fisheries Commission, and Pacific Salmon Commission December 2002.

A hatchery program on the North Fork Nooksack River at Kendall Creek, operated since 1988, produces early-run juveniles, a proportion of which are released at acclimation sites in the upper North Fork Nooksack River. Annual releases of 1.0 million spring-run juveniles accounted for about 6 percent of chinook salmon released in Puget Sound between 1991 and 2000. Releases in 2001 were 1.65 million. (Pacific States Marine Fisheries Commission, December 2002). The spring-run releases are supplemental to natural production, are believed to reduce the immediate extinction risks associated with very low natural returns, and are therefore listed under the ESA. Between 1991 and 2001, hatchery-origin spawning adults accounted for an estimated 59 percent of naturally-spawning chinook in the North Fork. The supplementation program, located at the Skookum Creek facility in the South Fork, was discontinued after 1992. Hatchery-origin adults made up 31 percent of natural-spawners in the South Fork during the same period, indicating that a substantial amount of straying may exist (Puget Sound Technical Recovery Team, *in preparation*).

Skagit River. The Skagit River watershed, the largest in Puget Sound, drains an area of more than 1,600 square miles. Chinook salmon spawn in approximately 270 miles of the Skagit River and its tributaries, the largest of which are the Baker and the Sauk Rivers. The Puget Sound Technical Recovery Team has identified six populations in the Skagit River system, including spring populations in the upper Cascade, Sauk, and Suiattle Rivers; summer populations in the lower Sauk and upper Skagit; and a fall-timed population in the lower Skagit River (Puget Sound Technical Recovery Team, April 8, 2002). All are Category 1 populations.

Summer-Fall Populations. The lower Sauk summer-run chinook spawn primarily from the mouth of the Sauk River to Rivermile 21 – separate from the upper Sauk spring spawning areas above Rivermile 32. The lower mainstem Skagit River fall population spawns downstream of the mouth of the Sauk River. The upper mainstem Skagit and lower Sauk River summer populations spawn from September through early October. Lower river fall population spawning lasts through October. Age at spawning is primarily 4 years, with significant numbers of Age-3 and Age-5 fish, as well. Most summer-fall chinook smolts emigrate from the river as fingerlings, 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).

The annual spawning escapement for the lower Skagit River fall population has remained well above the NMFS critical threshold of 250 fish from 1971 to the present. From 1971 through 1996, the average annual escapement was 2,507. However, escapement declined steadily from the 1970s to the mid-

1990s. Escapement averaged 1,540 from 1997 through 2001, well below NMFS' viable escapement threshold of 2,182 adult spawners. The most recent 3-year period has shown an increasing trend in escapement.

The critical threshold for the Lower Sauk River summer population is 200 adults, and the viable escapement threshold is 681. Adult spawning escapement averaged 892 from 1971 through 1996, after which returns fell to levels well below the viable escapement threshold through much of the 1990s. The geometric mean of escapements from 1997 through 2001 was 480, representing a moderate increase over the previous 5-year mean.

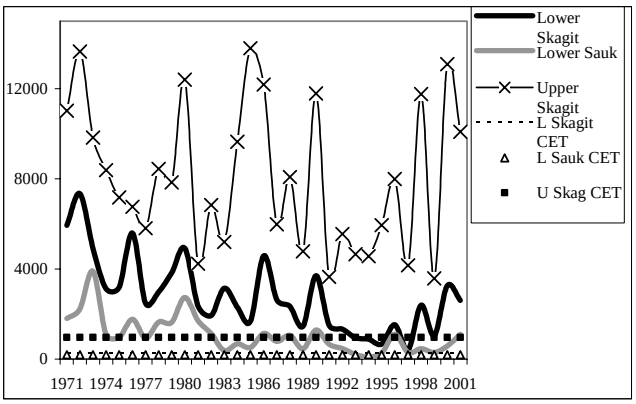
NMFS' critical threshold for the Upper Skagit summer population is 967, and the viable escapement threshold 7,454. There was a downward trend in spawning escapement from the early 1970s to the early-1990s for the Upper Skagit River summer population. Since then, there has been an increasing trend in spawning escapement, with the geometric mean for this period rising to 7,467 fish compared to 5,618 over the previous 5-year period (Figure 3.3-3). Exceptionally strong escapements were observed in three of the four latest return years (Puget Sound Technical Recovery Team, *in preparation*).

NMFS has set rebuilding exploitation rates of 49 percent for the Lower Skagit River population, 51 percent for the Lower Sauk River population and 60 percent for the Upper Skagit River population (NMFS 2000). Total fishery exploitation rates on the Skagit and Sauk River summer and fall populations are estimated to have averaged 60 percent from 1983 through 1996, and 29 percent from 1997 through 2000 (Fishery Regulation Assessment Model, December 2002). Since coded-wire tag data from Skagit River summer-fall chinook is insufficient, fishery impact distribution estimates are based on recoveries of the nearby Samish River fall-run chinook stock. Canadian fisheries accounted for 43 percent of mortality from 1997 through 2000, Washington fisheries approximately 55 percent, and Alaska fisheries approximately 2 percent. Puget Sound net fisheries accounted for 40 percent of fishing mortality, and sport fisheries 13 percent during this period (Figure 3.3-3) (Pacific Salmon Commission, October 2002).

Figure 3.3-3. Spawning escapement, fishing exploitation rate, and geographic distribution of fishing mortality for Skagit River summer-fall chinook.

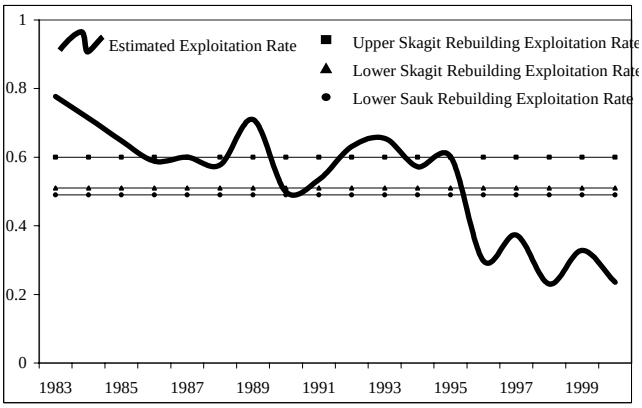
Spawning Escapement and Escapement Goal for Skagit River Summer-Fall Chinook

Estimated escapement of naturally-spawning adults compared to NMFS' Critical and Viable Escapement



Estimated Exploitation Rate on Skagit River Summer-Fall Chinook

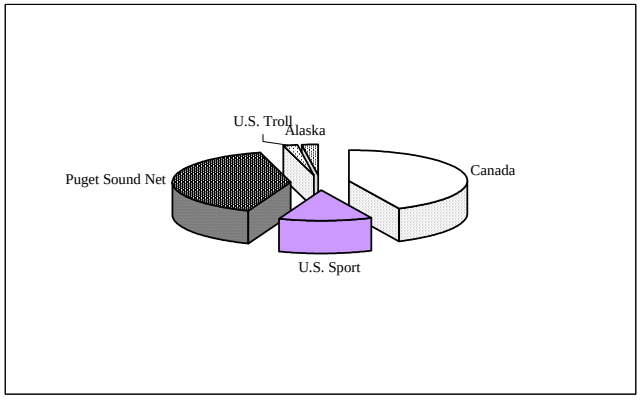
Estimated exploitation rate based on Fishery Regulations Assessment Model compared to NMFS' Recovery



Geographic Distribution of Fishing Mortality on Skagit River Summer-Fall Chinook

Distribution of fishing mortality based on coded-wire tag recoveries from Samish fall chinook indicator stock

Alaska	2%
Canada	43%
Puget Sound Net	40%
U.S. Sport	13%
U.S. Troll	2%



Sources: Puget Sound Technical Recovery Team (in progress), Northwest Indian Fisheries Commission, and Pacific Salmon Commission December 2002.

A hatchery at Marblemount produces spring, summer, and fall-run chinook. From 1990 through 2001, approximately 0.6 million fall-run and 0.4 million summer-run juveniles were released in the Skagit River. In 2001, approximately 0.2 million summer and 0.2 million fall juveniles were released as indicator stocks for the coded-wire tag program. The contribution of hatchery-origin fish to natural spawning has been estimated at less than 1 percent on the lower Skagit and lower Sauk Rivers, and 2 percent in the upper Skagit (Pacific States Marine Fisheries Commission December 2002; and Puget Sound Technical Recovery Team, *in preparation*).

Spring Populations. Spring-run chinook begin entering the Skagit River system in April, and spawn from late July through early September. The upper Sauk River population spawns in the mainstem, the Whitechuck River, and tributary streams. The Suiattle spring chinook population spawns in the mainstem and several tributaries. The upper Cascade spring chinook population is spatially separated from summer-run chinook in the lower Cascade River. The latter population is part of the upper Skagit River summer chinook population.

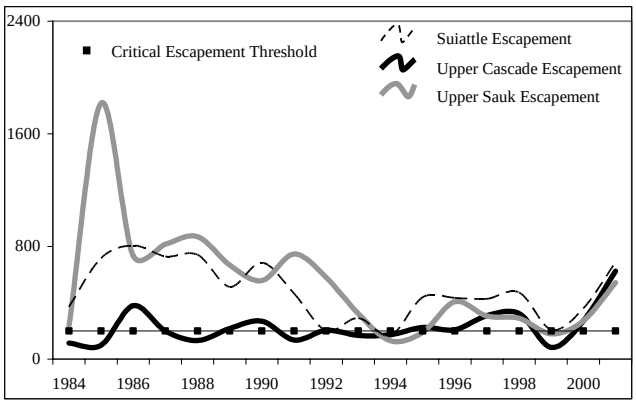
NMFS determined the critical escapement threshold for the Upper Cascade spring population to be 170, the Upper Sauk 130, and the Suiattle 170 adults (Puget Sound Technical Recovery Team, July 22, 2003). Viable escapement thresholds for the Upper Sauk and Suiattle have been set at 330 and 400 adults, respectively. A viable escapement threshold has not been determined for the Upper Cascade population. All three populations had downward trends in escapement from the early 1980s to the early 1990s. From 1984 through 1996, the geometric mean of escapement was 248 for the Upper Cascade, 361 for the Upper Sauk, and 378 for the Suiattle. In recent years, there has been an increasing trend in escapement. From 1997 through 2001, the geometric mean of escapement was 269 for the Upper Cascade population, 298 for the Upper Sauk population, and 401 for the Suiattle spring chinook population. The geometric mean of the commingled escapement for these three populations was 978 for this period, compared to 799 from 1992–1996 (Figure 3.3-4) (Puget Sound Technical Recovery Team, *in preparation*).

NMFS determined the rebuilding exploitation rate for the Upper Sauk to be 38 percent and for the Suiattle, 41 percent. A rebuilding exploitation rate has not been determined for the Upper Cascade population (Skagit Rebuilding Exploitation Rate Working Group 2003). From 1983 through 1996, the average annual exploitation rate was 58 percent. From 1997 through 2000, the annual exploitation rate averaged 31 percent (Fishery Regulation Assessment Model, December 2002). Fifty-three percent of fishing mortality occurred in Canadian waters, 45 percent in U.S. waters. Puget Sound sport fisheries accounted for approximately 42 percent of fishing mortality, and Puget Sound net fisheries 3 percent (Figure 3.3-4) (Pacific Salmon Commission, October 2002).

Figure 3.3-4. Spawning escapement, fishing exploitation rate, and geographic distribution of fishing mortality for Skagit River spring chinook.

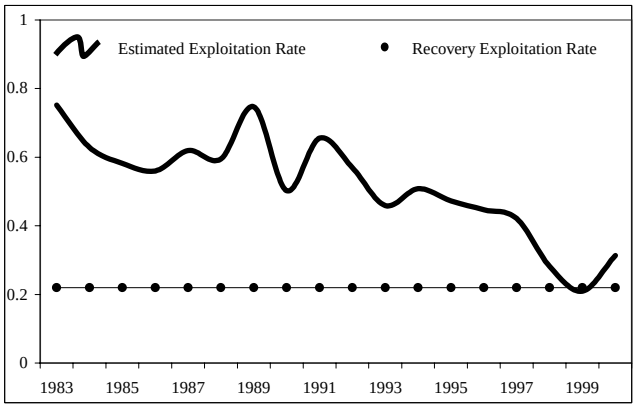
Spawning Escapement and Escapement Goals for Skagit River Spring Chinook

Estimated escapement of naturally-spawning adults compared to NMFS' VSP Guidelines Critical Escapement



Estimated Exploitation Rate and Goals for Skagit River Spring Chinook

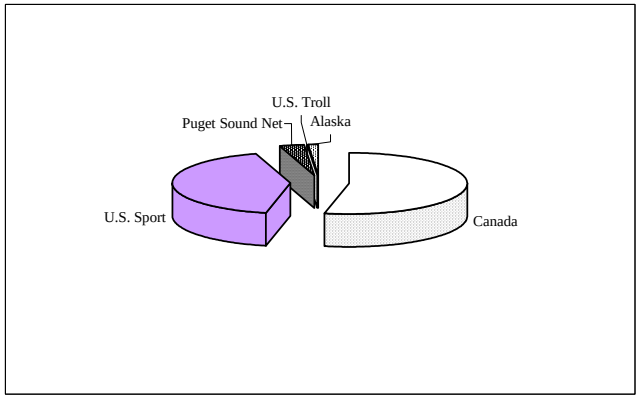
Estimated exploitation rate based on Fishery Regulations Assessment Model compared to NMFS' Recovery



Geographic Distribution of Fishing Mortality on Skagit River Spring Chinook

Distribution of fishing mortality based on coded-wire tag recoveries of Skagit spring chinook indicator stock

Alaska	1%
Canada	53%
Puget Sound Net	3%
U.S. Sport	42%
U.S. Troll	0%



Sources: Puget Sound Technical Recovery Team (in progress), Northwest Indian Fisheries Commission, and Pacific Salmon Commission December 2002.

From 1991 through 2000, approximately 0.4 million spring chinook juveniles were released annually in the Skagit River system, primarily in the Upper Cascade. Releases in 2001 were 0.42 million. These releases serve primarily as an indicator stock for the coded-wire tag program. Less than 1 percent of adults on the spawning grounds are estimated to be of hatchery origin (Pacific States Marine Fisheries Commission, December 2002; and Puget Sound Technical Recovery Team, *in preparation*).

Stillaguamish River. The North Fork Stillaguamish River is fed primarily by non-glacial sources in the Cascade Mountain foothills, flowing for most of its length through the Puget Lowland ecoregion. Its main tributaries are Squire Creek, Boulder River and Deer Creek. The South Fork Stillaguamish, which rises in the Cascades east of Fall City, has similar topography.

NMFS determined the North Fork Stillaguamish summer runs and South Fork Stillaguamish fall runs were distinct populations, based on genetic characteristics, spawn timing, and spawning distribution. Both are classified as Category 1 populations. The North Fork Stillaguamish River population, a composite of natural and hatchery-origin supplemental production, spawns primarily in the upper mainstem and tributaries above Rivermile 14. The South Fork population spawns in the mainstem, Pilchuck Creek, and lower Canyon Creek (Washington Department of Fisheries, et al. 1993).

North Fork Stillaguamish adults enter the river from May through August. Spawning begins in late August, peaks in mid-September, and continues past mid-October. The South Fork Stillaguamish chinook enter the river in August and September, and spawning peaks in early to mid-October. The age composition of mature North Fork Stillaguamish summer chinook, based on scales collected from 1985 through 1991, was as follows: 4.9 percent Age 2, 31.9 percent Age 3, 54.7 percent Age 4, and 8.5 percent Age 5. Ninety-five percent of juvenile Stillaguamish summer chinook emigrate as fingerlings (Washington Department of Fisheries et al. 1993).

The critical escapement threshold is 300 for the North Fork Stillaguamish and 200 for the South Fork. The viable escapement threshold is 552 for the North Fork and 300 for the South Fork. The estimated annual escapement (geometric mean) from 1974 through 1996 was 740 (range 309 to 1,403) in the North Fork, and 207 (range 65 to 283) in the South Fork. The estimated annual escapement (geometric mean) from 1997 through 2001 was 1,087 (range 845 to 1,403) in the North Fork, and 250 (range 226 to 283) in the South Fork (Figure 3.3-5). From 1974 through 1991, there was a declining trend in escapement to the North Fork. Since then, there has been an increasing trend. Consequently, the geometric mean of escapement from 1997 through 2001 is similar to that of the mid-1970s. There has been no significant trend in escapement in the South Fork Stillaguamish River over this period, and the

geometric for the most recent 5 years is similar to that of the early 1970s. NMFS determined the rebuilding exploitation rate to be 32 percent for the North Fork population, and 24 percent for the South Fork population (NMFS 2000; and McElhany et al. 2000). From 1983 to 1996, the total exploitation rate on these populations was 47 percent, and from 1997 through 2000, 23 percent (Fishery Regulation Assessment Model, December 2002). From 1997 through 2000, approximately 18 percent of fishing-related mortality occurred in Alaska, 50 percent in Canada, 29 percent in Washington sport fisheries, and 3 percent in Puget Sound net fisheries (Figure 3.3-5) (Pacific Salmon Commission, October 2002).

From 1991 through 2000, releases of chinook in the North Fork Stillaguamish system were less than 0.2 million juveniles annually. Releases in 2001 were 0.39 million. The supplementation program, which collects broodstock from the North Fork spawning escapement, was initiated in 1986 to rebuild the North Fork Stillaguamish population. It is considered essential to the recovery of the population, so these fish are also listed. Hatchery-origin adults comprised 32 percent of natural spawners in the North Fork from 1990 through 2001. Straying of hatchery fish in the South Fork has not been quantified (Pacific States Marine Fisheries Commission, December 2002; and Puget Sound Technical Recovery Team, *in preparation*).

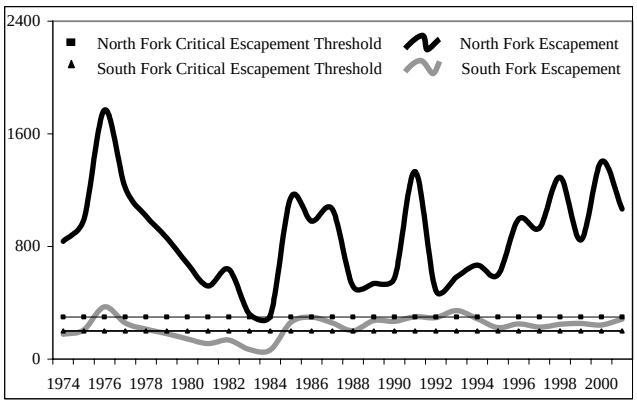
Snohomish River. The Puget Sound Technical Recovery Team has identified two populations in the Snohomish River system: Skykomish River chinook and Snoqualmie River chinook. They are both Category 1 populations (Figure 3.3-6).

Skykomish Chinook. The Skykomish population includes summer/fall-timed fish spawning in the Snohomish mainstem, the mainstem Skykomish, Sultan River, Bridal Veil Creek and the North and South Fork of the Skykomish River. A Category 2 population spawning in the Wallace River originates primarily from the hatchery located there, and is genetically similar to other chinook in the Skykomish River system (Puget Sound Technical Recovery Team 2001). Since the 1950s, spawning distribution of summer chinook has shifted upstream. That is, a much larger proportion of summer chinook currently spawn higher in the drainage, between Sultan and the forks of the Skykomish River, than in previous decades (Snohomish Basin Salmonid Technical Recovery Committee 1999). Summer chinook enter fresh water from May through July, spawning primarily in September. Fall chinook spawn from late September through October.

Figure 3.3-5. Spawning escapement, fishing exploitation rate, and geographic distribution of fishing mortality for Stillaguamish River summer-fall chinook.

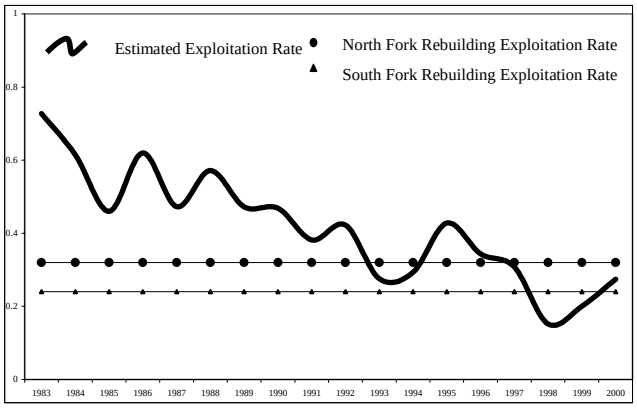
Spawning Escapement and Escapement Goals for Stillaguamish River Summer-Fall Chinook

Estimated escapement of naturally-spawning adults compared to NMFS' Critical Escapement Threshold



Estimated Exploitation Rate and Goals for Stillaguamish River Summer-Fall Chinook

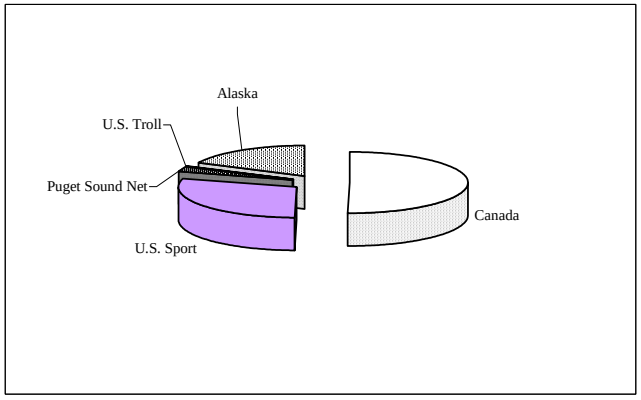
Estimated exploitation rate based on Fishery Regulations Assessment Model compared to NMFS' Recovery



Geographic Distribution of Fishing Mortality on Stillaguamish River Summer-Fall Chinook

Distribution of fishing mortality based on coded-wire tag recoveries of Stillaguamish chinook indicator stock

Alaska	18%
Canada	50%
U.S. (Puget Sound) Net	3%
U.S. Sport	29%
U.S. Troll	0%

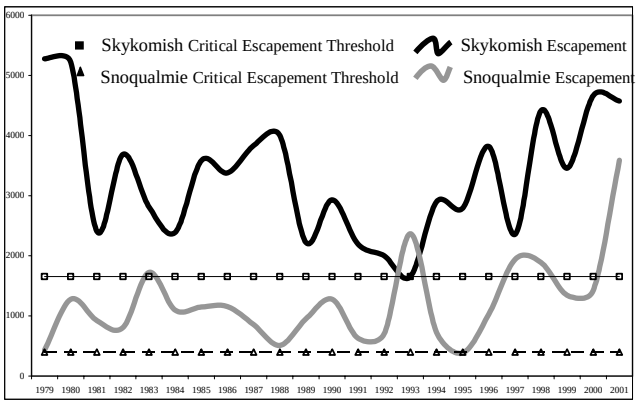


Sources: Puget Sound Technical Recovery Team (in progress), Northwest Indian Fisheries Commission, and Pacific Salmon Commission December 2002.

Figure 3.3-6. Spawning escapement, fishing exploitation rate, and geographic distribution of fishing mortality for Snohomish River summer-fall chinook.

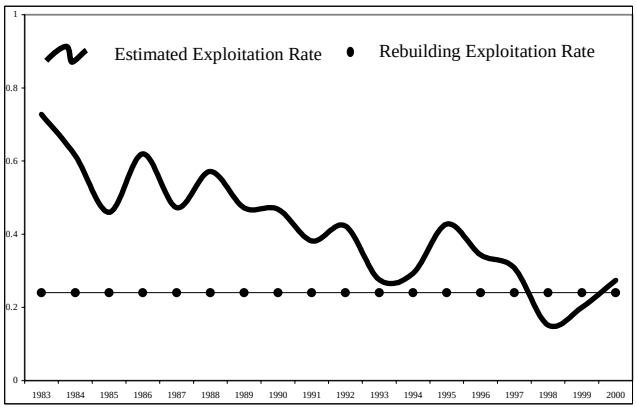
Spawning Escapement and Escapement Goals for Snohomish River Summer-Fall Chinook

Estimated escapement of naturally-spawning adults compared to NMFS' Critical Escapement Thresholds



Estimated Fishing Exploitation Rate on Snohomish River Summer-Fall Chinook

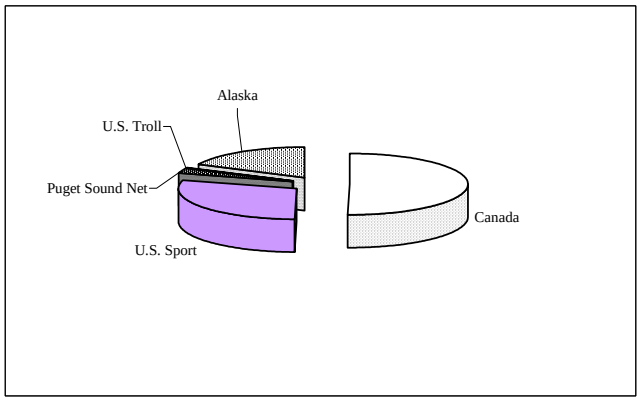
Estimated exploitation rate based on Fishery Regulations Assessment Model compared to NMFS' Recovery



Geographic Distribution of Fishing Mortality on Snohomish Summer-Fall Chinook

Distribution of fishing mortality based on coded-wire tag recoveries of Stillaguamish summer-fall chinook

Alaska	18%
Canada	50%
Puget Sound Net	3%
U.S. Sport	29%
U.S. Troll	0%



Sources: Puget Sound Technical Recovery Team (in progress), Northwest Indian Fisheries Commission, and Pacific Salmon Commission December 2002.

NMFS determined the critical escapement threshold for the Skykomish River population to be 1,653, and the viable escapement threshold as 3,500 spawning adults (personal communication e-mail from Susan Bishop, NMFS Sustainable Fisheries Division, January 12, 2003). The geometric mean of annual spawning escapement of the Skykomish River population was 3,023 from 1979 through 1996 (range 1,653 to 5,277). Escapement trended downward from the late 1970s to the mid-1990s, after which it has increased. From 1997 through 2001, the geometric mean of annual escapement was 3,775 (range 2,335 to 4,665) (Figure 3.3-6).

Snoqualmie Chinook. The Snoqualmie River chinook salmon population spawns in the Sultan and Snoqualmie Rivers and their tributaries from September through November.

Limited data show the Snoqualmie River fall chinook spawning population to have a somewhat larger component (28 percent) of Age-5 fish than most other Puget Sound fall populations, with Age-3 and Age-4 fish comprising 20 percent and 46 percent, respectively, of returns (Washington Department of Fish and Wildlife 1995, cited in Myers et al. 1998). Both summer and fall runs appear to have a relatively high percentage of fish that migrate to sea as yearlings.

The critical escapement threshold for the Snoqualmie River is 400. The viable escapement threshold has not yet been determined (65 Federal Register 42433). The trend in escapement for the Snoqualmie River population was relatively flat from the late 1970s to the mid-1990s. The geometric mean of annual escapement was 905 (range 385 to 2,366) from 1979 through 1996. In recent years, escapement has shown an increasing trend. The geometric mean of escapement from 1997 through 2001 was 1,907 (range 1,344 to 3,589), which is above the generic viable escapement threshold of 1,250. Spawning escapement to the Skykomish River showed a marked declining trend from the late 1970s until 1993, and a substantial increasing trend since then. Spawning escapement to the Snoqualmie River showed a declining trend from the late 1970s until 1996, but has shown an increasing trend since then (Figure 3.3-6).

The NMFS rebuilding exploitation rate for both the Skykomish and Snoqualmie River summer-fall populations is 18 percent (NMFS 2003c).[ii] Because juveniles from the Snohomish system were not consistently tagged, estimates of exploitation rates and distribution of fishing-related mortality for both the Skykomish and Snoqualmie River populations are based on coded-wire tag recoveries of Stillaguamish River fingerlings, which are believed to have a similar pattern of ocean migration and

[ii] The RER has recently been revised. It was 32% in 2001 and 2002.

timing (personal communication with Will Beattie, Conservation Planning Coordinator, Northwest Indian Fisheries Commission, January 12, 2003). The average exploitation rate from 1983 through 1996 was 57 percent, and from 1997 through 2001: 27 percent (Fishery Regulation Assessment Model, December 2002). Based on the same coded-wire tag data from Stillaguamish River chinook fingerlings, from 1997 through 2000, approximately 18 percent of fishing-related mortality on the Skykomish and Snoqualmie populations occurred in Alaska, 50 percent in Canada, 29 percent in Washington sport fisheries, and 3 percent in Puget Sound net fisheries (Pacific Salmon Commission, October 2002). The portion of fishery impacts in Canada has decreased in recent years (it was 59% from 1984 through 1995), owing to fishery restrictions (Figure 3.3-6).

An average of 1.6 million juvenile chinook were released into the Snohomish River system each year between 1991 and 2000, or 3.2 percent of Puget Sound releases. Fall-run fish accounted for approximately 40 percent of releases, summer-run 57 percent, and spring-run – released only in 1997 and 1998 – 3 percent. Virtually all fall and summer-run juveniles were produced in and released from the Wallace River hatchery on the Skykomish River. In 2001, 1.72 million summer-run juveniles were released. Fall-run hatchery production originally utilized the Green-Duwamish River stock. These hatchery fish stray to other areas in the Skykomish River, and may mix with summer chinook (Washington Department of Fisheries et al. 1993). From 1990 through 2001, an estimated 41 percent of naturally-spawning chinook in the Skykomish River and 23 percent of naturally-spawning chinook in the Snoqualmie River were of hatchery origin (Pacific States Marine Fisheries Commission, December 2002; and Puget Sound Technical Recovery Team, *in preparation*). Broodstock collection was changed beginning with the 1997 brood year to exclude fall chinook, and thus reduce the influence of out-of-basin populations on production (Puget Sound Indian Tribes and Washington Department of Fish and Wildlife 2003). Hatchery production of spring, summer, and fall chinook also occurs at the Tulalip Hatchery.

South Puget Sound

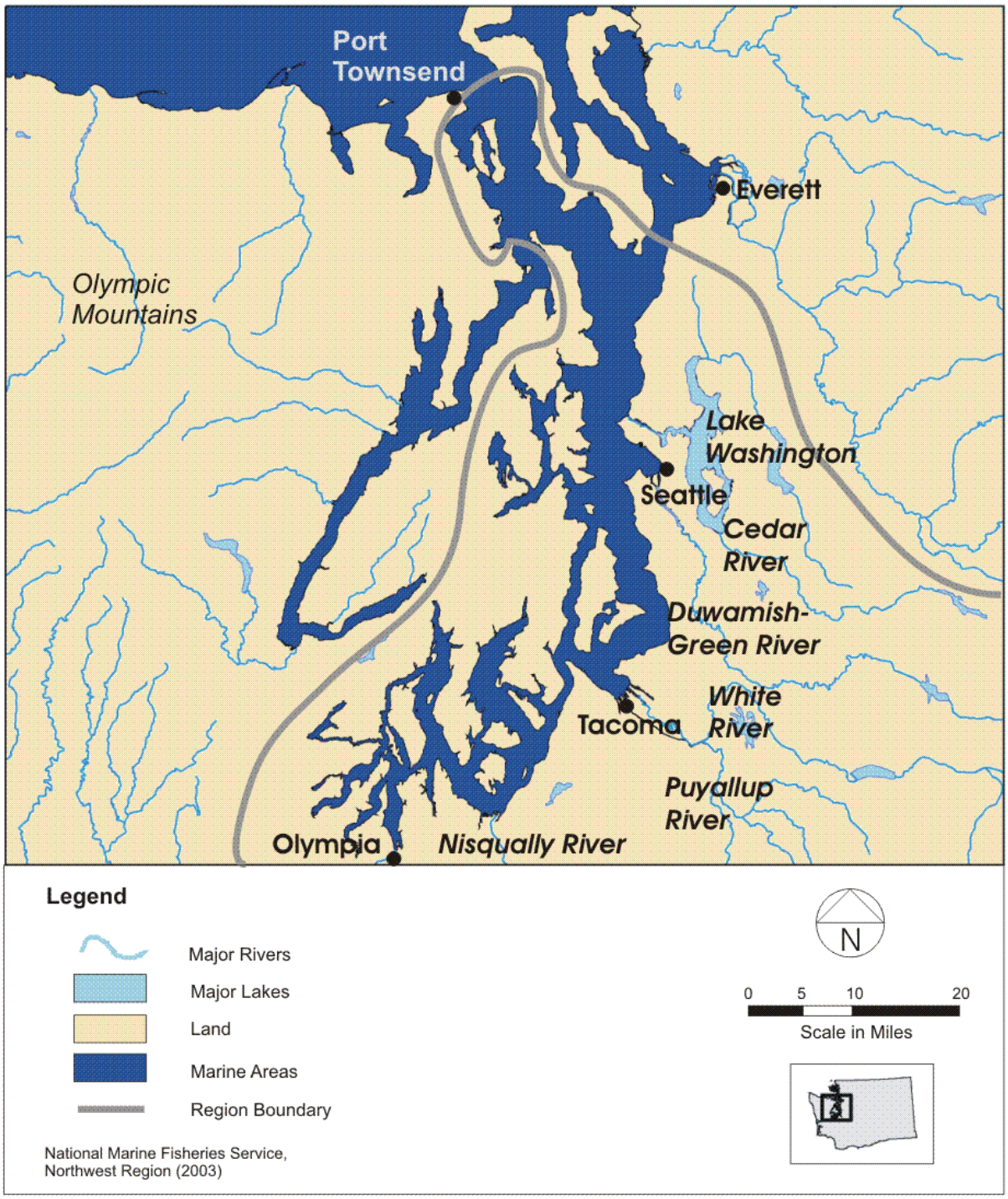
The southern region of the Puget Sound Action Area contains four major chinook-bearing watersheds. These are, from north to south, the Lake Washington, Green-Duwamish, Puyallup and Nisqually watersheds (see Figure 3.3-7). The Puyallup and Nisqually are glacially-influenced rivers originating from the glaciers of Mt. Rainier and surrounding foothills. The lower reaches of all these system flow through lowland areas that have been developed for agricultural, residential, urban or industrial use. There are also several smaller but important chinook-bearing streams in South Puget Sound and Hood Canal. The Puget Sound Technical Recovery Team has identified six populations in this region.

Numerous hatcheries in this area account for the majority of chinook salmon produced in Puget Sound. Hatchery transfers have affected most populations.

Lake Washington Watershed. The Puget Sound Technical Recovery Team identified two summer-fall chinook populations within the Lake Washington watershed: the Sammamish River, a Category 2 population, and Cedar River, a Category 1 population (Puget Sound Technical Recovery Team July 22, 2003). The Sammamish basin includes the Sammamish River, Swamp, North, Bear, Little Bear, and Issaquah Creeks. Historically, Chinook salmon also spawned in other smaller tributaries to Lake Washington such as May and Kelsey Creeks. Genetic samples from chinook in Bear/Cottage Creek are similar to those from Issaquah Creek, site of the Issaquah hatchery. It is not known whether this results from recent or historical intermingling among fish from these basins. Cedar River chinook may be genetically distinct, but closely related to those in the Green River (Washington Department of Fisheries et al. 1993). Until 1916, the Cedar River drained into the Green River, and from 1952 through 1964, Green River chinook were planted in the Cedar, so a close relationship is not surprising. Plants of hatchery fish were made to most other tributaries to the Lake Washington basin from the Issaquah and Green River hatcheries, from 1952 to at least the early 1990s.

Chinook salmon enter Lake Washington drainages from late May through early November. Spawning is usually complete by the end of November. Chinook spawning in the Cedar River is concentrated between Rivermile 4.0 and 19.0. Most Cedar River chinook emigrate to Lake Washington prior to April as fry, but some rear in the river and migrate to Puget Sound between May and July. The Lake Washington populations have a protracted smolt out-migration, with a large percentage of the run out-migrating after July 1.

Figure 3.3-7. South Puget Sound Region.



NMFS is currently evaluating critical or viable escapement thresholds for the Lake Washington populations, but will not complete its analysis prior to completion of this Environmental Impact Statement. An interim, generic critical escapement threshold of 200 spawning adults and an interim, generic viable escapement threshold of 1,200 adults has been set by NMFS (NMFS Memorandum 2003).The co-managers derived an escapement goal of 350 for the North Lake Washington Tributaries population based on patterns of escapement within the Lake Washington watershed. Actual escapements have been below this level in the majority of years since 1983, but have shown an increasing trend since 1997. The geometric mean of spawning escapement was 251 (range 33 to 544) from 1983 through 1996, and 251 from 1997 through 2001 (range 67 to 537). The co-managers' goal for the Cedar River population is 1,200, and actual escapements have been consistently below this since 1974. The geometric mean of spawning escapement was 576 (range 156 to 1,540) from 1983 through 1996, and 297 from 1997 through 2000 (range 120 to 810) (Figure 3.3-8) (Puget Sound Indian Tribes and Washington Department of Fish and Wildlife 2003; and Puget Sound Technical Recovery Team, *in preparation*).

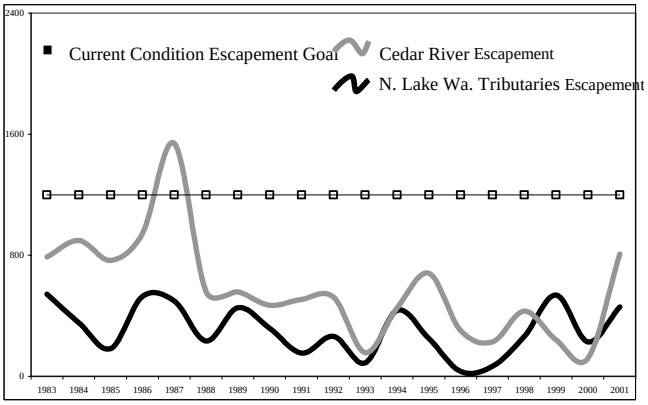
The total exploitation rate for chinook salmon returning to the Lake Washington watershed was 67 percent from 1983 through 1996, and 26 percent from 1997 through 2000 (Fishery Regulation Assessment Model, December 2002). Due to a lack of coded-wire tag data for Lake Washington chinook salmon populations, harvest distribution has been inferred from coded-wire tag data from the South Puget Sound fall fingerling indicator stock (comprised of releases from the Green River and Grovers Creek on the Kitsap Peninsula), which have a similar life history and genetic heritage. Consequently, the reader is referred to the discussion of harvest distribution for the Green-Duwamish River population. However, fisheries in Lake Washington have been limited to incidental harvest of chinook in fisheries targeted on other species, so the proportion of catch in the Lake Washington runs terminal area is much lower than for the Green River (Figure 3.3-8).

Releases of fall-run chinook salmon in the Lake Washington system accounted for about 5 percent of all Puget Sound releases from 1991 through 2000, or about 2.6 million fish per year. Eighty-seven percent of releases came from the Issaquah Creek hatchery, and 7 percent originated from the University of Washington hatchery in Seattle. Releases in 2001 were 2.2 million. There were no releases of chinook salmon in the Cedar River system (Pacific States Marine Fisheries Commission, December 2002). The hatchery stock used in the Issaquah hatchery originated from the Green-Duwamish River basin. Hatchery contribution to natural spawning has not been quantified, although there appears to be little straying of Issaquah Creek adults to the Cedar River (Puget Sound Technical Recovery Team, *in preparation*).

Figure 3.3-8. Spawning escapement, fishing exploitation rate, and geographic distribution of fishing mortality for Lake Washington summer-fall chinook.

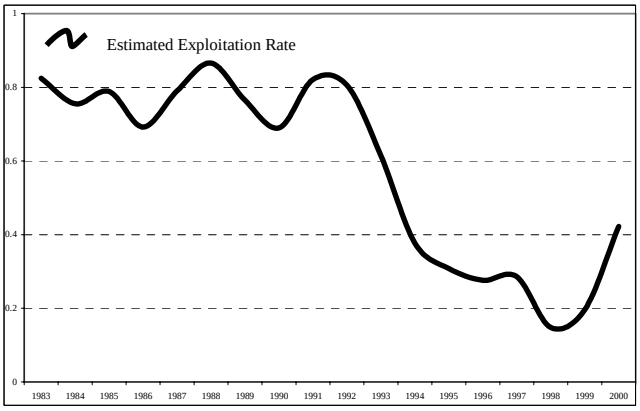
Spawning Escapement and Escapement Goals for Lake Washington Summer-Fall Chinook

Estimated escapement of naturally-spawning adults compared to current condition escapement goal.



Estimated Exploitation Rate for Lake Washington Summer-Fall Chinook

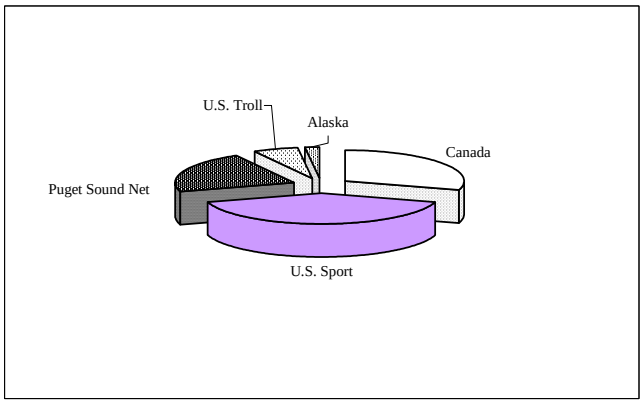
Estimated exploitation rate based on Fishery Regulations Assessment Model.



Geographic Distribution of Fishing Mortality on Lake Washington Summer-Fall Chinook

Distribution of fishing mortality based on coded-wire tag recoveries of Southern Puget Sound Indicator Stock

Alaska	2%
Canada	30%
Puget Sound Net	22%
U.S. Sport	41%
U.S. Troll	6%



Sources: Puget Sound Technical Recovery Team (in progress), Northwest Indian Fisheries Commission, and Pacific Salmon Commission December 2002.

Green-Duwamish River Chinook. Fall chinook spawn in the mainstem Green River and in two major tributaries – Soos Creek and Newaukum Creek. The Puget Sound Technical Recovery Team has determined that Green River chinook comprise a single population (Puget Sound Technical Recovery Team 2001). It is considered a Category 1 population.

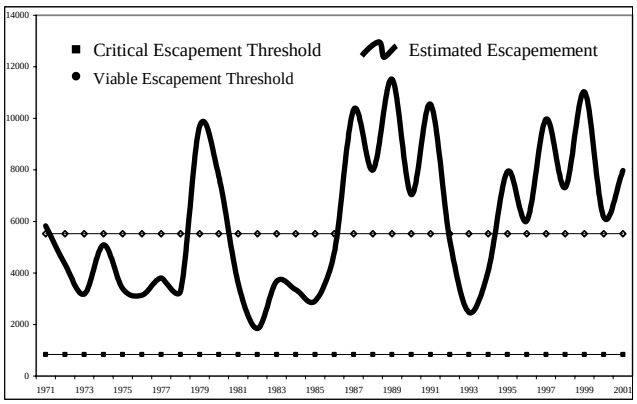
Spawning in the mainstem Green River occurs from Rivermile 26.7 to Rivermile 61 where the first of two dams operated by the City of Tacoma blocks spawning access. Chinook begin entering the Green River in July, and spawn from mid-September through October. Nearly all juveniles migrate seaward during their first year. Age-4 fish comprise 62 percent of adult returns, with Age-3 and Age-5 fish comprising 26 percent and 11 percent, respectively (Washington Department of Fisheries et al. 1993; and Washington Department of Fish and Wildlife 1995, cited in Myers et al. 1998).

NMFS has determined the critical escapement threshold of Green-Duwamish River chinook population to be 835 adult spawners, and the viable escapement threshold to be 5,523 adult spawners. The co-managers' escapement goal is 5,800 natural spawners (NMFS 2000). From 1971 through 2001, escapements have exceeded the viable escapement threshold in 15 of 31 years, and the long-term trend in escapement has been positive. The geometric mean of annual spawning escapement from 1971 through 1996 was 4,892 (range 1,840 to 11,515). The geometric mean of spawning escapement from 1997 through 2001 was 8,306 (range 6,170 to 11,025) (Figure 3.3-9) (Puget Sound Technical Recovery Team, *in preparation*).

Figure 3.3-9. Spawning escapement, fishing exploitation rate, and geographic distribution of fishing mortality for Green-Duwamish River summer-fall chinook.

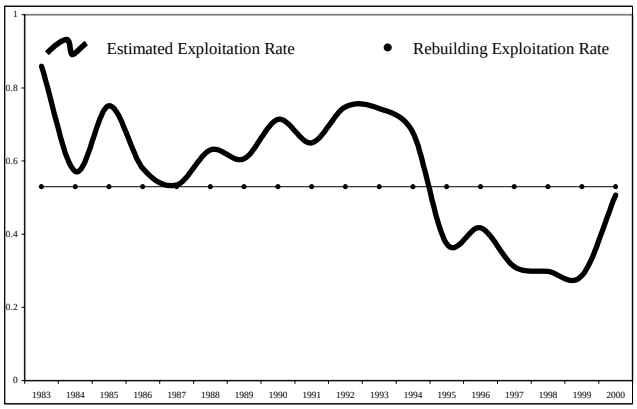
Spawning Escapement and Escapement Goals for Green-Duwamish River Summer-Fall Chinook

Estimated escapement of naturally-spawning adults compared to NMFS' critical and viable escapement thresholds



Estimated Exploitation Rate for Green-Duwamish River Summer-Fall Chinook

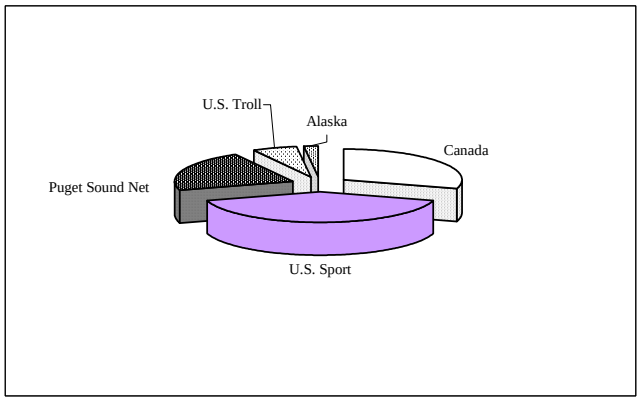
Estimated exploitation rate compared to NMFS' recovery exploitation rate. Estimated exploitation rate based on Fishery Regulations Assessment Model.



Geographic Distribution of Fishing Mortality on Green-Duwamish River Summer-Fall Chinook

Distribution of fishing mortality based on coded-wire tag recoveries of Southern Puget Sound Indicator Stock

Alaska	2%
Canada	30%
Puget Sound Net	22%
U.S. Sport	41%
U.S. Troll	6%



Sources: Puget Sound Technical Recovery Team (in progress), Northwest Indian Fisheries Commission, and Pacific Salmon Commission December 2002.

The NMFS rebuilding exploitation rate on the Green River population is 53 percent (NMFS 2000). Harvest mortality distribution for Green River chinook is estimated from recoveries of the South Puget Sound fingerling indicator stock mentioned previously. Total exploitation on this population fell from levels above 80 percent in the early 1980s, to levels below 40 percent in the 1990s. The average exploitation rate from 1983 through 1996 was 63 percent, while the average from 1997 through 2000 was 35 percent (Fishery Regulation Assessment Model, December 2002). From 1997 through 2001, Canadian fisheries accounted for 30 percent of fishing-related mortality, U.S. sport fisheries 41 percent, Puget Sound net fisheries 22 percent, U.S. troll fisheries 6 percent, and Alaska fisheries 2 percent (Figure 3.3-9) (Pacific Salmon Commission, October 2002).

The Green-Duwamish River system, with its large hatchery at Soos Creek, accounts for about 12 percent of Puget Sound hatchery chinook releases, with annual releases of 6.4 million juveniles from 1990 through 2001 (Pacific States Marine Fisheries Commission, December 2002). About 72 percent of the juveniles were released from the Soos Creek facility, with smaller releases throughout the system. Releases in 2001 were 4.2 million. From 1990 through 2001, hatchery-origin adults are estimated to have accounted for 71 percent of naturally-spawning chinook in the system (Puget Sound Technical Recovery Team, *in preparation*). Green River chinook stocks were transferred extensively to watersheds throughout Puget Sound, beginning in the 1950s (Myers et al. 1998).

Puyallup River. The Puyallup River is glacially-influenced as a result of its origin on the north slope of Mt. Rainier. The Puyallup River watershed also includes the Cascade foothills. The lower reaches of the Puyallup River flow through agricultural, residential, urban and industrial areas. Fall chinook salmon account for the vast majority of chinook returning to the Puyallup River system, but the White River – a main tributary – contains a spring-run population.

White River Spring Chinook. The Puget Sound Technical Recovery Team has identified the spring-timed chinook in the White River as a single, genetically distinct, Category 1 population, and the only spring chinook population in South Puget Sound (Puget Sound Technical Recovery Team 2001).

Mud Mountain Dam at Rivermile 23.4 limits upstream adult migration. A portion of White River spring chinook spawn below the dam, though habitat suitability is constrained by the flow regime. Natural-origin adult fish are trapped at a diversion dam below Mud Mountain Dam and transported into the upper watershed, above Mud Mountain Dam, where they spawn in the West Fork of the White River and tributaries. Spring chinook enter the Puyallup River from May through mid-September, and spawn from mid-September through October.

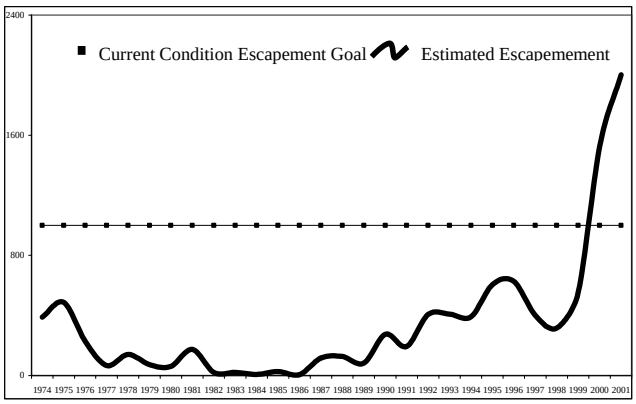
The status of White River spring chinook is critical because of chronically low escapements and the population's reliance on the hatchery supplementation program. NMFS is currently evaluating critical and viable escapement thresholds for the White River population, but will not complete its analysis prior to completion of this Environmental Impact Statement. In the interim, NMFS has established generic critical and viable escapement thresholds of 200 and 1,000 spawning adults, respectively. The co-managers' escapement goal is to allow at least 1,000 natural-origin adults to spawn upstream of Mud Mountain Dam, based on an assessment of available spawning habitat within the White River watershed and comparisons with similar systems in other areas (WDFW et al. 1996). Escapement of White River chinook may have exceeded 5,000 in the early 1940s (Puget Sound Indian Tribes and Washington Department of Fish and Wildlife 2003), but abundance had been reduced to critical levels in the 1970s by migration blockages, alteration of the flow regime, and degradation of spawning and rearing habitat. The geometric mean of annual spawning escapement was 115 (range 6 to 628) from 1974 through 1996, and 735 (range 316 to 2,002) from 1997 through 2001 (Figure 3.3-10) (Puget Sound Technical Recovery Team, *in preparation*). Spawning escapement has shown a substantial increasing trend since the late 1980s. However, later-timed summer-fall chinook have recently been returning to the White River in increasing numbers, which has confounded the counts of spring chinook (personal communication with Bruce Sanford, Washington Department of Fish and Wildlife, April 2, 2003). The population may not be currently viable in the absence of supplementation (NMFS 2000).

Increased fishery restrictions have all but eliminated impacts to this population in fisheries outside Puget Sound, and more conservative management in Washington waters lowered the overall exploitation rate from more than 38 percent between 1983 and 1996, to 22 percent between 1997 and 2000 (Fishery Regulation Assessment Model, December 2002). Nearly all fishery impacts on White River spring chinook occur in Puget Sound, primarily in recreational fisheries, which currently account for 91 percent of the harvest of this stock (Figure 3.3-10). This is due in part to release of yearling smolts from the White River and Hupp Spring hatcheries, which are believed to have a greater tendency to rear in Puget Sound, and in part due to intentional management of commercial fisheries to avoid impacts on all spring chinook (personal communication with Susan Bishop, NMFS Sustainable Fisheries Division, January 5, 2003). Juveniles released at older ages are thought to spend more time in Puget Sound.

Figure 3.3-10. Spawning escapement, fishing exploitation rate, and geographic distribution of fishing mortality for White River spring chinook.

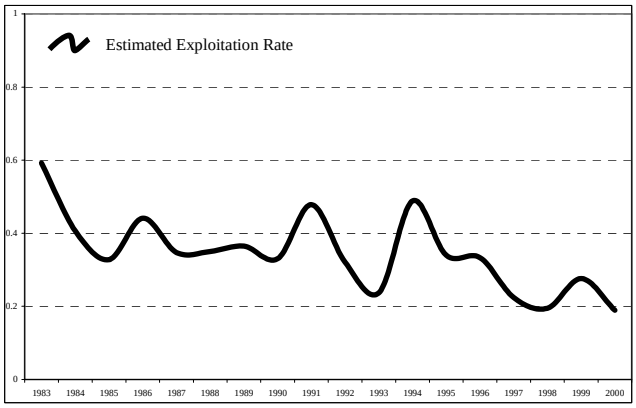
Spawning Escapement and Escapement Goals for White River Spring Chinook

Estimated escapement of naturally-spawning adults compared to current condition escapement goal



Estimated Exploitation Rate for White River Spring Chinook

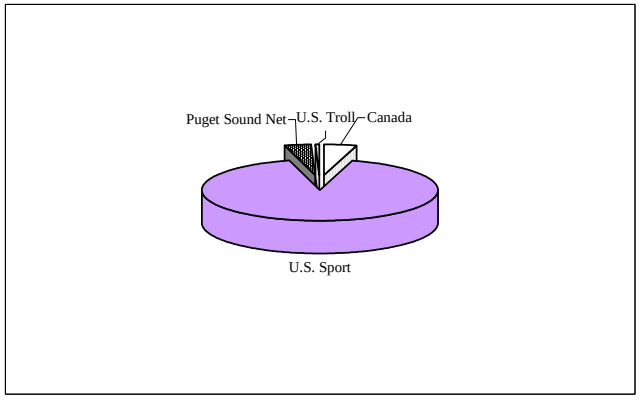
Estimated exploitation rate based on Fishery Regulations Assessment Model



Geographic Distribution of Fishing Mortality on White River Spring Chinook

Distribution of fishing mortality based on coded-wire tag recoveries of White River spring chinook indicator stock

Alaska	0%
Canada	4%
Puget Sound Net	4%
U.S. Sport	91%
U.S. Troll	1%



Sources: Puget Sound Technical Recovery Team (in progress), Northwest Indian Fisheries Commission, and Pacific Salmon Commission December 2002.

A hatchery supplementation program was begun in the mid-1980s to stabilize and rebuild White River spring chinook. Broodstock is trapped at the Buckley diversion dam on the White River. Unmarked[iii] fish in excess of hatchery needs are transported above Mud Mountain Dam to spawn to rebuild the naturally-spawning population. From 1991 through 2000, annual releases of approximately 0.8 million juvenile spring chinook comprised about 1.6 percent of the total annual chinook releases in Puget Sound. Releases in 2001 were 0.4 million (Pacific States Marine Fisheries Commission, December 2002). Some hatchery fingerlings are released from upstream rearing ponds. Fish from the White River hatchery supplementation program are considered essential to recovery of the population, and are therefore listed.

Puyallup River Fall Chinook. The Puget Sound Technical Recovery Team (2001) has identified a single fall-timed chinook population in the Puyallup River (Puget Sound Technical Recovery Team 2001). Because hatchery programs have introduced non-native stocks, primarily of Green River origin, into this system, Puyallup chinook are considered a Category 2 population. Puyallup fall chinook are genetically similar to Green River chinook (Puget Sound Technical Recovery Team 2001).

Puyallup River fall chinook spawn primarily in South Prairie Creek (a tributary of the Carbon River), the Puyallup River mainstem,Voights' Creek, and Kapowsin Creek. Adult passage has occurred at Electron Dam, at Rivermile 41.7, since 2001. A remnant native component may persist in South Prairie Creek. Adults begin entering the Puyallup River in late July, and spawning occurs from mid-September through mid-November. Spawning adults are 76 percent Age-4 fish, 16 percent, Age 3, and 6 percent Age 5. An estimated 97 percent of smolts emigrate as fingerlings after a few months of freshwater rearing (Washington Department of Fisheries et al. 1993, cited in Myers et al. 1998).

NMFS is currently evaluating critical and viable escapement thresholds for the Puyallup River fall chinook salmon population, but will not complete its analysis prior to completion of this Environmental Impact Statement. In the interim, NMFS has adopted a generic critical escapement threshold of 200 and a generic viable escapement threshold of 1,250 spawning adults (NMFS Memorandum 2003). Until recently, the natural-spawning escapement goal for Puyallup River fall chinook was 3,250; however, the system was managed primarily to achieve hatchery escapement, and the natural escapement goal was seldom met (NMFS 2000; and Puget Sound Technical Recovery Team, *in preparation*). The co-managers are currently updating the system goal. Until then, the co-managers' escapement goal is to

[iii] Denotes fish thought to be of natural-origin, although they could also be unmarked hatchery fish from facilities other than the White River Hatchery.

insure that at least 500 chinook spawn in South Prairie Creek (Puget Sound Indian Tribes and Washington Department of Fish and Wildlife 2003). This index of escapement is believed to represent adequate seeding of the entire system. The estimated geometric mean of annual spawning escapement was 1,437 from 1971 through 1996 (range 518 to 3,515), and 2,039 from 1997 through 2001 (range 1,193 to 4,995) (Figure 3.3-11) (Puget Sound Technical Recovery Team, *in preparation*).

Total exploitation rate for this population averaged 72 percent from 1983 through 1996, and 60 percent from 1997 through 2000 (Fishery Regulation Assessment Model, December 2002). Because a hatchery indicator stock has not been developed in the Puyallup River, the South Puget Sound fall fingerling indicator stock provides the most relevant description of Puyallup River chinook harvest distribution (Puget Sound Indian Tribes and Washington Department of Fish and Wildlife 2003).

Annual hatchery releases of 2.5 million fall chinook in the Puyallup River accounted for approximately 4 percent of Puget Sound chinook releases from 1991 through 2000. Releases in 2001 were 1.61 million. Hatcheries operated by the Washington Department of Fish and Wildlife at Voights' Creek and the Puyallup Tribe at Diru Creek account for about 78 percent and 21 percent of releases, respectively. No estimates have been made of hatchery-contribution to natural spawning.

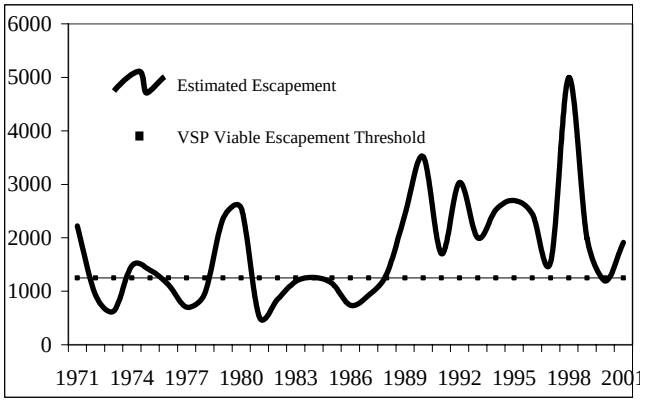
Nisqually River Chinook. The Puget Sound Technical Recovery Team identified one fall-timed chinook population in the Nisqually River watershed (Puget Sound Technical Recovery Team 2001). It is a Category 2 population. A partially glacier-fed system, the Nisqually River flows for most of its length through the Puget Lowland ecoregion. Nisqually chinook spawn in the mainstem and numerous side channels and tributaries from Rivermile 3 to Rivermile 42 where La Grande Dam blocks further access. Adult chinook enter the Nisqually River system from July through September, and spawning activity continues through November. Juveniles typically spend 2 to 6 months in fresh water before beginning their seaward migration. Forty-five percent of adults are thought to mature at Age 3, and 31 percent at Age 4 (Washington Department of Fisheries et al. 1993; and Washington Department of Fish and Wildlife 1995, cited in Myers et al. 1998).

Native spring and fall chinook populations have been extirpated from the Nisqually River system, primarily as a result of blocked passage at the Centralia diversion, dewatering of mainstem spawning areas by hydroelectric operations, a toxic copper ore spill associated with a railroad trestle failure, and other habitat degradation (Nisqually Chinook Recovery Team 2001).

Figure 3.3-11. Spawning escapement, fishing exploitation rate, and geographic distribution of fishing mortality for Puyallup River fall chinook.

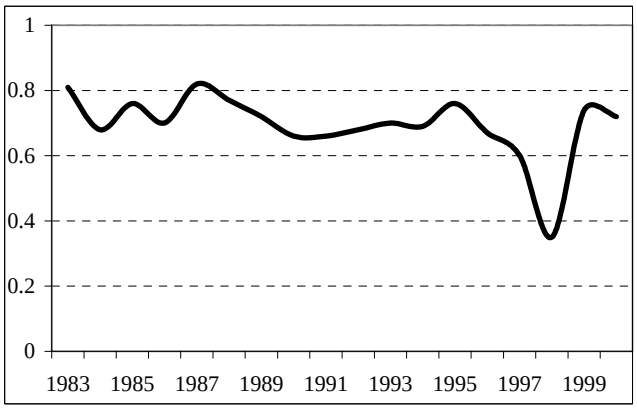
Spawning Escapement and Escapement Goal for Puyallup River Fall Chinook

Estimated escapement of naturally-spawning adults compared to NMFS' VSP Guidelines Viable Escapement



Estimated Fishing Exploitation Rate on Puyallup River Fall Chinook

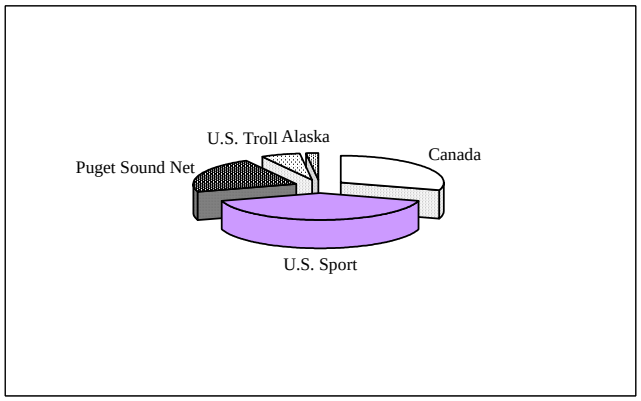
Estimated exploitation rate based on Fishery Regulations Assessment Model



Geographic Distribution of Fishing Mortality on Puyallup River Fall Chinook

Distribution of fishing mortality based on coded-wire tag recoveries of southern Puget Sound indicator stock

Alaska	2%
Canada	30%
Puget Sound Net	22%
U.S. Sport	40%
U.S. Troll	6%



Sources: Puget Sound Technical Recovery Team (in progress), Northwest Indian Fisheries Commission, and Pacific Salmon Commission December 2002.

Prior to 2001, the Nisqually River was managed to achieve egg-take goals for the hatchery enhancement program. NMFS is currently evaluating critical or viable escapement thresholds for the Nisqually River chinook population, but will not complete its analysis prior to completion of this Environmental Impact Statement. In the interim, NMFS has adopted a generic critical escapement threshold of 200 and a generic viable escapement threshold of 1,100 spawning adults (NMFS Memorandum 2003). In 2001, the system began to be managed primarily for natural spawning escapement. The co-managers' previous natural escapement goal of 900, which was met or exceeded in 48 percent of the years between 1979 and 1999, was increased to 1,100 in 2000 based on an assessment of available habitat (Puget Sound Indian Tribes and Washington Department of Fish and Wildlife 2003). The trend in escapement from 1979 through 2001 has been slightly upward. The geometric mean of escapement was 637 (range 85 to 2,332) from 1979 through 1996, and 883 from 1997 through 2000 (range 340 to 1,399) (Figure 3.3-12) (Puget Sound Technical Recovery Team, *in preparation*).

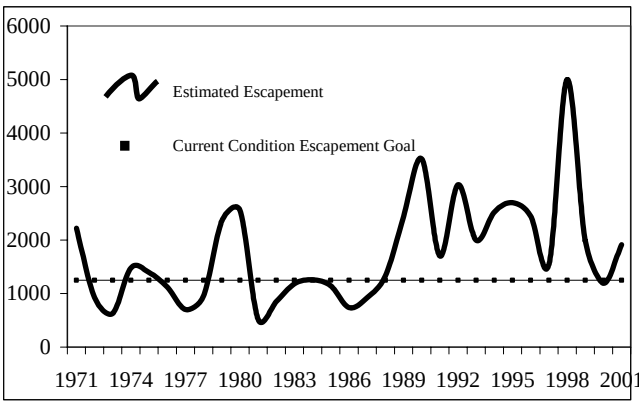
Based on coded-wire tag data, the exploitation rate on Nisqually River chinook averaged 83 percent from 1983 through 1996, and 68 percent from 1997 through 2001. From 1997 through 2000, 14 percent of harvest mortality occurred in Canada, 38 percent in U.S. sport fisheries, 45 percent in Puget Sound net fisheries, and 3 percent in U.S. troll fisheries. These numbers reflect decreasing harvest impacts in Canadian fisheries; from 1982 through 1995, Canadian fisheries, U.S. sport fisheries, and U.S. net fisheries each accounted for roughly 30 percent of harvest mortality (Figure 3.3-12) (Pacific Salmon Commission, October 2002).

The Kalama Creek and Clear Creek hatcheries operated by the Nisqually Tribe released approximately 2.9 million fall chinook annually (about 6 percent of total Puget Sound chinook releases) from 1991 through 2000. Releases in 2001 were 3.28 million (Pacific States Marine Fisheries Commission, December 2002). The hatchery stocks were derived from Puyallup and Green River fall-runs, and preliminary studies show hatchery and naturally-spawning populations are genetically similar (Puget Sound Indian Tribes and Washington Department of Fish and Wildlife 2003; and Washington Department of Fisheries et al. 1993, cited in Puget Sound Technical Recovery Team, April 8, 2002).

Figure 3.3-12. Spawning escapement, fishing exploitation rate and geographic distribution of fishing mortality for Nisqually River fall chinook.

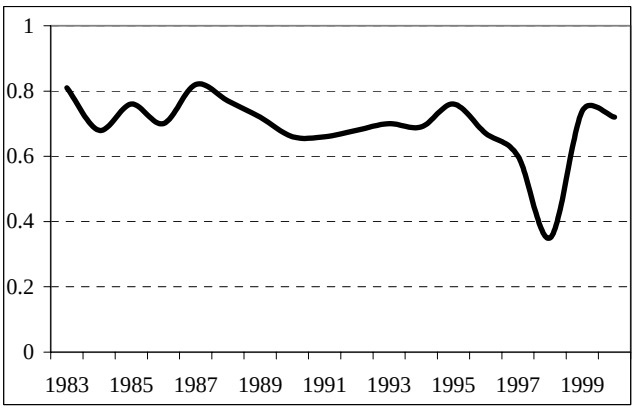
Spawning Escapement and Escapement Goal for Nisqually River Fall Chinook

Estimated escapement of naturally-spawning adults compared to current condition escapement goal



Estimated Fishing Exploitation Rate on Nisqually River Fall Chinook

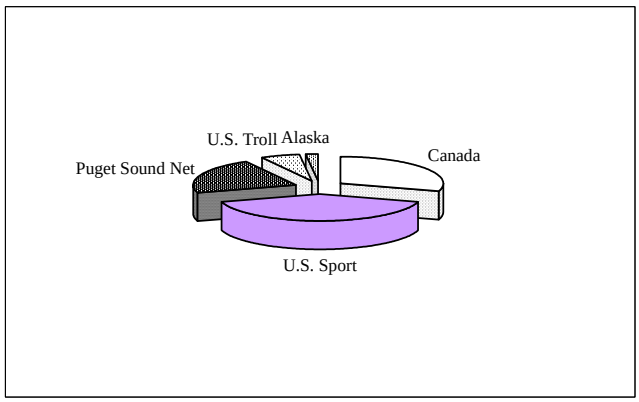
Estimated exploitation rate based on Fishery Regulations Assessment Model



Geographic Distribution of Fishing Mortality on Nisqually River Fall Chinook

Distribution of fishing mortality based on coded-wire tag recoveries of southern Puget Sound indicator stock

Alaska	2%
Canada	30%
Puget Sound Net	22%
U.S. Sport	40%
U.S. Troll	6%



Sources: Puget Sound Technical Recovery Team (in progress), Northwest Indian Fisheries Commission, and Pacific Salmon Commission December 2002.

Hood Canal

Skokomish River Chinook. The Puget Sound Technical Recovery Team identified one chinook population in the Skokomish River, one of two identified in Hood Canal. The Skokomish River enters Hood Canal at its southern end; thus, its chinook salmon population is spatially separated from rivers in the mid-Hood Canal management unit (see Figure 3.3-7). Historically, the Skokomish River supported the largest natural chinook run in Hood Canal. Presently, spawning takes place in the Skokomish River mainstem up to the confluence with the South and North Forks, in the South Fork of the Skokomish River, and in the North Fork to where Cushman Dam blocks higher access.

Skokomish River chinook are a composite of natural- and hatchery-origin fish that are genetically indistinguishable. The co-managers classify Skokomish summer-fall chinook as a Category 2 population. A small, self-sustaining population of landlocked chinook is present in Lake Cushman, upstream of the dams.

Chinook salmon enter the Skokomish River starting in late July, with the majority of the run entering from mid-August to mid-September, and spawning from mid-September through October. Peak spawning occurs during mid-October. Adults mature primarily at Age 3 (33%), and Age 4 (43%). Juveniles emigrate primarily during the spring and early summer of their first year (Lestelle and Weller 1994).

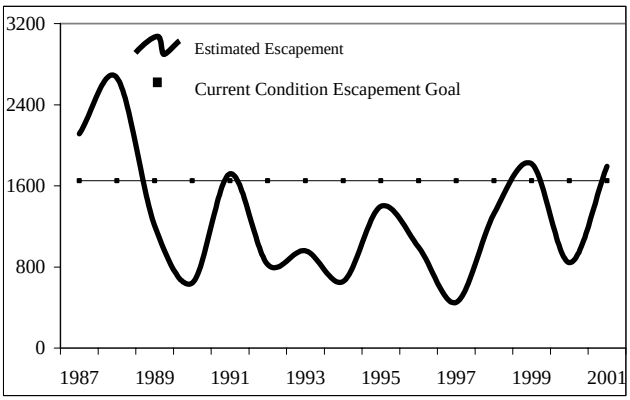
NMFS is currently evaluating critical or viable escapement thresholds for the Skokomish River population, but will not complete its analysis prior to completion of this Environmental Impact Statement. In the interim, NMFS has adopted a generic critical escapement threshold of 200 and a generic viable escapement threshold of 1,250 spawning adults (NMFS Memorandum 2003). From 1987 (the earliest year for which data are available) through 2001, natural-spawning escapement ranged from 452 to 2,666. While there has been a downward trend in escapement over this period, it has been relatively small. The most recent 5-year geometric mean of escapement was 1,105, compared to 937 from 1992 through 1996, and 1,496 from 1987 through 1991.

The overall exploitation rate for all Hood Canal summer-fall chinook salmon averaged 69 percent from 1983 through 1996, and 39 percent from 1997 through 2000 (Fishery Regulation Assessment Model, December 2002). Coded-wire tag recoveries (from the George Adams hatchery indicator stock) indicate Canadian fisheries accounted for 37 percent of harvest mortality, U.S. sport fisheries 45 percent, U.S. net fisheries 7 percent, and U.S. troll fisheries 9 percent from 1997 through 2000. This represents a substantial change from harvest distribution between 1982 and 1995, when Puget Sound net fisheries accounted for 28 percent of harvest mortality, U.S. sport fisheries 31 percent, and Canadian fisheries 33 percent (Figure 3.3-13) (Pacific Salmon Commission, October 2002).

Figure 3.3-13. Spawning escapement, fishing exploitation rate, and geographic distribution of fishing mortality for Skokomish River fall chinook.

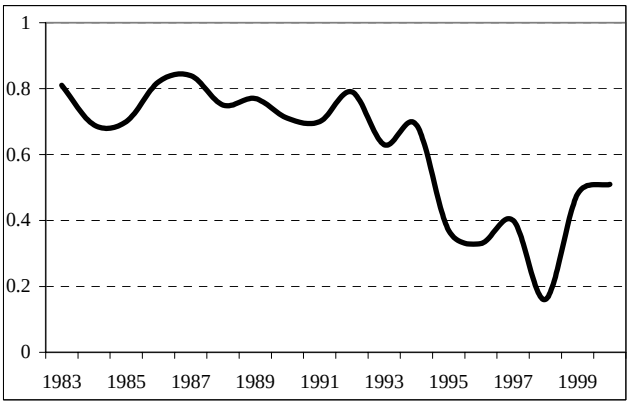
Spawning Escapement and Escapement Goal for Skokomish River Fall Chinook

Estimated escapement of naturally-spawning adults compared to current condition escapement goal



Estimated Fishing Exploitation Rate on Skokomish River Fall Chinook

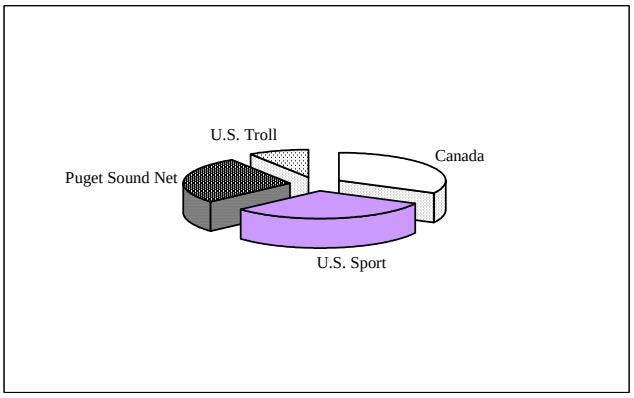
Estimated exploitation rate based on Fishery Regulations Assessment Model and George Adams Hatchery indicator



Geographic Distribution of Fishing Mortality on Skokomish River Fall Chinook

Distribution of fishing mortality based on coded-wire tag recoveries based on George Adams Hatchery indicator stock

Alaska	0%
Canada	37%
Puget Sound Net	7%
U.S. Sport	45%
U.S. Troll	9%



Sources: Puget Sound Technical Recovery Team (in progress), Northwest Indian Fisheries Commission, and Pacific Salmon Commission December 2002.

Fall-timed chinook, originally derived from Green River broodstock, are reared at the George Adams Hatchery on the Skokomish River. Approximately 0.4 million fall chinook (less than one percent of total Puget Sound releases) were released each year between 1991 and 2000 in the Skokomish River system. Additional production at Hoodsport Hatchery, which utilizes George Adams Hatchery broodstock, also enhances local fisheries. The contribution of hatchery-origin fish to natural spawning escapement in the Skokomish River is not known.

Mid-Hood Canal Fall Chinook. The Puget Sound Technical Recovery Team determined that summer-fall chinook salmon from the Dosewalips, Duckabush, and Hamma Hamma Rivers constitute an independent chinook population within Hood Canal (Puget Sound Technical Recovery Team, July 22, 2003), but noted that the degree to which chinook salmon spawning in these rivers were historically demographically linked is not clear. Chinook spawn mostly in the lower reaches of the Dosewalips, because falls and cascades above Rivermile 14 are only passable in high flow years. Genetic data are not expected to be informative in reconstructing the historical Dosewalips River chinook population structure or that of other streams tributary to Hood Canal, since many of the chinook spawning in Hood Canal appear be genetically similar to hatchery-origin chinook derived from Green River-origin broodstock (Puget Sound Technical Recovery Team, July 22, 2003).

Current chinook spawner surveys are typically limited to the lower reaches of each stream. In the Dosewalips River, the areas surveyed are transit areas and do not include all spawning areas; upper reaches have been occasionally surveyed since 1998. Prior to 1986, no reliable estimates are available because all escapement estimates for these rivers were made by extrapolation from the Skokomish River (Puget Sound Indian Tribes and Washington Department of Fish and Wildlife 2003). Escapement estimates have averaged 46 since 1998. Escapement estimates have varied so markedly in the Dosewalips River, that there is no apparent trend. Aggregate escapement to the three mid-Hood Canal rivers has averaged 452 since 1998. Aggregate escapement showed a marked increase subsequent to 1997. Aggregate escapement to the three mid-Hood Canal rivers has averaged 452 since 1998. The generic critical escapement threshold and viable escapement threshold for the Mid-Hood Canal population is 200 and 1,250 adults, respectively. Lack of coded-wire tag data makes direct assessment of harvest distribution and exploitation rates impossible. Managers assume marine harvest distribution of Mid-Hood Canal chinook similar to that of chinook from George Adams Hatchery; however, the terminal-area exploitation rate is lower because chinook fisheries are confined to southern Hood Canal and the Skokomish River.

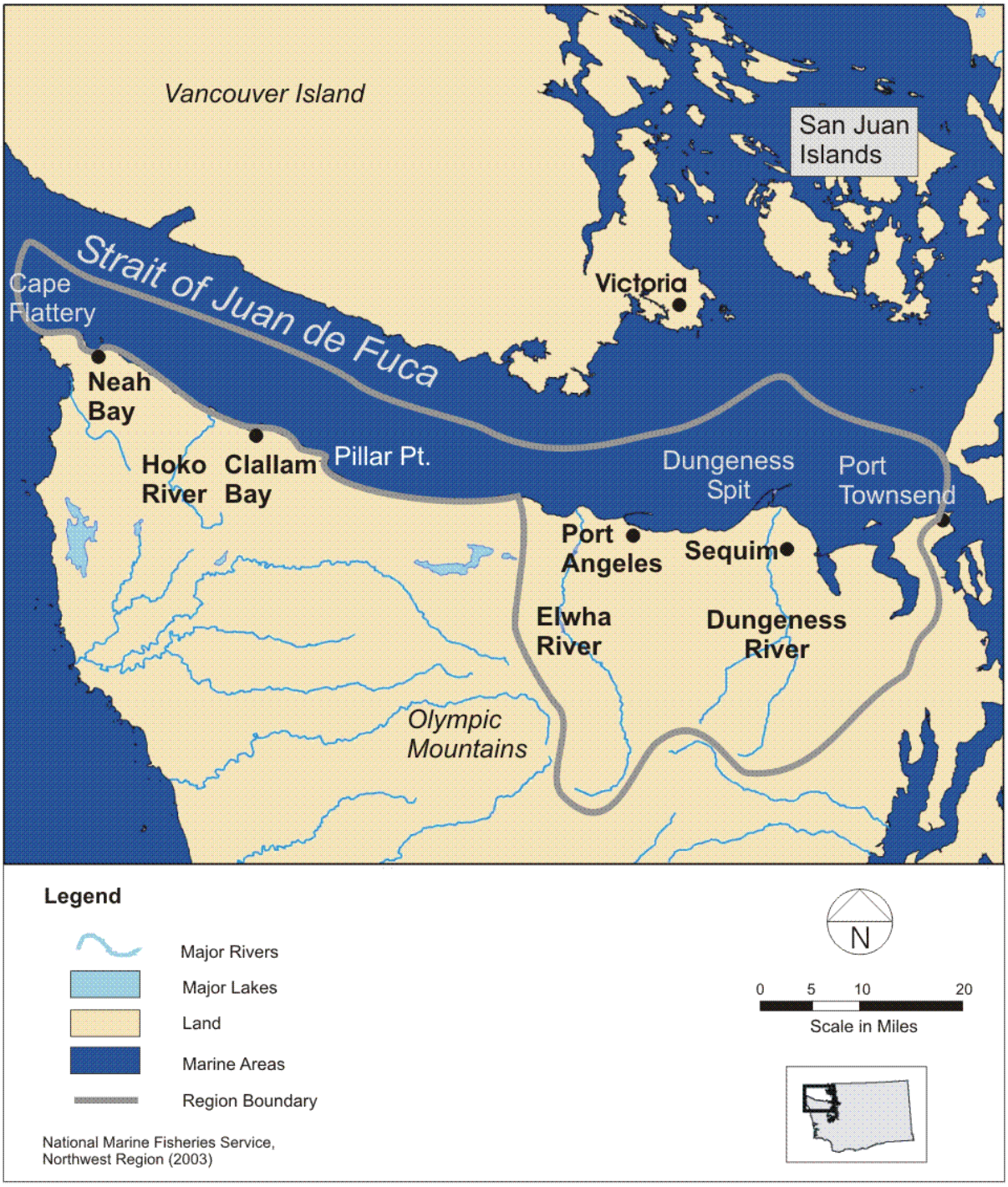
Annual Hood Canal hatchery releases of 2.8 million fall-run and 169,000 spring-run juveniles accounted for 6 percent of Puget Sound chinook released between 1991 and 2000. Spring chinook releases, which decreased steadily each year since 1991, were discontinued in 1997. Releases of fall chinook in 2001 totaled 3.3 million. Fall chinook are reared at numerous satellite locations throughout this area, but the great majority originate and are released from the Hoodsport facility (79%), and the Enetai hatchery (8%). The hatchery population is of mixed origin, with significant influence from transplants from South Puget Sound facilities.

Strait of Juan de Fuca Region

The two chinook-bearing streams in this area, the Dungeness and Elwha Rivers, both originate in the Olympic Mountain Range. The Dungeness River enters the Strait of Juan de Fuca in the vicinity of Sequim. The Elwha River enters the Strait of Juan de Fuca west of Port Angeles (see Figure 3.3-14).

Dungeness River. A native-origin, spring-summer chinook run spawns in the Dungeness River to Rivermile 18.9, where a falls just above the mouth of Gold Creek blocks further access, and in the Graywolf River, a major tributary. The Dungeness spring-summer chinook run is considered distinct from other Strait of Juan de Fuca populations based on spawn timing and geographic distribution (Puget Sound Technical Recovery Team, April 8, 2002), and is classified as a Category 1 population.

Figure 3.3-14. Strait of Juan de Fuca Region.



Mature chinook salmon enter the Dungeness River from early summer through September, and spawn from August through mid-October (Washington Department of Fisheries et al. 1993). More than 95 percent of Dungeness River juvenile chinook migrate to sea during their first year (Washington Department of Fisheries et al. 1993; Smith and Sele 1995; and Washington Department of Fish and Wildlife 1995, cited in Myers et al. 1998). Sixty-three percent of adults mature at Age 4, 25 percent at Age 5, and 10 percent at Age 3 (Point-No-Point Treaty Tribes 1995; and Washington Department of Fish and Wildlife 1995, cited in Myers et al. 1998).

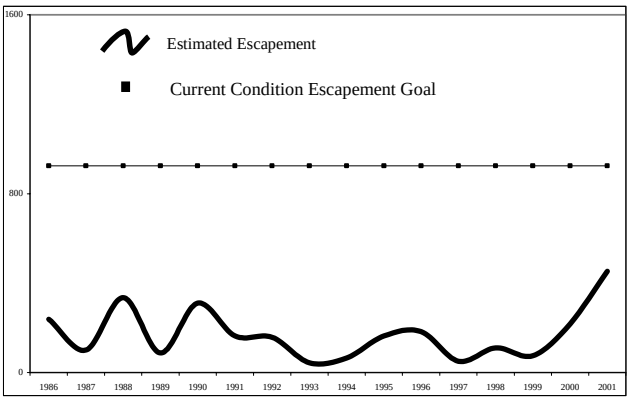
The Dungeness River spring-summer chinook population is classified as critical due to chronically-low spawning escapement levels (NMFS 2000; and Washington Department of Fisheries et al. 1993). NMFS has not yet determined critical or viable escapement thresholds for this population. The co-managers have set an escapement goal of 925 spawners based on an assessment of current suitable habitat and capacity (Smith and Sele 1994), which NMFS has adopted as the interim viable escapement threshold. NMFS has determined the critical escapement threshold to be 500 spawning adults (NMFS Memorandum 2003).Escapement has remained mostly below 250 spawners since 1986. The geometric mean of escapements was 142 (range 43 to 331) from 1986 through 1996, and 132 from 1997 through 2001 (range 50 to 453). The trend in escapement from 1986 to the present has been relatively flat, although there has been a marked increase in escapement since 1997 (Figure 3.3-15) (Puget Sound Technical Recovery Team, *in preparation*). Elwha River-tagged fingerlings offer the best available description of harvest distribution for Dungeness River chinook.

A captive broodstock program was implemented on the Dungeness River in 1996, with a goal of increasing the number of naturally-spawning fish. Approximately 1.5 million spring chinook salmon reared at the Dungeness hatchery were released annually into the Graywolf and Dungeness Rivers between 1996 and 2000. Releases in 2001 totaled 2.1 million. The contribution of hatchery fish to natural spawning is unknown, but believed to be substantial (Pacific States Marine Fisheries Commission, December 2002; and NMFS 2000).

Figure 3.3-15. Spawning escapement, fishing exploitation rate, and geographic distribution of fishing mortality for Dungeness River spring chinook.

Spawning Escapement and Escapement Goal for Dungeness River Spring Chinook

Estimated escapement of naturally-spawning adults compared to current condition escapement goal.



Estimated Fishing Exploitation Rate on Dungeness River Spring Chinook

Extremely small population size makes estimates problematic.

NOT AVAILABLE

Geographic Distribution of Fishing Mortality on Dungeness River Fall Chinook

Extremely small population size makes estimates problematic.

Alaska
Canada
Puget Sound Net
U.S. Sport
U.S. Troll

NOT AVAILABLE

Sources: Puget Sound Technical Recovery Team (in progress), Northwest Indian Fisheries Commission, and Pacific Salmon Commission December 2002.

Elwha River Chinook. The Elwha population is the westernmost population of the Puget Sound ESU, with genetic and life history traits more similar to coastal chinook populations than other Puget Sound populations (Myers et al. 1998; and Puget Sound Technical Recovery Team 2001). The Puget Sound Technical Recovery Team identified one fall-timed chinook population in the Elwha River. It is of native-origin, supported by hatchery supplementation, and is classed as a Category 1 population.

Adult chinook enter the Elwha River from June through early September. Spawning begins in late August, and peaks in late September to October (Washington Department of Fisheries et al. 1993). Elwha River chinook mature primarily at Age 4 (57%), with Age-3 and Age-5 fish comprising 13 percent and 29 percent, respectively, of annual returns (Myers et al. 1998). Naturally-produced juveniles emigrate primarily in their first year.

The degraded condition of currently usable habitat in the 5-mile reach below the Elwha Dam precludes a self-sustaining natural population. Prior to dam construction in the early 1900s, the Elwha basin contained as much as 70 miles of spawning habitat. Recovery of the population depends on restoring access to high quality habitat in the upper Elwha basin.

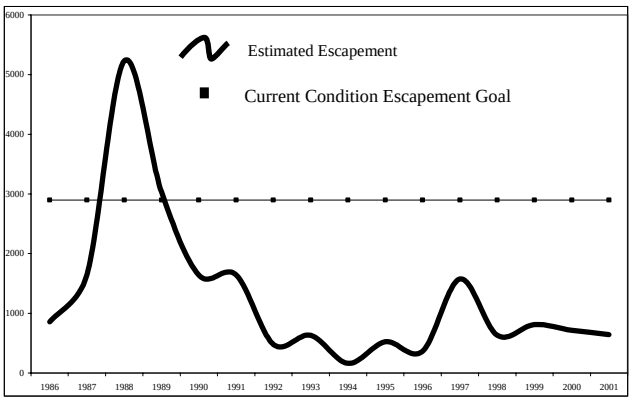
NMFS is currently evaluating critical or viable escapement thresholds for the Elwha River chinook population, but will not complete its analysis prior to completion of this Environmental Impact Statement. NMFS has determined an interim critical escapement threshold of 1,000 spawning adults and an interim viable escapement threshold of 2,900 adults for this population (NMFS Memorandum 2003).There has been a declining trend in escapement since the mid-1980s. The co-managers' nominal escapement goal of 2,900, which is a composite of 500 natural spawners and 2,400 adults for broodstock needs, was exceeded only twice between 1986 and 2001. The geometric mean of escapements was 950 from 1986 through 1996 (range 163 to 5,228), and 821 from 1997 through 2001 (range 633 to 1,578). Despite an apparent increasing trend in escapement since 1994, the overall trend in escapement has been downward (Figure 3.3-16).

The Elwha River chinook migrate to northern British Columbia and Southeast Alaska. Coded-wire tag data from 1991 through 1996, showed British Columbia accounted for 54 percent of harvest mortality, Alaska 10 percent, Washington sport fisheries 21 percent, Washington troll fisheries 5 percent, and Puget Sound net fisheries 9 percent (Figure 3.3-16) (Pacific Salmon Commission data cited in NMFS 2000).

Figure 3.3-16. Spawning escapement, fishing exploitation rate, and geographic distribution of fishing mortality for Elwha River summer-fall chinook.

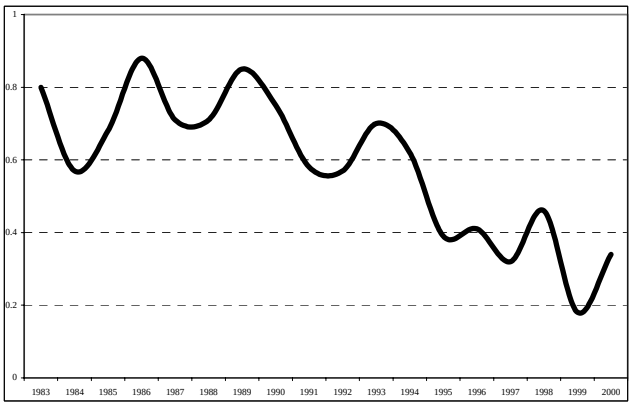
Spawning Escapement and Escapement Goal for Elwha River Summer-Fall Chinook

Estimated escapement of naturally-spawning adults compared to current condition escapement goal



Estimated Fishing Exploitation Rate on Elwha River Summer-Fall Chinook

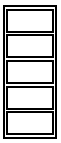
Distribution of fishing mortality based on coded-wire tag recoveries of Hoko River-Strait of Juan de Fuca indicator stock



Geographic Distribution of Fishing Mortality of Elwha River Summer-Fall Chinook

Estimates problematic

Alaska
Canada
Puget Sound Net
U.S. Sport
U.S. Troll



NOT AVAILABLE

Sources: Puget Sound Technical Recovery Team (in progress), Northwest Indian Fisheries Commission, and Pacific Salmon Commission December 2002.

Approximately 2.5 million fall chinook fingerlings from the Elwha hatchery were released each year from 1991 through 2000. Releases in 2001 were 2.6 million. The hatchery uses the native Elwha River population, and now no longer releases yearling smolts. Chinook produced at the Elwha hatchery are considered essential to run recovery, and thus are included in the listed ESU. The contribution of hatchery straying to natural spawning is unknown (Pacific States Marine Fisheries Commission, December 2002; Puget Sound Technical Recovery Team, *in preparation*; and NMFS 2000).

3.3.1.2 Hood Canal and Strait of Juan de Fuca Chum Salmon (*Oncorhynchus keta*)

NMFS listed the Hood Canal summer chum ESU as threatened in 1999. This ESU includes summer-run populations in Hood Canal and the eastern Strait of Juan de Fuca. Populations within this ESU exhibit considerable diversity in life-history features.

General Life History

Summer chum spawning occurs from late August through late October, generally within the lowest 1 to 2 miles of the river systems in which they occur. Summer chum fry emerge from stream gravels between February and the last week of May, and immediately begin migrating to estuarine areas. Following a brief residence in the estuarine zone, chum fry migrate seaward, returning 2 to 4 years later along a southerly migration path parallel to the coastlines of southeast Alaska and British Columbia. Summer chum mature primarily at 3 and 4 years of age, and a few return at Age 5. They enter the Strait of Juan de Fuca from the first week of July through September, and Hood Canal from early August through the end of September.

Population Structure

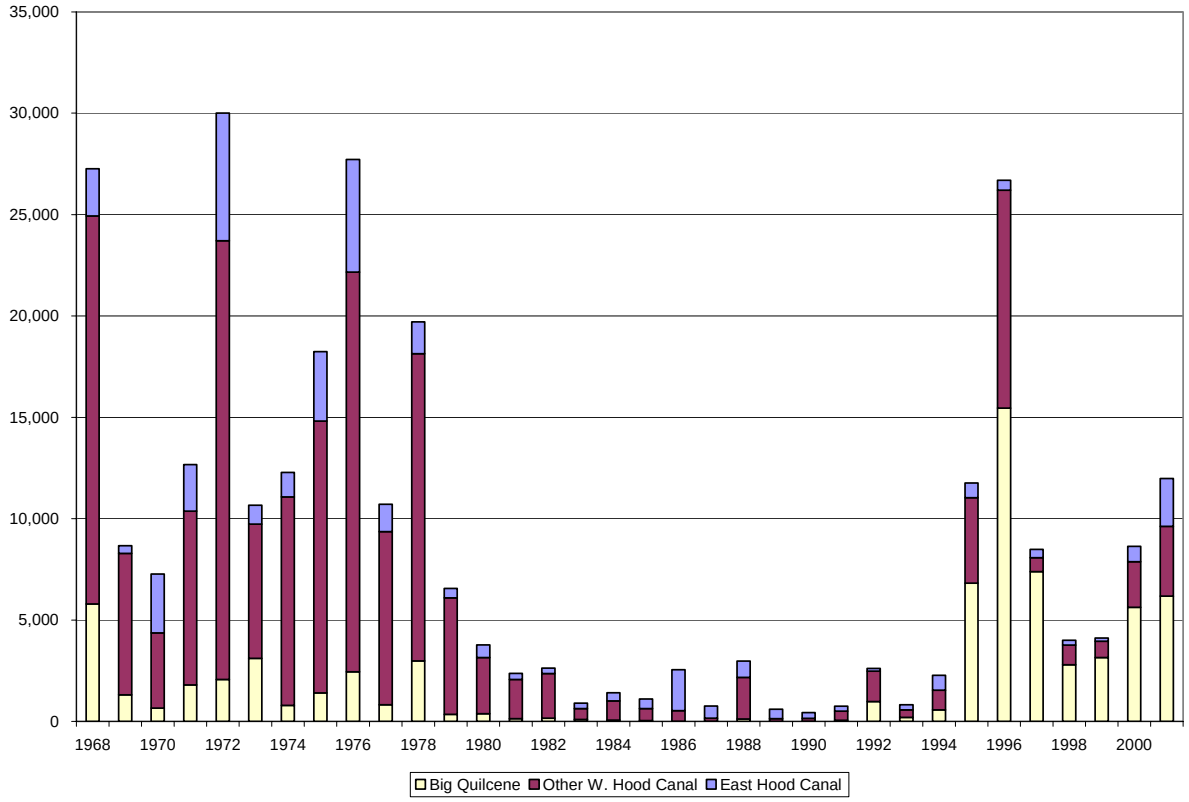
The Hood Canal Summer-Run ESU includes 16 summer-run populations in Hood Canal and the eastern Strait of Juan de Fuca, including seven populations that have become extinct. It is likely that summer chum were historically distributed among additional streams within the region. These early-timed populations are genetically distinct from fall and winter chum salmon (Washington Department of Fish and Wildlife and the Point-No-Point Treaty Tribes 2000).

Of the 16 populations of summer chum identified to have existed in the Hood Canal summer-run chum ESU, seven are considered *functionally extinct*: Skokomish River, Finch Creek, Anderson Creek, Big Beef Creek, Dewatto River, and Chimacum Creek (Washington Department of Fish and Wildlife and the Point-No-Point Treaty Tribes 2000). A summary of the status of Hood Canal and Strait of Juan de Fuca native summer chum populations is shown in Table 3.3-3. Summer chum are occasionally observed in other Hood Canal drainages, including the Skokomish River, that once supported a large

summer chum population (see Figure 3.3-7). Summer chum salmon populations in the eastern Strait of Juan de Fuca occur in Snow and Salmon Creeks and in Jimmycomelately Creek. The populations in Chimacum Creek and Big Beef Creek were extirpated, but were re-introduced in 1996. An unknown number of summer chum salmon return to the Dungeness River.

The average spawning escapement of summer chum in Hood Canal from 1968 through 1972 was 22,706 fish. By 1989, spawning escapement had reached its historical low of 519. Annual escapements began to increase in 1993, with escapements from 1998 through 2001 at 7,829. Escapement has been strongest in northern Hood Canal river systems, particularly on the west side of Hood Canal, including the Big Quilcene River, where a hatchery supplementation program is operated. Escapement in 1995 was more than 21,000 fish in northern Hood Canal. Streams on the east side of Hood Canal continued to have poor or no escapement (Figure 3.3-17) (Washington Department of Fish and Wildlife and the Point-No-Point Treaty Tribes 2000; Washington Department of Fish and Wildlife and the Point No Point Treaty Tribes 2000).

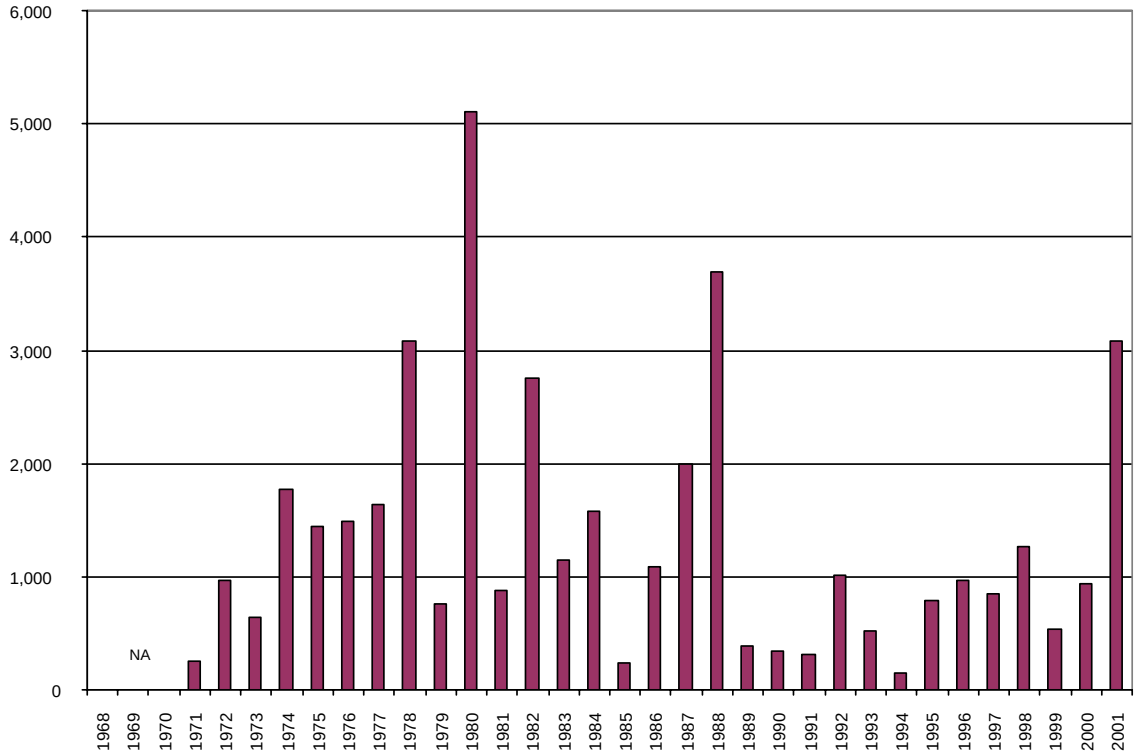
Figure 3.3-17. Summer chum salmon spawning escapement to the Big Quilcene, other west Hood Canal streams, and east Hood Canal streams, 1968–2001.



Source: Washington Department of Fish and Wildlife and the Point-No-Point Treaty Tribes 2000; Washington Department of Fish and Wildlife and the Point No Point Treaty Tribes 2000.

Summer chum escapements in the Strait of Juan de Fuca (Snow, Salmon, and Jimmycomelately Creeks) averaged 1,401 fish from 1974 through 1977, and 1,332 from 1998 through 2001 (geometric mean) (see Figure 3.3-18). (Washington Department of Fish and Wildlife and the Point-No-Point Treaty Tribes 2000; Washington Department of Fish and Wildlife and the Point No Point Treaty Tribes 2000).

Figure 3.3-18. Summer chum salmon spawning escapement to Strait of Juan de Fuca streams, 1971–2001.



Source: Washington Department of Fish and Wildlife and the Point-No-Point Treaty Tribes 2000; Washington Department of Fish and Wildlife and the Point-No-Point Treaty Tribes 2000.

Table 3.3-3. Summary of status of Hood Canal and Strait of Juan de Fuca native summer chum salmon populations.

Population	Status	Population	Status
Union	Healthy	Dungeness	Unknown
Hamma Hamma	Depressed	Big Beef	Re-introduced
Duckabush	Depressed	Anderson	Extinct
Dosewalips	Depressed	Dewatto	Extinct
Big / Little	Depressed	Tahuya	Extinct
Quilcene	Critical	Skokomish	Extinct
Snow / Salmon	Critical	Finch	Extinct
Lilliwaup	Critical	Chimacum	Re-introduced
Jimmycomelately	Critical		

Source: Washington Department of Fish and Wildlife and the Point-No-Point Treaty Tribes 2000.

Table 3.3-4. Summary of environmental and harvest-related factors impacting Hood Canal and Strait of Juan de Fuca summer chum populations.

Factor		Hood Canal	Strait of Juan de Fuca
Climate	Ocean Conditions	Undetermined	Undetermined
	Estuarine Conditions	Undetermined	Undetermined
	Freshwater Conditions	Moderate	Major
Ecological Interactions	Wild fall chum	Low	Low
	Hatchery fall chum	Low	Low
	Other salmonids (including hatchery)	Moderate	Low
	Marine fish	Low	Low
	Birds	Low	Low
	Marine mammals	Low	Low
Habitat	Cumulative impacts	Major	Major
Harvest	Canadian pre-terminal	Low	Moderate
	U.S. pre-terminal	Low	Low
	Terminal	Major	Low

Source: Washington Department of Fish and Wildlife and the Point-No-Point Treaty Tribes 2000.

Decline of the Hood Canal summer chum ESU has been attributed to a combination of high fishery exploitation rates, shifts in climatic conditions that have changed patterns and intensity of precipitation (thus altering stream flows), and the cumulative effects of habitat degradation (Washington Department of Fish and Wildlife and the Point-No-Point Treaty Tribes 2000; and Johnson et al. 1997 cited in NMFS 2000). The co-managers have ranked the relative importance of these factors for Hood Canal and Strait of Juan de Fuca summer chum.

Catch Distribution

Summer chum salmon are taken incidentally in Canadian and U.S. net fisheries targeting coho and sockeye salmon. They are taken occasionally in troll fisheries off the west coast of Vancouver Island, and infrequently by trollers or sport fishermen off the Pacific Coast and in the U.S. portion of the Strait of Juan de Fuca (Washington Department of Fish and Wildlife and the Point-No-Point Treaty Tribes 2000).

Historically, summer chum salmon were not a primary fishery target in Hood Canal since fisheries were focused on chinook, coho and fall chum salmon. However, because summer chum run timing overlaps that of chinook and coho salmon in many areas, they are caught in fisheries targeting these species. Prior to 1974, Hood Canal was designated a commercial salmon fishing preserve, and the only commercial fisheries permitted on Hood Canal were on the Skokomish reservation (Washington Department of Fisheries et al. 1973, in Johnson et al. 1997). When commercial fisheries were opened on Hood Canal in 1974, incidental harvest of chum increased rapidly, rising to 50 to 80 percent by the late 1980s in most parts of Hood Canal, and as high as 90 percent in Marine Catch Area 12A during the 1980s. In 1992, after fishery restrictions were put in place to protect summer chum, exploitation rates in Hood Canal were reduced to an average of 2.5 percent (Washington Department of Fish and Wildlife and the Point-No-Point Treaty Tribes 2000). Restrictions in Canadian fisheries that intercept summer chum also contributed to the decline in exploitation.

Hatchery Production

Hatchery programs have operated at the Quilcene National Fish Hatchery since 1992, rearing the local population to supplement production in the Quilcene River and the Little Quilcene River, and for re-introduction into Big Beef Creek. Supplementation programs also operate on Lilliwaup Creek, the Union River, the Hamma Hamma River, Salmon Creek, Chimacum Creek, and Jimmycomelately Creek.

3.3.1.3 Listed Columbia River Chinook Salmon

Small numbers of chinook from Columbia River ESUs may be taken in fisheries in Puget Sound and the Strait of Juan de Fuca. These include the Lower Columbia River, Upper Willamette River Spring-run, Upper Columbia Summer-Fall-run and Snake River Fall-run ESUs. Of these, the Lower Columbia, Willamette Spring and Snake River Fall ESUs are listed as threatened.

The exploitation rates on these populations in Puget Sound fisheries between 1984 and 1994 are all believed to have been less than 1.0 percent; 0.6 percent for the Snake River fall ESU, 0.48 to 0.59 percent for the Lower Columbia River ESU, and 0.21 percent for the Willamette Spring ESU (personal communication via e-mail from Dell Simmons, NMFS, to Susan Bishop, NMFS Sustainable Fisheries Division, December 2002).

3.3.1.4 Bull Trout (*Salvelinus confluentus*)

Puget Sound and Washington coastal bull trout populations were listed as threatened in November 1999 by the U.S. Fish and Wildlife Service (USFWS). At the same time, USFWS issued a 4(d) rule exempting from take prohibitions fishing activities taking place at that time (U.S. Federal Register, Volume 64 No. 210, November 1, 1999; proposed special rule: *Salvelinus confluentus*).

The bull trout is a char endemic to western North America that exhibits a number of life-history forms. The stream-resident form lives out its life in small headwater streams. The fluvial form lives as an adult in large rivers but spawns in small tributary streams, sometimes attaining large size. The lacustrine-ad fluvial form spawns in tributary streams but lives as an adult in lakes. It grows to a large size and usually reaches sexual maturity in about its fifth year. Little is known about the bull trout's marine life history (MacPhail and Baxter 1996). However, Kraemer (2003) found that bull trout from the Skagit system commonly switched between fluvial and anadromous forms.

Bull trout are declining in numbers throughout their range, especially at the southern edges of their distribution where a number of populations have become extinct (including streams in the Willamette River system, Oregon, and the McLeod River, California) (MacPhail and Baxter 1996).

The 1998 bull trout/Dolly Varden population inventory identified 80 populations in Washington. All bull trout/Dolly Varden populations in Washington are maintained by wild production. Of the 80 populations identified, 14 (18%) are healthy, 2 (3%) are depressed, 6 (8%) are critical, and the status of 58 populations (72%) is unknown. For a detailed inventory of the status of Puget Sound bull trout populations, the reader is referred to the 1998 addendum to the *Washington Salmon and Steelhead Stock Inventory* (SASSI) report, incorporated here by reference.

Char are occasionally caught in sport and commercial fisheries in Puget Sound, as well as in in-river net fisheries. These char are (apparently) bull trout. They are common in nearshore marine areas of Puget Sound from Everett north, and would be vulnerable to beach seine and set net fisheries. Salmon test fisheries in the Skagit River catch char, especially during the spring. Post-spawning adults may be taken in coho and chum fisheries. Char, including bull trout, are routinely caught in Skagit Bay while test seining for juvenile chinook. In marine waters, the char behave much like sea-run cutthroat, spending most of their time in shallow water (10 feet or less). Bull trout are quite commonly caught in local sport fisheries in both Port Susan and Skagit Bay, especially along northern Whidbey Island, Camano Island, and the mainland from Edmonds north (personal communication via e-mail from Curt Kraemer, Washington Department of Fish and Wildlife, May 2002 and April 2003).

3.3.1.5 Listed Columbia River Chum Salmon

In March of 1999, the National Marine Fisheries Service (NMFS) listed the Columbia River chum salmon ESU as a threatened. Johnson et al. (1997) apparently found no documented instances of Columbia River chum salmon being caught in Puget Sound fisheries. Using the presence of Washington coastal fall chum in Puget Sound catches as a surrogate for Columbia River fall chum, NMFS concluded the average annual catch of Columbia River fall chum in northern Puget Sound fisheries would range from 0 to 21 fish, and that it was unlikely that Columbia River fall chinook would be encountered in terminal area fisheries inside Puget Sound (NMFS 2000).

3.3.2 Unlisted Salmonids

3.3.2.1 Puget Sound and Olympic Peninsula Coho Salmon (*O. kisutch*)

General Life History

Coho salmon were historically distributed along the Pacific coast from Chamula Bay, Mexico (Miller and Lea 1972), to Point Hope, Alaska, through the Aleutians, and from the Anadyr River, USSR, south to Hokkaido, Japan (Scott and Crossman 1973). The Puget Sound and Washington Coastal ESUs are geographically intermediate in the coho's range.

More than 95 percent of coho salmon in Washington, Oregon, and California mature in their third year of life after rearing up to 15 months in fresh water and approximately 16 months in the ocean.

Juvenile coho prefer low-velocity stream habitats such as pools and backwaters. Coho usually migrate downstream as yearlings, after which they may reside in estuaries for a few months (Drucker 1972; and Crone and Bond 1976).

Regional Population Aggregates

The Puget Sound/Strait of Georgia Coho ESU includes populations from drainages of Puget Sound and Hood Canal, the Olympic Peninsula east of Salt Creek, and the Strait of Georgia from the east side of Vancouver Island (north to and including Campbell River) and the British Columbia mainland (north to and including Powell River), excluding the upper Fraser River above Hope. Coho salmon from this region differ genetically from those from the Columbia River and the Oregon and California coastal regions. Differences between coho salmon from the Puget Sound ESU and populations from the Olympic Peninsula are more modest (Weitkamp, et al. 1995).

Washington Department of Fisheries et al. (1993) identified 40 coho populations within the boundaries identified by NMFS for the Puget Sound ESU (Washington Department of Fisheries et al. 1993). While the majority of the populations were sustained by wild spawning, only three of these populations (Sumas/Chilliwack, Skagit, and Deer Creek [Stillaguamish River]) were determined to be of native origin. The rest were classed as being of mixed, non-native or unknown origin. However, natural production is predominant in the Skagit, Stillaguamish, and Snohomish River systems, and comprises a significant proportion of production in all other management units (Weitkamp et al. 1995).

Status and Abundance Trends. NMFS (1995) noted that while coho salmon within the Puget Sound ESU were abundant and, with some exceptions, run sizes and natural spawning escapements generally stable, there are substantial risks to whatever native production remains. The Puget Sound Coho ESU remains a candidate species for listing under the federal Endangered Species Act.

In summarizing assessments of Puget Sound coho salmon population status from four reviews, Weitkamp et al. (1995) aggregated populations into 15 watersheds and reported considerable variability in the status of populations from individual tributaries within these watersheds; in many cases, status ranged from healthy to depressed (Table 3.3-5).

Table 3.3-5. Summary of assessments of population status of Puget Sound coho salmon.

Population		WDF et al. 1993		
	Nehlsen et al. 1991 [1]	Origin [2]	Prod. Type [3]	Status [4]
North Puget Sound/ Strait of Georgia		N, M, U	W	U
Nooksack River	A+	M	C	U
Samish River		M	C	H
Skagit River		N, U	C	D, U
Stillaguamish River		N, M	W	D, U
Snohomish River		M, X	W, C	H, D
Lake Washington		M	C	H,D
Puyallup River		M	C	H, D
Nisqually River		M	C	H
South Puget Sound minor drainages	A (Chambers Creek)	M, X	W, C	
Hood Canal		M	W, C	H, D
Strait of Juan de Fuca minor drainages	A (Lyre River)	M	C	D
Dungeness River		M	C	D
Elwha River	A	M	C	H

Source: Weitkamp et al. 1995.
[1] A+ possibly extinct; A high risk; B moderate risk; C special concern; X extinct.
[2] N–native; M–mixed; X–non-native; U–unknown. [3] W–wild; C–composite.
[4] H–healthy; D–depressed; C–critical; U–unknown.

The co-managers group Puget Sound coho populations into six management units and further divide these into wild and hatchery components. From 1991 through 2000, the annual run size of Puget-Sound coho populations entering Puget Sound was 669,000, of which 44 percent was naturally spawning. The management units, and the portion of the wild coho run for which they account, are: Hood Canal (11%), Nooksack-Samish (6%), Strait of Juan de Fuca (2%), Skagit (8%), Southern Puget Sound (35%) and Stillaguamish-Snohomish (37%) (Table 3.3-6) (Pacific Fishery Management Council, Ocean Salmon Fisheries review, 2001).

Table 3.3-6. Summary of run size and escapement trends for Puget Sound wild coho population groups, 1981 through 2000.

Population Group	Wild Run (000s)	Hatchery Run (000s)	Wild Escapement Trend (1981 through 2000)	Wild Run Size Entering Puget Sound
Hood Canal	902	893	Marked Increase	Slight Increase
Nooksack-Samish	473	2301	Slight Increase	Marked Decrease
Strait of Juan de Fuca	166	289	Steep Increase	Slight Increase
Skagit River	660	374	Marked Increase	Slight Increase
South Puget Sound	2866	7156	Marked Decrease	Steep Decrease
Stillaguamish-Snohomish	3027	1146	Slight Increase	Substantial Decrease
Combined Wild Populations	8093	1146	Moderate Increase	Marked Decrease

Source: Based on data from Pacific Fisheries Management Council Ocean Salmon Review for 2000, Table B-41.

An analysis of trends in run size and escapement for the wild-spawning components of the six Puget Sound coho management units shows increases in escapement have come about primarily from a reduction in Puget Sound fisheries, allowing more fish to reach spawning grounds even though total run sizes entering Puget Sound decreased. Natural spawning increased for five of the management units: Hood Canal, Nooksack-Samish, Strait of Juan de Fuca, Skagit, and Stillaguamish-Snohomish, but runs entering Puget Sound showed slight to marked decreases for three of the populations, including the Stillaguamish-Snohomish group and the southern Puget Sound group that together account for 72 percent of the total Puget Sound wild coho run (Table 3.3-6) (Pacific Fishery Management Council Ocean Salmon Review 2001).

Factors Limiting Natural Production

Because Puget Sound coho spend up to 15 months rearing in fresh water before migrating to the ocean, availability of suitable riparian habitat plays a large role in determining the status of this ESU. Of particular concern are: the elimination of off-channel rearing habitat (e.g., slow-moving backwaters, wetlands) due to channel modification; elevated stream temperatures and increased stream velocity due to loss of shade vegetation, large woody debris and channel modification; and blockages to spawning migration caused by culverts and other obstacles. Artificial production has masked the status of natural productivity for many Puget Sound coho populations. High harvest rates, and a recent decline in average size of spawners is also a factor for concern, because of the potential for reduced fecundity and/or productivity (Weitkamp et al. 1995).

Puget Sound Fisheries

About 9 percent of Puget Sound coho salmon are harvested in British Columbia and Alaska fisheries, and 13 percent in ocean fisheries off the U.S. Pacific Coast. Puget Sound sport fisheries account for approximately 30 percent of the catch, freshwater sport fisheries 3 percent, pre-terminal net fisheries 9 percent, and terminal net fisheries 36 percent (*Fishery Resource Assessment Model Coho Impact Summary for 1999* provided by Washington Department of Fish and Wildlife).

Puget Sound coho salmon are caught in directed fisheries, and incidentally in fisheries directed at sockeye and pink salmon. Because the seasonal peak of most coho runs in Puget Sound is later than that of chinook runs, their encounter in chinook-directed fisheries increases from earlier to later in the season. For instance, in the Bellingham Bay chinook-directed fishery, coho comprised less than one percent of catch during the first week of August, 32 percent of the catch by the second week of September, and 92 percent by the first week of October. Similar patterns exist in other fisheries.

Hatchery Production

From 1991 through 2000, approximately 24 million juvenile coho were released into Puget Sound annually. Of these releases, approximately 57 percent were in basins in mid- and southern Puget Sound, 19 percent in the Nooksack-Samish basin, 7 percent each in the Stillaguamish-Snohomish basins, 6 percent in the Strait of Juan de Fuca, and 3 percent in the Skagit basin. Over this period, total releases decreased from about 40 million in 1991 to less than 10 million in 2000 (Pacific States Marine Fisheries Commission, December 2002).[iv]

Olympic Peninsula Coho ESU

The Olympic Peninsula Coho ESU contains populations from the Quinault, Queets, Hoh and Quillayute Rivers. Coho from the Olympic Peninsula ESU are rarely encountered in Puget Sound fisheries. According to coded-wire tag data from 1990 through 2000, 87 percent of coho from the Olympic Peninsula ESU are caught in Washington coastal fisheries, 10 percent in British Columbia, and less than 1 percent in Puget Sound fisheries (Pacific States Marine Fisheries Commission, December 2002).

[iv] Data may be incomplete for 2000. Releases in 1999 were about 12 million.

3.3.2.2 Puget Sound Sockeye Salmon (*O. nerka*)

General Life History

In North America, spawning populations of sockeye salmon range from the Columbia River northward to the Bering Sea, Alaska. The Strait of Juan de Fuca is considered to be near the southern limit of the sockeye's range. Sockeye salmon utilize stream systems with lakes, where fry reside from 1 to 3 years before migrating to the ocean. Spawning migrations take place from June through August. Sockeye typically migrate from lakes from March through July, and remain in estuaries for a relatively short time compared to other species. Sockeye spend 1 to 4 years at sea, returning to spawn as Age-3, Age-4, or Age-5 fish.

Population Structure

Washington Department of Fisheries et al. (1993) identified four distinct sockeye salmon populations in Puget Sound. The Baker River (tributary to the Skagit River) contains a native population maintained through a hatchery culture program, and is considered an Evolutionarily Significant Unit (ESU) (Gustafson et al. 1997). Historically, prior to construction of the Baker Dam, the run ascended the Baker River. Currently, sockeye are trapped below the dam and hauled above it to spawn.

Three other populations have been identified in the Lake Washington system, the largest being that returning to the Cedar River. This non-native population originated from fry plants of Skagit River sockeye in the 1930s, and is maintained through wild production, spawning throughout the 21 river miles below the Landsburg Diversion Dam. Returns to the Sammamish Slough and other small Lake Washington tributaries comprise the Bear Creek Provisional ESU, a population genetically dissimilar from the introduced Cedar River populations, and one that may be native to the Lake Washington system. Another distinct and possibly native population spawns on Lake Washington beaches.

Status

<u>Baker River ESU</u>. The Baker River sockeye population status is considered critical. The 1990 through 1994 average annual spawning escapement was about 2,700, compared to as many as 20,000 fish near the turn of the century and prior to construction of Baker Dam. Although population abundance has fluctuated considerably, the abundance trend from 1926 through 1995 decreased by approximately 2 percent per year. More recently (1986 through 1995), abundance has increased by approximately 32 percent a year. The escapement in 1994 of 16,000 fish was the highest since construction of Baker Dam. Like many sockeye populations, the Baker River ESU returns fluctuate markedly within a 4-year cycle, with the largest returns occurring regularly in a dominant brood year. The 1994 return and, subsequently, the 1998 return (13,000 fish) occurred in peak years for the run.

Big Bear Creek Provisional ESU. Recent average abundance in this ESU (10,000 to 20,000 spawning escapement) was judged by NMFS (1997) to be relatively high, and the ESU is not considered at risk of extinction or likely to become so.

Cedar River Sockeye. Washington Department of Fisheries et al. (1993) classified this population as depressed due to a long-term decline in freshwater survival and escapements. Escapements from 1967 through 1991 ranged from 76,000 to 365,000 annually.

Lake Washington Beach Spawning Populations. Washington Department of Fisheries et al. (1993) classed the Lake Washington beach-spawning sockeye population as depressed due to a long-term negative trend in escapement.

Factors Limiting Natural Production

The primary limiting factor on Baker River sockeye is the near absence of natural spawning habitat. This population is vulnerable to water quality problems and associated diseases in its rearing basin. Lake Washington sockeye runs are vulnerable to the effects of human population growth in the area. The hydrology of the Cedar River has been altered by diking throughout the majority of its length below the Landsburg Diversion Dam.

Fishery Impacts in Puget Sound

Baker River Sockeye. Because the migration of the Baker River sockeye run occurs well in advance of the more abundant Fraser River and other more northern sockeye runs, commercial net fisheries, at least in the Strait of Juan de Fuca region, probably have little impact on this run. Relatively small numbers (from less than 40 per week in late August to as many as 1,490 per week in mid-September between 1996 and 2001) of sockeye salmon are taken in the early weeks of the Bellingham Bay and Samish Bay chinook-directed fisheries, but the origin of these fish is unknown (Washington Department of Fish and Wildlife, December 2002). Sockeye salmon are rarely taken in marine sport fisheries in Washington, including those directed at chinook.

Lake Washington Sockeye. Sport and tribal commercial sockeye fisheries in Lake Washington have occurred sporadically in recent years, when run size is expected to exceed the escapement goal of 350,000. The sport fishery in Lake Washington attracts high angler effort when the season does open, and the allowable catch is taken within a few days or weeks. Impacts of marine salmon fisheries on Lake Washington sockeye salmon populations have only recently been estimated by the Fraser Panel Technical Committee. Because the migration of this run occurs well in advance of the more abundant

summer- and late-run Fraser River stocks, commercial net fisheries in the Strait of Juan de Fuca have measurable impact on Lake Washington sockeye when they target early Fraser River stocks.

3.3.2.3 Washington Coastal Chinook and Unlisted Columbia River Chinook

Unlisted Columbia River Chinook

There are two unlisted Columbia River chinook ESUs, the mid-Columbia spring-run ESU and the upper-Columbia summer-fall run ESU. Fish from these ESUs are rarely taken in Puget Sound fisheries. Based on coded-wire tag recoveries of upper Columbia summer-fall chinook, approximately 0.2 percent of fishery mortalities occurred in Puget Sound fisheries, mostly in the Marine Catch Area 4B treaty troll fishery and other fisheries in the western Strait of Juan de Fuca. Coded-wire tag recoveries also show that less than 0.1 percent of fishing mortalities on the mid-Columbia River spring ESU occur in Puget Sound.

Coastal Populations

Chinook from the Washington coastal ESU are taken somewhat more frequently in Puget Sound fisheries than Columbia River chinook. Coded-wire tag-data show that approximately 3 percent of fishing mortality on this ESU takes place in Puget Sound fisheries (Pacific States Marine Fisheries Commission, January 2003).

Chinook from the Oregon Coastal Natural Coho ESU are very rarely encountered in the Puget Sound Action Area. For the period 1991 through 2000, recoveries of coded-wire tagged chinook from indicator populations in the Northern Oregon Coastal ESU accounted for less than one-half of one percent of tags recovered from this ESU (Pacific States Marine Fisheries Commission, December 2002).

3.3.2.4 Puget Sound Chum Salmon (Unlisted)

Washington Department of Fisheries et al. (1993) identified 45 fall chum populations in Puget Sound, including nine in the northern area (Canada-Washington border to Stillaguamish), 30 in the southern area (Snohomish watershed south and Hood Canal), and six in the Strait of Juan de Fuca. The status was *unknown* for 13 of these populations and *healthy* for all others.

Total estimated run size for Puget Sound fall chum averaged slightly more than 1.0 million from 1968 through 1999, and just fewer than 1.5 million from 1991 through 1999. During the former period, run sizes have fluctuated from a low of 156,000 to more than 2.4 million fish. The long-term trend has been upward since the late 1960s. Thirty-seven percent of the total run originates in Hood Canal, 33 percent

in South Puget Sound, 29 percent in North Puget Sound, and 1 percent in the Strait of Juan de Fuca (Washington Department of Fish and Wildlife, Chum Salmon Web Site).

Chum salmon from Washington appear to migrate northward along the coast along a path closer to shore than coho, chinook or steelhead. Most chum mature at 3 to 5 years of age. A higher proportion of chum from Washington mature at Age 3 than do those from more northerly areas. Because the peak of the mature chum salmon migration in Puget Sound (October-November) occurs later than that for chinook (August-September), chum are infrequently taken in chinook-directed fisheries (approximately 1 chum per 250 chinook between 1996 and 2001). Conversely, chinook are also rarely taken in fisheries targeting chum salmon (1 chinook per 476 chum between 1996 and 2001) (Washington Department of Fish and Wildlife, December 2002).

From 1991 through 2000, an average of more than 5.1 million hatchery chum salmon per year were released into Puget Sound. Of these, approximately 91 percent were fall chum (i.e., generally spawning after mid-October), and 1 percent were winter chum (i.e., generally spawning prior to mid-October) (Pacific States Marine Fisheries Commission, December 2002).

3.3.2.5 Puget Sound Steelhead (*O. mykiss*)

After hatching, steelhead typically spend from 2 to 4 years in their natal stream before migrating to sea. The juvenile steelhead migration usually occurs from April to June. They then spend up to 3 years in salt water prior to spawning. Unlike other species of *Oncorhynchus*, some steelhead populations may spawn more than once. Steelhead typically live from 6 to 8 years.

The Puget Sound Steelhead ESU occupies river basins of the Strait of Juan de Fuca, Puget Sound, and Hood Canal, Washington. Included are river basins as far west as the Elwha River and as far north as the Nooksack River. Puget Sound steelhead generally form a coherent group, distinct from populations elsewhere in Washington.

The majority of steelhead populations in Puget Sound are winter-run, but summer-run steelhead are also present, usually in subbasins of large river systems and above seasonal hydrologic barriers. Winter run (also known as *ocean-type*) steelhead typically spend less time rearing in streams as juveniles than do summer-run (also known as *stream-type*). Most summer-run fish are found in the Skagit, Stillaguamish, and Skykomish River systems. Mature summer-run steelhead enter streams between May and October. Spawning occurs anywhere from December to April of the following year. In the Skagit, Stillaguamish, and Snohomish systems, winter-run steelhead may enter their streams as early as mid-October. In contrast, winter-run steelhead enter rivers and streams in the Lake Washington basin,

South Sound, and Hood Canal, beginning in November or December, and the peak of spawning occurs between March and May of the following year (Busby et al. 1996).

Total run size for Puget Sound steelhead in the early 1980s can be calculated from estimates in Light (1987) as approximately 100,000 winter steelhead and 20,000 summer steelhead. Light provided no estimate of hatchery proportions specific to Puget Sound streams, but for Puget Sound and coastal Washington combined, he estimated that 70 percent of steelhead in ocean runs were of hatchery origin. The percentage in escapement to spawning grounds would be substantially lower due to differential harvest and hatchery rack returns.

Washington Department of Fisheries et al. (1993) identified 53 stocks within the Puget Sound Steelhead ESU, of which 31 were considered to be of native origin and predominantly natural production. Their assessment of these 31 stocks was: 11 healthy, 3 depressed, 1 critical, and 16 unknown. Their assessment of the remaining (not native/natural) stocks was 3 healthy, 11 depressed, and 8 unknown.

Recent 5-year average natural escapements for streams with adequate data range from less than 100 to 7,200, with corresponding total run sizes of 550 to 19,800. Total recent run size for major stocks in the Puget Sound Steelhead ESU was more than 45,000, with total natural escapement of about 22,000.

Johnson et al. (1996) concluded that steelhead stocks in the Puget Sound ESU were probably naturally self-sustaining, but noted there was concern about summer steelhead stocks that are typically small, occupy limited habitat, and in most cases are subject to introgression by hatchery fish.

Washington has maintained an extensive hatchery program for steelhead for several decades. From 1990 through 2001, 2.3 million hatchery-reared steelhead smolts were released in Puget Sound, of which 80 percent were winter-run. Thirty-seven percent of these smolts were released in the Stillaguamish and Snohomish basins, 28 percent in mid-Puget Sound streams, 20 percent in the Skagit system, 8 percent in southern Puget Sound streams, 4 percent in the Nooksack River, and 3 percent in Hood Canal (Pacific States Marine Fisheries Commission, December 2002). The hatchery program is intended to augment natural production, and harvest rates on hatchery stocks are typically high (Busby et al. 1996).

Steelhead sport fishing is very popular in Washington. The most recent (1999 to 2000) annual sport steelhead catch in Puget Sound rivers was approximately 11,000 fish. Two river systems, the Snohomish and Stillaguamish, accounted for more than half of this catch (Washington Department of

Fish and Wildlife 2002). In the late 1970s, the Washington Department of Wildlife began requiring anglers to release steelhead from naturally-spawning parents.

Tribal fishermen also take steelhead in commercial, ceremonial and subsistence fisheries, primarily with set nets. The tribal steelhead catch within the Puget Sound Action Area averaged approximately 3,600 fish annually from 1991 through 2001 (personal communication with Will Beattie, Conservation Planning Coordinator, Northwest Indian Fisheries Commission, December 2002).

Steelhead are rarely taken in ocean or Puget Sound marine commercial fisheries (NMFS 2000). They are occasionally taken in near-terminal fisheries or in-river fisheries targeting chinook. However, because nearly all (98%) of terminal-area commercial chinook landings occur before October, there is little overlap with migration of winter-run steelhead. Some overlap occurs between summer-run steelhead and chinook in August and September. Tribal landings data show an average of 91 steelhead taken in these two months combined between 1990 and 2001 (Washington Department of Fish and Wildlife commercial fisheries landing data provided by Lee Hoines, Washington Department of Fish and Wildlife 2002). Steelhead may occasionally be taken by anglers targeting chinook salmon in river fisheries.

3.3.2.6 Puget Sound Pink Salmon (*O. gorbuscha*)

Pink salmon mature at the smallest average size of any species of Pacific salmon. Their spawning distribution ranges from Puget Sound to Norton Sound, Alaska, in North America, and from North Korea Anadyr Gulf, Russia, in Asia (Heard 1991 and Mathisen 1994). Between 70 and 80 percent of the Washington pink salmon spawning escapement occurs in North Puget Sound (Washington Department of Fisheries et al. 1993; and Big Eagle & Associates and LGL, Ltd. 1995).

Pink salmon spawn during the late summer and fall in both large and small rivers, and tend to spawn closer to tidewater than other species of Pacific salmon – generally within 30 miles of a river mouth (Heard 1991, Washington Department of Fisheries et al. 1993). Fry migrate downstream primarily in March and April, although migration can extend into May. Puget Sound pink salmon appear to rear in nearshore areas for a few weeks to a few months, then move offshore. Some Puget Sound pink salmon, and possibly some from Hood Canal, spend their entire marine phase in the nearshore environment (Jewell 1966 and Heard 1991).

Because essentially all pink salmon mature at 2 years of age, this species lacks variable age structure. Two broodlines (even- and odd-year) result from generations spawning in alternate years. Twelve odd-year spawning populations have been identified in Washington: four in the Nooksack, Skagit,

Stillaguamish, and Snohomish Rivers in North Puget Sound; two in South Puget Sound in the Puyallup and Nisqually Rivers; three in Hood Canal in the Hamma Hamma, Duckabush, and Dosewalips Rivers; and three on the Strait of Juan de Fuca in the upper Dungeness, lower Dungeness, and Elwha Rivers. One even-year population in the Snohomish River has been identified (Hard et al. 1996).

The National Marine Fisheries Service (NMFS) conducted a review of pink salmon ESUs in 1996. Available data suggested the even-year pink salmon population in the Snohomish River had been increasing since 1980. Most populations of Puget Sound odd-year pink salmon appear to be healthy, with overall abundance close to historical levels. The NMFS biological review team did express some concern about populations in the Strait of Juan de Fuca; however, they concluded that neither the Puget Sound even-year ESU nor the Puget Sound odd-year ESU warranted listing under the Endangered Species Act. Because the run timing of pink and chinook salmon in Puget Sound overlap considerably, pink salmon are taken in chinook-directed commercial fisheries. A review of commercial catch data for 1997, 1999 and 2001, showed one pink salmon landed per every 2.4 chinook in areas where there were chinook-directed fisheries, primarily in Marine Catch Areas 7B (Bellingham Bay) and 8D (Tulalip) in September. Salmon anglers may also catch pink salmon while targeting chinook. In fact, when pink salmon presence coincides with chinook presence, pinks are much more frequent in the catch than are chinook. During the peak of the pink salmon run (August-September), approximately one chinook is landed per every 37 pink salmon (Washington Department of Fish and Wildlife, December 2002.)

Relatively small numbers of pink salmon are reared in Puget Sound hatcheries. Approximately 3.0 million pink salmon juveniles were released in each odd-year between 1990 and 2001 (Pacific States Marine Fisheries Commission, December 2002).

3.3.3 Non-Salmonid Fishes (Groundfish)

At least 80 species of groundfish occur in Puget Sound. Most common are flatfishes such as sole and flounders, rockfishes, surf perches, halibut, sculpins, spiny dogfish, lingcod and Pacific cod. In recent history, walleye pollock were also very abundant, but have declined markedly over the past two decades. Flatfish, which include Pacific sandabs, butter sole, Dover sole, sand sole, starry flounder and other species, currently make up the largest part of the catch (46%). Rockfish make up 30 percent of the catch, with most of this occurring on five species: copper, quillback, black, brown, and yellowtail constitute more than 90 percent of the rockfish catch. Surf perches account for approximately 10 percent of the non-salmonid catch, Pacific halibut 2 percent, sculpins 2 percent, spiny dogfish 1 percent, and lingcod 1 percent. Pacific cod, which, like walleye pollock were formerly abundant, are now rarely taken.

Status of Puget Sound Groundfish Populations

An assessment by the Washington Department of Fish and Wildlife classified 55 percent of groundfish stocks in South Puget Sound and 44 percent of stocks in North Puget Sound as being in poor condition (Puget Sound Water Quality Action Team 2002). Pacific cod are in depressed or critical condition in most areas, as are walleye pollock and spiny dogfish in South Puget Sound. Lingcod and halibut stocks in most areas are at or above average levels. The status of rockfish species is considered depressed in both North and South Puget Sound. The status of flatfish stocks varies by area and species from critical to above average.

In response to a petition to list Puget Sound rockfish as threatened under the federal Endangered Species Act (Wright 1999), NMFS conducted a status review of Puget Sound brown, copper and quillback rockfish, and concluded that ESA listing was not warranted.

Trophic Interactions

Groundfish are widely distributed, and are important components of most ecosystems where they occur. Larvae and juveniles of several species, including rockfishes, have significant trophic value in pelagic ecosystems as prey for a variety of fishes, including chinook salmon (Ralston 1990) and coho salmon (Healy 1980). Sub-adults and adults of many groundfish are important top predators and competitors in nearshore benthic ecosystems, some species possibly having keystone roles in structuring biodiversity and promoting energy transfer in these systems.

Incidental Catch of Groundfish Species in Chinook Fisheries

Groundfish species, including rockfish and halibut, are frequently caught by anglers targeting chinook (or other salmon species) in Puget Sound. Based on data collected through creel surveys between 1986 and 1999, Palsson estimated anglers targeting salmon in Puget Sound caught 0.65 groundfish, including 0.05 rockfish per angler trip. Incidental groundfish catch varied by marine catch area from a high of 2.09 per angler trip in Marine Catch Area 5 (Sekiu-Pillar Point), to a low of 0.024 per angler trip in Marine Catch Area 11 (Tacoma-Vashon) (personal communication via e-mail from Wayne Palsson, Washington Department of Fish and Wildlife, December 2002). Groundfish species commonly taken other than rockfish include pollock, dogfish, Pacific cod, lingcod, and ratfish. Halibut are infrequently caught by anglers targeting salmon (personal communication with Greg Bargmann, Washington Department of Fish and Wildlife, January 2003).

Commercial net fishers targeting salmon may inadvertently take groundfish species. However, this is typically disruptive of their salmon fishing, and is therefore avoided to the extent possible. With few exceptions, groundfish catches are not landed and not reported.

3.3.4 Forage Species (Pacific Herring, Sandlance, Smelt)

Forage fish are so-called because they are an important part of the food chain of other fishes (including chinook salmon), seabirds, and mammals. Changes in the abundance of forage fish can have impacts on other species. The base of prey supporting fish-eating species in Puget Sound primarily consists of herring, sandlance, smelt, juvenile hake and juvenile pollock (West 1997). Puget Sound is typical of many marine environments that contain a large number of lower trophic-level species such as plankton; a substantial number of higher trophic-level species such as larger fish, seabirds and mammals; and relatively few intermediate trophic-level species such as small pelagic fish (Washington Department of Fish and Wildlife Forage Fish Management Plan). The Washington Department of Fish and Wildlife has established a *Priority Habitats and Species List* to identify species and habitats of special concern. Pacific herring, surf smelt and Pacific sandlance are included on this list. Washington Administrative Code (WAC) 220-110-250 established *saltwater habitats of special concern* including smelt, herring and sandlance spawning beds. Construction projects may be prohibited or conditioned in these areas during certain times of the year (Washington Administrative Code 220-110-217) (Washington Department of Fish and Wildlife, *Forage Fish Management Plan*). NMFS conducted a Pacific herring status review in response to a petition to list this species. The review team concluded that the *distinct population segment* represented by stocks in the Georgia Basin and Puget Sound was not at risk of extinction, nor likely to become so. However, most members expressed concern that they could not entirely rule out the possibility that the Georgia Basin (Puget Sound) population segment at present is likely to become in danger of extinction (Stout et al. 2001).

3.3.5 Fish Habitat Affected by Salmon Fishing

Habitat Types Affected

Fish habitat potentially affected by salmon fishing within the Puget Sound Action Area includes benthic substrate and associated plant and animal communities in marine areas where gillnets, purse seines and beach seines are used, especially in shallower areas or areas of eelgrass beds. Spawning and riparian rearing habitat may be affected by in-river fisheries, by wading fishermen, the wakes of fishing craft, or other mechanical disturbances.

Gear Types with Detectable Habitat Impacts

The most common habitat impact that may result from actively-fished gear would be scouring of the seabed or river bottom by the weighted line at the bottom of gillnets, purse seines and beach seines. While this undoubtedly occurs in many areas, fishermen endeavor to avoid entanglement and abrasion to their fishing gear by minimizing bottom contact. While local effects may be observable, it is unlikely that impacts are detectable on a broad scale.

Derelict Fishing Gear

Fishing gear in all types of salmon fisheries is lost as a result of entanglement with bottom structures, logs and debris, or because of storms, flood events and other occurrences. While lost fishing gear is most commonly associated with marine fisheries, river set-nets are also lost. Salmon, other fishes, seabirds, mammals and other animals may become entangled in derelict nets or in monofilament fishing line. Gillnets, in particular, pose a problem as the nets continue to entangle fish or other species long after they are lost or abandoned. Submerged gillnets typically drift until they become entangled on submerged features or structures where they may impact bottom-dwelling organisms (personal communication via e-mail from Jeffrey June, Natural Resources Consultants, November 2002). Palsson reported recent investigations that suggest the direct and indirect effects of lost fishing gear likely outweigh the negative effects that may occur from contact with bottom habitat or the incidental entanglement of fishes, mammals or birds during actual fisheries (personal communication from Wayne Palsson, Washington Department of Fish and Wildlife, November 2002).

Hook and Line Angling and Effects of Stream Wading

Anglers frequently lose terminal tackle in river salmon and steelhead fisheries when their weights become stuck or tangled. Because many artificial baits used in these fisheries are buoyant, they float above bottom where they may continue to attract (and hook) fish.

Trampling of spawning redds during stream wading has the potential to cause high mortality of salmonids. Most information on redd disturbance is anecdotal; however, one study observed 46 to 49 percent mortality of alevins with only one or two passes by wading anglers per day. The extent or cumulative effect of this type of damage is not known (Roberts and White 1992).

Studies in Alaska and New Zealand have found that in shallow water where boat use is frequent, developing salmon eggs and alevins in the gravel can suffer high mortalities (Horton 1994; Sutherland and Ogle 1975). Fishery managers sometimes try to ameliorate these potential effects by closing important spawning reaches to boating or wading (Pacific Fisheries Management Council 1999,

Appendix A). Ongoing studies on Alaska's Kenai River (where angler trips exceed 300,000 per year) have focused on the impact of boats and shore anglers on key riparian rearing habitat for juvenile chinook. The studies have found a relationship between shore angler use, a decrease in riparian plant diversity, and bank erosion. The same studies have also found an increase in bank erosion in those areas of the river with high power boat use (King 2002).

3.3.6 Marine-Derived Nutrients from Salmon Spawners

Pacific salmon accumulate almost all of their body mass while in the marine environment (Groot and Margolis 1991). When they return to the streams where they were born, to spawn, adult salmon deliver a substantial quantity of marine-derived nutrients to freshwater ecosystems, as a direct food source for juvenile or resident salmonids and invertebrates, and as their decomposition supplies basic nutrients to the ecosystem (Larkin and Slaney 1996; Gresh et al. 2000; Murota 2002; and Wipfli et al. 1998).

Stream biological communities incorporate salmon-derived nutrients through three primary pathways: 1) animals and other organisms consume plants, insects and other primary producers that directly feed on or derive nutrients from salmon carcasses and eggs; 2) bacteria, algae and other streambed microfauna consume dissolved organic matter released by salmon carcasses; and 3) animals, juvenile fish, insects and other organisms directly consume salmon carcasses, eggs and fry (Cederholm et al. 1999; and Bilby et al. 1998). High flow and scavenging by birds and mammals (Cederholm et al. 1989; and Ben-David et al. 1998) can deliver salmon-derived nutrients to areas adjacent to and upland from streams in which salmon spawn (Garten 1993; Wilson and Halupka 1995; Helfield and Naiman 2001; Hocking and Reimchen 2002; and Reimchen et al. 2002).

Nutrient recycling by salmon is particularly important in nutrient-limited river systems in the Pacific Northwest. Addition of nutrients to freshwater systems, in the form of carcasses or inorganic fertilizer, can influence biological community structure and increase stream productivity at several levels of the freshwater food chain (Kline et al. 1990; Piorkowski 1995; and Quamme and Slaney 2002). Addition of nitrogen and phosphorous during lake enrichment programs has elevated primary production and increased rearing capacity for juvenile sockeye salmon in lake systems (Hyatt and Stockner 1985; Kyle et al. 1997; and Bradford et al. 2000). In river systems, biological benefits of nutrient recycling may also include increased growth and density of juvenile salmonid populations (Johnston et al. 1990; Bradford et al. 2000; and Ward and Slaney 2002). In turn, increased fish size may result in higher survival of juvenile coho salmon (Bell 2001; Brakensiek 2002; Hartman and Scrivener 1990; Johnston et al. 1990; Quinn and Peterson 1996; and Holtby 1988) and steelhead (Ward and Slaney 1988; Hager and Noble 1976; and Bilton et al. 1982). Salmon carcasses and eggs are also an important food source for freshwater salmon and trout communities (Bilby et al. 1996; Helfield and Naiman 2001; Kline et al. 1990; Piorkowski 1995; and Winter et al. 2000), and may play a critical role when other food items are less available. A study by Cederholm et al. (1989) also revealed significant predation on salmon carcasses by mammals and birds. Cederholm et al. (2000) also documented more than 138 species having a strong positive life-history relationship to Pacific salmon.

However, results of these studies do not universally indicate the degree of importance or pathways of marine-derived nutrients across different freshwater systems. These are dependent on the characteristics of the freshwater river systems themselves. For example, Bilby et al. (1996) stress the importance of chemical absorption of nutrients in headwater streams in the Pacific Northwest, typically preferred for spawning by adult coho salmon (Sandercock 1991), where primary production is limited during winter due to cold temperatures, low light levels, and frequent scouring by high flow events. On the other hand, Piorkowski (1995) found that although salmon carcasses and eggs were an important food source for salmon and trout juveniles, consumption by plants, insects and other primary producers was insignificant. He attributed the differences between his findings and others to 1) the size of the stream relative to the size of the salmon run; and 2) the intensity of precipitation that flushed nutrients from the system. Direct consumption of salmon carcasses and nutrient contribution is dependent on their retention time in streams, and so may vary annually due to the intensity of water flow, the size of river systems, type of habitat, amount of large-woody debris in the river, and the species of salmon (Cederholm and Peterson 1985; Cederholm et al. 1989; and Glock et al. 1980). Therefore, although research to-date provides evidence of the role of salmon-derived nutrients in ecosystem function, this complex relationship remains poorly understood.

Research on salmon and marine-derived nutrients frequently implies that current harvest management strategies risk further decline or prevent recovery of salmon populations (Michael 1995 and 1998). Specifically, this research implies that spawning escapements realized under current harvest objectives are inadequate to provide the nutrient input necessary for ecosystem function. Many studies assert that declining salmon abundance and escapement currently exacerbate nutrient limitation in many systems. Gresh et al. (2000) estimated that the current contribution of marine-derived nutrients from adult Pacific salmon to rivers in the Pacific Northwest is as low as 6 to 7 percent of historic levels, and that the resulting nutrient deficit could be exacerbating continued declines in salmon abundance or impeding recovery. Harvest management planning objectives, and the implementation of annual fishing regimes, are principal determinants of the levels of natural spawning escapement achieved for all salmon species, and therefore influence nutrient loading in each system. However, research has not advanced to the point of quantifying threshold nutrient loading levels associated with adult salmon necessary to support ecosystem function and optimize the survival of post-emergent juvenile salmon. Nutrient dynamics in aquatic systems are complex (Northcote 1988; Polis et al. 1997; Bisson and Bilby 1998; Murphy 1998; and Naiman et al. 2000), and depend on numerous site-specific factors including the species of salmon, spawning density and location, stream discharge regimes, stream habitat complexity, basin geology, light, temperature and community structure. In particular, the role of adult

chinook in this regard must be examined in the context of 1) the limitations of current research, and 2) chinook life history and abundance (i.e., escapement) relative to the much higher escapement of coho, pink, and chum salmon in the large river systems that support chinook populations.

Bilby et al. (2001) found that enrichment levels increased with increasing coho carcass abundance. However, the relationship also revealed a point of diminishing enrichment above carcass abundance levels of 0.004 pounds per square foot (approximately 310 fish per square mile), above which marine nutrients in juvenile coho salmon rapidly approached a saturation level. Based upon spawner escapement data and research findings, the authors concluded that the majority of coho salmon spawning in western Washington streams are well below capacity for incorporating more marine-derived nutrients. From a purely scientific perspective, however, there are limitations to wide application of results from this work (many of which the researchers acknowledge). First, study sites were purposely chosen to only include areas with spawning coho salmon and returns of no other anadromous salmonid species. This implies that results may only be applicable in such areas, and questions whether marine nutrient dynamics would be similar in systems with returning runs of multiple salmon species. The temporal distribution of spawning by numerous species of salmon can mean prolonged input of marine-derived nutrients, which may be more effectively incorporated within a system (due to nutrient flushing) at a lower density of spawners for a given species. Second, juvenile coho salmon alone are probably not an appropriate indicator for determining whether productivity in a system is nutrient-limited (Simberloff 1998). The nutrients attributable to salmon carcass deposition found in juvenile coho salmon has been primarily attributed to direct consumption of salmon carcasses and eggs. If this is indeed the primary mechanism for nutrient uptake, then juvenile coho salmon are less revealing of other pathways for incorporation and trophic distribution of marine-derived nutrients within a system. Third, uncertainty remains as to whether increasing the input of salmon-derived nutrients to river systems will subsequently result in higher returns of adult salmon.

While it appears that salmon-derived nutrients can benefit sockeye salmon, cutthroat trout and coho salmon populations, at this time there are no research publications that directly establish the relationship between marine-derived nutrients and chinook salmon. Chinook populations in Puget Sound primarily exhibit an ocean-type life history, with relatively short freshwater residence compared to coho, sockeye and steelhead salmon. The latter species are the focus of most marine-derived nutrients studies. It is not known whether newly-emerged chinook salmon fry actively feed on salmon carcasses and eggs, or if carcasses are retained for a sufficient period of time to allow direct consumption, especially in large river systems with peak winter flow events. Freshwater survival,

through the egg-to-smolt phases, is undoubtedly constrained by other biotic and physical factors. For example, high streamflow during the incubation period is significantly correlated with egg-to-smolt survival in the Skagit River and Cedar River (Seiler et al 1999). Degraded stream and estuarine rearing habitat reduces smolt survival in many Puget Sound systems (Stillaguamish Technical Advisory Group 2000; WDFW and Puyallup Tribe 2000). The benefits of marine-derived nutrients for juvenile chinook salmon may be more fully realized in estuaries (Simenstad 1997), where most chinook rear for a critical period prior to migrating seaward. However, little is currently known about the roles of marine-derived nutrients in estuaries. In addition, in some instances the eutrophication of estuaries associated with agricultural and urban runoff may be negatively affecting fish habitat and survival.

Finally, in many river systems throughout the Pacific Northwest, returns of chum and pink salmon comprise the majority of spawner biomass. These species typically spawn in the lower portion of stream and river systems. This implies that chum and pink salmon contribute substantial inputs of marine-derived nutrients to environments used by ocean-type juvenile chinook salmon. Whether survival of juvenile chinook salmon is limited by nutrient deficiencies needs to be evaluated in a multi-species context. Furthermore, the relative contribution by adult returns of different salmon species to both ecosystem function and salmon populations with unique life-history strategies needs to be more fully recognized. Consequently, it has not been demonstrated that carcass nutrient limitation, as it may affect secondary production of prey species or direct enhancement of food supply, currently exerts a significant limitation on the productivity of chinook or other salmon species in Puget Sound systems.

3.3.7 Selectivity on Biological Characteristics of Salmon

The transfer from parents to offspring (*inheritance*) of certain biological traits such as age at maturity, growth rate, and the effect of these traits on each other has been extensively researched and documented (Clark and Blackbird 1994; Donaldson and Menasveta 1961; Hankin 1993; Hankin et al. 1993; Hard et al. 1985; Heath et al. 1994a; and Silverstein et al. 1998). Under certain circumstances, fishing may influence the biological traits of salmon that return to spawn, and thus the traits that are conveyed to their offspring. The potential long-term effects of selective fishing may be two-fold. First, possible reductions in the long-term yield of the fishery (Ricker 1976) and smaller fish size could erode the economic viability of the fishery. In other words, fishermen would have to increase catch to maintain the same level of income (assuming other economic factors remain relatively stable). Researchers have found that total yields in mixed-stock ocean fisheries may be considerably less than those that could be achieved if populations could be managed and harvested separately (Ricker 1958; Henry 1972; Ricker 1976; and Hilborn 1985). Second, selective fishing may affect the diversity of size, age and sex ratio in the salmon escapement. Diversity in biological traits is necessary if populations are to respond successfully to changing environmental conditions. For example, numerous studies have emphasized the possible importance of large size in naturally-spawning populations of chinook salmon for mate choice and reproductive success (Baxter 1991; Berejikian et al. 2000; Healey 2001; Healey and Heard 1984; and Silverstein and Hershberger 1992). Since the second issue is the basis for the first, it is the focus of this discussion.

Selective fishing is defined in this subsection, and the potential consequences of selective fishing are explored. Generally, a fishery is characterized as *selective* whenever fish with particular characteristics are caught more frequently than they occur in the population at large. Salmon fisheries may be size- or age- selective within stocks, stock-selective, or species-selective.[i]

[i] Indirect sex-selectivity may result due to different size distributions and age structures between male and female chinook. In general, males mature at a younger average age than females (Groot and Margolis 1991).

Size-Selective Fisheries

Size-selective fisheries catch fish within a certain size range at a greater rate than smaller or larger fish. For example, ocean commercial and recreational fisheries typically have minimum size limits, thereby potentially generating greater exploitation rates on larger and older fish than on younger and smaller fish. Terminal gillnet fisheries may select for fish that are within an intermediate size range because the size of the net mesh is set to target the size range that characterizes the runs or general size of the target species. Often, such terminal gillnet fisheries represent *age-selective* fishing because fish of a certain age generally fall within a certain size range. For example, in California's Klamath River, the gillnet fishery uses mesh size that predominantly catches Age-4 fish; most Age-3 and Age-2 fish pass through the nets, whereas many Age-5 fish are too large to be caught by gillnets.

The "theory of a fishery," as first advanced by Baranov (1918; see Ricker 1978), proposes that the direct cumulative effect of removing larger and older fish may be to shift the distribution of a reproducing fish population toward smaller, younger (Hankin and Healey 1986) and slower-growing fish. For example, in ocean fisheries for chinook salmon, minimum commercial size limits typically mean that only a fraction of the Age-3 adults from a given stock are vulnerable to commercial capture. If those Age-3 fish that are above the legal size limit were genetically-programmed *fast-growing* fish, then one might conclude that selective fisheries would be generating long-term selection for reduced growth rates.

Possible fishery-induced selection for reduced growth rates may be complicated, however, by several factors in chinook salmon fisheries. First, the actual size that a salmon reaches at a particular age may not be highly correlated with a genetically determined *growth rate* for several reasons. The realized size of a fish at a given age must reflect unknown interactions between inherent growth rate, variability in supply and quality of food, and variability in environment (especially water temperature). Because of this variability, actual size at age may not, in general, be highly correlated with the underlying genetically-controlled growth rate.

Second, long-term genetic selection due to size-selective fisheries may be stronger for reduced age at maturity than for growth rate[ii]. If age at maturity has a heritable component, older-aged parents will tend to produce progeny that mature at older ages, whereas younger-aged parents will produce progeny

[ii] If the heritable component for age is larger than the heritable component for growth rate.

that mature at younger ages. Therefore, if younger-aged salmon spawned randomly on the spawning grounds, then size-selective fisheries for larger, older chinook might select for earlier age at maturity.

Third, for chinook salmon, there is substantial evidence that age at maturity depends in part on size at age (see Hankin et al. 1993 and references therein). For a fixed age, say Age-2, fish that are smaller are less likely to mature at that age than are fish that are larger.[iii] Through this interaction between size at age and maturity, removal of fish that are larger at age might instead select for fish that mature at later ages,[iv] counteracting the effects described in the previous paragraph. This effect probably becomes less pronounced at older ages.

Finally, spawning behavior of naturally-spawning chinook salmon may, to some extent, alleviate the kind of long-term genetic shift toward younger age at maturity that might be expected to result from size-selective fisheries. Baxter (1991) found that larger and older chinook salmon, especially males, had greater reproductive success on spawning grounds than younger and smaller males. (also argued by Healey 1986). Thus, even if size-selective fisheries generated substantial shifts toward younger spawners, the greater reproductive success of larger and older males might at least partially buffer against such fishery-induced shifts to younger ages. In summary, a long-term shift to younger spawners may result 1) *if* chinook salmon mate randomly, without regard to age, on spawning grounds, and 2) *if* age at maturity is independent of growth rate. However, 3) larger and older male chinook salmon (and possibly females) generally have greater mating success than smaller and younger male chinook salmon (and possibly females); 4) fast-growing chinook salmon tend to mature at younger ages than slow-growing chinook salmon, but are likely to be selected *against* in size-selective ocean fisheries; and 5) size at age may have only a weak correlation with some inherent genetically-inherited *growth rate*. Together, items 3) through 5) may counteract the kinds of long-term genetic effects that one might expect if items 1) and 2) were valid.

Hard (Hard 2004) used age-structured quantitative genetic models to assess the possible long-term evolutionary effects of size-selective fishing on chinook salmon. Based on genetic data from one Puget Sound population, Hard concluded that under most conditions, directional selection imposed by size-selective fishing is likely to produce, at most, modest short-term reductions in size, but the effects depend critically on the harvest rate, harvest size threshold, the strength of stabilizing natural selection on size, and most likely the age structure and heritability of each trait, as well. He also found that the

[iii] This may be less true at older ages.

capacity of size-selective fishing to reduce size depends on correlations among size, age and growth rate.

Stock-Selective fisheries

Stock-selective fisheries harvest some populations at different rates than other populations. They may occur in two ways. In marine waters, a large number of salmon populations originating from different river basins may be vulnerable to fishing at similar times and locations, and may therefore experience similar marine exploitation rates. This phenomenon is commonly referred to as the *mixed-stock harvest problem* (see, for example, Bevan 1987). To avoid overexploiting vulnerable populations, harvest policies would instead call for application of stock-specific exploitation rates that depend on the underlying stock productivity, which varies among salmon stocks. Fisheries are deliberately structured to be stock-selective by shaping the time, location or physical attributes of fish that may be caught.

Stock-selective fisheries may also take place in fresh water as a consequence of regulations. For example, in a large river system with a large number of distinct chinook salmon stocks, each with its own distinct river entry pattern, open and closed periods for fisheries may result in differential exploitation rates being applied to different stocks. If harvest is not allowed until a substantial number of fish have escaped to spawn, then it seems inevitable that exploitation rates are lower for those stocks that enter earlier as compared to those stocks that enter when fisheries are open. In that case, the fishery-related mortality rate would be much lower for fish in the early part of the run than for fish in the late part of the run. Because run timing is thought to be an inherited trait, such fishery harvest policy may, in the long term, unintentionally select for early-returning fish. (See Nicholas and Hankin 1988 for examples of this phenomenon in a hatchery setting.)

Other examples of stock-selective fisheries for salmon are those that call for the release of all fish caught without an identifying mark (e.g., intact adipose fins), while a certain number (specified by bag or possession limits) of fish with marks may be retained. These policies are deliberately designed to produce, at least in theory, greater exploitation rates for hatchery fish (marked) than for wild fish (unmarked).

Species-Selective Fisheries

Finally, fisheries may also be species-selective as, for example, results when chinook salmon must be released if caught, whereas coho salmon may be retained. Harvest managers have implemented stock-

[iv] However, this will depend on the relationship between growth rate and age at maturity.

and species-selective fisheries in Puget Sound. There are currently recreational mark-selective fisheries for chinook salmon in the Strait of Juan de Fuca and limited areas of the Snohomish River .

Selective Effects of Fishing in Puget Sound

Although the potential consequences of size-selective fishing have been recognized, the ability of fisheries managers to address the potential long-term consequences is limited. In part, this is because much of the evidence for selective effects of fishing (e.g., change in the size or age composition of catch or spawners) is circumstantial, and is confounded by other factors such as data quality and several ecological variables, including marine productivity, density-dependent growth and mate choice on the spawning grounds (Heath et al. 1999; Ricker 1972; Riddell 1986; Ricker 1995; and Hard 2004). For example, Bigler et al. (1996) found a decreasing average body size in 45 of 47 salmon populations in the Northern Pacific. They found that body size was inversely related to population abundance, and speculated that enhancement programs during the 1980s and 1990s increased population sizes but reduced growth rates due to competition for food in the ocean. Clearly, these kinds of causes could result in the same kinds of reductions in size at age as might be caused by long-term fishery selection against fast-growing fish.

In addition, the magnitude of selective effects will vary depending on the intensity of selective-fishing on a particular salmon population, the period of time over which those effects are encountered, and the biological characteristics of the population itself (Heath et al. 1994b; and Hard 2004). Hard (2004) predicted that, in general, reducing the exploitation rate reduces the selection intensity, and that changes in life history traits under most of the harvest scenarios he examined were modest, at best, over a few generations. His study of chinook salmon returning to the Grover's Creek Hatchery in Puget Sound predicted that effects on age, weight, growth rate, and spawn timing are likely to increase under higher exploitation rates and intensity of natural selection. Under selective conditions most likely to exist, expected effects on these traits over 25 years were low to undetectable below exploitation rates of 40 percent. The greatest expected effects were on length at age and mean weight, which declined by 0.12 to 0.28 of an inch and less than 7 ounces, respectively, over this period.[v]

Information on the effects of fishery selectivity on Puget Sound chinook salmon is very limited. The National Marine Fisheries Service (NMFS) found a decline in the size of Puget Sound coho spawners

[v] One should be cautious in applying these results widely since the study was limited to a single, hatchery population and effects of selection will depend on the characteristics of the individual population. However, it does provide some basis for comparison.

since the 1970s, and noted it as a risk factor (Weitkamp et al. 1995). However, in its review of west coast chinook salmon populations (Myers et al. 1998), NMFS did not note any trends in recent decades for size, weight, or age for Puget Sound chinook salmon that might be the result of fishing activities.

The lack of an observed selective-fishing effect may be the result of the way Puget Sound fisheries are structured. Puget Sound salmon fisheries, including those harvesting chinook salmon, are managed for stock-specific exploitation rates that depend on the underlying productivity of each population. In other words, fisheries are managed to protect the less abundant, or weaker, populations. Such an approach is commonly referred to as *weak stock management*, and often results in foregoing catch on abundant populations in order to protect less abundant populations. In most areas, Puget Sound chinook salmon harvest generally occurs throughout their run timing. In a few areas, harvest may be focused on the early or late part of the chinook salmon run in order to protect the majority of the population while allowing some harvest on other salmon species that occur earlier or later in timing. However, this would generally affect 10 percent or less of the population on either end of its run timing, depending on the specifics of the annual fishing regime.

With regard to the potential age-selectivity of gear types, Puget Sound gillnet fisheries do not appear to be any more age-selective for chinook than gear types like purse seines that use small mesh and are thus considered to be relatively non-selective (Table 3.3.7-1 and Figure 3.3.7-1). Ricker (1980, 1981, 1995) documented a decline in the average weight of Puget Sound chinook salmon caught between the 1950s and 1970s, which stabilized at a lower level in the 1980s. However, his analysis was not population specific and was conducted on mixed-stock fishery data which included populations returning both to Canada and Puget Sound. Based on the Puget Sound population-specific data that is available, there are no trends in age structure observed in Puget Sound chinook salmon escapement over the last 24 to 30 years (including the period observed by Ricker) that one might expect if there were fishing-down effects[vi] (Figure 3.3.7-2). In addition, the mean age of escapement differs from that in the catch by only 0.3 year (15 to 16 weeks) over the same period.

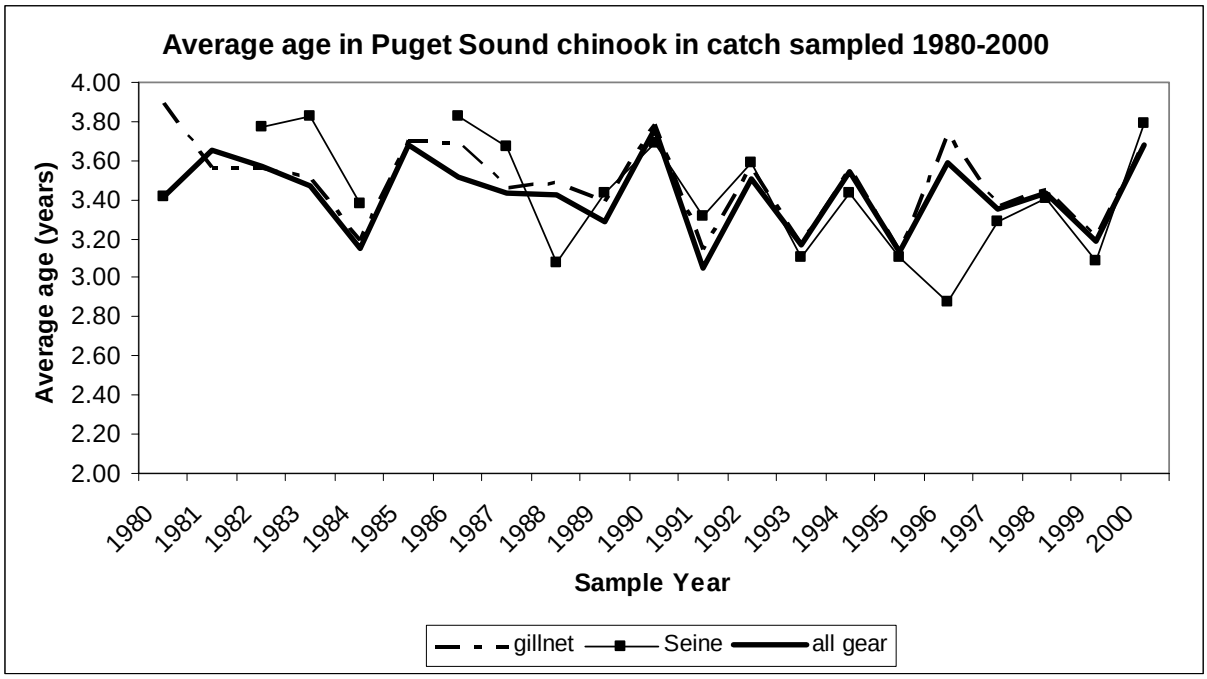
[vi] Although it is possible that shifts in age structure caused by fishing activities occurred before the time period for which these are data, any trends from that time do not appear to have continued.

Table 3.3.7-1. Average age composition of the Puget Sound chinook salmon catch by gear type.

Gear Type	Age composition of Puget Sound chinook salmon catch (1980–2000)			
	Age-2	Age-3	Age-4	Age-5
bGillnet	3%	34%	59%	5%
Purse seine	7%	37%	54%	4%
All gear types	3%	35%	56%	6%

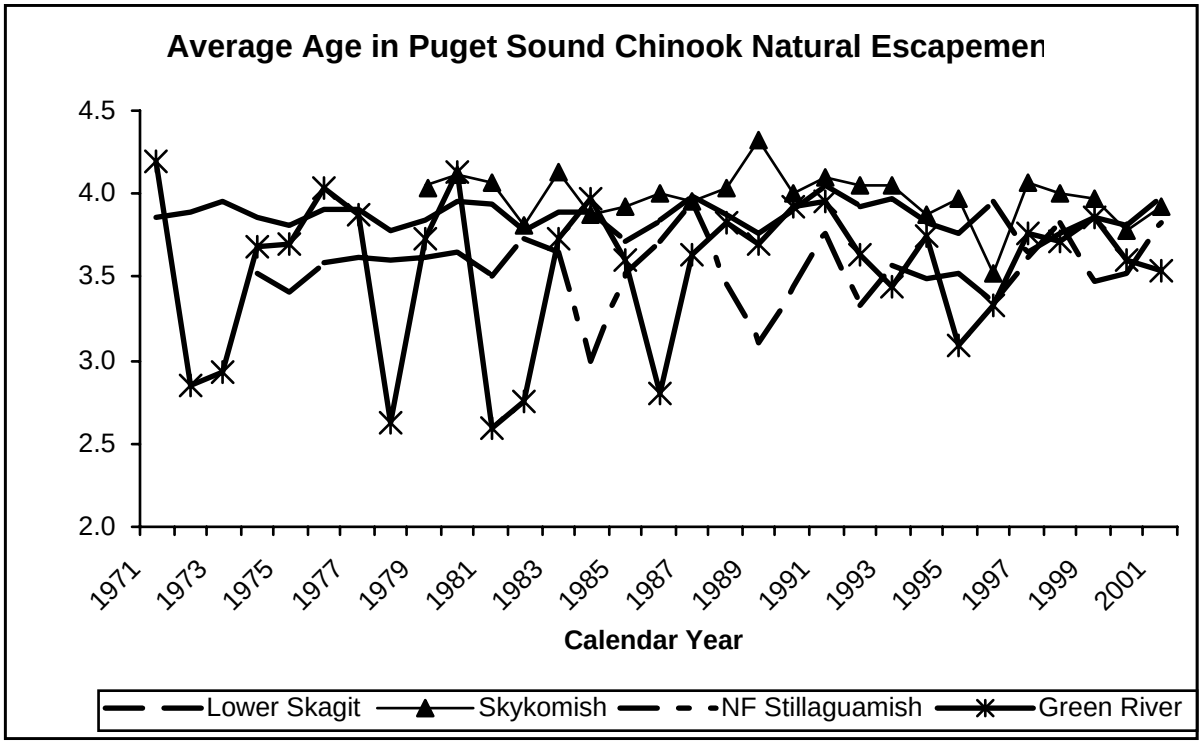
Source: Washington Department of Fish and Wildlife.

Figure 3.3.7-1. Age composition of Puget Sound chinook salmon catch: relatively stable since 1980.



Source: S. Bishop, National Marine Fisheries Service, Northwest Region. based on data provided by the Washington Department of Fish and Wildlife, 2001.

Figure 3.3.7-2. Age composition of Puget Sound chinook salmon escapement: stable since the 1970s.



Source: Puget Sound Technical Recovery Team data.

Analysis not yet Complete

The analysis described above examined whether there had been any detectable changes in age composition of Puget Sound Chinook salmon. NMFS is currently conducting analyses to determine whether there are detectable changes in size at a specific age of Puget Sound chinook salmon and, if so, whether they might be attributable to fishing effects. That is, although there might not be a change in the age composition, fish of the same age could be getting smaller or larger over time. While these analyses were not available for inclusion in the Draft Environmental Impact Statement, they will be included in the Final Environmental Impact Statement. A brief description of the analyses is included here so that the public is aware of the approach that NMFS is taking and so that the public has as much information as possible at this time on which to comment.

As discussed earlier in this subsection, diversity in both age and size are important so that populations can respond successfully to changing environmental conditions. For example, larger females may be able to bury their eggs more deeply, thereby protecting them from washing away in high water flow

conditions. On the other hand, smaller body size may allow some adults to return to successfully reproduce in drought years when larger adults become stranded or are more vulnerable to predators under low water flow conditions.

In conducting its analyses, NMFS will examine whether there is a difference in size at age between Puget Sound chinook salmon caught in the fishery and those that spawn. NMFS is focusing its analyses on a subset of Puget Sound chinook salmon populations for which sufficient information is available and that represent some diversity in life history (spring and fall) and fishing intensity. NMFS is also limiting its analysis to terminal in-river net and recreational fisheries[vii] for which data is available so that it is not confounded by the catch of immature fish that commonly occurs in marine fisheries. While NMFS is aware that marine fisheries may also be selective through the use of size limits or selective gear, the analyses should narrow the number of environmental factors that might account for a change in size at age detected in the analysis. To do this, the analyses should evaluate adults experiencing as similar an environment as possible. It would not be possible to determine whether a change in size at age from analyses that included immature fish were due to a change in the size of returning adults of a particular age, or due to differences in growth rates from fish that matured at a given age versus those that would have grown and matured to an older age. While fisheries may act to affect either size directly or growth rate (see earlier discussion), these analyses are intended to examine the direct effect of fisheries on size. Although we can theoretically explore the effects of fisheries on growth rate (Hard 2004), it is not technically feasible with the tools and data available at this time to directly assess the effects of Puget Sound fisheries on growth rate.

To assess possible change in size at age of Puget Sound chinook salmon, the analyses will be broken into two steps. First, for a selected group of Puget Sound chinook salmon populations, NMFS will compare the average size at age of coded-wire tagged fish recovered in the terminal net fishery with those recovered in the hatchery escapement during the period 1980-2000. These coded-wire tag fish are part of the Pacific Salmon Commission indicator stock program which was implemented specifically to assess survival, distribution and fishing-related mortality for Puget Sound Chinook salmon. This will ensure that the analysis includes only fish from the same population based on the unique coded-wire tag code implanted into the fish prior to their release from the hatchery.

[vii] These fisheries intercept fish returning to a single river system; the one in which the fishery occurs.

Secondly, NMFS will use size at age information collected from naturally spawning adults to compare with results from the first step. To the extent possible, the analysis will separate hatchery-origin fish spawning naturally from naturally produced fish spawning naturally. This aspect of the analyses is intended to compare adult spawners that are naturally produced with the hatchery-based comparison of recovered coded-wire-tagged adults from the same population. Hatchery-origin adults contribute significantly to natural escapement for many Puget Sound chinook populations and the use of mark-selective fisheries for hatchery fish is limited. Therefore, fisheries are thought to act equally on the hatchery and natural components of the populations so that there would not be a difference in the response of the hatchery and natural components. This step of the analyses will test this assumption.

Finally, if there is a detectable change in size-at-age, further analysis will be conducted to see whether the magnitude of change in size can be linked to the intensity of the fishery. To do this, the populations will be divided into high and low exploitation rate groups based on the conclusions of Hard (2004) to determine whether there is a pattern in the results of the size at age analysis that corresponds to the magnitude of exploitation rate.

3.3.8 Hatchery-Related Fishery Effects on Salmon

Salmon harvest management plans, such as the Proposed Action and alternatives addressed in this Environmental Impact Statement, set management objectives for individual populations or management units. The alternatives are different fishing regimes that set management objectives in terms of exploitation rates and/or escapement goals. The Puget Sound Chinook Harvest Resource Management Plan alternatives encompass 15 natural management units and 22 chinook salmon populations. Many of these units have associated hatchery programs that are managed either to enhance fisheries or supplement natural production. Achieving appropriate conservation objectives for this diverse group of units presents a highly complex technical and political task. Fisheries objectives can exert substantial control over the escapement of hatchery- and natural-origin chinook, as well as the five other salmon species.[xii]

This subsection examines some of the possible, ancillary ecological and genetic effects that may result from hatchery programs associated with the harvest regimes considered in this evaluation. These effects associated with any of the alternatives may potentially lead to different levels of escapement of natural- and hatchery-origin fish, and varying interactions between wild and hatchery-origin chinook on the spawning grounds.

3.3.8.1 Effects of Hatchery-Origin Chinook on Natural-Spawning Chinook Salmon

Artificial propagation programs may lead to beneficial effects and/or risks for natural-origin chinook salmon populations.

Benefits

Beneficial effects that may result from the use of hatchery techniques have been summarized by Waples (1996) and Cuenco et al. (1993). Hatchery supplementation may be used to reduce the short-term risk that a population on the verge of extirpation will be lost by expeditiously boosting the number of emigrating juveniles in a given brood year. Supplementation may be used to preserve or increase salmon populations while other factors causing decreased abundance are addressed. Supplementation may be used to accelerate recovery of populations by increasing abundances in a shorter time frame than may be achievable through natural production. Supplementation programs may be used to create a reserve population for a particular chinook salmon genetic profile to prevent loss of the entire

[xii] The principal factor controlling abundance is ocean cycling/productivity. Other major factors affecting abundance include dams and habitat quantity and quality.

population due to natural or human-caused catastrophes. Hatchery techniques may also be used to reseed vacant habitat capable of supporting salmon through reintroduction to streams where populations have been eliminated, assuming that the causes that led to elimination of the population are being addressed. Finally, artificial propagation may be used to provide scientific information regarding the use of supplementation in conserving natural populations.

The potential benefits of hatchery production to the recovery of the Puget Sound Chinook Salmon Evolutionarily Significant Unit were recognized by NMFS in its 1999 listing determination (FR 64 14308, March 24, 1999). Chinook salmon produced by hatcheries operating in the Elwha, Dungeness, Nooksack, Stillaguamish, and White River watersheds were listed with the natural populations in Puget Sound, because the juvenile and adult fish produced by these programs were deemed essential to the recovery of the Puget Sound Chinook Evolutionarily Significant Unit. Management of fisheries to ensure adequate escapement of returning hatchery-origin chinook salmon produced for conservation purposes will benefit recovery of the listed Evolutionarily Significant Unit.

Risks

Fisheries managed to achieve an exploitation rate appropriate for harvesting returning hatchery-origin chinook salmon may reduce the abundance and status of commingled, less productive natural-origin chinook populations. Conversely, if fishery managers choose a harvest rate that is less than the ideal harvest rate for the hatchery population, the escapement of hatchery fish will increase above broodstock requirements. Not all of the hatchery fish in the escapement return to their release point where they may be captured and removed. The fidelity of return and subsequent level of removal varies with the physical location of the hatchery, the efficiency of the trapping and removal system, weather conditions and flows, and other factors. As discussed above, straying may be the objective of wild population supplementation or reintroduction programs. However, where the primary objective of the hatchery program is to harvest the returning adults, fish that are not captured and removed may spawn naturally in areas used by the local population, or stray into other watersheds. The unintentional escapement and straying of hatchery-origin chinook salmon produced for harvest augmentation purposes may lead to adverse impacts to the survival and productivity of indigenous, naturally-spawning chinook salmon populations.

Adverse effects to natural-origin chinook salmon that may result from the use of artificial propagation may be ecological, genetic, or demographic in nature. Potential adverse effects of this nature on natural-origin chinook salmon are summarized below. These descriptions are provided to identify

hatchery-related issues that may be germane to the fishery management alternatives analyzed and compared within this Environmental Impact Statement.

Ecological Effects

Hatchery-origin adults may compete with naturally-spawning fish for spawning habitat, or may interbreed with naturally-spawning fish. Adverse effects of competition may result from direct interactions, whereby hatchery-origin fish interfere with the accessibility of wild fish to limited resources; or through indirect means, such as when utilization of a limited resource by hatchery fish reduces the amount of that resource available to wild fish (Species Integration Work Group 1984).

For adult salmonids, the potential for hatchery/wild fish competition in fresh water is assumed to be greatest in the spawning areas (U.S. Fish and Wildlife Service 1994). Hatchery-origin adult salmonids may home to, or stray into, natural production areas during wild fish spawning or egg incubation periods, posing an elevated competitive and behavioral modification risk. Returning or straying hatchery fish may compete for spawning habitat. Superimposition of redds by similarly-timed or later spawners disturbs or removes previously-deposited eggs from the gravel, and has been identified as an important source of natural salmon mortality in some areas (Bakkala 1970). Adult salmonids originating from hatcheries can also compete with wild fish of the same species for mates. If the hatchery fish are a non-indigenous population, or have substantially diverged from the native population, interbreeding between hatchery- and natural-origin chinook salmon may lead to an increased potential for outbreeding depression, to the detriment of the natural-origin population.

Juvenile salmonids rearing in fresh water and estuaries compete for food and space (Species Integration Work Group 1984). The progeny of the hatchery fish that have spawned in the wild may compete for suitable habitat, reduce access to food, or cause behavior that makes wild fish more susceptible to predation (Hillman and Mullan 1989; Steward and Bjornn 1990; and Species Integration Work Group 1984).

Genetic Effects

Native salmon populations have developed a complex set of local adaptations that promote the productivity of the population within their local environment. Characteristics such as body size, return timing, egg size, migration timing, and many others are tailored by natural selection to adapt the population to its environment. Hatchery-reared salmon are subject to different selective pressures in the hatchery environment that may cause them to genetically diverge from their wild ancestors. When hatchery fish are imported from another basin, this difference between local and hatchery populations

is exacerbated. When hatchery strays interbreed with wild fish, the resulting progeny may be less fit, and the genetic integrity of the local wild population may be permanently affected.

The genetic risks from hatchery fish spawning in the wild, or interbreeding with wild fish, are associated with reduction in the genetic variability (diversity) within and among populations (Cuenco et al. 1993; Hard et al. 1992; National Research Council 1996; and Waples 1996). Specifically, these risks involve genetic drift, inbreeding depression, or domestication. Genetic traits are carried at specific places in the genetic material of fish called *alleles*. The type and frequency of the alleles in a population constitutes the genetic diversity of the population. In the discussion that follows, the processes that cause a loss of diversity or genetic divergence within the hatchery population are considered, along with how the introduction of hatchery fish into wild populations may impact the productivity of the wild population.

Loss of Within-Population Diversity. Reisenbichler and Rubin (1999) cite five studies indicating that hatchery programs for steelhead and stream-type chinook salmon (i.e., programs holding fish in the hatchery for one year or longer) genetically change the population and thereby reduce survival for natural rearing. The authors report that substantial genetic change in fitness can result from traditional artificial propagation of salmonids held in captivity for one-quarter or more of their life. Bugert et al. (1992) documented morphological and behavioral changes in returning adult hatchery spring chinook salmon relative to natural adults, including younger age, smaller size, and reduced fecundity (number of eggs per female). Information on Puget Sound chinook salmon is limited. However, as described in Subsection 3.3.7, no decline in average age has been detected for Puget Sound chinook salmon populations for which data are available, including the Green-Duwaumish in which there has been a substantial hatchery augmentation program since the early 1900s. In most years, hatchery-origin adults constitute the majority of the naturally-spawning chinook salmon in the Green River (Puget Sound Technical Recovery Team 2003).

Leider et al. (1990) reported diminished survival and natural reproductive success for the progeny of non-native hatchery steelhead when compared to native wild steelhead in the lower Columbia River region. The poorer survival observed for the naturally-produced offspring of hatchery fish could have been due to the long-term artificial and domestication selection in the hatchery steelhead population, as well as maladaptation of the non-indigenous hatchery stock in the recipient stream (Leider et al. 1990). Chilcote (1997 and 2003) reported a strong negative correlation between the proportion of naturally-spawning hatchery steelhead and population productivity, when examining spawner-recruit relationships for a range of Oregon steelhead populations. Nickelson (2003) found negative

correlations between the average number of hatchery coho released and the population productivity of wild coho in fourteen Oregon river and lake basins.

Berejikian (1995) reported that wild-origin steelhead fry survived predation by prickly sculpins (*Cottus asper*) significantly better than size-matched offspring of locally-derived hatchery steelhead that were reared under similar conditions. Alteration of the innate predator avoidance ability through domestication was suggested by the results of this study. However, Joyce et al. (1998) reported that an Alaskan spring chinook stock under domestication for four generations was not significantly different from offspring of wild spawners in the ability of individuals within this population to avoid predation. The domesticated and wild chinook groups tested showed similar growth and survival rates in freshwater performance trials.

Loss of Genetic Diversity Among Different Populations. Loss of genetic diversity among different populations is caused by the introduction of genes from outside the population (e.g., from hatchery-origin spawners or strays from other systems), at rates greater than what would naturally occur. This process can affect the genetic uniqueness of a population, and may reduce its fitness through a process called outbreeding depression. Outbreeding depression arises because natural salmonid populations adapt to the local environment, and this adaptation is reflected in the frequency of specific alleles that improve survival in that environment. When excessive gene flow occurs, alleles that may have developed in a different environment are introduced. These new alleles may not benefit the survival of the receiving population, leading to outbreeding depression. Outbreeding depression from gene flow can also occur when eggs and fish are transferred among populations, and/or when out-of-basin hatchery populations are released to spawn with the local population (Busack and Currens 1995).

Evidence indicating local adaptation of salmonid populations exists, but the only empirical data on outbreeding depression in fish involves extremely distantly-related populations (Busack and Currens 1995). Pacific Northwest hatchery programs historically contributed to the loss of genetic diversity among populations through routine transfer between watersheds of eggs and fish from different hatchery populations. The release of hatchery fish into populations different from the introduced fish has also resulted in gene flow above natural levels (genetic introgression), reducing the genetic diversity among populations. Research based primarily on findings in the Kalama River, Washington, for summer-run steelhead has suggested that interbreeding between non-indigenous Skamania hatchery stock steelhead (a highly selected, inbred stock) and native wild fish may have negatively affected the genetic diversity and long-term reproductive success of wild steelhead (Hulett et al. 1996; and Leider et al. 1990). Non-indigenous hatchery and native wild steelhead crosses may be less effective at

producing adult offspring in the natural environment compared to wild fish (Chilcote et al. 1986 and 1997).

Campton (1995) examined the risks of genetic introgression to wild fish, and noted the need to distinguish the biological effects of hatcheries and hatchery fish from the indirect and biologically-independent effects of fisheries management actions. In his review of the scientific literature for steelhead, Campton found that most genetic effects detected to date appear to be caused by fisheries management practices such as stock transfers and mixed-stock fisheries, not by biological factors intrinsic to hatcheries or hatchery fish. However, loss of among-population genetic diversity as a result of these types of hatchery practices has been documented for western trout, where unique populations have been lost through hybridization with introduced rainbow trout (Behnke 1992). Phelps et al. (1994) found evidence for introgression of non-native hatchery steelhead stock into a number of natural populations within southwest Washington. However, in other areas where hatchery production has been extensive, native steelhead genotypes have been shown to persist (Phelps et al. 1994).

Hatchery programs can be managed to minimize the risk of among-population diversity reduction effects by limiting the duration of the hatchery program to a few salmon generations, using the local, natural-origin chinook population as broodstock, and by applying rearing and releasing strategies that promote high fidelity of return of adult fish to the hatchery release location.

Demographic Effects

Hatchery programs may also lead to adverse demographic effects on natural-origin populations through masking of the status of natural chinook salmon population abundance and productivity, and through overfishing.

Masking. If hatchery- and natural-origin fish are indistinguishable in appearance, the presence of hatchery-origin fish on the spawning grounds may mask the status of the wild population by causing over-estimation of the abundance and productivity of the naturally-produced population. Failure to detect the declining or critical status of natural populations may prevent or delay the implementation of conservation measures. Masking the status of natural productions was cited in listing the Puget Sound Chinook Evolutionarily Significant Unit as “threatened” under the Endangered Species Act (FR 64 14308, March 24, 1999; and Myers et al. 1998). This risk may be mitigated through application of a mark or tag to juvenile hatchery-origin chinook salmon prior to their release from the hatchery. In Puget Sound, almost all of the hatchery fish have been marked in recent years so that the hatchery

chinook salmon may be readily differentiated from natural-origin fish in rearing, migration, and spawning areas.

3.3.8.2 Overfishing

Subsection 3.3.8.1 described the potential benefits and risks of hatchery fish interacting with wild fish on the spawning grounds once they have escaped the fisheries. This subsection discusses the potential effect of managing fisheries to meet harvest mortality objectives on wild and hatchery populations. Fisheries exploitation rates or escapement goals may be established for each salmon population or management unit that will best achieve its conservation objective. These harvest objectives are primarily a function of the productivity of the population and the capacity of freshwater habitat. Higher productivity populations can withstand higher exploitation rates than lower productivity populations. In the ideal case, each population will be harvested at the rate appropriate for its unique productivity and capacity. However, many fisheries take place on mixtures of populations, some of which are productive and can withstand a higher exploitation rate, and others that are less productive and have a lower ideal harvest rate. If mixed-stock fisheries are managed to achieve a high exploitation rate appropriate to productive populations, the commingled weaker populations will be over-harvested, leading to decreased spawner escapement abundances, and potentially, a declining natural-origin chinook population trend.

This mixed-stock problem is apparent where hatchery and wild fish commingle. Hatchery populations can sustain very high harvest rates, provided that escapement meets broodstock requirements. When hatchery and wild populations are commingled in fisheries, managers are faced with the decision whether to constrain fisheries and lower exploitation rates to levels appropriate to weak populations, or allow fisheries to remove the entire harvestable surplus of hatchery fish, and “overfish” some commingled natural populations. In some areas, fisheries can harvest hatchery production selectively, without undue impact on weak natural populations. Selective fisheries are implemented by the co-managers in some areas as part of the suite of regulations comprising the annual fishing regime that would be implemented through the framework of the Proposed Action or one of its alternatives (see Subsection 3.3.6 of this Environmental Impact Statement).