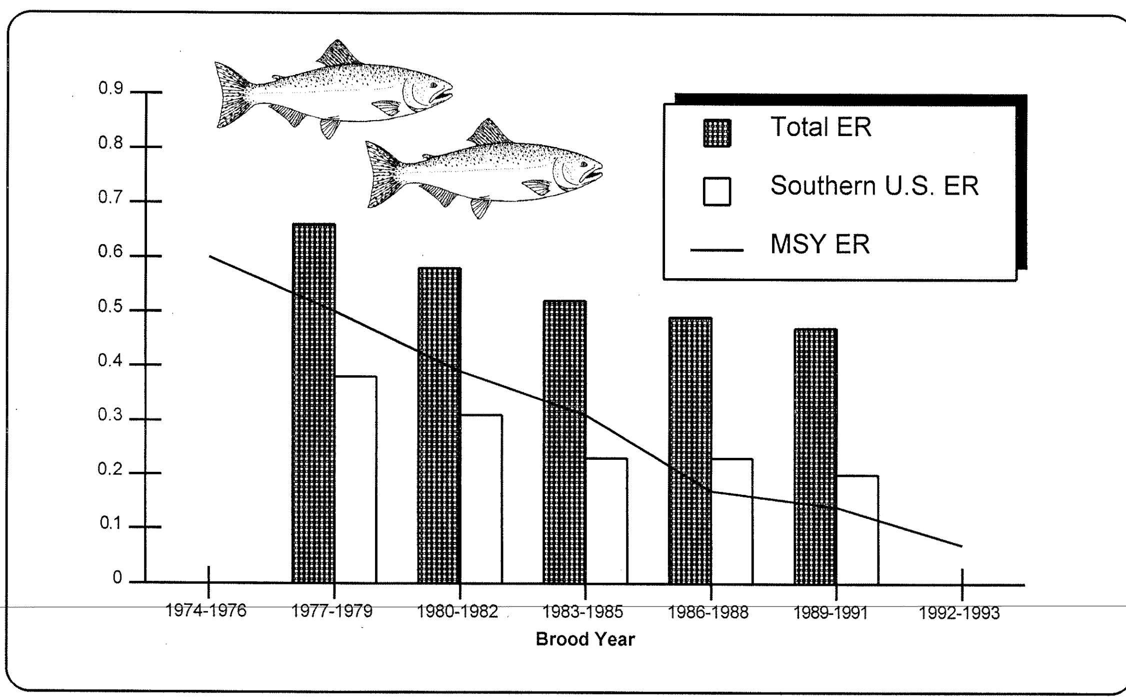
PUGET SOUND SALMON STOCK REVIEW GROUP REPORT 1997

AN ASSESSMENT OF THE STATUS OF
PUGET SOUND CHINOOK AND STRAIT OF JUAN DE FUCA COHO STOCKS
AS REQUIRED UNDER THE SALMON FISHERY MANAGEMENT PLAN



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ACRONYMS AND ABBREVIATIONS

AEQ	adult (spawner) equivalent
BBC	Big Beef Creek (WDFW Research Station)
BRT	Biological Review Team
CAM	Coho Assessment Model
Council	Pacific Fishery Management Council
CTC	Chinook Technical Committee of the Pacific Salmon Commission
CWT	coded-wire-tag
EEM	estuarine emergent marsh
ER	exploitation rate
ESA	Endangered Species Act
FAB	U.S. District Court's Fisheries Advisory Board
FMP	fishery management plan
FRAM	Fishery Regulation and Assessment Model
KCSWM	King County and Snohomish County Surface Water Management
LWD	large woody debris
MOU	memoranda of understanding
MSY	maximum sustainable yield
NMFS	National Marine Fisheries Service
PEF	production expansion factor
PFMC	Pacific Fishery Management Council
PNPTC	Point-No-Point Treaty Council
PSC	Pacific Salmon Commission
PSSMP	Puget Sound Salmon Management Plan
PSSSRG	Puget Sound Salmon Stock Review Group
PST	Pacific Salmon Treaty
RM	river mile
SASSI	(Washington State) Salmon & Steelhead Stock Inventory
SCSWM	Snohomish County Surface Water Management
SIRC	Stillaguamish Implementation Review Committee
SJF	Strait of Juan de Fuca
SSC	Skagit System Cooperative
THRG	Tolt Habitat Restoration Group
USFS	U.S. Forest Service
USGS	U.S. Geological Service
WDFW	Washington Department of Fish and Wildlife
WDOE	Washington Department of Ecology

Introduction

1.0 CHARGE AND PURPOSE

The Magnuson-Stevens Fishery Conservation and Management Act states "Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry." The implementation of Amendment 10 to the Pacific Fishery Management Council's salmon fishery management plan (FMP) in 1991 provided a definition of overfishing for each stock or stock complex covered in the FMP.

The Council's definition of overfishing states:

> Overfishing is an occurrence whereby all mortality, regardless of the source, results in a failure of a salmon stock to meet its annual spawning escapement goal or management objective, as specified in Section 3.5 of the salmon framework FMP, for three consecutive years, and for which changes in the fishery management regime offer the primary opportunity to improve stock status. While this condition is defined as overfishing in a broad sense, it is recognized that this situation may also be the result of non-fishing mortality, and fishery management actions may not adequately address the situation.

Under this definition, the determination of overfishing a stock is a two-step process. The first step occurs when a salmon stock fails to meet its annual spawner escapement objective for three consecutive years. The second step is a review by a Council-appointed work group to investigate the causes of the shortfall and to report its conclusions and recommendations for assuring future productivity to the Council.

This is the second review of Puget Sound chinook and coho stocks since Amendment 10 of the salmon FMP was implemented. The first assessment, in 1992, of chinook and coho stocks specified in the FMP indicated that five stocks in Puget Sound met the definition criterion (see Table 1). The Puget Sound Salmon Stock Review Group appointed by the Council to examine the causes leading to the failure to meet annual escapement objectives, reported its conclusions in two reports (Puget Sound Salmon Stock Review Group 1992a and 1992b). Subsequent to these reports, in 1993, the Council added an additional stock to the list, but no additional review was done at that time.

In 1995, the Council identified several more Puget Sound chinook and coho stocks that had failed to meet spawner objectives for three consecutive years and appointed a new Puget Sound Salmon Stock Review Group. This group was formally charged with reviewing only those stocks newly identified by the Council in 1995. However, the group concluded at its first meeting that it would be most useful to review all chinook stocks on the list which continue to meet the criteria of Amendment 10, along with the single coho stock identified in 1995. This report, which was presented in final draft at the March 1997 Council meeting, is the result of that review.

2.0 STOCK STATUS AND BACKGROUND INFORMATION

For all Puget Sound chinook and coho stocks requiring a review under the Council's definition of overfishing since 1992, Table 2-1 lists spawning escapement numbers for the years 1988 through 1995, along with preseason expected escapement numbers or escapement targets.

Puget Sound chinook stocks, in particular, have been chronically below desired spawning escapement levels for many years. They have been the focus of rebuilding programs under the Pacific Salmon Treaty (PST) since 1985, as well as local and regional efforts undertaken by state and tribal comanagers. The previous stock review reports documented that harvest rates on Puget Sound chinook did, in fact, decline since 1985 when harvest management controls were instituted under the PST. Despite the reduced harvest rates, escapements have continued on a downward trend since the last overfishing review.

TABLE 2-1. Washington salmon stocks requiring review under the Council's overfishing definition.

		Postseason Escapement Estimate							
Stock	Goal	1988	1989	1990	1991	1992	1993	1994	1995
		CHINOOK (thousands of fish)							
Identified in 1992:									
Skagit Spring	3.0	2.1	1.5	1.6	1.4	1.0	0.8	0.9	2.0
Stillaguamish Summer/Fall	2.0	0.7	0.8	0.8	1.6	0.8	0.9	1.0	0.8
Snohomish Summer/Fall	5.3	4.5	3.1	4.2	2.8	2.7	4.0	3.6	3.7
Identified in 1995:									
Skagit Summer/Fall	14.9	12.0	6.8	17.2	6.0	7.7	5.9	6.1	7.2
Lake Washington	1.6	0.8	1.0	0.8	0.7	0.8	0.2	0.9	1.5
Green River	5.8	8.0	11.5	7.0	10.5	5.3	2.5	4.2	8.3
Dungeness	1.0	0.34	0.09	0.31	0.16	0.15	0.04	0.06	0.16
		COHO (thousands of fish)[a/]							
Identified in 1992:									
Skagit	30.0	19.0 (24.0)	17.0 (19.2)	15.0 (23.4)	7.8 (26.8)	7.5 (28.2)	13.4 (20.5)	29.1 (15.5)	13.4 (23.6)
Hood Canal	19.1[b/]	12.2 (14.2)	16.0 (18.9)	7.0 (19.2)	12.7 (16.1)	19.4 (9.7)	22.3 (30.6)	56.4 (13.0)	39.9 (18.2)
Identified in 1993:									
Stillaguamish	17.0	18.0 (17.0)	6.0 (17.0)	15.0 (17.0)	4.0 (17.0)	12.5 (15.8)	8.8 (17.7)	25.6 (9.2)	17.7 (27.2)
Identified in 1995:									
Strait of Juan de Fuca	14.9	5.0 (6.7)	7.8 (5.6)	4.2 (5.5)	4.5 (6.6)	6.5 (6.9)	3.6 (5.0)	2.9 (6.6)	5.4 (2.9)

a/ Numbers in parentheses are annual spawner objectives given preseason expected abundances. If inseason information indicates higher abundance, the allowable escapement increases up to the greater of the goal or the annual spawner objective.

b/ Since 1994, the goal has been an exploitation rate comparable to achieving an escapement of 23,650 adult spawners.

Factors Contributing to the Escapement Failure

3.0 FRESHWATER AND ESTUARINE HABITAT

3.1 INTRODUCTION

We examined freshwater components which contribute to the decline of Puget Sound chinook and Strait of Juan de Fuca (SJF) coho salmon to identify factors that affect chinook and coho production capacity and survival, and to identify effects of land-use on freshwater life stages. We used a case study approach to highlight key issues rather than providing a comprehensive summary of currently available information on salmonid habitat conditions and stocks of concern.

Each case study focuses upon either production capacity or survival (productivity) issues which affect the stock of concern. A case study for SJF coho combines both capacity and survival to provide a simulated life history example for the Pysht River watershed. Capacity is defined as the amount of smolts or potential to produce smolts in a given river system. Capacity is based upon the amount of freshwater spawning or rearing habitat available in a river system, and can be used to estimate historical losses in habitat and production (Beechie *et al.* 1995). Beechie *et al.* (1995) quantified historic (approximately 100 years ago) habitat and production and examined the amount of habitat and production loss (e.g., mainstem, side-channel sloughs, distributary channels, and tributaries) due to land use practices such as diking, dredging, dams, agriculture, forestry, and urbanization.

Survival relates to the overall quality of habitat, and the effects of habitat degradation on each life stage. For example, McHenry *et al.* (1994) found that elevated fine sediment levels in spawning gravels in SJF watersheds, such as the Pysht, decreased the potential survival rate of developing salmonid eggs to the alevin and emergent fry stage. Both capacity, which is the quantity of habitat, and survival, which is the quality of habitat, are critical to our basic understanding of how freshwater life history works, and how land use and other factors may affect adult salmon abundance and subsequent levels of escapement.

Section 3.2 discusses the Skagit case study and examines some of the life history strategies of summer/fall Skagit chinook. Section 3.3 examines the spawning life stage for Stillaguamish summer/fall chinook. The section focuses on potential survival effects due to changes in sediment supply and flow. Section 3.4 examines both survival and capacity issues for SJF coho, including a simulated life history model for a representative watershed in the area. Section 3.5 provides specific and overall conclusions for the contribution of freshwater habitat alterations to the escapement failure for each stock.

3.2 SKAGIT SUMMER/FALL CHINOOK

3.2.1 Chinook Life History Types

Wild chinook populations of the Skagit River Basin exhibit ocean-type (sub-yearling smolt) and stream-type (yearling smolt) life history patterns. Adult scale samples collected from spawning areas indicate that the ocean-type life history pattern dominates the fall and summer chinook races, while the stream-type life history pattern is most common in spring chinook of the Suiattle and Upper Sauk Rivers (Washington Department of Fish and Wildlife [WDFW] unpublished scale data).

Hayman *et al.* (1996) have identified at least three distinct juvenile life history types existing within the ocean-type chinook of the Skagit River Basin. One type consists of emergent fry that migrate directly to the bay early in the year. A second type consists of fry migrants that apparently emerge from the spawning areas and move relatively quickly downstream to the estuarine habitats, where they rear for a period of weeks before moving to marine areas. A third type consists of fingerling migrants, also referred to as 90-day type. Migrants emerge from spawning areas and disperse to rear in the freshwater environment (some with a possible preference for off-channel and backwater habitat areas) for several months following emergence. Fry migrants bypass the estuary, moving directly to marine areas in late spring and early summer at approximately the same size that fry migrants move from the estuary to marine areas.

Little is known about the stream-type life history pattern because very few yearling chinook were collected in the recently completed sampling by Hayman *et al.* (1996). Sampling, however, did identify where yearling chinook do not rear.

Ocean-type life history patterns were identified by profiling juvenile chinook habitat use throughout the outmigration period. The profile is based upon sampling of sub-yearling chinook abundance and length frequency throughout the Skagit River Basin from the area of emergence to Skagit Bay (Figures 3-1 and 3-2). Migration past the WDFW mainstem trap in the lower river, near Burlington, had multiple peaks (Figure 3-1). Mean fork length of sub-yearling chinook in the upper river (in the spawning area) and the lower river were similar through management week 15. After week 15, the mean length in the lower river became larger than in the upper river, where mean fork length remained constant through week 20. Upper river abundance declined after week 15.

The change in mean fork length between the upper and lower river, and decline in upper river abundance is due to: 1) a reduced rate of emergence after week 15; 2) emigration of some fry to estuarine habitats (Figure 3-2), and 3) immigration of other fry to areas in the lower river and to off-channel habitats. Evidence of this pattern is also confirmed by the timing of peak migration from different areas. The peak migration of fish leaving off channel habitat was later than peak abundance in the upper mainstem, but earlier than peak migrations of fish of the same large size past the Burlington trap (Figure 3-1). The timing and mean length of fish leaving the off-channel habitat was similar to that of fish in the Brown Slough estuary habitat (Figures 3-1 and 3-2).

Sub-yearling chinook at all estuary and river sites had similar mean fork lengths through week 14. Peak migration in the lower river and an increase in abundance at the estuary sites also occurred during this time (Figures 3-1 and 3-2). Mean fork length at estuary sites was generally greater than in the lower river from week 14 to week 24. After week 24, mean fork length in both the estuary and lower river approximated 70 mm, however, very few sub-yearling chinook remained in the estuary (Figure 3-2). The sub-yearling chinook population in the estuary decreased after week 17, suggesting that fish were moving to the more marine areas of Skagit Bay.

Hayman *et al.* (1996) hypothesize that the immigration rate of new, and smaller, fish coming from the river to estuarine habitat was lower at Brown Slough than at the other estuarine sites because Brown Slough is the estuarine site most distant from the source of juvenile chinook (i.e., the North and South Forks) (Figure 3-3). The increase in length at Brown Slough from weeks 14 through 17 may thus approximate the true growth of juvenile chinook in the estuary. After week 17, the rate of increase in mean fork length at Brown Slough declined (Figure 3-2), and mean length did not increase much above 70 mm. Reduced growth rates (mean fork length) in Brown Slough suggest that 1) larger fish moved out of the estuary, and into Skagit Bay first and 2) a minimum mean fork length needs to be achieved prior to movement into more marine habitats. Fork lengths of approximately 70 mm or greater may have been the size at which fish moved to the more marine habitats. The data suggests that one chinook life history type appears to migrate from spawning areas to the estuarine river area and then rears until achieving a mean length of approximately 70 mm before migrating out to the bay.

A second life history type, fish migrating directly to Skagit Bay after emergence, is also suggested by bay length patterns (Figure 3-2). After week 17, Skagit Bay mean length decreased to approximately the length of the Brown Slough fish, which coincided with the estuary emigration. This implies that, prior to this time, there were larger fish present in the bay than were observed either in the river or estuary.

Data collected by Hayman *et al.* (1996) indicated that after week 22, only about 10% of the chinook that used the estuary remained, and more than 40% of the emigration had not yet passed Burlington, located approximately 15 miles upstream of the estuary (Figure 3-2). This implies a third life history type in which fish rear in the river up to the same threshold size (approximately 70 mm or greater) as those in the estuary, and then migrate directly to the bay without further rearing in the estuary.

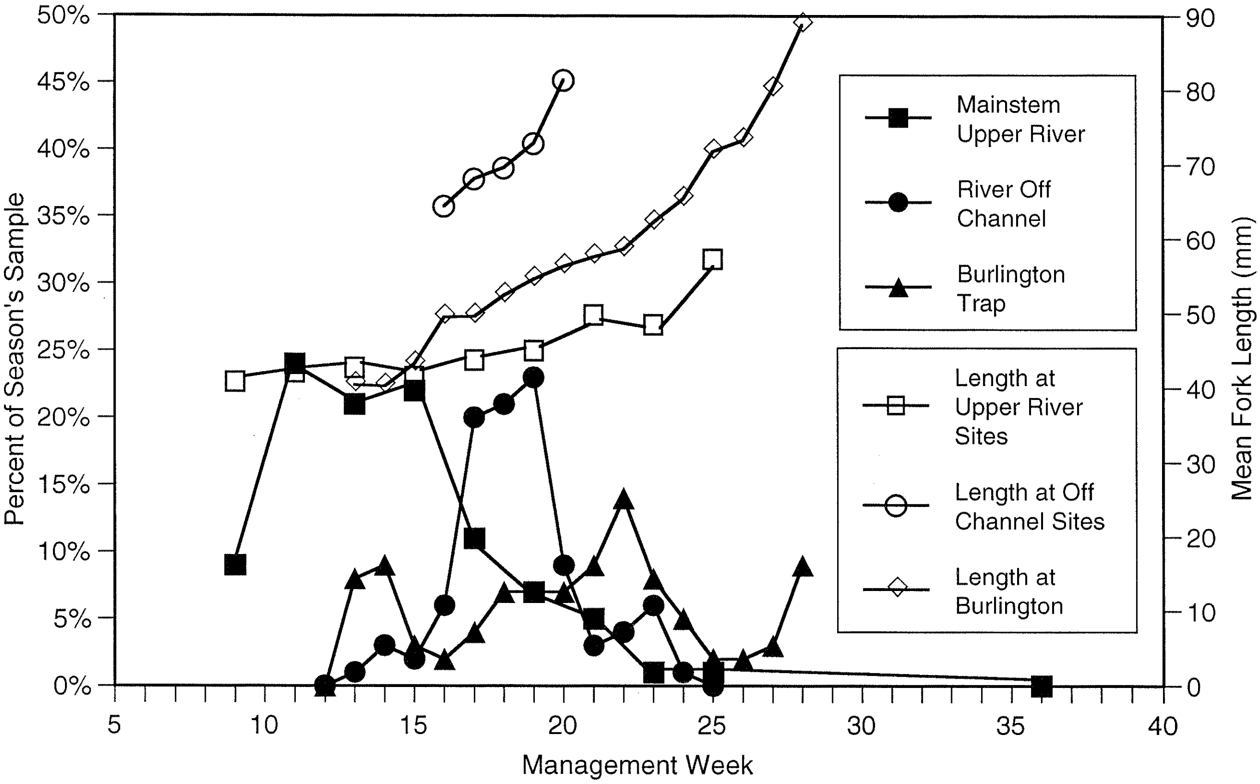


FIGURE 3-1. Length and outmigration timing of wild age 0+ chinook in the Skagit River, 1995 (from Hayman *et al.* 1996).

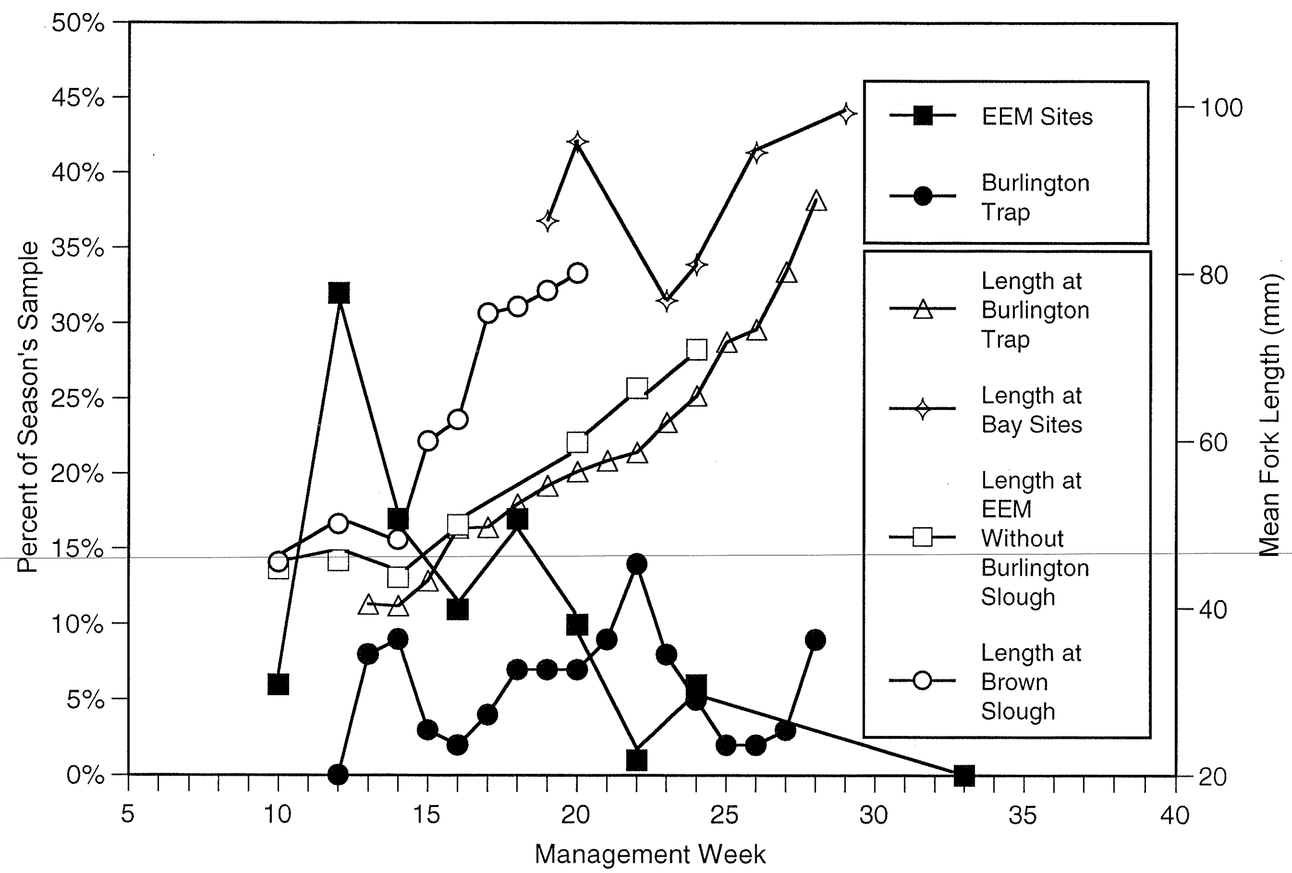
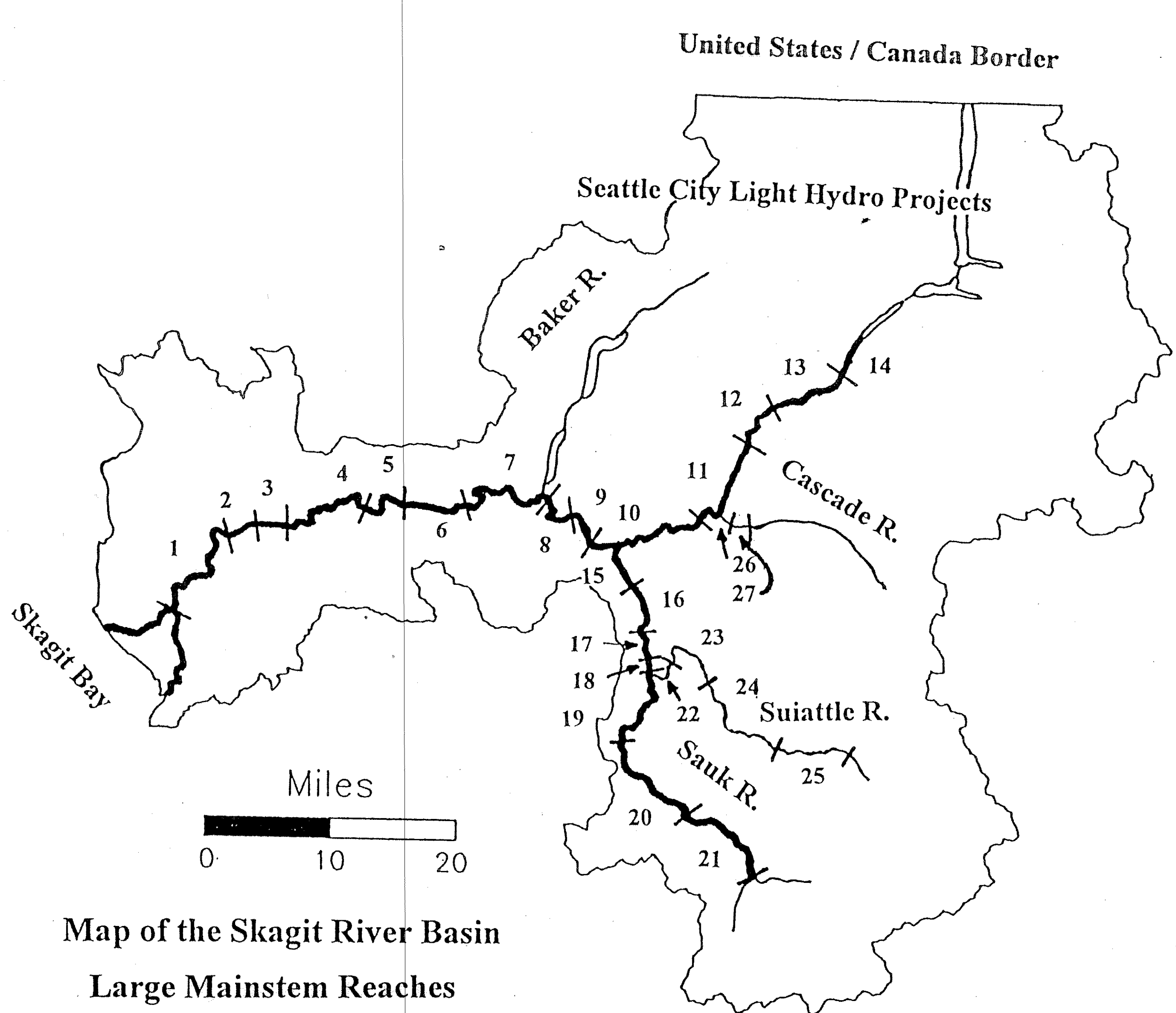


FIGURE 3-2. Length and outmigration timing of wild age 0+ chinook in the Skagit estuary, 1995 (from Hayman *et al.* 1996).



Large Mainstem Reaches

1	SK030
2	SK040
3	SK050
4	SK060A
5	SK060B
6	SK070
7	SK080A
8	SK080B
9	SK090
10	SK100
11	SK110
12	SK120
13	SK130
14	SK140
15	Sa010
16	Sa020
17	Sa030
18	Sa040
19	Sa050
20	Sa060
21	Sa070
22	Su010
23	Su020
24	Su030
25	Su040
26	Ca010
27	Ca020

FIGURE 3-3. Skagit River Basin, Washington showing large mainstem reaches (from Hayman et al. 1996).

3.2.2 Freshwater Habitat in the Skagit River Basin

3.2.2.1 Spawning Habitat in Small Rivers

Hayman *et al.* (1996) use a stream classification system developed by Montgomery and Buffington (1993) to categorize reaches in small rivers (10-50 m bankfull width) where chinook are known to spawn. Channels are identified as one of four types: 1) pool-riffle, 2) plane-bed, 3) forced pool-riffle, and 4) step-pool. Pool-riffle channels have low gradients that range between about 0.5-2.0%, and exhibit regularly spaced alternate bars and pools that are predominantly formed without in-channel obstructions. Plane-bed channels have a moderate gradient that ranges between about 2.0-4.0%, and consist primarily of riffle area because they lack the free-forming bars and pools present in pool-riffle channels. In addition, plane-bed channels lack in-channel obstructions such as large woody debris (LWD) to create pools. Forced pool-riffle channels are also found at gradients similar to plane-bed channels, but have more than half of their pools and bars formed as a consequence of in-channel obstructions such as LWD. Step-pool channels exhibit channel-spanning steps visible in the low-flow water surface profile. The steps are generally formed by boulders or LWD, and can be organized into small dams. These channels are found at higher gradients, ranging from about 4.0-8.0%.

Channel type was related to chinook redd density in the 50 stream reaches studied by Hayman *et al.* (1996) in the Skagit River Basin. Pool-riffle and forced pool-riffle reaches were consistently used by chinook for spawning, usually at levels exceeding plane-bed or step-pool channels by an order of magnitude. This trend is also evident in other river basins such as the Stillaguamish (Table 2-1).

TABLE 3-1. Distribution of chinook spawning redds in the Skagit and Stillaguamish River Basin.

Channel Type	Years of data	Sample Size	Mean Redds/Km	Std Dev of Redds/Km
Skagit River				
Pool-riffle (<2%)	2	4	35.3	33.1
Forced pool-riffle (1-3%)	2	21	28.1	24.7
Plane-bed (2-4%)	2	17	1.8	3.3
Step-pool (4-8%)	2	8	0.5	1.5
Stillaguamish River				
Pool-riffle (<2%)	23	9	19.7	13.4
Forced pool-riffle (1-3%)	3	6	27.6	3.5
Plane-bed (2-4%)	4	6	1.6	2.8

3.2.2.2 Rearing Habitat in Large Rivers

An inventory of large river (>50 m bankful width) juvenile rearing habitat was completed by Hayman *et al.* (1996) for the Skagit River Basin. Twenty-seven large river reaches were identified according to differences in hydromodification, channel pattern, channel gradient, and width (Figure 3-4). A sub-sample of eight reaches was inventoried to estimate total habitat for each reach. Habitat units were classified into two main groups: edge or mid-channel units. Mid-channel habitat units (riffles, glides, or pools) were not inventoried because sub-yearling chinook were not found in those areas during previous studies. Edge habitat units were divided into bank, bar, or backwater units. Banks had a vertical, or nearly vertical shore; bars had a shallow, low-gradient interface with the shore; and backwaters were enclosed, low-velocity areas separated from the main river channel. Edge habitat units were distinguished from mid-channel units by current; edge units had lower velocity. The demarcation line between edge and mid-channel units was generally a visible current shear line between the two units.

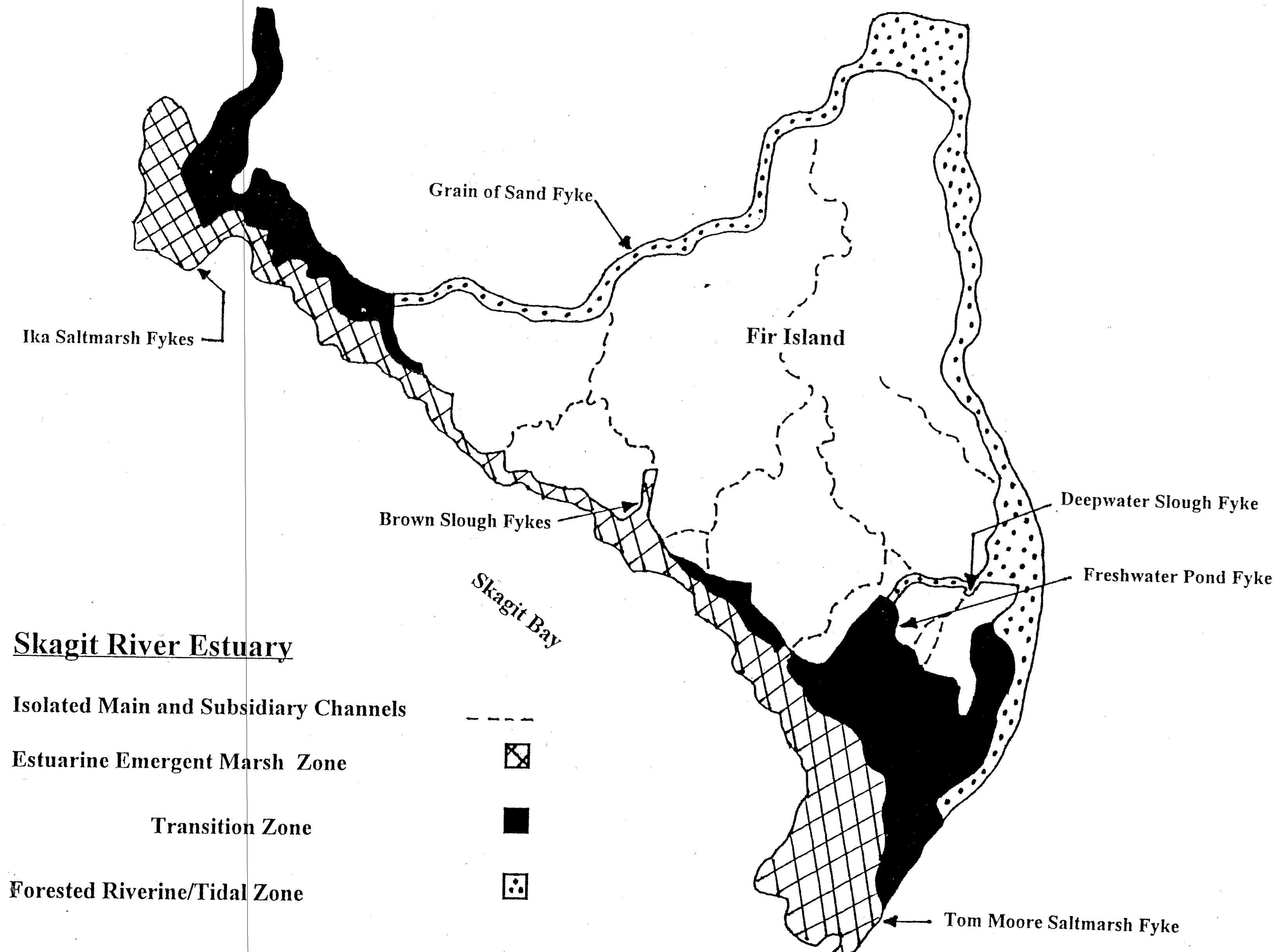


FIGURE 3-4. Location of estuary habitat zones and sampling sites in the Skagit River estuary (from Hayman et al. 1996).

The study estimated the mainstem channel area of the Skagit River Basin at almost 4,000 ha, of which 369.5 ha were edge habitat composed of 53.9 ha backwater, 86.5 ha bank and 229.1 ha bar habitat. About 2,400 ha of the mainstem channel area were in the mainstem Skagit River and included 209.2 ha of edge habitat consisting of 26.7 ha backwater, 58.7 ha bank and 123.8 ha bar habitat. Within the three different reach types identified, there were differences in the amount of edge habitat types and the total edge habitat area (Table 3-2). Hydromodified reaches always had a single channel pattern, negligible backwater area and the smallest amount of edge habitat area. In contrast, unmodified multiple channel reaches had the highest backwater area, while unmodified single channel reaches had the highest ratio of total edge habitat to channel area.

TABLE 3-2. Percent average of edge habitat type by reach classification (from Hayman *et al.* 1996).

Hydro-modification	Channel Pattern	Percent of Channel Area			
		Backwater	Bank	Bar	Total Edge Habitat
no	multiple	1.8%	1.2%	6.3%	9.4%
no	single	1.0%	4.0%	6.0%	11.1%
yes	single	0.0%	2.5%	2.3%	4.8%

3.2.2.3 Juvenile Chinook Use of Large River Habitat

Hayman *et al.* (1996) electrofished by boat to estimate habitat preference ratios for sub-yearling chinook from the relative density of juveniles captured in 24 edge habitat units within eight large river reaches. The results indicated that juvenile chinook densities were higher in backwater and natural bank habitat than in hydromodified bank and bar habitat. Chinook density estimates for the 0+ age class were 1.78 chinook/m^2 in backwaters, 0.97/m^2 in natural banks, 0.35/m^2 in hydromodified banks, and 0.44/m^2 in bar habitat. By using fish-weeks, Hayman *et al.* (1996) estimated 0+ chinook production at 1.86 chinook/m^2 in backwaters, 0.91/m^2 in natural banks, 0.28/m^2 in hydromodified banks, and 0.45/m^2 in bar habitat.

3.2.3 Estuary Habitat in the Skagit River Basin

3.2.3.1 Rearing habitat in the Skagit Estuary

Hayman *et al.* (1996) also completed an inventory of estuary habitat to estimate the rearing capacity for ocean-type juvenile chinook in the Skagit delta. They classified three general zones within the estuary following features of Cowardin *et al.* (1979). The zones were assumed to be formed primarily by various combinations of elevation, and tidal and river hydrology. Zones were identifiable from aerial photographs based on the dominance of certain indicator habitat types (vegetative communities). The three zones were: estuarine emergent marsh (EEM), emergent/forested transition (transition), and forested riverine/tidal (forested).

Juvenile chinook used four channel types that were identified within each zone--main, subsidiary, large blind channels, and small blind channels (Simenstad 1983). Large blind channels (> 20 m wide) were historically subsidiary channels that were isolated by diking, which converted them to blind channels. Small blind channels (< 20 m wide) were primarily formed and maintained naturally by tidal energy.

The study estimated the total riverine/tidal area of the Skagit estuary at 2,556 ha, of which 1,015 ha were EEM, 1,000 ha were transition and 541 ha were forested (Figure 3-3). Hayman *et al.* (1996) determined the area of different channel types within each of these zones and estimated that the estuary is composed of 581.3 ha of mainstem channels, 87.4 ha of subsidiary channels, 24.0 ha of large blind channels and a maximum of 93.7 ha of small blind channels.

3.2.3.2 Juvenile chinook Use of the Skagit Estuary

The estuary sampling, which was conducted from weeks 7 through 33, yielded 3,468 sub-yearling wild chinook, but only 2 yearling chinook. Emigration timing at the EEM sites is shown in Figure 3-2. From these catches, Hayman *et al.* (1996) estimate that approximately 800,000 chinook (age 0+), or about half of the emigration, reared in small blind channels within all three estuarine zones, and in large blind channels within the EEM zone in 1995. The estimates were considered very approximate and they did not include main or subsidiary channel habitat.

A review of over 60 different references was completed to summarize our understanding of the biological functions provided by various estuary habitat types for the benefit of juvenile ocean type chinook (Table 3-3). Estuary habitat types correspond to those described in Hayman *et al.* (1996) while the biological functions were gleaned from literature. The table assigns a "yes" to habitats where literature supported the idea that a specific function is provided by a specific habitat. For example, *prey production* was determined to be provided (designated by a "yes" in the table) in habitats where the prey items of juvenile chinook were known to be produced. *Feeding* was determined to be provided in habitats where juvenile chinook were shown to ingest prey. In contrast, *rearing* was assigned as having value in habitats where individual juvenile chinook had been shown to reside long enough to grow (i.e., a change in individual fish length or weight was detected).

The review indicates that subsidiary channel provides all seven biological functions and the intermittently inundated forested scrub-shrub habitat provides only one function. The remaining habitat types all provided six of the listed functions. Main channels are important migratory corridors, but not refugia during high flow events. In contrast, blind channels and regularly inundated marsh habitat were not considered migratory corridors, but were important refugia during floods. While we are unable to give any order of importance for the biological functions, it is noteworthy that all seven of the functions listed were hypothesized as being limiting factors to chinook.

TABLE 3-3. Summary of biological functions provided by estuarine habitats for the juvenile phase of ocean type chinook based on literature review.

Biological Functions	Main Channel	Subsidiary Channel	Blind Channel	Estuarine Emergent Marsh	Tidally Influenced Scrub-Shrub Forested Habitat
Prey Production	yes	yes	yes	yes	yes
Predator Avoidance	yes	yes	yes	yes	
Velocity Refuge		yes	yes	yes	
Migratory Corridor	yes	yes			
Osmoregulatory Transition	yes	yes	yes	yes	
Feeding	yes	yes	yes	yes	
Rearing	yes	yes	yes	yes	

3.2.4 Skagit River Capacity Issues and Implications

The ocean-type chinook in the Skagit system showed several different life history patterns that occupied different habitats throughout the river and estuarine areas (Hayman *et al.* 1996). Any degradation or loss of the specific habitats which these life history types are dependent on would reduce the production of that life history type.

3.2.4.1 Freshwater Habitat

Beechie *et al.* (1994) reported that in the past century nearly 275,000 m^2 (64%) of distributary sloughs and 424,000 m^2 (45%) of side channel sloughs in the Skagit River have been eliminated. The majority of habitat loss has been in the lower Skagit River floodplain and delta areas, and is the result of hydromodification.

Hydromodified reaches in large river habitat of the Skagit were found to be single channels (Hayman *et al.* 1996). This reach type is dominated by hydromodified banks and has very little secondary channel, backwater, or total edge habitat area (Table 3-2). Juvenile chinook density along natural banks is three to four times greater than hydromodified banks. Hydromodified habitat has less of what is used by juvenile chinook. According to Hayman *et al.* (1996), the Skagit River has three reaches (approximately 18 miles) where hydromodification dominates the reach, however, the authors noted that future inventory work needs to quantify the numerous intermittent hydromodifications throughout the other reaches.

Habitat loss in smaller tributaries of the Beechie study were grouped into two categories: losses from habitats that have been degraded and losses from habitats that have been completely removed from production. For habitats completely removed from production, the Upper Baker and Lower Baker dams have inundated an estimated 43,400 m^2 of tributary habitat. Impacts associated with forestry practices are thought to significantly degrade tributary habitats important for chinook. The impacts are manifest by the loss of pool area due to increased sediment, or removal of LWD.

The results from Hayman *et al.* (1996) and data from other basins suggest that spawning chinook prefer pool-riffle and forced pool-riffle over plane-bed and step-pool channel types. This finding is important because forced pool-riffle and plane-bed are thought to be interrelated, depending on the amount of in-channel LWD (Montgomery *et al.* 1995). A forced pool-riffle channel could become a plane-bed channel with a reduction in LWD, while an increase in LWD could convert a plane-bed channel to forced pool-riffle morphology. Conversion of forced pool-riffle channels to plane-bed channels will reduce the amount of preferred spawning habitat in a river basin which could limit chinook production.

Land management activities influence the amount and recruitment potential of LWD in streams. Stream clearance from salvage logging or drainage improvement projects lowers LWD levels in streams. LWD recruitment potential to streams is lowered by logging and grazing in the riparian zone. Capital improvements (e.g., dams or bridges) that disrupt the natural pattern of LWD recruitment, transport and deposition in the downstream channel network also result in LWD loss. Changes in LWD can also occur naturally during high stream flow events where LWD is scoured and transported out of the reach or buried by sediment deposits. However, if the riparian zone has ample LWD recruitment potential, high flow events often result in additional instream LWD.

3.2.4.2 Estuary Habitat

Bortleson *et al.* (1980) reported a total loss of 4,200 acres of tidal marsh area in the Skagit River delta. This is a 59% loss of the delta's entire tidal marsh; 2,965 acres were lost prior to 1889, while 1,235 acres were lost after 1889. Diking associated with agricultural and urban lands accounted for the largest percentage of habitat lost in both studies. Moreover, some of the distributary losses reported in Beechie *et al.* (1994) (see above) occurred in the tidally influenced part of the river system.

Hayman *et al.* (1996) compared estuarine smolt densities with total smolt emigration estimates. For sites where data were available from previous years, the comparison indicated that increases in smolt emigration above 2.5 million did *not* increase rearing densities at two forested zone sites, and increases above a lower number did not increase rearing density at one transition zone site. Density increased with smolt emigration only at an EEM zone site on the South Fork. The limited data implies that capacity in the forested and transition zones may be reached at emigration sizes of less than 2.5 million, which would indicate that restoration work in the estuary should focus first on the transition zone, and then on the forested riverine/tidal zone.

3.2.5 Skagit Survival Issues and Implications

3.2.5.1 Habitat Fragmentation

Recent literature (Lichatowich and Mobrand 1995, Lichatowich *et al.* 1995, Lestelle *et al.* 1993) has described the importance of identifying life history patterns and favorable habitats for different life history stages in determining the effectiveness of management actions. Although these habitats may only be occupied seasonally, they nevertheless provide critical habitat for certain life stages, and in some cases could be considered the limiting factor (Reeves *et al.* 1991). If the preferred habitats in the juvenile chinook life history become fragmented or out of sequence, then fish will be forced occupy less favorable habitats, or travel longer distances to preferred habitats, reducing survival. This would be a secondary impact of habitat loss in a river basin. The impact is currently not quantified.

3.2.5.2 Effect of High Flow on Chinook Egg to Migrant Fry Survival

Recent work in the Skagit River Basin indicated the existence of a negative relationship between incubation flow and egg to fry survival (Seiler 1996). Figure 3-5 illustrates this effect for wild chinook in the Skagit for brood years 1989-1995. Flood events of over 120,000 cfs result in egg to migrant fry survival of <5%, while peak incubation flows below 30,000 cfs resulted in survivals of about 20%.

3.3 STILLAGUAMISH SUMMER/FALL CHINOOK

3.3.1 North Fork Stillaguamish Summer/Fall Stocks

Key freshwater environmental factors that affect spawning and incubation in the Stillaguamish River include reduced low summer flows, loss of pool area (>1 m) and high summer water temperatures. In particular, the loss of pool depth in the North Fork Stillaguamish, where 75% to 80% of all summer/fall chinook spawn, may have the greatest effect. The area where the majority of chinook spawn, river mile (RM) 34 to 21, is a 6th order reach and has a drainage basin area of approximately 420 km^2.

The importance of holding pool habitat was evaluated during the summer of 1995. Results indicate spawning location is positively correlated with pools. Greater than 80% of the chinook redds surveyed in the North Fork occurred within 60 meters of a pool, even though pool spacing is one every 207 m (Figure 3-6). Habitat and redd surveys indicated that over 80% of the spawning occurred in less than half of the spawnable area. This conclusion results from the fact that spawning tended to occur in riffles, even though more than half of the potential spawning gravel area is associated with glides (Figures 3-7 and 3-8).

Loss of pool area has been hypothesized to be linked to large scale changes in channel morphology and bed particle size due to several discrete pulses of coarse sediment, or sediment waves, that have moved through the mainstem North Fork Stillaguamish between 1978 and 1987 (Pess and Benda, 1994). Sediment waves have been documented using field and aerial photo techniques. Between 1978 and 1987 there was a six-fold increase in sediment supply due to an increase in the number of landslides in the upper North Fork Stillaguamish. Approximately 92% of the landslides were due to timber harvest and road construction activities (Pess and Benda 1994). This increase in sediment supply was coupled with ten of the fourteen largest peak flow events on record (gage installed in 1928) occurring over the last twenty years (Pess and Benda, 1994). This change in sediment supply and peak flow resulted in particular reaches of the North Fork Stillaguamish widening over 100%. In addition, the channel bed elevation varied as much as 2 m over an 11 year period. Channel aggradation and widening can potentially increase spawning area, however, it can also reduce large holding pool quantity due to pool filling, as well as increase the duration of summer low flows and exacerbate temperatures. USGS cross-sections from 1970 to 1994 at the Arlington gage confirmthe filling of pools by showing that residual pool depth decreased by 50% between 1986 and 1991, and returned to its previous depth after sediment supply in that reach decreased (Figure 3-9).

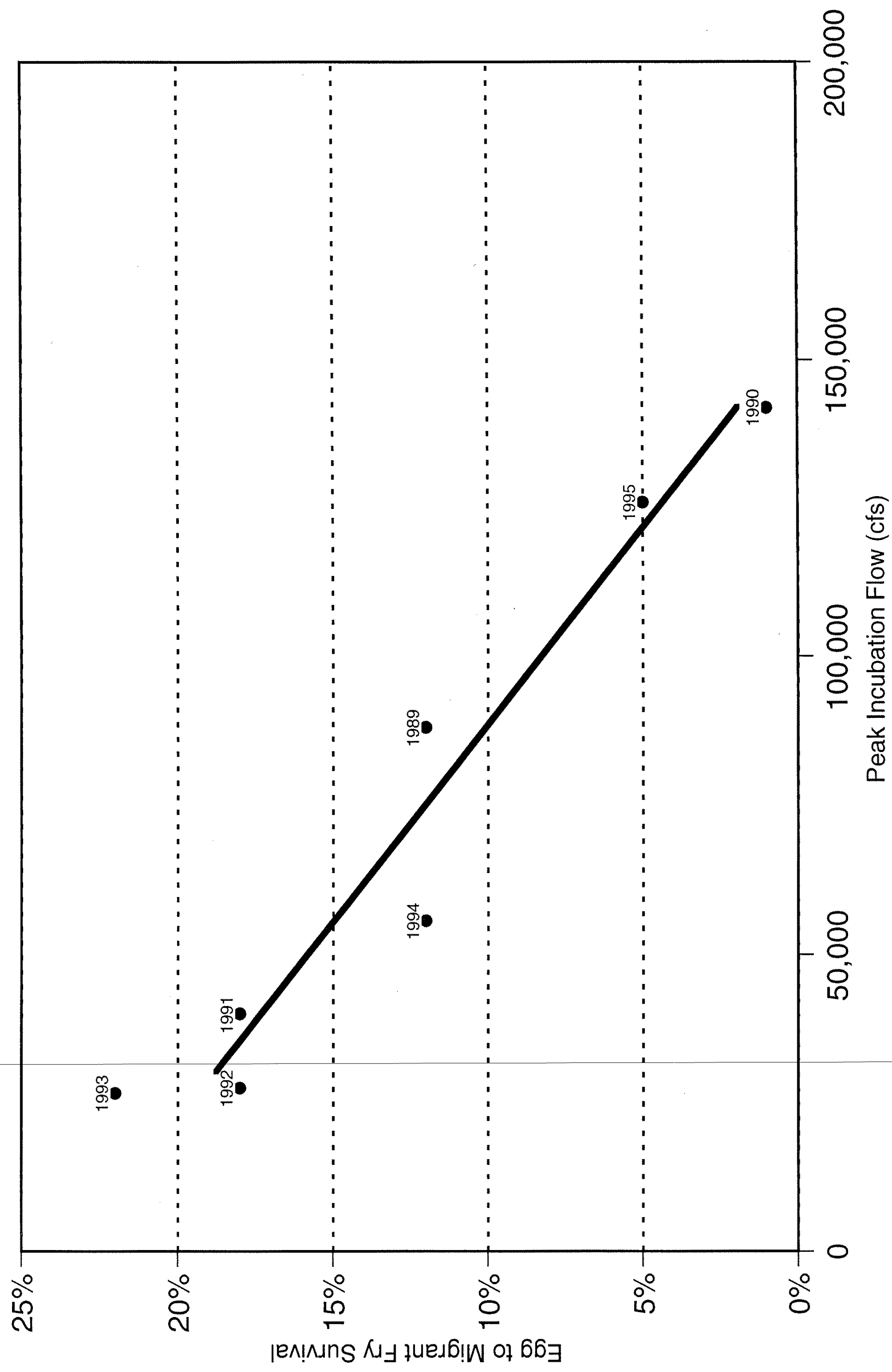


FIGURE 3-5. Survival of wild age 0+ chinook in the Skagit River by brood year (from Seiler 1996).

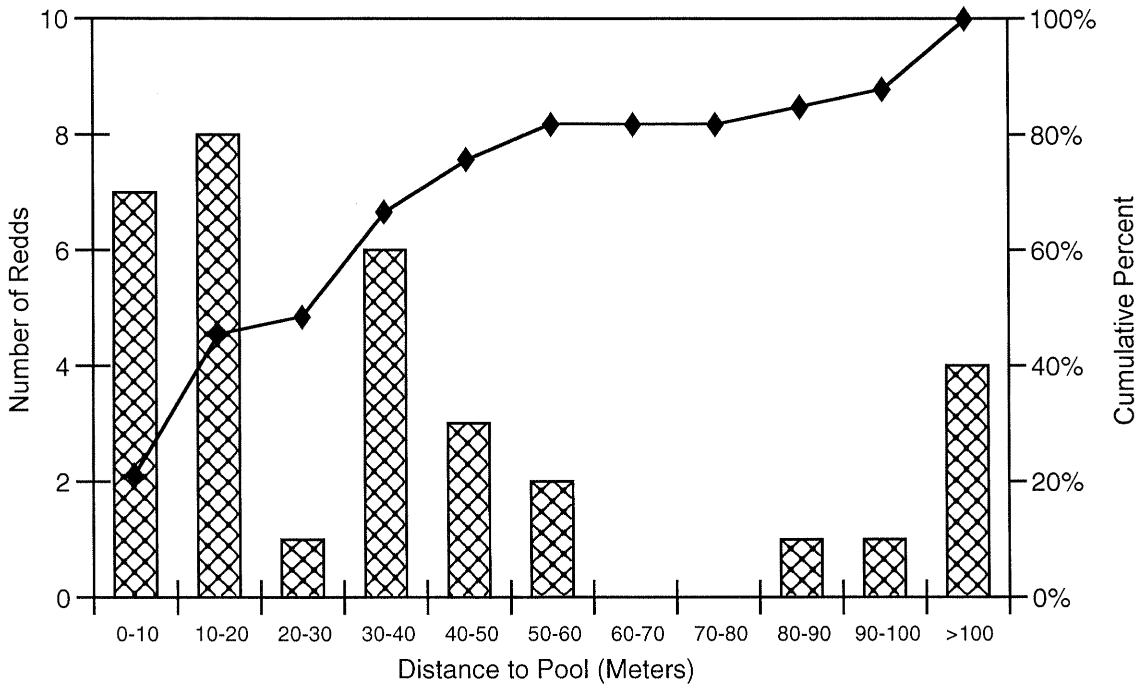


FIGURE 3-6. North Fork Stillaguamish redd distance to pool, RM 22 to RM 26, 1995.

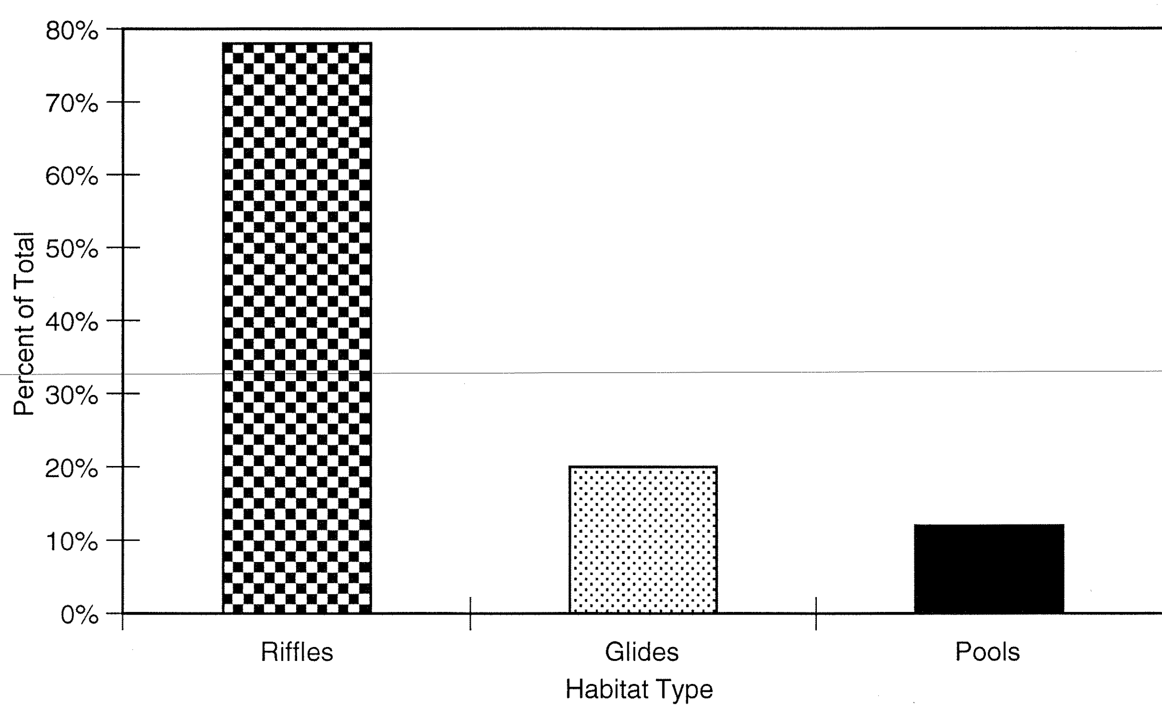


FIGURE 3-7. Percentage of chinook redds by habitat type in the North Fork Stillaguamish River, 1995.

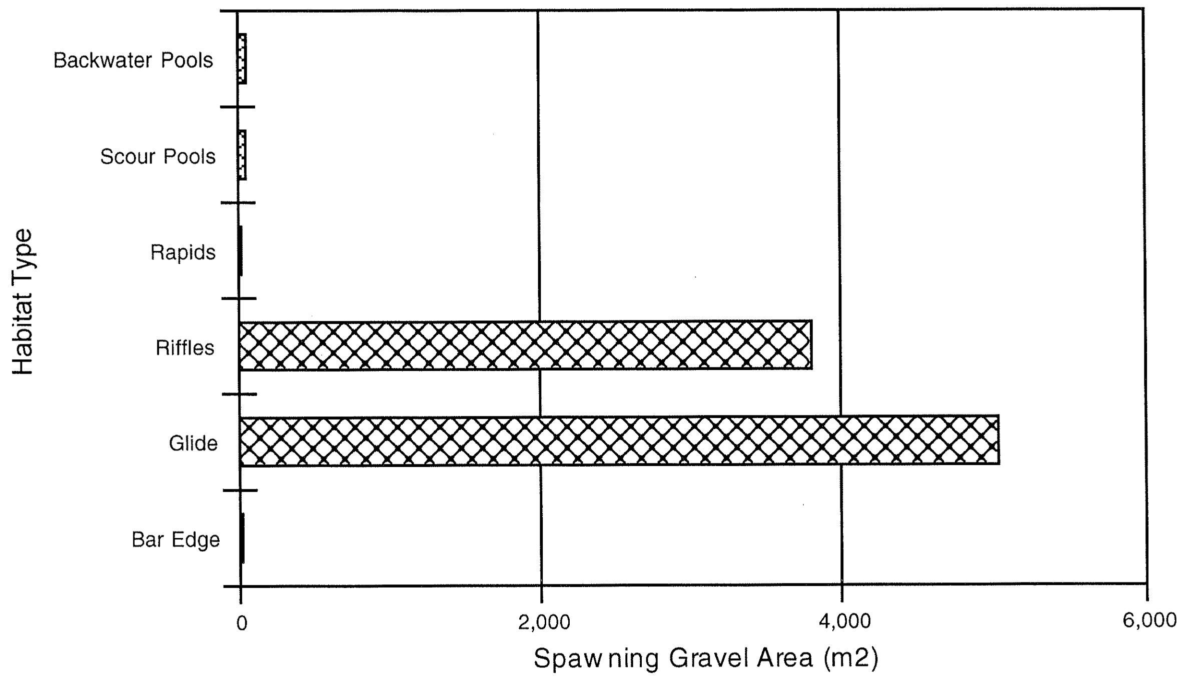


FIGURE 3-8. North Fork Stillaguamish chinook spawning gravel area, 1995.

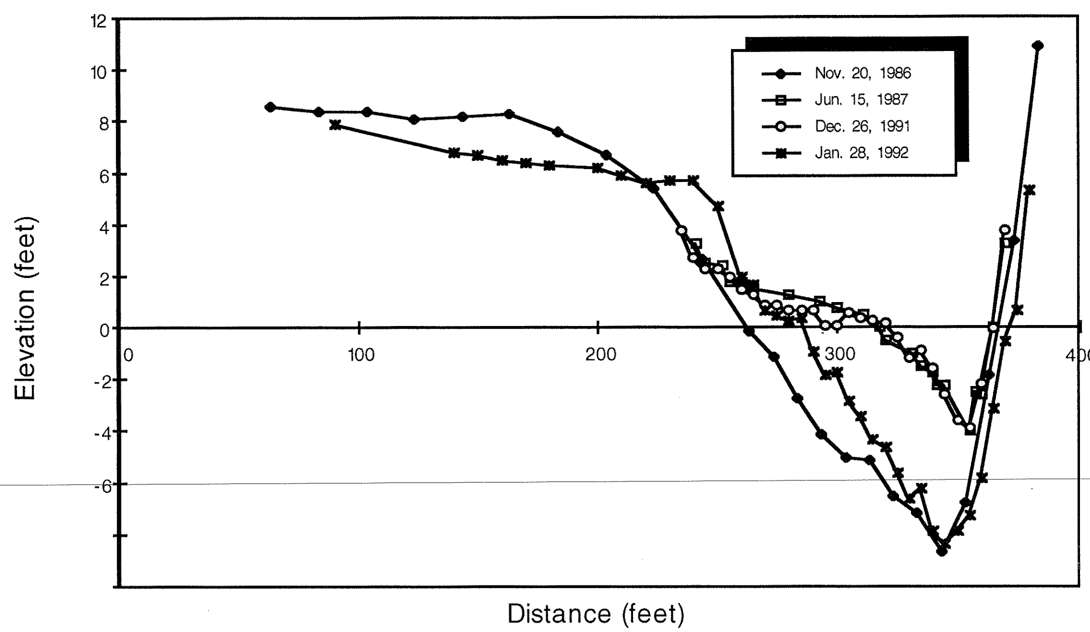


FIGURE 3-9. Channel cross sections at North Fork Stillaguamish Gage Station, November 1986 to January 1992.

Viewed on a longer time scale, these data show that the level of annual fluctuation in pool depth is increasing. Between 1971 and 1986, the annual depth change in the pool at the North Fork Stillaguamish gage station averaged 1 ft (Figure 3-10). Between 1986 and 1992, this average increased to 2.5 ft, with a maximum pool filling of 4.5 ft. This increase over time may be related to increasing frequency and amplitude of sediment waves.

The loss of pool area due to sediment waves, in combination with reduced low summer flows (Pess and Benda 1994), have resulted in a downstream shift in the distribution of peak chinook spawning. Between 1976 and 1991, the peak number of spawning chinook per mile has moved from RM 27 to RM 22 with annual movement rates ranging from 200 to 2,300 m (Pess and Benda 1994). This movement relates to the loss of holding pool area.

The effects of large scale changes in sediment supply and low flows on survival to emergence is not well understood, but USGS cross-section data suggests an increase in potential scour and fill depths of up to 100% between 1986 and 1992. This inference in potential increase is based upon local bed elevation change (Figure 3-11). Between 1971 and 1985 estimated scour and fill averaged 1 ft. Between 1986 and 1994, estimated scour and fill increased by 100% to 2 ft, including a maximum observation of 4 ft. The change in scour and fill is hypothesized to be related to increases in sediment supply and peak flow events. Increases in scour and fill of channel bed gravels reduce chinook egg survival.

3.3.2 Conclusions

Increase in sediment supply due to timber harvest activities and peak flows, coupled with reduced summer low flow levels, can affect where the Stillaguamish chinook adults hold and spawn, and potential egg to fry emergence survival. Holding pools and associated riffles with the appropriate flow and sediment size characteristics are critical to the utilization of spawnable habitat. This is evidenced by greater than 80% of the redds being located within 60 m of a pool, even though pool spacing was one every 207 m. In addition, more than 75% of the spawning occurred in riffles, even though riffles make up less than 25% of the total potentially spawnable area.

These results suggest that changes in channel morphology are linked to changes in sediment production and can affect where chinook spawning occurs. Recovery of chinook populations in the North Fork Stillguamish will, in part, depend upon the maintenance and increase in large holding pool areas over time.

Similar to the Skagit, the relationship between larger peak flow events decreasing egg to migrant fry survival is also hypothesized to be the case in the Stillaguamish, where increases in sediment supply have been coupled with large peak flow events over the last 20 years (Pess and Benda 1994). The result is increases of up to 100% in bed elevation changes from 1986 to 1994, which correspond to a 6-fold increase in sediment supply and 10 of the 14 largest flow events on record (Pess and Benda 1994). The combination resulted in a decrease in residual pool depth, as well as an increase of up to 100% in potential scour and fill. The increase is hypothesized to be at the same scale as the change in local bed elevation.

The results suggest that a reduction in number and size of holding pools, due to increases in sediment supply or peak flows, influences where redds are constructed. A loss of holding pools could mean a loss in potential spawning area. Examination and quantification of spawning capacity may encompass more than depth, velocity and substrate size. Spawning may become a physical freshwater limiting factor to chinook production, where it has not been before, due to the loss of pool area.

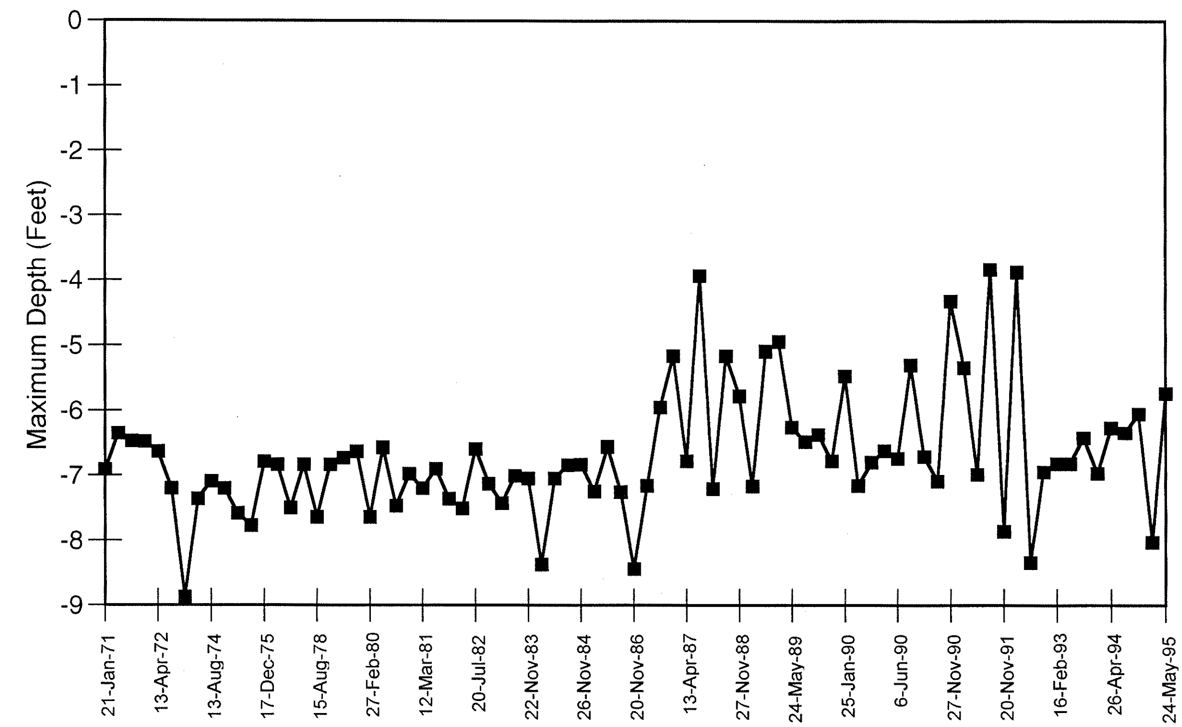


FIGURE 3-10. Maximum depth of pool below North Fork Stillaguamish Gage at Arlington, 1971-1995.

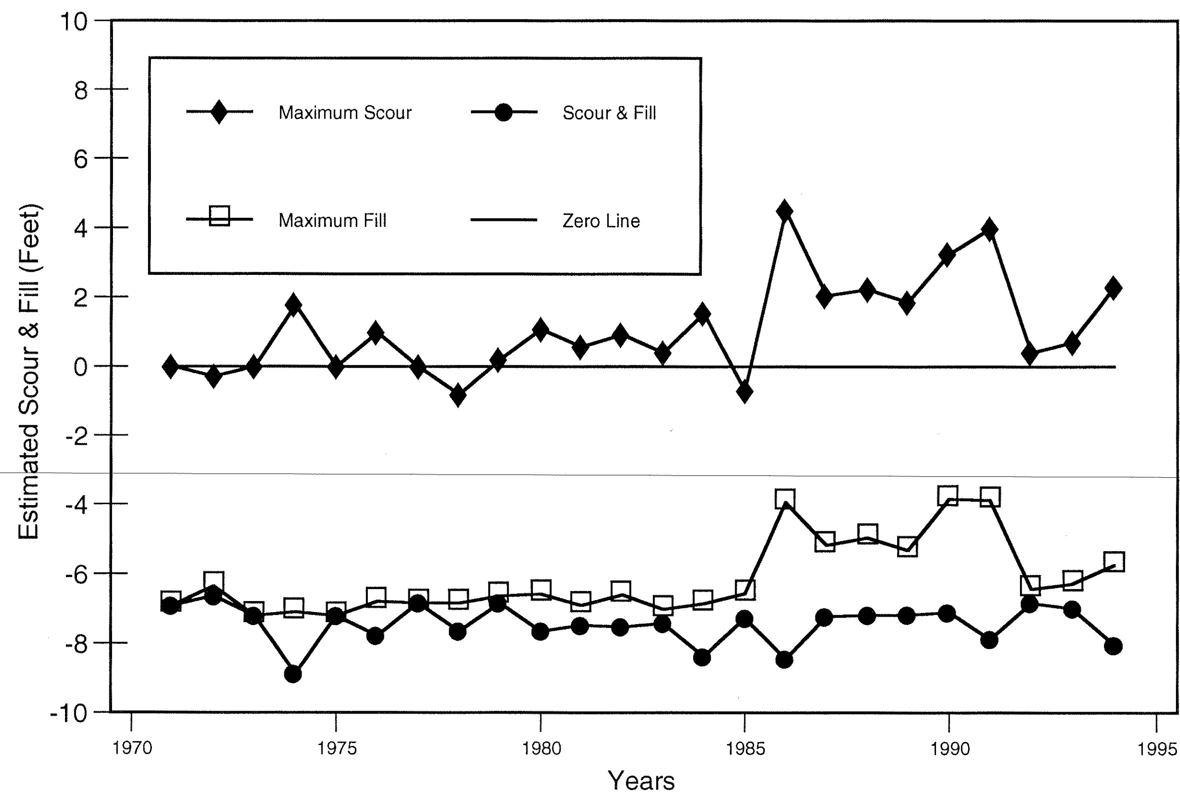


FIGURE 3-11. Scour and fill at North Fork Stillaguamish Gage Station, 1971-1994.

3.4 STRAIT JUAN DE FUCA COHO

The Strait of Juan de Fuca (SJF) region covers an area of approximately 1,500 mi^2 and includes some 48 independent watersheds that support coho, ranging in size from less than 10 mi^2 to more than 300 mi^2. Hydrologic conditions due to differences in watershed size, elevation and position with regard to the rainshadow of the Olympic Mountains, are highly variable in the region. Coho salmon populations in the SJF are significantly influenced by degradation of freshwater habitats (McHenry *et al.* 1996). Low marine survival rates and high interception rates also hamper stock productivity. Based upon the minimum numbers of fish necessary to prevent genetic introgression (WDFW Draft Wild Salmonid Policy 1996), we were unable to identify any healthy stocks of coho in the region. This finding is directly in contrast to other stock assessment studies (WDFW *et al.* 1994).[1/]

This section on SJF coho includes a case study for the Pysht River which combines both capacity and survival information into a life history model to identify some of the key freshwater issues that may lead to escapement failure.

Substantial evidence exists that increased mortality occurs at all stages of coho life history in the SJF. Impacts to freshwater habitat are arguably amongst the greatest of any region in Washington. The two largest and potentially most productive watersheds in the region have been heavily hydromodified and are currently managed primarily for hatchery production. All watersheds in the region, except the Elwha, have been subjected to intensive logging operations and are highly destabilized. Streams in the eastern SJF are influenced by rainshadow cast by the Olympic Mountains and have flow conditions that are similar to those of streams at the extreme southern edge of their range (northern California/southern Oregon). Habitat degradation caused by logging, urbanization and agricultural activities in combination with these flow conditions is severe enough to cause local extirpation of coho stocks. Recent data (unpublished) collected by the WDFW and the Lower Elwha Klallam Tribe indicate that this may have already occurred in a number of eastern SJF streams. Habitat loss due to culvert blockage in the SJF has also led to the reduction in amount of available freshwater habitat. Approximately 21 streams along the SJF have a full or partial blockage due to U.S. Highway 101 and S.R. 112 (WDFW unpublished data).

3.4.1 Elwha River

Construction of hydroelectric dams without passage facilities on the Elwha River at RM 4.9 and RM 12.0, effectively eliminated 35.9 mi of mainstem and 42.9 mi of tributary habitat from production. Much of this habitat is considered pristine, located within the boundaries of Olympic National Park. Conditions in the lower 4.9 mi of the Elwha (below Elwha Dam) are severely degraded due to cumulative effects of channelization and loss of gravel recruitment. The Elwha River is currently managed almost entirely for hatchery coho production. Using the methods described in Zillges (1977), we estimated the potential smolt coho production from a restored Elwha River may represent between 36-65% of the total from the SJF region as a whole. Restoration of the Elwha River may represent one of the best opportunities to improve natural production of coho.

3.4.2 Dungeness River

Habitat conditions in the Dungeness River are so severely degraded that only limited natural production occurs. The lower 11 mi of the Dungeness River has been extensively channelized and systematically cleared of large woody debris. Water withdrawals place additional strain on salmon populations located in marginal flow conditions. Surface water withdrawals on the Dungeness River currently average about 60% of the river's natural stream flow. A total of 579 cfs may be legally removed from the Dungeness River, even though the summer low flows average approximately 200 cfs. Over 400 mi of irrigation canals have been constructed in the Dungeness valley to deliver river water for agricultural purposes. Many of these diversions are either unscreened or ineffectively screened.

1/ The minimum population size for coho salmon based on genetic concerns (i.e., avoidance of inbreeding) is 167 for a critical stock, 1,067 for a stock of concern and over 3,000 for a healthy stock.

3.4.3 Eastern Strait of Juan de Fuca

In the eastern SJF, the cumulative effects of agricultural development, water withdrawals, channelization and urbanization, in combination with high exploitation rates and limited natural flow regimes, have driven coho populations perilously low. Recent survey data indicates that coho populations in the eastern SJF are in serious jeopardy with many stocks declining at an alarming rate. Water production per unit area in this portion of the SJF is more similar to that of southern Oregon or northern California. These conditions present a higher risk of local extinction in the SJF, similar to those seen for salmon stocks at the geographic extremes of their natural distribution (Lichatowich 1993).

In a historical assessment of Chimacum Creek, Bahls and Rubin (1996) showed that destruction of riparian forests and associated wetlands, extirpation of beaver and channelization have resulted in a 94% and 97% loss of summer and winter habitat for coho salmon, respectively. The losses parallel declines in productivity for coho in the basin.

3.4.4 Western Strait of Juan de Fuca

The western SJF is located in one of the highest runoff yield zones in western Washington (Naiman *et al.* 1992). Hydrologic stress on biological systems are extremely high in the western SJF, including:

1. Soil types with high water delivery potential,
2. High drainage densities,
3. High road densities,
4. Destabilized channel networks from LWD depletion, accelerated sediment yield and channelization.

In the western SJF, impacts to freshwater habitat are primarily limited to those associated with 80 years of intensive timber harvest, and in some cases hydromodifications on lower mainstem rivers. The region's old-growth forests have been rapidly converted to tree farms, as Olympic National Park affords little protection to SJF drainages. Historic management practices have left watershed conditions typically destabilized with high road densities, accelerated rates of mass wasting and altered riparian communities. Past management practices such as stream cleanouts, cedar salvage and channelization have further deteriorated habitat conditions. Because of these conditions, current forest practices rules, though improved, may be inadequate to permit watershed recovery in the western SJF.

3.4.5 Coho Salmon Life History Models

In order to facilitate the discussion of impacts to coho salmon during freshwater residence for eastern and western SJF streams, two simplified models that describe mortality factors for coho salmon in freshwater were developed. Sufficient data have been collected from some SJF streams to develop estimates of the effects of habitat degradation on coho salmon. Two systems, the Pysht River and Chimacum Creek, represent examples of the different types of land management practices that occur in the SJF. The case history for Chimacum is based upon a habitat restoration assessment conducted by Bahls & Rubin (1996). The model for the Pysht River is based on basin wide habitat surveys conducted in 1993 (unpublished data, Lower Elwha Klallam Tribe), assessments of intergravel survival (McHenry *et al.* 1994) and streambed scour (unpublished data, University of Washington-Center for Streamside Studies). Paradoxically, although these streams represent extremes of hydrologic conditions encountered in the SJF, they share similar impacts with regards to loss of over-wintering habitat. Conditions encountered in Chimacum Creek and the Pysht River are representative of the majority of the SJF stream mileage. The remaining streams in the SJF (14%) are impacted by hydromodification and urbanization.

3.4.5.1 Chimacum Creek

Draining an area of 37 mi^2, Chimacum Creek is the largest and most productive drainage in the Admiralty Inlet area of the eastern SJF. The system is "Y" shaped, with the East and West Forks flowing together to form the mainstem at RM 3.0. Chimacum Creek is located in the Olympic rainshadow and receives about 22 in per year of precipitation. Land uses adjacent to Chimacum Creek include forestry in headwaters areas and extensive agricultural development along low-gradient alluviated portions of the mainstem and lower East and West Forks. (Lichatowich 1993; Bahls & Rubin 1996; McHenry *et al.* 1996).

The Chimacum Valley historically supported cedar and spruce swamps, wet prairies and beaver ponds. At or before the turn of the century, most of the lowlands were drained and converted to pasture. The area was settled beginning in the 1850s. Initial development consisted primarily of logging and clearing in the valley bottoms for homesteads. The surrounding hillsides were then logged and roaded. Beginning in 1919, main stem and tributary streams in the valley were channelized to drain agricultural land. Ditching continued into the 1970's and reed canary grass was widely introduced as forage for livestock.

These activities dramatically changed the habitat conditions in Chimacum Creek (Figure 3-12). Basin-wide surveys conducted by biologists from the Port Gamble S'Klallam Tribe quantified the extent of historical changes in the basin and related these to coho freshwater life history:

- Spawning habitat has been reduced by 12% due to impassable culverts. The remaining accessible spawning habitat has been generally degraded due to sedimentation.

- Summer rearing areas have been reduced by 94%. Water temperatures between 16-21 °C were recorded in all non-forested reaches; dissolved oxygen levels less than 5 mg/l were recorded at four sites. Because of degraded conditions, summer parr were generally absent from extensive reaches of the West and East Forks. Clearing, ditching, groundwater extraction and elimination of beaver have likely altered summer flow patterns to the detriment of salmonids.

- Development activities have reduced winter rearing areas by 97%; the majority of the drainage has little or no instream LWD; and flooding may strand juvenile coho in pastures after flood waters recede.

3.4.5.2 Pysht River

The Pysht River is a moderate sized drainage (approximately 30,000 acres) located in the western SJF. The Pysht mainstem is 16.5 mi long and receives drainage from several significant tributaries. Precipitation patterns in the Pysht are more similar to those found in the coastal Olympics. Although historic estimates of coho salmon production are unavailable, anecdotal information supports the contention that the Pysht supported a sizable and diverse salmon population.

In contrast to Chimacum Creek, the Pysht is managed almost entirely for commercial timber production. The basin was historically occupied by bands of S'Klallam peoples who lived permanently at a settlement near the mouth of the river. The area was first settled by Euro-Americans in the 1870s. Commercial timber operators followed, and by 1915 full-scale railroad logging operations were initiated. By 1925, the majority of old growth timber, accessible to railroad logging, had been harvested. After World War II, truck logging, which allowed access to upper portions of the drainage network proliferated. Intensive clear-cutting peaked in the late 1940s and again in the late 1980s[2/].

2/ Clear-cutting in the 1980s was driven by corporate financing debts ("junk bond forestry"). The forestry practices used in the Pysht inspired controversy that helped persuade the state of Washington to revise its Forest Practices Code.

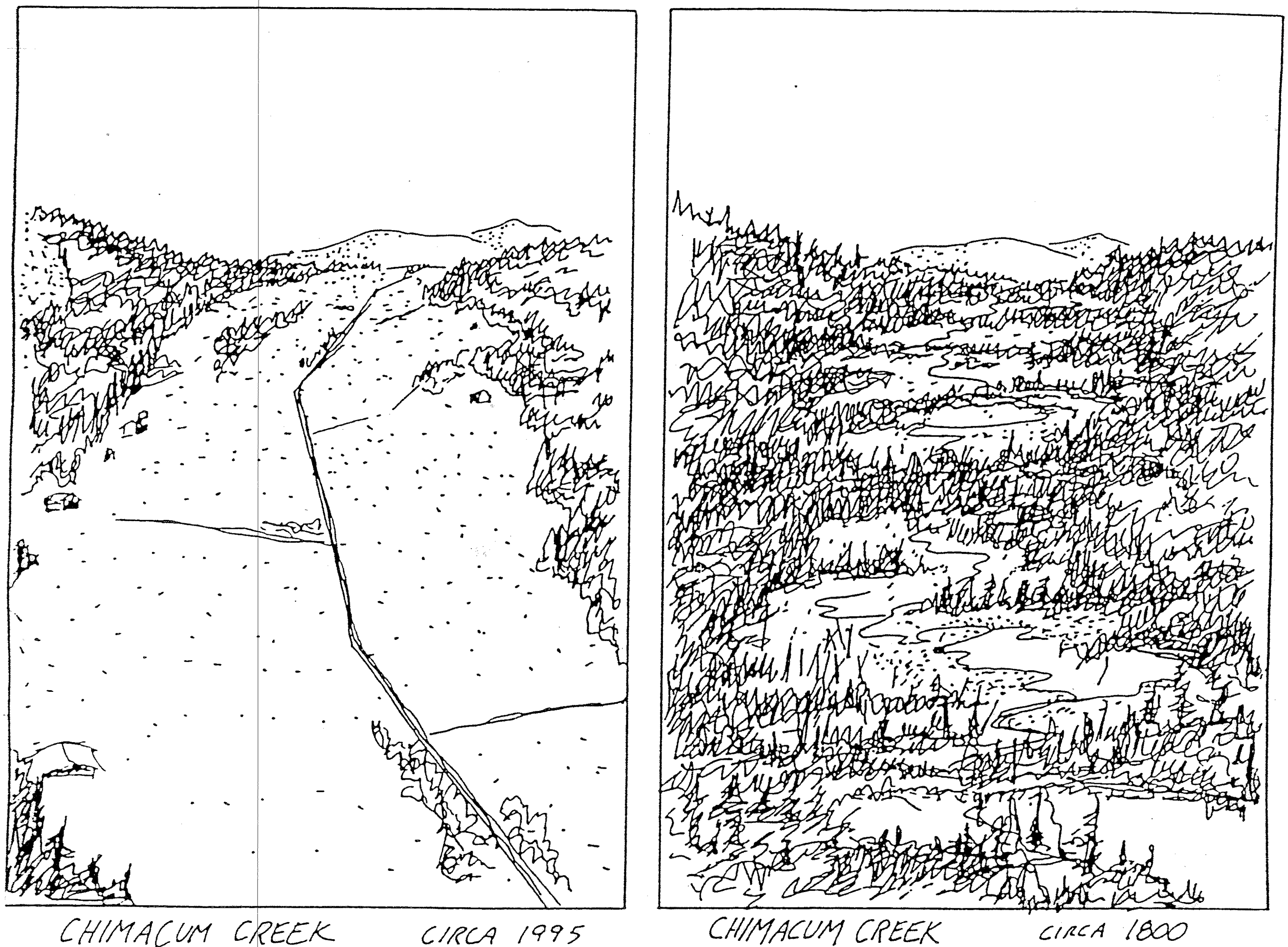


FIGURE 3-12. Changes in stream habitat in Chimacum Creek between circa 1800 and 1995. From Bahls and Rubin (1996).

Logging has significantly affected salmon habitat in the Pysht River. Sediment yield as a result of intensive roading and landsliding has increased (Benda 1993; Shaw 1993). Channel conditions, particularly as affected by loss of LWD and increased sediment yield, have been degraded. The thermal regime has likely been altered as a result of logging. Recent improvements in forest practices and ongoing restoration projects, combined with the cooperation of one large landowner, may result in increased coho productivity over the long term. The Pysht still contains habitat characteristics necessary for coho salmon, particularly over-wintering habitat areas and an intact estuary.

3.4.5.3 Pysht River Coho Life History Simulation

We assumed a hypothetical escapement of 1,000 adults to the Pysht River. Actual estimates of total escapement to the Pysht are unavailable, but are likely less than 1,000 fish annually. Based upon a 1:1 sex ratio[3/] and an average fecundity of 2,500 eggs/female for Washington origin coho (Salo and Bayliff 1958; Fraser *et al.* 1983), a yield of up to 1.25 million eggs may be expected in spawning habitats of the Pysht River.

Incubation Survival

A complete assessment of spawning gravel quality has been conducted in the Pysht River. Based upon 135 McNeil Core samples collected in mainstem and tributary spawning areas, McHenry *et al.* (1993) found that the levels of fine sediment <0.85 mm averaged 17.3%. Increasing levels of fine sediment in intergravel environments are known to be detrimental to developing salmonid eggs. In western Washington watersheds, Peterson *et al.* (1993) have shown that fine sediment levels <12% are considered favorable, levels between 12-17% are considered moderately degraded, and levels exceeding 17% are harmful. In order to assess expected egg survival, we compared average fine sediment values in the Pysht to coho egg survival curves developed from both laboratory and in-situ studies in the Northwest (Chapman 1988). From these curves a range of survival values was determined (9-55%). Applying these expected survival rates to the total egg deposition yields low, medium and high estimates of **112,500; 312,500 and 687,500** total fry emergence, respectively.

Survival to emergence is also affected by channel scour processes in the SJF streams and should be considered an additive mortality factor. Streambed scour is affected by the relationship between peak flow, sediment size and yield, and channel characteristics (gradient, roughness). Although these processes have been widely observed, its relationship to land management practices has not been quantified. However, there appears to be a relationship between scour and streams that are channelized (Orsborn and Ralph 1995), depleted of woody debris (Smith *et al.* 1993) or heavily aggraded with sediment (Schuett-Hames *et al.* 1995). These are conditions common to many streams in the SJF. Morrill *et al.* (in preparation) concluded that bankful discharges of a 1-2 year recurrence rate caused significant mortality to developing coho embryos in the Pysht River. Based on these observations, we have added a mortality factor of 0.5. Applying this factor to the range of survival values expected from fine sediment mortality yields **56,250**; **156,250** and **343,750** total fry.

Spring-Summer Parr

Newly emerged coho fry (length around 30 mm) typically emigrate to quiescent water areas such as stream margins and backwater areas to begin feeding. By early summer, fry disperse to stream habitats, particularly pools, where they compete for food and space. Competition for available space is intense, with the most favorable habitats typically being occupied by the largest individuals. Displaced fish are forced to locate new territories or are eventually displaced downstream, and in some cases to the estuary (Mason and Chapman 1965). Predation is also a mortality factor. The abundance of coho in a stream during summer is directly related to the number and complexity of territories available (Larkin 1977; Nickleson *et al.* 1992). At current seeding levels in the Pysht River, summer rearing habitat for coho does not appear to be limiting. A basin-wide survey of stream habitat indicates that approximately 70,000 and 123,000 m^2 of tributary and mainstem

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3/ The literature indicates that sex ratios for coho are variable and are often skewed by large numbers of jacks. Literature values for ratio of male to female coho from Alaska and British Columbia ranged from 0.9:1 to 2.1:1 (Sandercock 1991).

summer rearing habitat, respectively, are available for summer parr in the Pysht (unpublished data, Lower Elwha Klallam Tribe). Despite the basin-wide depletion of LWD, a variety of pool types (largely formed by bed features) are available for rearing. A combined spring-summer survival factor of 0.65 was assumed for the Pysht River (Reeves *et al.* 1989). Applying this factor to potential fry survival yielded a range of **36,563**; **101,562** and **223,438** total summer parr. Assuming even distribution over available habitats, juvenile coho densities of 0.18/m^2 (low), 0.52/m^2 (medium), and 1.15/m^2 (high) could be expected. The low range compares favorably with actual coho summer parr densities found in Pysht River tributaries (unpublished data, Elwha Klallam Tribe).

It should be noted that summer habitat in the Pysht River becomes fully utilized at a level of 328,100 fry [assuming a density of 1.7 fish/m^2 of pool area (Reeves *et al.* 1989)]. Based upon assumptions of intergravel mortality factors, as few as 1,470 adults (1:1 sex ratio) could fully utilize ("seed") the available summer rearing habitat in the Pysht River under high freshwater survival conditions. Conversely, under low freshwater survival conditions, nearly 9,000 fish would be necessary to produce enough summer parr to fully utilize Pysht River habitats.

Winter Parr

With the onset of winter and decreasing water temperatures, juvenile coho salmon redistribute into deeper pools (particularly with complex cover) and off-channel habitats (Bustard and Narver 1975; Scarlett and Cederholm 1984). Movement is generally in a downstream direction (in response to freshets) and considerable distances may be involved. Coho streams with the best over-wintering habitat typically contain spring-fed ponds, beaver ponds, or side-channels (Narver 1978). Coho that are able to access such wintering habitats typically survive at very high rates. For example, survival of winter parr in Carnation Creek, British Columbia (prior to logging) exceeded 67% (Tscpalinski and Hartman 1983). In western Washington streams, over-wintering habitat has been substantially altered. Estimates of over-winter survival for winter parr in western Washington and Oregon generally average less than 35% (Bustard and Narver 1975, Reeves *et al.* 1989). In the SJF, over-winter survival may be much lower. In the Pysht River, potential over-winter habitat[4/] was estimated at 15,340 m^2 for tributaries and 38,275 m^2 for lower mainstem areas. There is however, no data available to assess actual survival in these areas. Based upon the literature values for over-wintering habitat, we assigned an average survival rate of 0.325. Applying this to the total expected summer parr yields a range of **11,883**; **33,008** and **72,617** potential coho smolts.

Smolt to Adult Survival

Estimates of smolt to adult (marine) survival are available from Snow Creek in the eastern SJF and from Big Beef Creek, a tributary to Hood Canal. These data show some disturbing trends in marine survival of coho salmon. In Big Beef Creek for the years 1976-1978, Quinn (1994) found that survival to adult averaged 20.1%. More recent estimates for the period 1973-1989 show that marine survival averaged 22.9% (Lestelle *et al.* 1993). There are indications that marine survival rates for SJF coho are much lower than those for Puget Sound stocks. For Snow Creek, only combined ocean mortality (natural and harvest) estimates are available (Lestelle *et al.* 1993). For the period 1976 to 1989, smolt to adult return rates averaged 3.9% (range 1.1 to 7.7%). The authors observed a declining rate of return that was not attributable to any one specific cause. We applied a marine survival of 15.5% to the range of smolt yields and obtained estimates of **1,188**; **3,301** and **7,262** adult coho.

4/ Over-wintering habitat is defined as pools formed by large wood (logs, roots, or jams) with a residual depth >1 m, side-channels or off-channel ponds.

Summary

The modeling results indicate that mortality factors for Pysht River coho were significant in the winter (Table 3-4). Losses in the intergravel environment due to elevated fine sediment levels and scour may exceed 75% during some years. Over-wintering mortality is also suspected to be high (70%), as habitat has been lost to diking, road construction and LWD depletion. At current seeding levels, summer habitat is adequate. However, at marginally higher escapements, this habitat type may also become limiting.

TABLE 3-4. Summary of life history impacts to coho salmon of the Pysht River, Washington, a representative stream of the western SJF. Based upon escapement of 1,000 fish.

Life Stage	Fish Produced	Comments
Incubation	56,250-343,750	Survival as a function of gravel quality/channel stability
Summer Rearing (at a 0.65 survival factor)	36,563-223,438	Density estimates are a function of summer low flows and pool quality, which is a function of LWD, cover and residual pool depths
Winter Rearing (at a 0.325 survival factor)	11,883-72,617	Loss of off-channel habitat and subsequent alteration in peak flows
Smolt to Dec. Age-2 (at a 0.1 survival factor)	1,188-7,262	Marine survival may be lower for SJF stocks, when compared to Puget Sound
Dec. Age-2 to Escapement (at a 0.75 third year survival and 0.65 exploitation rate)	312-1,906	The majority of the harvest is often outside U.S. jurisdiction

3.5 CONCLUSIONS

The Skagit, Stillaguamish, Snohomish, and Strait of Juan De Fuca (SJF) watersheds have experienced comparable changes in habitat capacity and habitat quality, because of the cumulative effect of various land uses. Reductions in habitat capacity and habitat quality have each contributed to escapement shortfalls for Puget Sound chinook and SJF coho.

Historic loss of tributary and mainstem habitat due to dams has been documented in the Skagit and SJF. The Upper and Lower Baker dams resulted in a loss of 43,400 m^2 of tributary habitat to the Skagit River Basin, while the Elwha dam has resulted in a loss of 35.9 miles of mainstem and 42.9 miles of tributary habitat in the SJF region. The dams have directly reduced chinook and coho production in each river basin.

All basins examined in this report have experienced a loss of slough and side channel habitat (off-channel and over-wintering) due to the construction of dikes and dredging (hydromodification) earlier this century. Hydromodification in the Skagit has resulted in a 64% loss of distributary sloughs and a 45% loss of side channel sloughs. The majority of this loss has been in the floodplain and delta, both of which are critical to the chinook life history types identified by the Skagit System Cooperative (SSC). A Skagit estuary loss of 4,200 acres, due to diking for the conversion to agricultural and urban lands, also affects the juvenile life stage of all three chinook life history types. Hydromodification can also reduce habitat quality as is evidenced by data from the Skagit which suggests three to four times the amount of juvenile chinook use along natural banks vs. hydromodified reaches.

Chimacum Creek has lost 94% to 97% of potential coho summer and winter rearing habitat due to channelization, loss of wetlands from land conversion, and removal of riparian vegetation.

Habitat quality has declined in all areas due to land management activities that influence the amount and recruitment potential of large woody debris (LWD), exacerbate low flows during summer low flow periods, and increase sediment supply. Land use activities such as stream clearance of LWD, bank hardening, riparian forest clearing (logging or grazing), and a reduction in floodplain area all potentially reduce the amount of LWD in stream channels either directly or disrupt the natural pattern of LWD recruitment, transport, and deposition in watersheds. LWD helps create and maintain freshwater habitat such as deep holding pools or backwater pools, or the quality of a given habitat type (e.g., cover), that is critical to specific life stages for chinook and coho.

Data from the Skagit and Stillaguamish suggest that chinook prefer to spawn in channels with higher LWD loading levels (e.g., forced pool-riffle channel types). A loss of LWD over the last 80 years has affected Western SJF streams such as the Pysht, which has led to a reduction in summer rearing, and loss of winter rearing habitat. Currently, LWD densities are 80% less than historic volumes (McHenry *et al.* in preparation). Channelization and the clearance of LWD in the lower 11 miles of the Dungeness River has reduced habitat quality and production potential. Streams located within the Eastern SJF are naturally low-flow limited. Land use practices which compound low flow effects, such as irrigation withdrawals, can lead to increased summer temperatures, reduced dissolved oxygen levels and a reduction in summer rearing habitat quality and quantity for coho.

An increase in sediment supply levels from land use activities, such as certain forestry practices, can result in a loss of pool area and an increase channel bed fine sediment levels. Sediment supply, flow, habitat, and spawning data suggest that changes in channel morphology to the North Fork Stillaguamish is linked to changes in sediment production, which can affect where chinook spawning occurs. Deep pools and associated riffles were documented as critical to the utilization of spawnable habitat for chinook in the Stillaguamish. Loss of deep holding pools affected where Stillaguamish chinook spawned, and it is hypothesized that less favorable spawning habitat had to be utilized. It is also hypothesized that egg to fry survival is reduced due to the less favorable spawning habitat conditions, or longer travel distances to more favorable habitat conditions. Collection of fine sediment data and historical analysis in the SJF streams suggest that two life stages, early incubation and winter rearing, have been impacted more than others. This is due to a combination of a decrease in habitat quality (elevated fine sediment levels and scour effects) and reduction in habitat quantity (loss of limited off-channel habitat).

4.0 MARINE SURVIVAL

Variations in the survival of salmon while inhabiting the marine environment can have a very significant affect on the total production from any given brood. Therefore, trends in marine survival rates must be considered in evaluating the causes of stock depression and potential overfishing for Puget Sound chinook and Strait of Juan de Fuca (SJF) coho stocks.

A comparison of the estimated smolt-to-adult survival rates among marked hatchery and naturally produced salmon, released in close proximity to marine waters of the Pacific Coast, indicates significant variation among releases of different broods of the same stock. Several stocks show variations in the range of 2 to 6 fold within survival rates among all stocks which range from 0.2% to nearly 20% (Shaul 1994; Pearcy 1992; Garrison *et al.* 1994). The broad geographic relationship of very low smolt-to-adult survivals during periods of extreme ocean environmental change, such as occurred during El Niño events in 1982-1983 and 1991-1993, supports the conclusion that the marine proportion of the survival is a significant part of the total variation.

4.1 PERTINENT ENVIRONMENTAL FLUCTUATIONS

Our understanding of the interaction of salmonids with changes in the marine environment is not extensive. Kope (1994) summarizes three processes which we currently relate as significant oceanographic changes affecting survival of Pacific salmon. They are El Niño events, the relationship of the Californian and Alaskan Currents along the Pacific Coast, and wind driven coastal upwelling. All three processes are driven by changes in global atmospheric circulation patterns and pressure gradients within the ocean. A very brief description of these processes is provided below. Pearcy (1992 and 1997) provides a more detailed description of the important processes and how they relate to productive conditions for salmon.

The first process, an El Niño, results in temporarily warmer sea surface temperatures along the eastern Pacific Coast when there are certain changes in the normal atmospheric circulation pattern along the equator. El Niños occur at irregular intervals and may develop and sustain themselves over several months or more. Major recent El Niños occurred in 1982-1983, 1986-1987 and 1992-1993 (Pearcy 1997). The 1982-1983 and 1992-1993 events resulted in particularly severe depressions of salmon abundance for stocks as far north as southern British Columbia.

The second marine process involves changes in the eastward flowing Subarctic Current as it approaches the Pacific Coast and bifurcates into the southward flowing California and northward flowing Alaskan Currents. As pressure gradients within the ocean and atmospheric circulation patterns change, the amount of the Subarctic Current flowing north and south changes. When more water flows south in the California Current, coastal sea surface temperatures from southern British Columbia to Baja California are cooled and favor production conditions for salmon rearing in those areas. When more water is diverted northward, conditions for salmon are improved in the Gulf of Alaska by the slight warming of very cold waters.

Major fluctuations in the strength of the California and Alaskan Currents seem to extend over periods of 10 to 20 years or more. Fish scale deposition data from ocean floor core samples in the Santa Barbara Basin indicate cycles of sardine and anchovy abundance in 60 to 100 year cycles. Existing marine temperature data indicate a warm period from 1927-1947, a cool period from 1948-1976 and the most recent warm episode from 1977 to the present (Pearcy 1997).

The third process, wind driven upwelling, is important in bringing nutrient rich, cool waters to the surface along the Northeast Pacific Coast from southern British Columbia to Baja California. These nutrient rich waters stimulate nearshore plankton production, forming the food chain base for all ocean organisms, including salmon. The upwelling is favored by strong northwest winds and the conditions which create a strong California current. The upwelling is often disrupted or weakened by El Niño events.

Our understanding of the exact mechanism by which these changes in sea temperatures and upwelling affect salmon abundance is not complete. Warm water intrusions reduce upwelling and subsequent plankton production which, in turn, limits abundance of forage species utilized by salmon and other fishes. In addition, the warmer water may expand the range of some predators (such as mackerel) to more salmon rearing areas. Thus, additional reduction in salmon abundance may occur due to increased predation, lack of forage in normal rearing areas, changes in oceanic distribution of salmon or some combination of these factors (Kope 1994).

4.2 CONCLUSIONS

Since 1976, a major change in ocean climate and a geographic shift in salmon production has occurred in the Northeast Pacific Ocean which appears to correlate with a weakening of the California current and strengthening of the Alaskan current (Pearcy 1997). The resulting general increase in sea surface temperatures off the Pacific Coast of North America has led to increases in the production of Alaskan salmon stocks and a decrease in the production of many more southerly rearing stocks, which would include Puget Sound chinook and SJF coho. It is important to note, however, that even within an overall warm cycle, marine conditions are not always uniform and that certain stocks may experience years of high survival during these generally depressive periods.

The overall unfavorable marine conditions coincide with the period in which the productivity of Puget Sound chinook and SJF coho has appeared to decrease. It appears likely that some of the observed stock depression is due to a general reduction in the marine survival of these stocks. It also appears likely that the loss of freshwater habitat and subsequent loss of geographic, temporal and genetic diversity experienced by these stocks, may exacerbate the negative impacts from marginal environmental conditions within the ocean.

5.0 HARVEST MANAGEMENT

5.1 CHINOOK SALMON ASSESSMENT

This section of the report reviews the status of seven Puget Sound chinook stocks and potential explanations for the failure of the stocks to achieve escapement objectives. The section begins with a short discussion of the basis of the escapement goals and methods for estimating escapements. Stock assessments are then provided in three broad categories:

1. **Terminal Area Management Evaluation (Green River Summer/Fall)** - In the years 1992, 1993, and 1994, the inseason estimate of abundance for the Green River stock indicated fewer fish than had been projected preseason, but more than were needed for escapement. Consequently, any shortfall in the Green River chinook escapement was the result of management actions in the terminal area.

2. **Qualitative Evaluation (Lake Washington Summer/Fall)** - Although no coded-wire-tag (CWT) groups are available for the Lake Washington stock, a qualitative examination of potential factors affecting the escapement was completed.

3. **Exploitation and Survival Analysis (Skagit Summer/Fall, Stillaguamish Summer/Fall, Snohomish Summer/Fall)** - The escapements of stocks included in this category have either been less than the goal or declining for many years. In order to evaluate the cause of the escapement shortfalls, a computer model of the Chinook Technical Committee was used to estimate the interactive effects of brood exploitation rates and survival rates upon escapement.

No stock assessment is provided for either the Dungeness or the Skagit spring stocks. The Dungeness stock has no coded-wire-tag (CWT) groups currently available to estimate exploitation rates or survival rates; the Skagit spring stock was included in a previous review (PSSSRG 1992) and no additional data are available.

5.1.1 Escapement Goals and Escapement Estimation

Escapement goals for most wild stocks of chinook in Puget Sound were established by the Washington Department of Fisheries in the late 1970s. The basis of each of these goals is summarized below:

Dungeness - The escapement goal is based on the estimated number of redds per mile of available spawning habitat that would seed all available rearing habitat (Smith and Sele 1994).

Skagit Spring - The escapement goal for the Skagit Spring stock was based on an analysis of past spawning levels and their relation to run sizes in subsequent cycle years. The largest total returns were achieved with spawning levels over 3,000 fish, which was also the average escapement in the years 1959-1968 (Puget Sound Salmon Stock Review Group 1992a)

Skagit summer/fall, Snohomish summer/fall, Green summer/fall - The escapement goal for these stocks is the average escapement in the years 1965-1976 (Ames and Phinney 1977).

Stillaguamish summer/fall - The escapement goal for the Stillaguamish stock is the average escapement in the years 1973-1976. A shorter range of years was used than for the Snohomish stock due to concerns that spawner densities had been inadequate prior to 1973 (Ames and Phinney 1977).

Lake Washington summer/fall - The escapement goal is based on an average of earlier years escapements when the run sizes were considered to be healthier (Hage *et al.* 1994).

The 1996 Letter of Agreement among the U.S. representatives to the Pacific Salmon Commission (PSC) required the U.S. section to review the relation of the escapement goals for a number of stocks (including the Skagit summer/fall and Stillaguamish) to maximum sustainable yield (MSY) or other biologically-based escapement objectives. The Chinook Technical Committee (CTC) is now working on this task.

Methods for estimating the escapement of wild stocks varies between regions, but are generally based on redd counts expanded for unsurveyed areas, average numbers of redds/female, and average sex ratios (Smith and Castle 1994).

5.1.2 Green River Summer/Fall Chinook - Terminal Area Management Evaluation

Management of the Green River chinook stock was reviewed with the intent of identifying factors which might explain the escapement shortfall in 1992, 1993 and 1994. In 1992-1993, the inseason prediction of abundance for the Green River wild stock indicated fewer fish than had been projected preseason (Table 5-1), but more than were needed for escapement. Since harvestable chinook are calculated by subtracting the escapement goal from the predicted abundance, any shortfall in the Green River chinook escapement was the result of one or more of the following factors: (1) inaccurate inseason predictions of abundance (including the hatchery/wild proportion); (2) management imprecision (e.g., fishery catch greater than anticipated); (3) inaccurate postseason estimates of harvest and (4) inaccurate postseason estimates of escapement.

5.1.2.1 Inseason Predictions of Abundance

Abundance is predicted inseason from a regression relationship between the run reconstruction estimate of the total (hatchery plus wild) run entering Elliott Bay and the catch (either adjusted or unadjusted for effort) for a test fishery (the commercial catch was also used in 1994) in Elliott Bay and the Duwamish River (the lower 11 miles of the Green River). The abundance of the wild stock is then predicted by multiplying the total predicted abundance by the preseason forecast of the proportion of the run comprised of wild fish.

The predictive capability of the regression model used in 1992 was excellent, but performance was degraded when the 1992 and 1993 data points were added. Using data from test fisheries conducted from 1978-1991 (excluding 1979 and 1986-1988), the model was evaluated by sequentially leaving one year out of the database and using the remaining years to predict the run size for the excluded year. Using this procedure, the mean prediction error of the 1992 model was 0.1%, and the mean absolute percent error was 13.4%. Sufficient concerns existed regarding the 1994 model that it was not used for the final inseason estimate in 1994. Instead, the final inseason estimate used an average of the lower 95% confidence intervals for two models, each of which used both commercial and test fishery data.

Since the proportion of the run comprised of wild fish is not estimated inseason, errors in the preseason forecast of this statistic could also cause an escapement shortfall. However, preseason and postseason estimates were generally similar, and only in 1993 did the preseason forecast predict a significantly greater proportion of the run to be comprised of wild fish than was estimated postseason (Table 5-1).

As previously discussed in PSSRG (1992a), the run reconstruction does not include chinook salmon caught in sport fisheries in Elliot Bay or Green River. Despite the absence of sport catches from the database, the allowable commercial catch can still be computed by subtracting the escapement goal from the inseason estimate if the harvest rate in the sport fishery remains constant. However, an increase in the sport fishery harvest rate relative to the years included in the regression will result in a failure to achieve the escapement goal.

Evaluating the harvest rate in the Elliot Bay and Green River sport fishery is difficult because catch estimates are not available for the Elliot Bay component separate from the total Area 10 catch through 1994. Therefore, it is not possible for us to determine whether the harvest rate of the terminal area sport fishery increased and contributed to the escapement shortfall.

TABLE 5-1. Preseason, inseason and postseason catch and abundance statistics for the Green River summer/fall chinook stock, 1992-1994.

Statistic	Fishing Year 1992	1993	1994
Escapement Goal (Wild Stock)	5,800	5,800	5,800
Preseason Abundance Forecast	27,155	29,000	14,600
Wild	13,050	13,500	7,100
Hatchery	14,105	15,500	7,500
Final Inseason Abundance Prediction	21,000	21,000	22,000
Wild	10,092	9,776	10,699
Hatchery	10,908	11,224	11,301
Postseason Abundance Estimate	17,781	12,545	17,131
Wild	9,660	5,071	8,226
Hatchery	8,121	7,474	8,905
Percent Wild			
Preseason Abundance Prediction	48%	47%	49%
Postseason Estimate	54%	40%	48%
Total Predicted Allowable Net Catch	8,931	8,541	10,073
Wild	4,292	3,976	4,899
Hatchery	4,639	4,565	5,157
Estimated Total Net Catch (Elliott Bay and Green River)	8,086	6,413	8,269
Wild	4,393	2,592	3,971
Hatchery	3,693	3,821	4,298
Estimated Total Sport Catch	Unknown	Unknown	Unknown
Elliott Bay	Unknown	Unknown	Unknown
Green River	194	423	399
Total Estimated Escapement	9,695	6,132	8,862
Wild	5,267	2,479	4,255
Hatchery	4,428	3,653	4,607
Wild Escapement Shortfall			
Number	533	3,321	1,545
Percent	9%	57%	27%

5.1.2.2 Management Imprecision

An escapement shortfall could occur if the management of the fisheries resulted in a catch that exceeded the inseason target. This was not the case for the net fisheries in Elliot Bay and the Duwamish River. Catches in those fisheries were less than the target catch in each year (Table 5-1), with deviations ranging from 845 fish in 1992 to 2,128 fish in 1994. Target catches were not established for the sport fishery and postseason estimates of the catch are not available.

5.1.2.3 Inaccurate Postseason Estimates of Harvest

An escapement shortfall could also result from unreported or underestimated harvest. Treaty commercial, subsistence and ceremonial net catch is reported on fish tickets; estimates of the sport catch in Elliot Bay were combined with the catch in Area 10 through 1994. No estimate is made for the sport catch taken by fishers angling from the shore of Elliot Bay or from docks, piers and vessels along the industrial waterway.

5.1.2.4 Inaccurate Postseason Estimates of Escapement

Escapement is estimated from counts of spawners in documented index areas, expanded to represent an escapement value for the total naturally spawning stock (Smith and Castle 1994). The estimated escapement could be biased low or high if run timing or the spatial distribution of the escapement was abnormal. For example, if spawning distribution changed between the surveyed and unsurveyed areas, the estimate might be biased. The accuracy and precision of the escapement estimates is unknown.

5.1.3 Lake Washington Summer/Fall Chinook - Qualitative Evaluation

The preseason projections for 1992, 1993 and 1994 indicated that no harvestable chinook were available to any fisheries. The only harvest management response took place in terminal fisheries. Treaty net fisheries were reduced in time in 1992, further reduced in 1993, and were closed in 1994. Sport fisheries in Lake Washington were managed to prevent the taking of chinook in 1994. Closure of coho sport fisheries in Area 10 also provided some protection for chinook.

Two additional factors may have contributed to overestimation of the run. Predation by California sea lions (*Zalophus californica*) has been well documented by the National Marine Fisheries Service (NMFS) as a significant impact on adult winter run steelhead. What has been less publicized is the impact on downstream migrating smolts. Sea lions have been observed eating smolts as they swim out of the fish ladder (Muckleshoot Tribe, unpublished data). The passage of smolts through the pipes and valves that operate the locks has also been observed to kill or wound smolts. Wounded smolts are subsequently subject to avian predation (Muckleshoot Tribe and WDFW, unpublished data).

5.1.4 Exploitation Rate and Survival Analysis

5.1.4.1 Methods

Distribution of Adult Equivalent Mortality

The distribution among fisheries of the total adult (spawner) equivalent (AEQ) fishing mortality for the Skagit, Snohomish, and Stillaguamish summer/fall stocks was obtained from the chinook model of the CTC of the PSC. The total AEQ fishing mortality includes sources of non-landed fishing mortality such as shakers and chinook nonretention fisheries. All estimates are reported in terms of AEQs, the probability that a fish of a given age would spawn in the absence of fishing, in order to equalize the escapement value of fish harvested at different ages.

Potential Escapement

The CTC chinook model was also used to estimate the potential escapement of these stocks. The potential escapement is defined as the escapement (age 3-5) that is predicted to occur in the absence of a) all fisheries or b) fisheries in the southern U.S. (Washington, Oregon, and California). The potential escapement in the absence of all fisheries was computed by multiplying a stock and age specific maturation rate by the estimated cohort size (reduced for natural mortality) obtained from the CTC chinook model. A similar procedure was used to compute the potential escapement in the absence of southern U.S. fisheries except that the estimated mortality in Alaskan and Canadian fisheries was subtracted from the cohort size.

Exploitation Rates Associated with Maximum Sustainable Yield

The exploitation rate associated with the maximum sustainable yield (MSY ER) is the proportion of the stock (computed as the sum of total AEQ fishing mortality and escapement) that could be harvested if the long-term yield was to be maximized. The MSY ER is typically computed assuming stable stock productivity, although annual variability may occur. However, if trends in stock productivity are apparent, an MSY ER can be computed for a limited period of years, assuming that the stock productivity during those years was constant.

The survival rate index incorporated in the CTC chinook model provides a measure of the annual variability in stock productivity. Under the assumption that the variability results from density independent factors, the initial cohort size of each wild stock included in the model is computed by multiplying the index by the cohort size predicted by a Ricker spawner recruit function:

$$Cohort=(r)(S)e^{a(1-\frac{S}{b})}$$

where r is the survival rate index, S is the age 3-5 escapement, and a and b are Ricker stock productivity parameters. The survival rate index is estimated during the calibration of the model by minimizing the difference between the predicted terminal run (predicted based on brood escapement, a spawner-recruit function, and estimated fishing mortality) and the observed terminal run for each stock.

For three year intervals, the escapement (O) which would maximize the long-term harvest was computed by solving the following equation:

$$1=(r)e^{a(1-\frac{O}{b})}(1-\frac{(a)(O)}{b})$$

The MSY ER for the interval was then computed simply as:

$$MSY\ ER=1-\frac{O}{rOe^{a(1-\frac{O}{b})}}$$

Exploitation Rates Associated With Stock Replacement - The exploitation rates associated with maintaining stock abundance were computed for each brood year using the following steps:

1. The initial cohort sizes, survival rate indices, base period exploitation rates, and base period maturation rates were obtained from the CTC chinook model.

2. A simple model was constructed which computed the natural and fishing mortality, the age specific escapement, and the production resulting from the escapement.

3. The fishing mortality was scaled until the production computed in Step 2) was equal to the initial cohort size in Step 1).

4. The exploitation rate associated with stock replacement was computed as simply the ratio of AEQ fishing mortality to AEQ fishing mortality plus escapement.

The average stock replacement exploitation rate was computed for the same three year intervals as for the MSY ERs. However, 1988 (or 1987 for Skagit) was the last brood year for which the stock replacement exploitation rate could be computed because the procedure requires estimates of brood survival rates in the subsequent cycle. For example, the estimates for the 1988 brood requires estimates of the survival rates for the cohort resulting from age-3 fish spawning in 1991, age-4 fish spawning in 1992, and age-5 fish spawning in 1993.

5.1.4.2 Distribution of AEQ Mortality

The greatest proportion of AEQ fishing mortality of these stocks occurs primarily in Canadian fisheries, with the proportion ranging from 53% for the Snohomish summer/fall stock to 73% for the Skagit summer/fall stock. Puget Sound sport and net fisheries are the second largest source of mortality. In total, these fisheries comprise approximately 25% of the AEQ of the Skagit and Stillaquamish stocks, and 45% of the total AEQ mortality for the Snohomish stock. The Council fisheries are estimated to comprise less than 1% of the total AEQ mortality of each of these stocks.

5.1.4.3 Potential Escapement

Skagit Summer/Fall

The potential escapement for the Skagit summer/fall stock for both the total and southern U.S. was less than the escapement goal in the years 1992-1994 (Figure 5-1). The potential escapement has generally been declining since 1979, with the smallest value for both the total and U.S. potential escapement occurring in 1994.

Stillaguamish Summer/Fall

The potential escapement for the Stillaguamish summer/fall was also generally less than the escapement goal in the years 1992-1994 (Figure 5-2). The only exception was 1992, when the total potential escapement slightly exceeded the escapement goal. Unlike the Skagit summer/fall stock, no trend in the potential escapement is evident for the years 1979-1995. However, the potential escapement for the southern U.S. exceeded the escapement goals in only three years during this entire period.

Snohomish Summer/Fall

The potential escapement for the Snohomish summer/fall stock has declined in each year since 1979 (Figure 5-3). Although the southern U.S. potential escapement exceeded the goal in each year from 1979-1995, it has declined by approximately 70% (15,000 fish relative to a goal of 5,250) during this period.

5.1.4.4 Exploitation Rates

Skagit Summer/Fall

MSY ERs for the Skagit summer/fall stock have decreased from near 70% for the 1974-1976 broods to less than 20% for the 1989-1991 broods (Figure 5-4). As MSY ERs declined, the exploitation rates declined as well, but not as rapidly. Total AEQ exploitation rates were approximately twice as large as the MSY ERs for the 1989-1991 broods.

As could be anticipated from the graphs of potential escapement, the total AEQ exploitation rates exceeded the allowable rates for stock replacement in three out of the four intervals from 1977-1988 (Figure 5-5). For the 1986-1988 interval, the total AEQ exploitation rate exceeded the replacement rate by 32 percentage points (total AEQ exploitation rate of 0.39 versus a stock replacement rate of 0.07). For that time period, even the AEQ exploitation rate in southern fisheries exceeded the stock replacement rate by 9 percentage points.

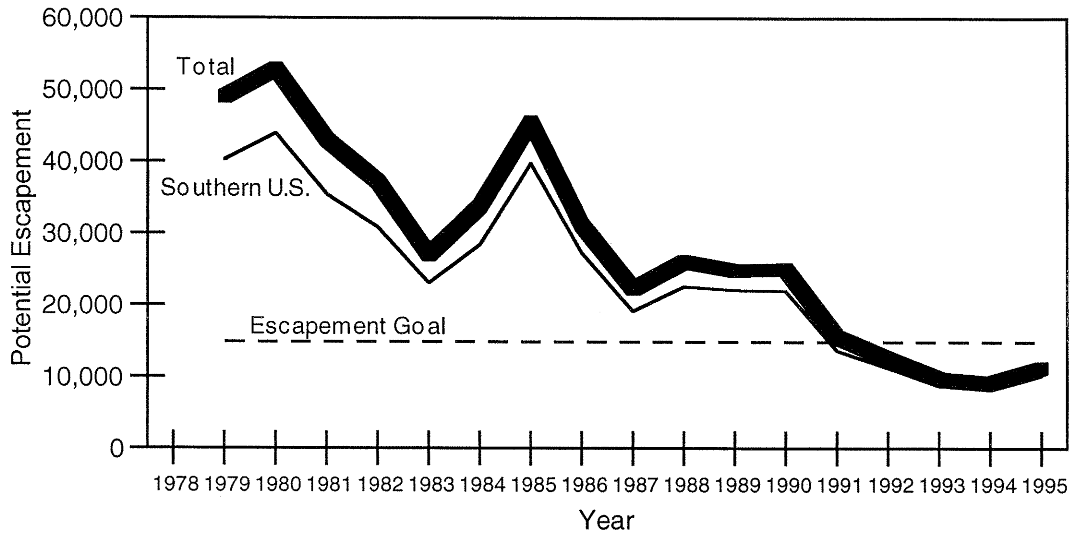

FIGURE 5-1. Potential escapement of Skagit Summer/fall chinook.

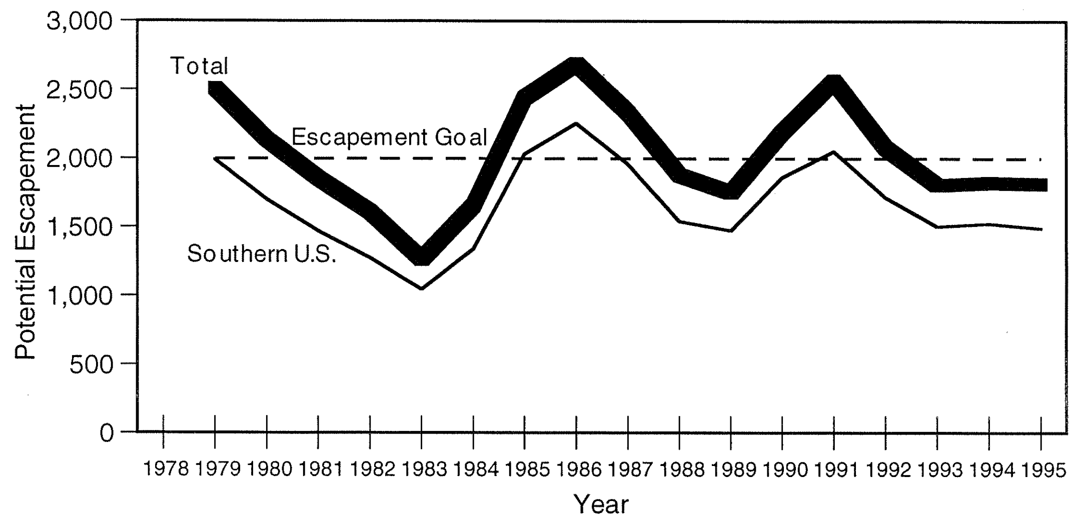

FIGURE 5-2. Potential escapement of Stillaguamish Summer/fall chinook.

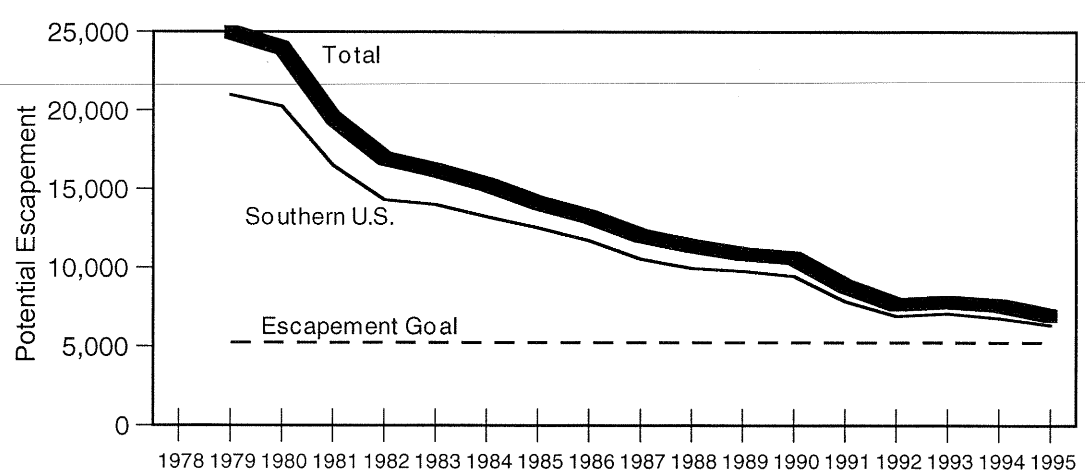

FIGURE 5-3. Potential escapement of Snohomish Summer/fall chinook.

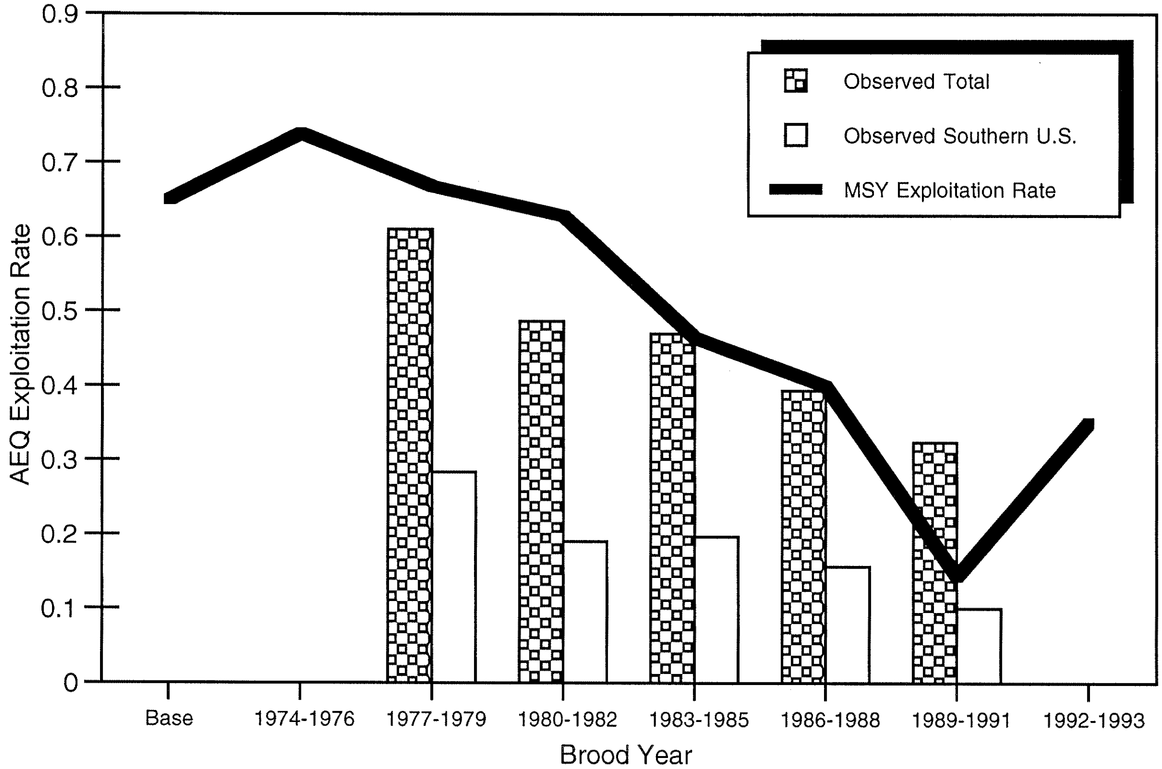

FIGURE 5-4. The AEQ and MSY exploitation rates for Skagit summer/fall chinook.

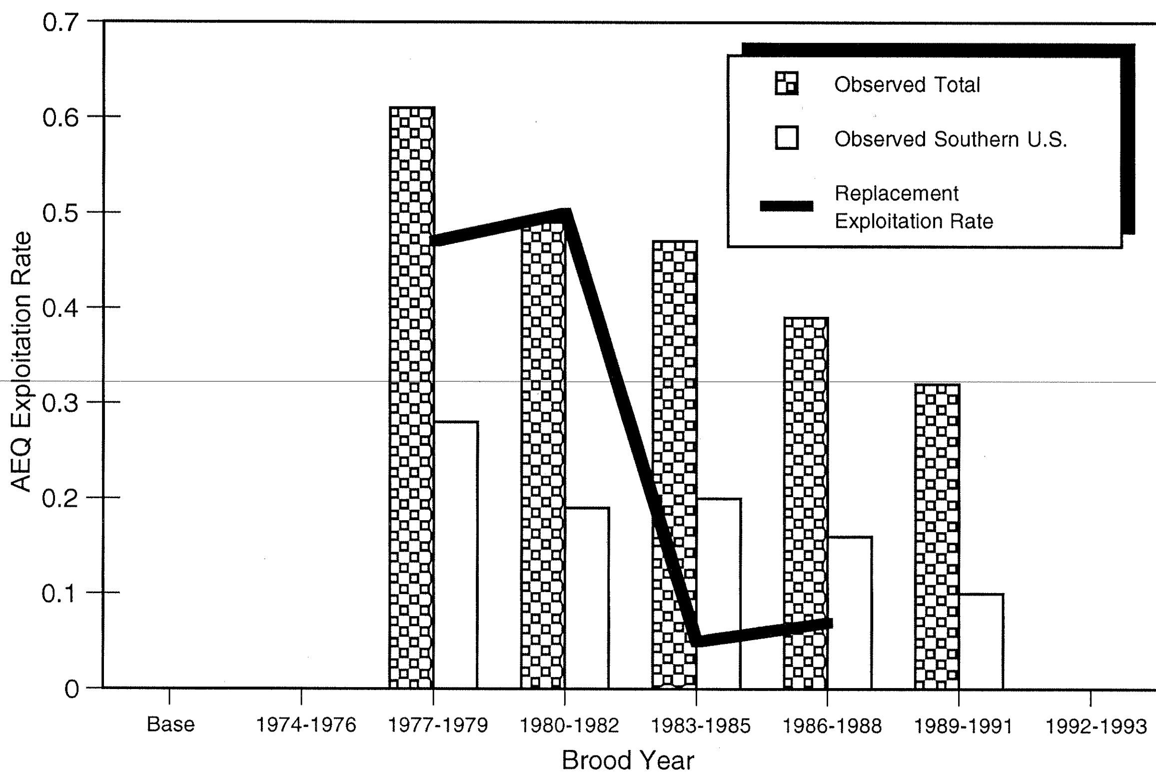

FIGURE 5-5. The AEQ and stock replacement exploitation rates for Skagit summer/fall chinook.

Stillaguamish Summer/Fall

MSY ERs for the Stillaguamish summer/fall stock exhibit a decline which is similar to that observed for the Skagit summer/fall stock (Figure 5-6). MSY ERs for the 1974-1976 broods were approximately 60%. By the 1991-1993 broods, the MSY ER had declined to less than 10%. The total AEQ exploitation rates for all fisheries exceeded the MSY ER in every year, and even the AEQ exploitation rate for the southern U.S. exceeded the MSY ER for the 1986-1988 and 1989-1991 intervals.

Total AEQ exploitation rates have exceeded the stock replacement rates in three of the four intervals from 1977-1988 (Figure 5-7). The difference has been relatively small, and was 9 percentage points for the most recent time interval (1986-1988) with complete data. The AEQ exploitation rates in the southern U.S. fisheries were less than the stock replacement rate in every interval.

Snohomish Summer/Fall

The MSY ERs for the Snohomish summer/fall stock have also declined, but not to the extent estimated for the previous two stocks (Figure 5-8). MSY ERs ranged from approximately 80% for the 1974-1976 broods, to approximately 50% for the 1989-1991 brood year interval. The estimated total AEQ exploitation rates have exceeded the MSY ERs in four of the five intervals, but the AEQ exploitation rate in the southern U.S. was less than the MSY ER in every interval.

Consistent with the progressive decline in potential escapements, total exploitation rates have exceeded the replacement exploitation rate in each of the four intervals from 1977-1988 (Figure 5-9). The difference has ranged from 15 percentage points for the 1980-1982 interval to 18 percentage points for the 1983-1985 interval.

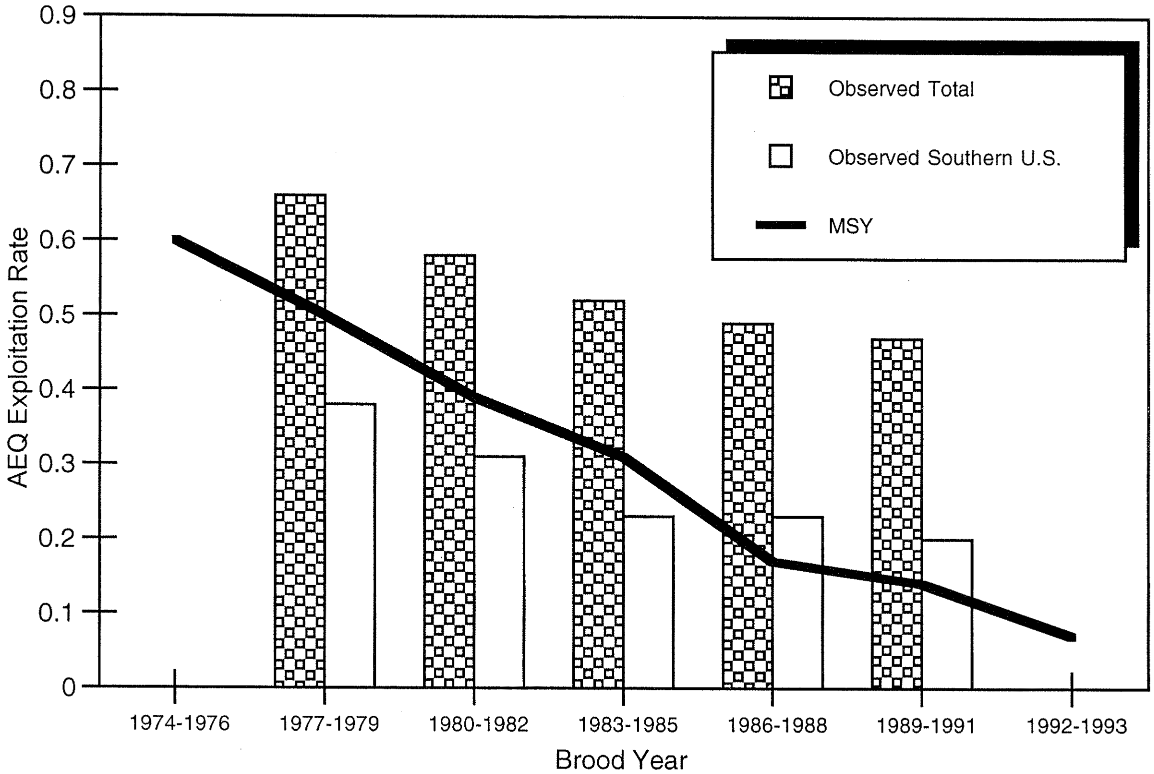

FIGURE 5-6. The AEQ and MSY exploitation rates for **Stillaguamish summer/fall chinook**.

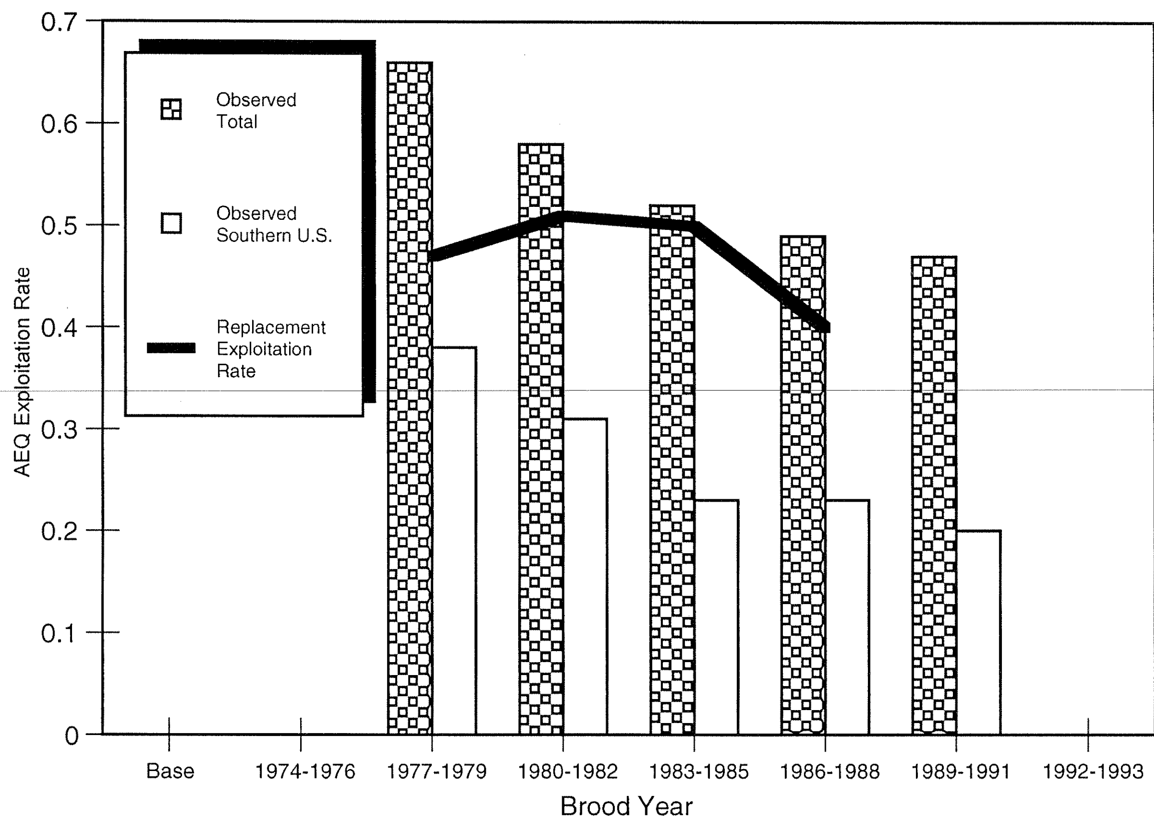

FIGURE 5-7. The AEQ and stock replacement exploitation rates for **Stillaguamish summer/fall chinook**.

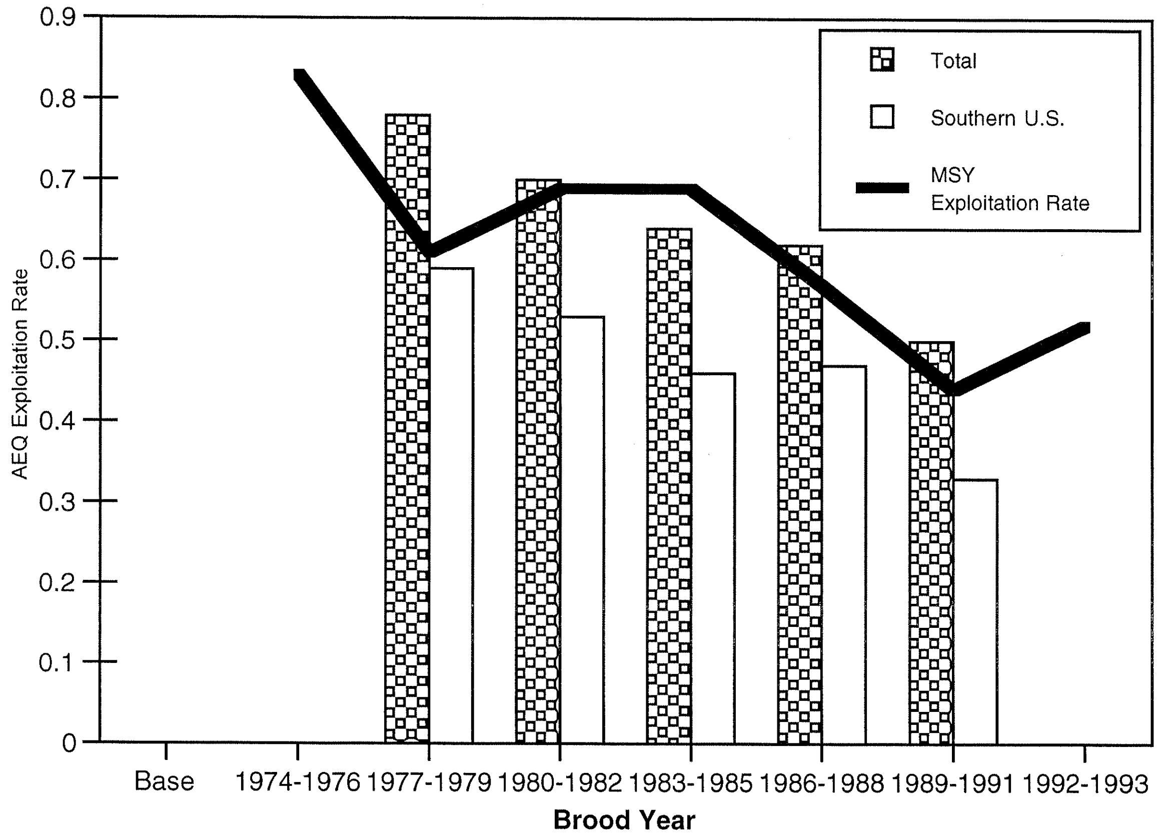

FIGURE 5-8. The AEQ and MSY exploitation rates for **Snohomish summer/fall chinook**.

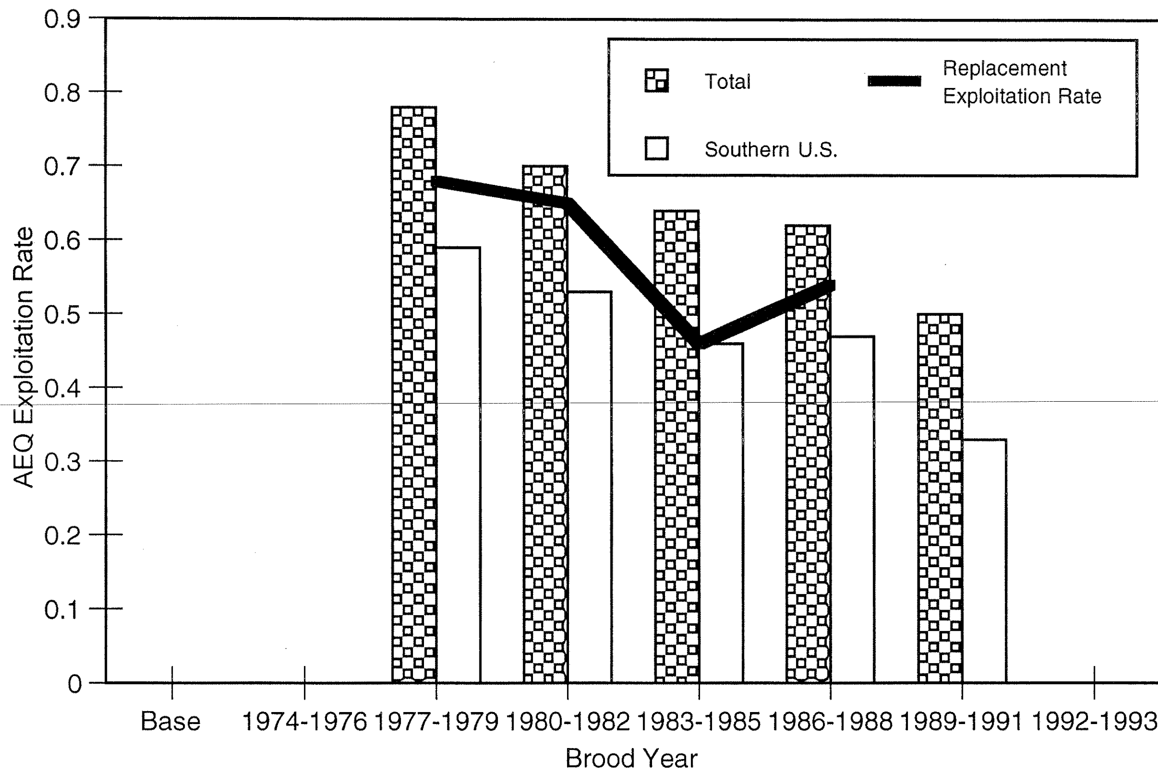

FIGURE 5-9. The AEQ and stock replacement exploitation rates for **Snohomish summer/fall chinook**.

5.2 STRAIT OF JUAN DE FUCA COHO SALMON ASSESSMENT

5.2.1 Forecasts

Preseason forecasts of abundance provide a framework to formulate initial harvest schedules prior to obtaining inseason estimates of run size. However, in the case of Strait of Juan de Fuca (SJF) wild coho, no independent run size forecast had been formulated before 1996. No inseason estimates of abundance have been made for runs in this region managed for wild stock escapement goals. Of the two runs managed for hatchery-based harvest and escapements, the Dungeness has been updated throughout each season since 1980, while for the Elwha, inseason estimates were attempted and found to be unreliable during the early 1980s.

Prior to 1996, preseason forecasts of SJF wild coho used a historical correlation between summer instream low flows and the Puget Sound run size component available to net fisheries and spawning escapement two years later. The total wild Puget Sound run size was subsequently apportioned to regions and individual river systems within regions, usually on the basis of the estimated distribution of the parent brood. Assumptions in this forecasting method included a relatively constant recruitment per spawner, across regions, and a relatively constant exploitation rate by intercepting troll, sport and foreign fisheries across regions and years. More recently, as both assumptions became less reliable, independently estimated forecasts were sought for each Puget Sound region. When independent estimates for some regions became available, those estimates were subtracted from the Puget Sound total, and the remainder was apportioned to the remaining regions and river systems. In 1992, that remainder consisted of the Nooksack/Samish, South Puget Sound and the SJF regions. In 1993 and 1994, the remainder consisted of the Nooksack/Samish and SJF. Before 1994, the regional forecast did not include the forecasted abundance for Chimacum Creek, which was reported separately as "Area 9 Independents". The forecast, thus assigned to the SJF, was further apportioned between the Dungeness, Elwha, and miscellaneous streams (Point No Point Treaty Council *et al.* 1995). For preseason simulation modelling purposes, the regional forecast was expanded, using a fixed rate, to provide a forecast of December age-2 recruitment usable by the Coho Assessment Model (CAM) and currently by the Fishery Regulation and Assessment Model (FRAM).

5.2.2 Escapement

5.2.2.1 Historical Escapement Estimates

Annual spawning escapements of wild coho salmon, in streams along the SJF have been estimated in three separate segments. These segments are subsequently summed to produce an estimate of the total escapement. The three segments are: eastern SJF (streams from Point Wilson westward, including the Elwha River); western SJF (streams west of the Elwha River to Cape Flattery) and Chimacum Creek (draining into Port Townsend Bay). Chimacum Creek was included in this region only recently and therefore is still listed separately under Area 9 Independents in various agency summaries. The methods used to estimate spawning escapements are summarized below.

Table 5-2 summarizes the historical escapement estimates for wild coho in the western and eastern SJF streams managed for wild stock escapement goals (excluding Elwha River and Dungeness River which are managed for hatchery harvests and escapements).

TABLE 5-2. Expected and observed escapements of naturally spawning primary coho salmon (except Chimacum Creek) in SJF streams.[a/]

Year	Expected Management Target	Observed	Goal
1980	7,300	9,400	7,050
1981	7,300	3,700	7,050
1982	9,500	10,100	7,050
1983	6,350	2,800	11,900
1984	9,875	4,000	11,900
1985	8,700	1,800	11,900
1986	4,800	8,600	11,900
1987	5,400	4,400	11,900
1988	5,629	3,500	11,900
1989	4,109	6,000	11,900
1990	3,817	2,800	11,900
1991	4,872	3,300	11,900
1992	5,387	5,700	11,900
1993	3,637	3,100	11,900
1994	5,388	2,500	11,900
1995	2,845	5,400	11,900
1996	2,085	NA	11,900

a/ Does not include the Elwha and Dungeness Rivers.

5.2.2.2 Escapement Estimation Methods

Escapements of coho salmon into natural spawning areas along the SJF have been estimated from 1965 to the present, using a variety of data sources and methods. However, unlike other Puget Sound regions, no base year spawning escapement level was established for SJF streams until 1980. Between 1965 and 1978, wild coho escapement estimates for SJF streams were estimated using escapement surveys from both inside and outside the area, or using rack estimates and other data (Zillges 1977). The overall estimation method approach generally relies on a comparison of a measured index quantity (live spawners, total fish seen, number of redds, etc) with the same measurement taken in a year when the total escapement is also assumed to be known:

$$\frac{Total\ a\ in\ Year\ i}{Total\ a\ in\ Base\ Year} \times Base\ Year\ Escapement = Escapement\ in\ Year\ i$$

Where, for SJF, **a** has been fish days, cumulative redd counts, peak live counts, weir counts, or weir counts times ten. Index areas are provided in Table 5-3.

The current Puget Sound escapement database was established using 1965 as the "base year". That year was chosen because of relatively high numbers of spawners. The total escapements were then estimated using all available instream information, peak spawner counts in index reaches and what can be best described as a "best guess". However, since inadequate survey data were available for the SJF, it was estimated that the escapement in 1965 was approximately one-half the escapement goal. In subsequent years, the availability of additional information enabled the agencies to establish a base year for this region. The estimation approach for each of the three portions of the SJF region is described in the next three subsections.

TABLE 5-3. SJF wild coho escapement indices.

WRIA Stream No.	Stream Name	Index R.M.
Eastern Strait		
17-0285	Jimmycomelately Creek	0.0-1.5
18-0160	McDonald Creek #1	1.7-3.1
18-0160	McDonald Creek #2	3.1-4.4
18-0173	Siebert Creek #1	0.9-2.4
18-0173	Siebert Creek #2	2.4-4.2
Western Strait		
19-0007	Salt Creek	5.6-6.4
19-0014	Unnamed (Salt Creek tributary)	0.0-0.8
19-0115	South Fork Pysht River #1	5.7-6.6
19-0148	Hoko River #2	20.8-22.5

Eastern Strait of Juan de Fuca

The 1980 escapement into the eastern Strait streams was used to establish a "base year". In that year, it was assumed that the spawning escapement equalled that of 1965 (5,000 fish). Base year information collected included index live-counts at Jimmycomelately Creek, and spawner enumeration at research weirs on Snow Creek and Salmon Creek, as well as redd counts. Escapement estimates obtained from these indices were apportioned to individual streams along the eastern SJF on the basis of the escapement goal proportion attributable to each stream. In subsequent years, one or more of these index measurements were used to obtain escapement estimates. For years prior to 1980, the 1980 base year was applied to the 1978 and 1979 escapements. A summary of the methods used each year is listed in Table 5-4.

Western Strait of Juan de Fuca

Prior to 1980, no direct "base year" estimate was available for escapements into the western SJF streams. In that year, escapement was arbitrarily assumed to be approximately 3,000 coho. In that year, both spawner counts and cumulative redd counts in index areas were examined. Since water conditions often preclude consistent spawner estimation, redd counts have emerged as the primary tool in this area. A summary of the methods used each year is listed in Table 5-4.

Chimacum Creek

In Chimacum Creek, escapement estimates are currently obtained using cumulative redd counts which are then compared to those of 1986 (the base year). In that year, escapement was estimated to be 1,081.

5.2.2.3 Escapement Goals and Management Targets

Escapement goals for SJF naturally spawning coho salmon were initially described in Zillges (1977). Those goals were used through 1982. They were modified by the U.S. District Court's Fisheries Advisory Board (FAB) in 1983 (FAB 83-39). The current escapement goals for the individual streams draining into the SJF are outlined in Table 5-5. Of these, the Elwha and Dungeness are classified under the Puget Sound Salmon Management Plan (PSSMP) as "secondary", meaning that the actual escapement targets are controlled annually by the harvest rate(s) necessary to achieve the full harvest of commingled hatchery stocks returning to these rivers. Therefore, for practical management purposes, only the escapement goals of all other streams, except the Elwha and Dungeness Rivers, are of "primary" concern.

TABLE 5-4. Methods used to estimate wild coho escapements in the SJF, from 1978 to the present.

Escapement Year	Eastern Strait	Western Strait
1978	Snow Crk. weir count[a/]	Cumulative redd counts
1979	Snow Crk. weir count	Cumulative redd counts
1980	Snow Crk. weir count	Cumulative redd counts
1981	Peak live counts[b/]	Ratio of eastern to western Strait[c/]
1982	Number of fish days[d/]	Number of fish days[e/]
1983	Snow Crk. weir count	Avg. of fish days, redd counts and peak live count methods[f/]
1984	Snow Crk. weir count	Avg. of fish days, redd counts and peak live count method results[f/]
1985	Best guess[g/]	Cumulative redd counts
1986	Snow Crk. weir count	Cumulative redd counts
1987	Avg. of peak live and weir count method results[h/]	Cumulative redd counts
1988	Cumulative redd counts	Cumulative redd counts
1989	Number of fish days[d/]	Cumulative redd counts
1990	Snow Crk. weir count	Cumulative redd counts
1991	Cumulative redd counts	Cumulative redd counts
1992	Cumulative redd counts	Cumulative redd counts
1993	Cumulative redd counts	Cumulative redd counts
1994	Cumulative redd counts	Cumulative redd counts
1995	Cumulative redd counts	Cumulative redd counts

a/ Snow Creek weir counts were used either in their raw form, or multiplied by ten in "area under the curve" (AUC) calculations.
b/ Peak live counts for Jimmycomelately Creek only.
c/ Estimate based on 1980 ratio of western to eastern Strait.
d/ Number of fish days for Jimmycomelately Creek only.
e/ Number of fish days for Hoko River and Salt Creek only.
f/ Used an average of three methods: number of fish days; cumulative redd counts and peak live counts.
g/ Available survey data was incomplete and weir counts were not available.
h/ Average of two methods: Snow Creek weir counts and peak live counts from Jimmycomelately Creek.

Annual management targets for these primary units, as outlined in joint agency stock status reports, are summarized in Table 5-5. Expected escapements have been used as the management targets each year after the planned harvests in marine areas, minimal inriver recreational fisheries and no inriver net fisheries. The estimated escapements, as indicated in Table 5-2 and Figure 5-10, however, have consistently failed to meet the established escapement goals, and have often failed to meet the preseason escapement expectation (target). From 1983-1994 (after off-station plants of yearling coho salmon were largely discontinued), the estimated escapements met, or exceeded, the preseason target only three times, and reached 70% of the goal only once (see Table 5-2 and Figure 5-10).

It should be noted that from 1977 to the present, no management actions have been undertaken in prior intercepting fisheries for the express purpose of meeting the escapement requirements of naturally spawning "primary" runs of coho salmon in this region. Management actions designed to protect escapements have been limited to a tribal prohibition on instream coho fisheries and WDFW limitations on freshwater recreational fisheries.

TABLE 5-5. Summary of SJF wild coho salmon escapement goals.[a/]

Stream	WDFW Technical Report #28	Fisheries Advisory Board #83-39
Sekiu River	570	900
Hoko River	1,570	2,200
Clallam River	820	1,150
Pysht River	970	1,650
East & West River	510	1,050
Lyre River	180	250
Western Strait Miscellaneous	1,100	2,200
Elwha River (Secondary Unit)	230	250
Dungeness River (Secondary Unit)	1,500	1,750
Eastern Strait Miscellaneous	1,330	2,500
Chimacum Creek	940	950
Subtotal Primary Units	7,990	12,850
Subtotal Secondary Unit	1,730	2,000
Region Total	9,720	14,850

a/ Chimacum Creek and associated small independent streams were (1) initially assigned to the Hood Canal, (2) subsequently assigned to "area 9 Independents" and (3) currently included in the SJF region. All estimates have been adjusted accordingly.

5.2.3 Enhancement

Artificial production of coho salmon for stock enhancement and mitigation purposes in the SJF has been occurring primarily in the Dungeness River system, following the establishment of the Dungeness Hatchery in the early 1900s. More recently, the Elwha Rearing Channel began releasing yearling coho in 1976 (brood 1974) and the Elwha Hatchery (Lower Elwha S'Klallam Tribe) made its first release of yearling coho from the 1977 brood. Prior to 1965, less than a million yearlings were released annually from all sources. From brood year 1977 to the present, the annual yearling release has ranged from 0.5 million to 3.8 million, averaging 1.48 million. Fry and fingerling planting levels have varied dramatically, both in volume and in geographic extent. Release numbers have ranged from 0 to 5.9 million, averaging 1.6 million per year from brood year 1977 to the present (Table 5-6).

The great majority of fingerling and yearling coho releases have been confined to the Dungeness and Elwha River systems, where harvest management is controlled by hatchery-based production and harvest needs (Tables 5-7 and 5-8).

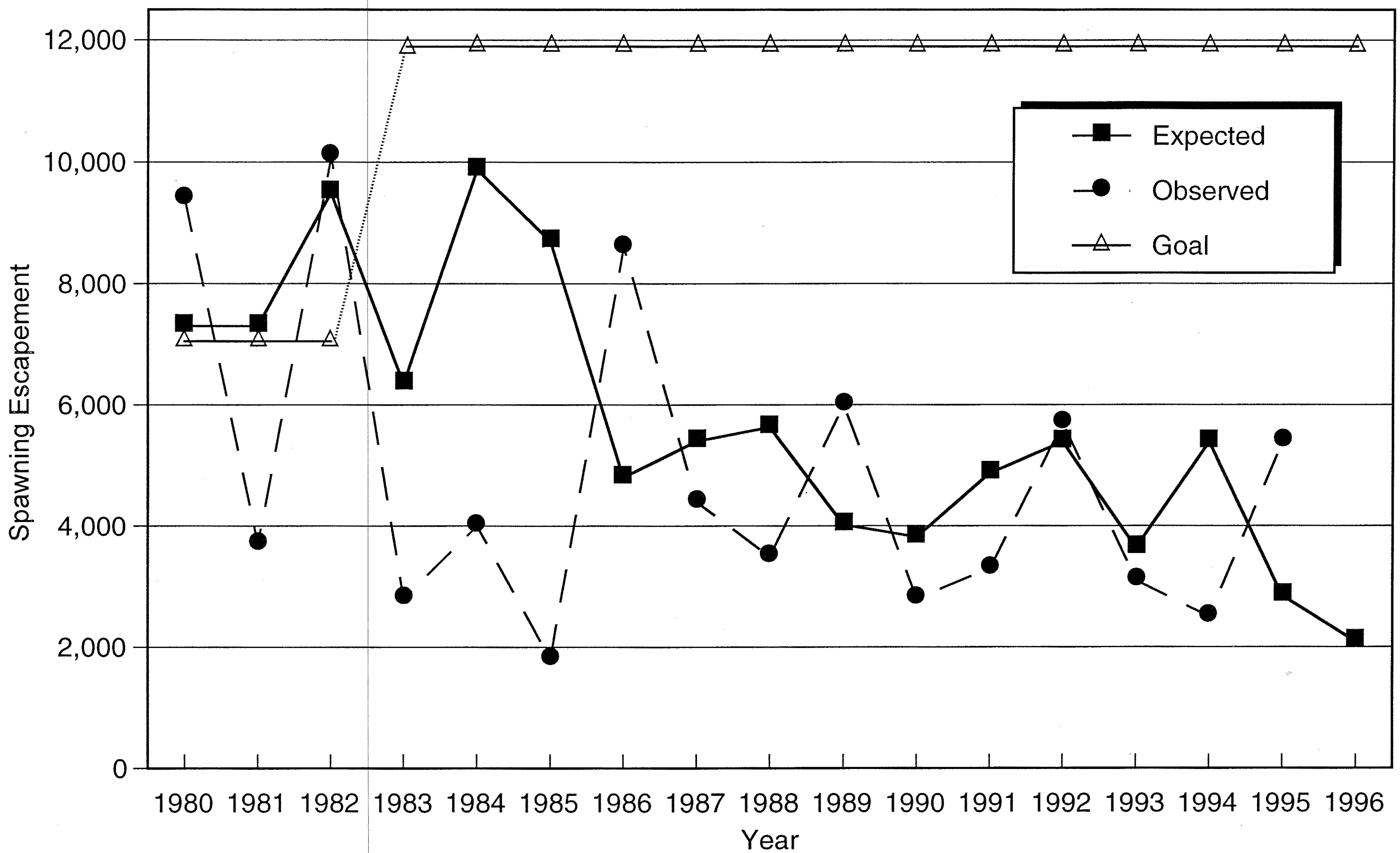

FIGURE 5-10. Expected and observed escapements of naturally spawning coho in SJF streams.

TABLE 5-6. Numbers of fingerling and yearling coho salmon released in the Strait of Juan de Fuca streams.

Brood Year:	1977	1978	1979	1980	1981	1982	1983	1984
Fingerling	1978	1979	1980	1981	1982	1983	1984	1985
Yearling	1979	1980	1981	1982	1983	1984	1985	1986
Return Year:	1980	1981	1982	1983	1984	1985	1986	1987
Fingerlings:	1,807,175	1,304,226	1,261,019	5,334,724	5,852,025	559,908	2,012,328	1,483,700
Yearlings:	1,571,597	2,072,065	3,850,980	3,610,234	597,798	939,010	943,414	1,340,000

Brood Year:	1985	1986	1987	1988	1989	1990	1991	1992
Fingerling	1986	1987	1988	1989	1990	1991	1992	1993
Yearling	1987	1988	1989	1990	1991	1992	1993	1994
Return Year:	1988	1989	1990	1991	1992	1993	1994	1995
Fingerlings:	899,126	1,259,900	747,481	552,034	436,595	356,966	920,350	503,400
Yearlings:	1,679,100	538,515	777,529	1,129,504	988,048	1,189,296	920,000	1,546,718

TABLE 5-7. Numbers of fingerling and yearling coho salmon released in the **Elwha** River.

Brood Year:	1977	1978	1979	1980	1981	1982	1983	1984
Fingerling	1978	1979	1980	1981	1982	1983	1984	1985
Yearling Released:	1979	1980	1981	1982	1983	1984	1985	1986
Return Year:	1980	1981	1982	1983	1984	1985	1986	1987
Fingerlings:	-	-	-	-	590,205	4,282	-	-
Yearlings:	837,809	1,168,705	2,845,149	2,518,302	597,798	751,010	645,41	836,000

Brood Year:	1985	1986	1987	1988	1989	1990	1991	1992
Fingerling	1986	1987	1988	1989	1990	1991	1992	1993
Yearling Released:	1987	1988	1989	1990	1991	1992	1993	1994
Return Year:	1988	1989	1990	1991	1992	1993	1994	1995
Fingerlings:	101,624	151,600	54,433	2,078	208,400	200,539	3,400	180,000
Yearlings:	728,500	212,715	433,479	786,804	691,646	755,621	580,000	866,718

TABLE 5-8. Numbers of fingerling and yearling coho salmon released in the **Dungeness** River.

Brood Year:	1977	1978	1979	1980	1981	1982	1983	1984
Fingerling	1978	1979	1980	1981	1982	1983	1984	1985
Yearling	1979	1980	1981	1982	1983	1984	1985	1986
Return Year:	1980	1981	1982	1983	1984	1985	1986	1987
Fingerlings:	1,563,570	828,261	1,094,725	4,811,724	3,267,620	-	200,000	-
Yearlings:	399,228	709,673	929,413	1,065,932	-	188,000	298,000	320,000

Brood Year:	1985	1986	1987	1988	1989	1990	1991	1992
Fingerling	1986	1987	1988	1989	1990	1991	1992	1993
Yearling	1987	1988	1989	1990	1991	1992	1993	1994
Return Year:	1988	1989	1990	1991	1992	1993	1994	1995
Fingerlings:	-	326,700	-	236,772	16,441	15,200	822,050	323,400
Yearlings:	748,600	320,800	359,050	342,700	296,402	433,675	340,000	680,000

Off-station releases in other SJF streams, where coho populations are managed for specific escapement goals, have been sporadic. In these systems, releases of yearling coho salmon were terminated by 1982 (although a few were released in the Clallam and Hoko rivers in the mid-1980s). Fingerling and fry releases were minor prior to 1982, increased to an average of over 1 million annually from 1982 to 1988, and have decreased to zero by 1994 (Tables 5-9 and 5-10).In addition to instream releases, intermittent releases have been made from marine net pens at Sekiu/Clallam Bay (beginning with brood 1979-1980) and in Port Angeles Harbor (beginning with brood 1985). All of these programs have relied primarily on local stocks, but there have been imports from numerous Puget Sound hatcheries as well as coastal and lower Columbia River hatcheries.

Coho enhancement has probably been less effective in the SJF than in other Puget Sound areas. Survival rates of on-station yearling releases have been very low. The average survival to landed catch and escapement for Dungeness Hatchery yearling releases has been 50% lower than the average for George Adams yearling releases. Survival from the Elwha Hatchery averages about 40% lower than that of Dungeness Hatchery. Since off-station releases experience substantially lower survival rates than on-station releases, the probable contribution of the off-station program has been low. Over the past 15 years, instream releases of coho salmon have been either ineffective (fry-fingerling), or have had no lasting effect on rebuilding (yearling). This conclusion is based on our review of the planting records and subsequent returns. Additionally, evidence from neighboring coastal systems indicates that fry-fingerling releases may be simply displacing native coho fry (Haymes and Tierney 1996).

5.2.4 Estimated Abundance and Harvest

5.2.4.1 Population Components

Wild coho salmon from streams along the SJF have been accounted by a number of different methods. In years prior to 1994, abundance estimates included all naturally spawned coho salmon, except those in Chimacum Creek. From 1994 on, coho salmon in Chimacum Creek have been included in the SJF totals.

During preseason modelling exercises in all years, wild coho salmon from the Elwha and Dungeness Rivers have been included in the total, despite the fact that these two populations are managed as "secondary", and therefore are subjected to hatchery-based rates of exploitation in the extreme terminal areas. This approach can result in a biased view of the planned and actual rates of exploitation for SJF wild coho managed to meet specific escapement goals.

To provide a comparison with preseason modelled estimates of abundance, the 1992-1994 returning cohorts of wild coho salmon were reconstructed initially to include all wild coho and were compared to the preseason estimates in Table 5-11. However, to focus on the wild stocks managed for specific escapement goals, which excludes the Dungeness and Elwha, Table 5-12 was constructed and used as the basis for all further review and analysis.

5.2.4.2 Cohort Reconstruction Results

The survival and contributions of the 1989, 1990 and 1991 broods (return years 1992-1994) were reconstructed using available coded-wire tag information and cohort reconstruction techniques outlined elsewhere in this report. In Table 5-11, the cohort-reconstructed estimates of wild coho abundance (all SJF stocks) are noted as "postseason", and are compared with the preseason estimates, based on the final preseason CAM/FRAM model runs reflecting the Council's adopted plans.

The information in Table 5-11 is particularly useful in that it reveals a consistent positive bias in the preseason forecasts for this region. The catch-plus-escapement forecast, in the three years examined, was 150.6%, 240.1% and 279.1% of the cohort-reconstructed return. The effect of this bias is to indicate to fishery planners that the stocks may be healthier than they actually are.

TABLE 5-9. Numbers of fry and fingerling coho salmon released in SJF streams (other than Elwha and Dungeness Rivers).

Brood Year:	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	
Release Year:	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Average
Return Year:	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Level a/
Chimacum Creek	243,605	216,660	166,294	129,700	233,000	89,126	234,000	114,800	63,700	310,000	322,448	113,800	146,981	91,000	44,400		167,968
Jimmycomelately Creek					54,000	28,200	39,000	31,400									38,150
Misc. 6B creeks											35,000	43,020	50,892	34,800	35,200		39,782
McDonald Creek					124,000		12,200	101,100	80,200	130,600		78,582					87,780
Siebert Creek					179,400		90,000	100,400	79,300	131,000		77,782					109,647
Bagley Creek					24,700		33,000			20,000							25,900
Morse Creek							88,000	149,700		24,200							87,300
Port Angeles creeks								19,900	19,900				13,881	15,427	15,300		16,882
Coville Creek					30,900	32,000	19,900	21,600	20,000								24,880
Salt Creek					60,000												60,000
Whiskey Creek					59,800	29,000	19,900	21,600	20,000								30,060
Field Creek					30,400	30,500	20,500	21,600	20,000								23,833
Lyre River					31,500	30,000	21,000	21,600	20,200								24,860
E&W Twin Rivers					139,200	134,400	132,200	52,600	50,100								101,700
Deep Creek						85,800	147,700	101,200									111,567
Jim Creek					4,800	21,000	11,400	10,100	10,800								11,620
Pysht River		150,150			223,500	75,600	182,300	257,400	81,900								161,808
Clallam River				393,300	97,400		94,800										195,167
Hoko River					349,300		231,800	188,700	152,700	145,800	131,564						199,977
Sekiu River		109,155			352,300		118,000		127,300								176,689
Sail Creek							195,572	230,000	17,134		154,661						149,342
Neah Bay creeks							121,056	40,000	34,268		49,375						61,175
Annual Totals:	243,605	475,965	166,294	523,000	1,994,20	555,626	1,812,32	1,483,70	797,502	781,600	693,048	313,184	211,754	141,227	94,900		685,862

a/ Averages are for years in which releases were made.

TABLE 5-10. Numbers of yearling coho salmon released in SJF streams (other than Elwha and Dungeness Rivers).

Brood Year:	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	
Release Year:	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	Average Level[a/]
Return Year:	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	
Chimacum	21,270	82,696	15,399														39,788
McDonald Creek	24,976	19,965	15,594														20,178
Siebert Creek	19,969	19,965															19,967
Morse Creek	24,745	37,059	15,525														25,776
Clallam River	243,600	34,002	29,900	26,000					5,000	5,000	5,000						49,786
Hoko River								184,000	197,000								190,500
Annual Totals:	334,560	193,687	76,418	26,000				184,000	202,000	5,000	5,000						128,333

a/ Averages are for years in which releases were made.

TABLE 5-11. Comparison of preseason and post-season estimates of Strait of Juan de Fuca runs of wild (primary and secondary) coho salmon abundance.

	1992			1993			1994		
	Preseason	Post-season	Pre-Post	Preseason	Post-season	Pre-Post	Preseason	Post-season	Pre-Post
Parent Escapement		7,800			4,200			4,500	
Total Recruits (DEC-2)		25,478			12,054			9,871	
Natural Mortality		6,105			2,850			2,384	
Non-landed (NL) Mortality		594			269			186	
North Central British Columbia	404	946	-542	292	0	292	299	20	279
West Coast Vancouver Island	12,598	7,460	5,138	9,154	3,232	5,922	11,144	3,148	7,996
Georgia Strait	387	240	147	233	0	233	442	0	442
Juan de Fuca Strait	1,142	442	700	1,601	0	1,601	1,234	364	870
Southeast Alaska	8	919	-911	8	0	8	8	0	8
North of Falcon Troll	959	390	569	1,534	534	1,000	29	0	29
North of Falcon Recreational	580	70	510	505	832	-327	0	10	-10
South of Falcon	183	92	91	45	0	45	5	0	5
Puget Sound Troll	22	26	-4	72	0	72	13	0	13
Strait of Juan de Fuca Recreational	692	335	357	1,113	709	404	19	0	19
Puget Sound Marine Recreational	34	115	-81	60	0	60	24	0	24
Freshwater Recreational	0	27	-27	174	35	139	14	50	-36
Strait of Juan de Fuca Net	350	757	-407	662	0	662	314	592	-278
San Juan Island Net	82	0	82	219	0	219	57	0	57
Puget Sound Marine Net	685	233	452	743	0	743	216	17	199
Terminal area net	2,833	277	2,556	1,700	53	1,647	524	250	274
Spawning Escapement	6,243	6,450	-207	3,987	3,540	447	6,553	2,850	3,703
Escapement Goal	14,850	14,850	0	14,850	14,850	0	14,850	14,850	0
Catch plus Escapement (w/o NL)	27,202	18,779	8,423	22,101	8,935	13,166	20,895	7,301	13,594
Estimated Harvest Rate (w/o NL)	77.05%	65.65%		81.96%	60.38%		68.64%	60.96%	

TABLE 5-12. Postseason reconstruction of Strait of Juan de Fuca primary runs of wild coho salmon. [a/]

	1992			1993			1994		
	Number of Fish	Exploitation Rate	Harvest Ppn	Number of Fish	Exploitation Rate	Harvest Ppn	Number of Fish	Exploitation Rate	Harvest Ppn
Parent Escapement	7,200			3,700			3,700		
Total Recruits (DEC-2)	23,109			11,103			7,841		
Natural Mortality	5,537			2,625			1,894		
Non-landed (NL) Mortality	540			250			148		
North Central British Columbia	860			0			16		
West Coast Vancouver Island	6,782			3,001			2,502		
Georgia Strait	218			0			0		
Juan de Fuca Strait	402			0			289		
Canada Subtotal (incl. NL)	8,670	0.4934	0.7558	3,154	0.3720	0.6090	2,933	0.4932	0.8509
Southeast Alaska	835			0			0		
North of Falcon Troll	355			496			0		
North of Falcon Recreational	64			773			8		
South of Falcon	84			0			0		
U.S. Ocean Subtotal (Incl. NL)	1,403	0.0799	0.1223	1,333	0.1572	0.2574	8	0.0014	0.0024
Puget Sound Troll	24			0			0		
Strait of Juan de Fuca Recreational	305			658			0		
Puget Sound Marine Recreational	105			0			0		
Freshwater Recreational	0			0			0		
Puget Sound Recreational/Troll Subtotal (Incl. NL)	454	0.0258	0.0396	692	0.0816	0.1336	0	0.0000	0.0000
Strait of Juan de Fuca Net	688			0			471		
San Juan Island Net	0			0			0		
Puget Sound Marine Net	212			0			14		
Terminal area net	0			0			0		
Puget Sound Net Subtotal (Incl. NL)	944	0.0537	0.0823	0	0.0000	0.0000	506	0.0850	0.1467
Total Exploitation (Incl. NL)	11,472	0.6529		5,178	0.6108		3,447	0.5796	
Spawning Escapement	6,100	0.3471		3,300	0.3892		2,500	0.4204	
Escapement Goal	12,850			12,850			12,850		
Catch plus Escapement (Incl. NL)	17,572			8,478			5,947		
Catch plus Escapement (w/o NL)	17,032			8,228			5,799		
Estimated Harvest rate (w/o NL)	0.6418			0.5989			0.5689		

a/ Information in this table pertains only to runs managed for wild stock escapement goals (i.e., all stocks except Dungeness and Elwha).

Information from cohort reconstruction, with that used during the preseason planning processes, has also revealed another source of bias in the forecasts. As Table 5-13 indicates, the positive bias in the forecasts may be exacerbated by the higher degree of over-prediction found in the hatchery forecasts.

TABLE 5-13. Wild stock proportion of SJF runs of coho salmon.

Estimate	1992	1993	1994
Preseason Estimate	33.3%	29.9%	36.9%
Postseason Estimate	53.5%	45.8%	45.9%

The simulation models used during the North of Cape Falcon preseason process are only capable of providing region-wide estimates of stock impact, which are then apportioned to wild and hatchery impacts on the basis of a fixed preseason ratio of relative abundance. A bias in this ratio, of the magnitude shown in Table 5-13, would serve to underestimate the absolute impact to wild stocks from any fishery scenario examined.

5.2.4.3 Methods Used in Cohort Reconstruction

Choice of Tag Codes

No tagged natural stocks are available for cohort reconstruction of SJF natural coho for 1992-1994. The hatchery tag codes that represent SJF production, excluding net pen tag codes, are:

Return Year	Elwha Hatchery Codes	Dungeness Hatchery Codes
1992	211858	634316-17
1993	212047	None
1994	212220	634821-22

Estimation of Production Expansion Factors

The preferred production expansion factor (PEF) calculation includes the number of recoveries of the indicator codes in the terminal fisheries and the escapement in the denominator, and the run reconstruction estimate of the SJF natural coho terminal run size in the numerator. This approach was used with a corrected estimate of the actual number of recoveries of Elwha tags in the Elwha River fishery, since the actual number of recoveries was too small to account for the hatchery origin proportion of the run. The highest percentage that could be accounted for was 66.7% in 1992. The other two years were much lower. The corrected Elwha estimate uses the tag ratio at release and the run reconstruction estimate of the in-river catch of hatchery fish to yield the following recommended PEFs.

Year	Recommended PEF
1992	18.33
1993	87.59
1994	9.78

Cohort Reconstruction

The catch of SJF natural coho in pre-terminal fisheries is estimated as:

Expanded Indicator Tag Recoveries x PEF

The catch in terminal fisheries is estimated as the run reconstruction estimate of net catch of natural stocks. The freshwater sport fishery catch is estimated using proportional abundance assumptions.

	Primary and Secondary		
Year	Terminal Net Catch	Freshwater Sport Catch	Escapement
1992	277	27	6,450
1993	39	55	3,540
1994	250	Not Available, (assumed to be 50)	2,850

Comparison with Preseason FRAM/CAM Estimates of Impacts

The attached table compares the postseason cohort reconstruction estimates of fishery impacts with the preseason estimates. All of the preseason estimates are from the CAM/FRAM final runs, except that the terminal net fishery estimates are from the status reports.

In all three years, the postseason impacts were lower than the preseason estimates in all three of the major fishery groups: Canada/Alaska, U.S. ocean and Puget Sound. It is apparent that the forecasting method used in 1992-1994 is consistently overestimating the abundance of SJF natural coho if the following assumptions are correct:

- Tagged hatchery fish are accurate indicators of fishery impacts on natural stocks.
- Natural escapement estimates and run reconstruction estimates of natural stock impacts in the terminal net fisheries are accurate.
- The "corrected" estimates of Elwha hatchery tag recoveries in the Elwha River net fishery are accurate.

5.2.4.4 Exploitation Rates and Fishery Contributions

The postseason reconstruction of the "primary" wild coho runs to the SJF, shown in Table 5-12, indicates that in 1992, 1993 and 1994, the exploitation rates experienced by these stocks were 65.3%, 61.1%, and 58.0% respectively.

Table 5-12 and Figures 5-11 through 5-13 indicate that the highest proportional contribution from these stocks, in all years, accrued to Canadian fisheries, approaching a level of 50% of the total population available for harvest and escapement. However, in 1993, "savings" from an apparent reduction in Canadian harvest impact was fully made up by increased exploitation in the North-of-Cape-Falcon troll and sport fishery, resulting in an annual exploitation rate which was nearly the same as that of 1992. In 1994, when the Canadian exploitation rate matched 1992, marginally lower exploitation rates were achieved through a nearly complete closure of Washington coho fisheries. In that year, the Washington exploitation rate on these stocks amounted to only 8.6%.

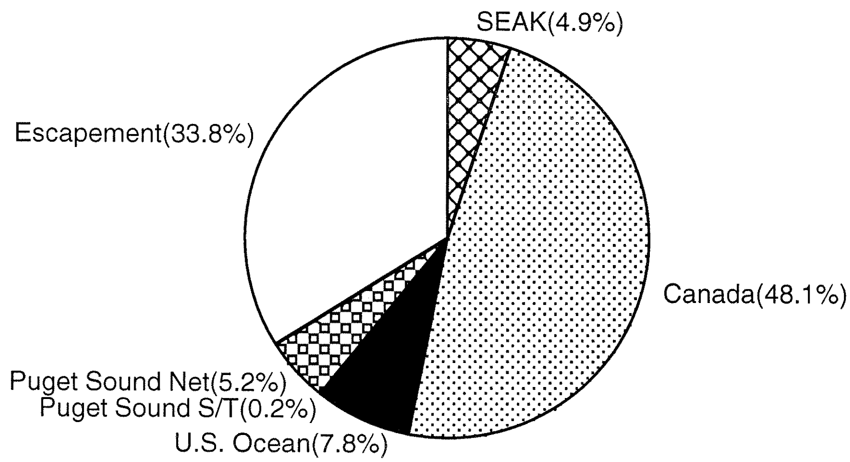

FIGURE 5-11. Strait of Juan de Fuca wild coho salmon contributions in the **1992** run year.

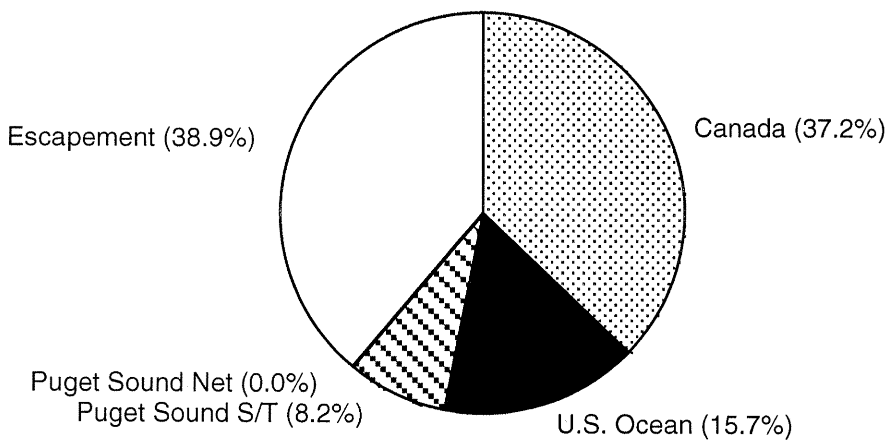

FIGURE 5-12. Strait of Juan de Fuca wild coho salmon contributions in the **1993** run year.

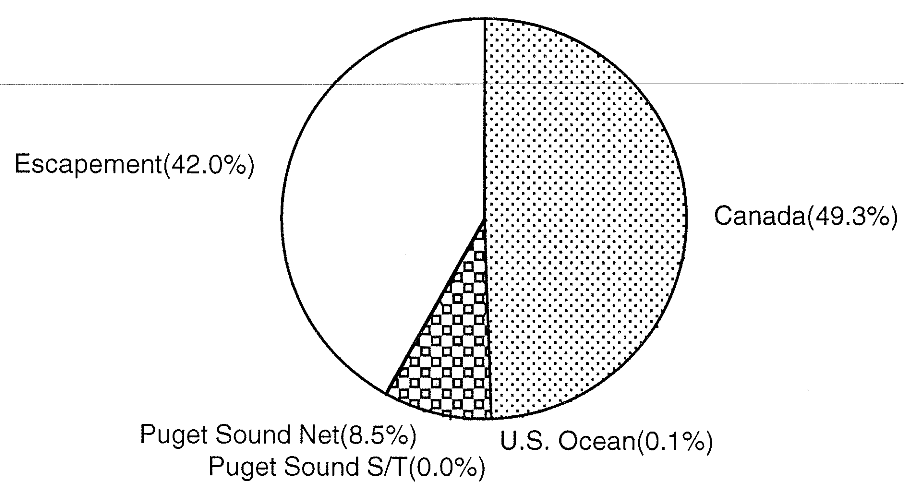

FIGURE 5-13. Strait of Juan de Fuca wild coho salmon contributions in the **1994** run year.

In Puget Sound, these stocks contribute to the nontreaty marine recreational fisheries, and the nontreaty, and treaty Indian net fisheries. The most significant net fishery contributions (as indicated by available data) occurred in the SJF during fisheries directed at other species (sockeye, pink and chum salmon) and in Central Puget Sound during coho-directed fisheries targeting other stocks.

5.2.4.5 Replacement Exploitation Rates

Replacement exploitation rates are generally defined as the rates of exploitation that would, at the least, provide adequate numbers of escaping spawners to replace each run's parent brood. The concept of replacing the parent brood rests on the assumption that if freshwater and marine survival conditions were relatively constant, a decline in stock abundance could be prevented. However, while this concept cannot ensure stock stability (because of errors in estimation and faulty assumptions), it is useful as an indicator of overfishing because a consistent failure to provide for replacement of the parent brood is indicative of "mining" a stock. On the other hand, if a stock requires rebuilding, exploitation rates must certainly be lower than those that would merely provide for replacement of the parent brood.

Given the levels of escapement in these runs' parent broods, the estimated recruitment, per spawner, to all fisheries and escapement in the third year of life was 2.44, 2.29 and 1.61 coho for each of the years, respectively.

Keeping in mind the fact that the three years examined are generally considered to be "low survival" years, the above returns-per-spawner, although generally low, compare favorably with recruitment from Hood Canal where wild coho recruitment has generally fluctuated from approximately 2.0 to 4.0.

As Table 5-2 and Figure 5-10 indicate, the escapement trend of the SJF wild coho has been generally declining and brood spawners have generally not been replaced since 1986. Within this overall decline, it also appears that two of the three broodlines are reaching extremely low levels.

In the years examined, the maximum allowable exploitation rates that would have provided for replacement of the parent broods, would have been 59.0%, 56.4% and 37.8%, respectively. The estimated exploitation rates in those years were 65.3%, 61.1% and 58.0%, respectively. The result was that the observed exploitation rates were respectively 10.7%, 8.3% and 53.4% higher than the replacement rates. However, given the high proportion of the total interception attributed to Canadian fisheries, replacement of the parent brood escapement would have been possible only in 1992 and 1993 if U.S. exploitation rates did not exceed 9.7% and 19.2%, respectively (the observed rates were 17.1% and 23.9%). This points to the fact that the Council, the states and tribes responsible for the management of this resource may simply have "too little to work with" to rebuild this stock under present conditions and management practices.

6.0 SYNTHESIS OF FACTORS AFFECTING SURVIVAL AND ESCAPEMENT

The analyses of the individual factors contributing to the escapement failures of the Puget Sound chinook and Strait of Juan de Fuca (SJF) coho stocks, presented in Sections 2 through 5 above, could be combined into a single model to fully elucidate their relationships. Unfortunately, the review group has not had the time or resources to complete such a synthesis. However, in this section we briefly discuss how such an analysis could be accomplished.

It is necessary to synthesize all factors affecting stock status in order to consider the appropriate range of management actions necessary for restoring stock productivity. The most common management response to underescapement is to reduce harvest rates. This will result in greater escapements than otherwise would be observed without the reductions. However, this action, by itself, may not solve the production problem or achieve restoration goals if the main problem is suboptimal freshwater and marine survival.

When harvesters are asked to reduce their impacts on a stock, they will insist that other human activities that affect productivity be reduced correspondingly. The synthesis that we envision here should show how the requirements for reduction in impacts could be allocated among the factors affecting each salmon life stage.

The phenomenon of spawner-recruit relationships that change over time illustrates the point that consideration of only one type of impact is insufficient either to explain or to correct observed declines in stock abundance. For example, Figure 6-1 shows the relationship between brood year escapement and terminal run size for Skagit River chinook salmon. As is evident from the graph, this relationship has changed over time, with much greater returns expected for a given escapement level in the mid 1970s compared to the expected production from the same escapement in the mid 1990s. Clearly, harvest rate reductions alone will not be sufficient to return this stock to the levels observed 20 years ago. To restore this stock, the cause of the general decline in productivity at a given escapement level must be detected and corrected.

A model of survival from life stage to life stage would be appropriate for this synthesis. Paulik (1973) considered the overall spawner-recruit relationship to be a composite of four relationships between life stages, each with possibly a different functional form. His approach is a potential starting point for the type of analysis we envision here. This analysis would require two determinations for each life stage: 1) the functional form of the relationship and 2) the parameters of the curves. While these have not yet been calculated for any of these stocks, one could, as a first step, use existing information to estimate survival rates between life stages.

Table 6-1 illustrates, for Skagit River summer/fall chinook, current estimates of survival rates at different life stages for several brood years. There was insufficient time to derive any estimates for several of the rates and many of the estimates shown are preliminary, not reviewed and cursorily derived. Therefore, this table is only an example of how these data could be used to analyze the reasons why escapement targets were not met and not an actual analysis of why those targets were not met for Skagit summer/fall chinook.

From Table 6-1, the analysis of why escapement targets were not achieved in recent years might be approached by starting with years when the escapement targets were achieved, then determining what has changed to prevent those targets from being achieved in the subsequent cycle. For example, the Skagit summer/fall escapement goal was achieved in 1985 and 1986. Why was it not achieved the next cycle? If the rates shown in Table 6-1 were accurate, egg-to-smolt survival rates have ranged from 1% to 20%, with a median of about 10%. For the 1985 and 1986 broods, egg-to-smolt survival was well below the median. This low freshwater survival was compounded in the 1985 brood by a low marine survival rate.

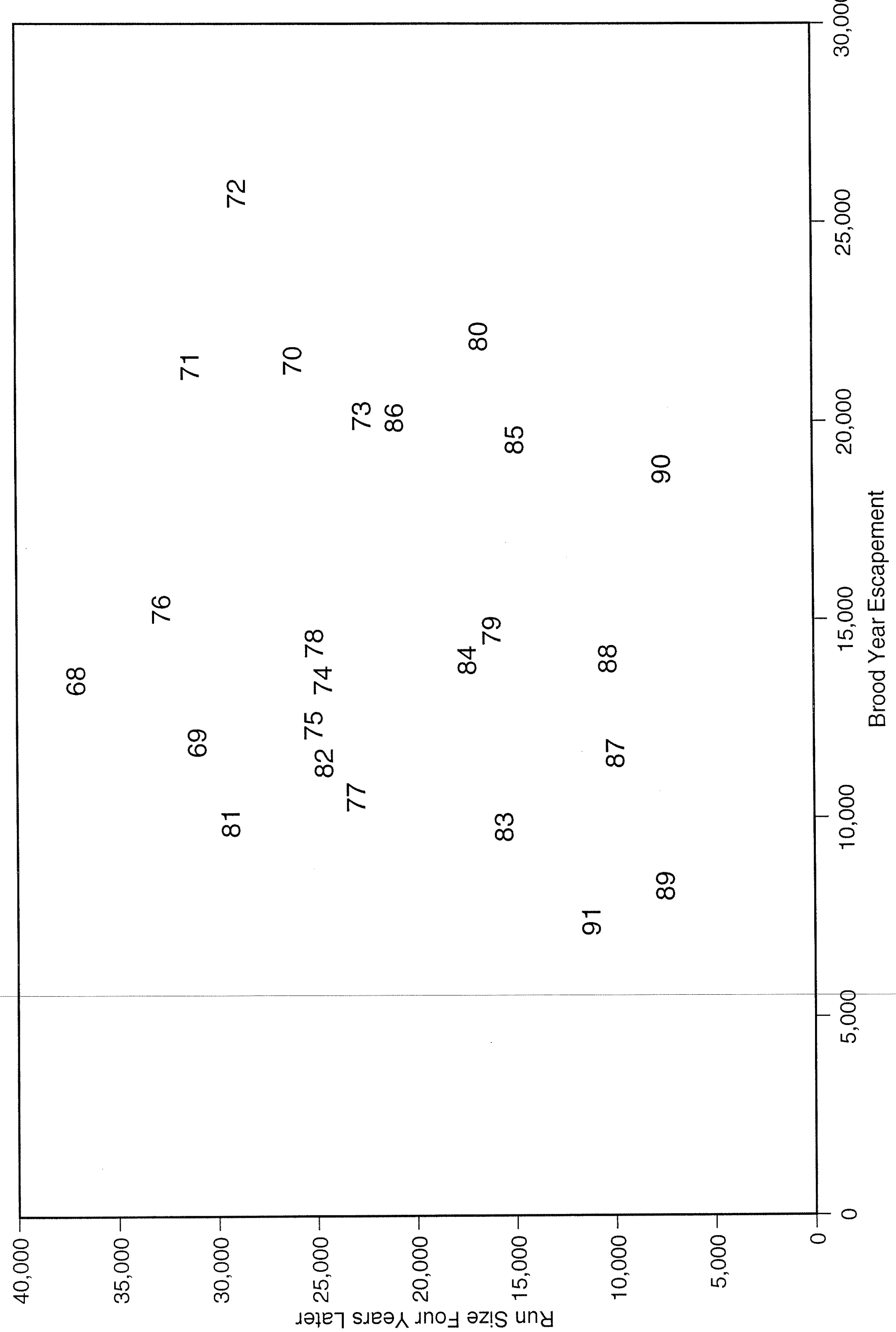

FIGURE 6-1. The relationship between brood year escapement and terminal run size for Skagit River chinook salmon (spring and summer/fall).

TABLE 6-1. Synthesis of gravel-to-gravel stock survival values, using Skagit summer/fall chinook as an example. The values shown in this table are FOR EXAMPLE ONLY, as many values are highly preliminary and subject to significant revision.

Brood Year	Brood Escapement	Eggs[a/] (millions)	Smolts[b/] (millions)	Smolts/ Spawner	Egg to Smolt Survival	Adult Recruits[c/]	Marine Survival	Canadian Exploitation Rate	Canadian Catch	U.S. Recruitment	U.S. Exploitation Rate	U.S. Catch	Escapement
1974	12,901						26.2%						
1975	11,555						9.8%						
1976	14,479												
1977	9,497	20.9											
1978	13,209	29.1											
1979	13,605	29.9	0.4	26.1	1.2%	77,622	21.9%						
1980	20,345	44.8				85,879							
1981	8,470	19.1				51,677							
1982	10,439	23.0				36,099							
1983	9,080	20.0				101,281							
1984	13,239	29.1				59,860							
1985	16,298	35.9	2.1	127.8	5.8%	28,061	1.3%						
1986	18,127	39.9	0.5	27.0	1.2%	49,355	10.1%						
1987	9,647	21.2	1.3	139.0	6.3%	35,705	2.7%						
1988	11,954	26.3	3.5	289.6	13.2%	49,269	1.4%						
1989	6,776	14.9	1.7	250.9	11.4%	22,336	1.3%						
1990	17,206	37.9	0.5	29.1	1.3%	22,121	4.4%						
1991	6,014	13.2	2.4	399.1	18.1%	15,470	0.6%						
1992	7,671	16.9	3.0	391.1	17.8%	12,002	0.4%						
1993	5,916	13.0	2.7	456.4	20.7%								
1994	6,232	13.9	1.5	240.7	10.8%								
1995	7,155	15.8	0.7	97.8	4.4%								

a/ The brood year 1974-1993 egg production values use the brood year 1994-95 observed indicator stock fecundities of 2,200 eggs/spawner.
b/ Smolt production values are highly preliminaryand must be reviewed. This also affects the smolts/spawner and freshwater survival values.
c/ Age-2 recruitment expressed in adult equivalents using a factor of 0.5844.

SOURCES: Brood escapement from Puget Sound run reconstruction tables (WDFW). Smolts: brood years 1989-1995 from D. Seiler, WDFW (pers. comm.); pre-1989 as recruitment/marine survival. Marine survival: brood years 1989-1992 as recruits/smolts; pre-1989 as Samish survival index (TCCHINOOK 94-1:I-4), relative to brood years 1989-1992 marine survival rates.

Conversely, marine survival was high for the 1986 brood. If exploitation rate estimates were completed, it would be possible to determine whether high exploitation rates in Canadian or U.S. fisheries contributed further to the failure to achieve escapement targets. Further analysis would then be needed to identify why egg-to-smolt survival was low (floods? drought? slides? predators? disease?) and which specific fisheries had the high exploitation rates. From this gravel-to-gravel synthesis, the managers could then recommend actions to address problems in productivity, as well as harvest problems.

These answers, however, are not yet available. For some rates, the data necessary to calculate them do exist, but no one has had time to do the calculations. For example, coded-wire-tag (CWT) data exist with which to calculate exploitation rates for some of the brood years for Skagit chinook. This may allow an allow an analysis in the near future. For other rates, additional research is needed.

There are studies currently underway on Skagit chinook (Hayman *et al.* 1996) and Hood Canal coho (Lestelle *et al.* 1995) to identify and quantify the factors that limit productivity for these runs. Studies such as these should be advocated and supported by the Council. In addition, it should be noted that CWT data, from which marine survival rates and exploitation rates are calculated, are absolutely vital for this kind of analysis. Any actions that reduce the integrity of CWT data will make it impossible for managers to ever determine why escapement targets are not being met and what actions are necessary to rebuild the affected stocks.

Recommendations

7.0 REVIEW OF 1992 RECOMMENDATIONS

As a result of the 1992 review of Puget Sound salmon stocks not meeting their escapement goals for three or more consecutive years, the review group made several recommendations for recovery of the stocks. The recommendations and an assessment of their implementation is provided below.

7.1 CHINOOK SALMON RECOMMENDATIONS

1. **Create an annual management forum for Puget Sound chinook which establishes a common management objective for troll, sport, and net fisheries in Puget Sound.**

   Implementation: No forum specifically directed at chinook management has been established, but management would likely be done within the existing North of Falcon forum. The first steps toward managing chinook for common objectives in this forum were taken in 1995, with the recognition that chinook should also be protected in recreational fishery closures aimed at protecting coho; however, no specifically-quantified common management objectives for chinook were used to set levels for all fisheries in Puget Sound.

2. **Utilize a consistent analytic tool for assessing the impacts of all fisheries upon Puget Sound stocks of chinook.**

   Implementation: The Fishery Regulation Assessment Model (FRAM) was used as a chinook analysis model for the first time in 1995; additional refinements in the output tables have been made for 1996. These refinements should make the model more useful for guiding management of Puget Sound chinook, but completion has been slow.

3. **Evaluate enhancement options which are consistent with natural stock management and can be used to speed rebuilding of depressed chinook stocks.**

   Implementation: In 1994, a work group was formed to evaluate and propose actions, including enhancement actions, that would restore Skagit chinook. This group is still compiling information and has not yet evaluated or proposed any restoration actions, other than research projects. At the work group's recommendation, the Skagit System Cooperative, with Pacific Salmon Commission (PSC) funding, has been acquiring the information needed to develop a model that will have the capability of evaluating enhancement options for restoring Skagit chinook. A first version of this model should be available in 1997; testing could begin then, but data for model input will need to be acquired over several additional years.

7.2 COHO SALMON RECOMMENDATIONS

1. **Establish a management framework, such as the "Stepped Harvest Management Approach", which streamlines the preseason planning process and reduces its dependence upon preseason estimates of abundance and exploitation.**

   Implementation: Attempts to establish such a framework, which had stalled in December 1990, were resumed in May 1993, when the "Comprehensive Coho" process began. This process was suspended in June 1994, when key personnel and resources were diverted to other tasks, primarily to mass marking/selective fisheries analyses, ESA, intertribal allocation, and development of a Wild Salmonid Policy. The Comprehensive Coho process was revived in July, 1996.

2. **Conduct annual postseason assessments of stock abundance and exploitation rates and use these to improve the run prediction database.**

Implementation: This is being done by State and tribal biologists through the coho cohort reconstruction database, which uses coded-wire tags (CWTs) to estimate the total annual catches of each run in each fishery postseason, and then estimates the total abundance of each run. An agreed upon version of this database, for the years 1986-1991, is available.

3. **Evaluate and update the Coho Assessment Model based upon the results from the annual postseason evaluation, particularly with respect to the level of temporal and fishery stratification used in the model.**

   Implementation: The code of the Coho Assessment Model (CAM) has been rewritten (it's now called FRAM) to allow more flexibility in grouping fisheries for analysis. The input harvest rates, however, are still derived from 1979-1981 fishery data; they have not been updated for more recent years' data.

7.3 GENERAL DATA NEEDS

1. **Identify and quantify those factors in the freshwater and marine habitat which limit the productivity of chinook and coho salmon stocks. Initiate programs to protect, rehabilitate, and enhance critical habitat with particular emphasis on the limiting factors.**

   Implementation: Freshwater limiting factors for coho have been identified and quantified for the Skagit River by the Skagit System Cooperative (Beechie *et al.* 1994), and for Hood Canal by Lestelle *et al.* (1993). For chinook, the Skagit System Cooperative has begun research to identify and quantify limiting factors in the freshwater and estuarine habitat. Limiting factors in the marine habitat have not been identified or quantified for either species, although some attention has been paid to upwelling indices, mackerel abundance, and dogfish predation. Programs to protect, rehabilitate, and enhance critical habitat have been limited to piecemeal attempts in individual areas.

2. **Insure that stocks representative of the "overfished" stocks are tagged on an annual basis.**

   Implementation: Stocks assumed to represent the "overfished" stocks identified in 1992 have been tagged on an annual basis.

3. **Review escapement estimation methods, including the stray rates of tagged hatchery indicator stocks, and recommend improvements to the methods as necessary.**

   Implementation: For Skagit coho, this review has nearly been completed. For Hood Canal coho, a draft review (Lestelle and Weller 1995) has been prepared. No review of escapement estimation methods has been done for the chinook runs.

4. **Review the appropriateness of the current escapement goals.**

   Implementation: Coho escapement goals are under review as part of the Comprehensive Coho process. There has been no recent review of the chinook escapement goals, due primarily to data limitations. Several projects are now being conducted to acquire the data needed to review chinook escapement goals.

5. **Continue development of improved preseason forecasts with an emphasis on obtaining direct estimates of total recruitment which include indicators of marine survival.**

   Implementation: In recent years, forecasts for both Skagit and Hood Canal coho have been direct forecasts of total recruitment. Completion of the coho cohort reconstruction database (see above) should help improve these estimates. Although indicators of marine survival have, at times, been used in these forecasts, the reliability of these indicators has been questionable.

7.4 FRESHWATER HABITAT

1. **Develop a comprehensive resource and habitat assessment for all watersheds that includes a general inventory of current habitat and the identification of factors limiting fish production and survival.**

   Implementation: This assessment, an evaluation of current habitat and historic losses throughout Western Washington, has been funded and is now underway. Known as the Salmon and Steelhead Habitat Inventory and Assessment Program, it will be presented as a supplement to the Washington State Salmon and Steelhead Stock Inventory (SASSI) document. Completion is expected in about 1½ years. In addition to this effort, the Tulalip Tribes, in cooperation with the Stillaguamish Tribe and Snohomish County Surface Water Management (SCSWM), have entered into an interlocal agreement that will identify the freshwater limiting factors of coho in the Stillaguamish. The project will identify historic and potential production for the entire basin, as well as point to areas to protect and restore.

2. **Tribal and state fisheries management agencies should develop a coordinated long-term program to monitor the status of fish populations, stream habitat, and the effectiveness of habitat protection and restoration efforts. The program should be established with the goal of improving our knowledge regarding the quantitative relationship between land use, habitat condition, and fish production.**

   Implementation: Salmon run sizes and escapements are estimated annually. However, no complementary coordinated program for monitoring stream habitat currently exists, except as a follow-up to item #1 above.

3. **Local, tribal, state, and federal governments should develop a comprehensive coordinated approach to habitat protection and restoration on a watershed and regional basis.**

   Implementation: This has not been done, in a comprehensive coordinated manner. For the Skagit River, 1993 and 1994 memoranda of understanding (MOUs), between WDFW and the Skagit tribes, included commitments to do this, but these commitments were not followed through. There was greater success achieving the commitments laid out in the 1995 Skagit MOU, and further efforts have been described in the 1996 Skagit MOU. No coordinated federal effort for protection has been undertaken; rather than focusing on habitat protection, entities have concentrated on restoration opportunities. In the Snohomish and Stillaguamish river basins, there have been 4 state watershed analyses and 2 federal watershed analyses. State watershed analyses result in prescriptions for a watershed, while federal watershed analysis does not. Coordinated watershed restoration has also occurred in these basins.

4. **The PFMC should request specific action from local, tribal, state, and federal governments to protect and restore critical habitat for stocks of concern. PFMC comments should be directed to permitting and policy processes which include, but are not limited to the following:**

   - **Federal and state wetlands regulation and policy development**
   - **Hydroelectric facility permitting**
   - **Forest practices on federal and state regulated lands**
   - **Flood control projects such as diking, dredging, and flood control reservoirs.**

   Implementation: In 1993, PFMC created a steering group for its Habitat Committee and revised its habitat strategy. Since then, letters have been written to government agencies concerning comprehensive habitat planning, optimal flows in the Klamath, and spills on the Columbia and Snake. It is unclear whether these letters have resulted in any actions to protect and restore habitat. They have had no effect at the local level.

In addition to these general freshwater habitat recommendations, the 1992 report also listed the habitat recommendations by river basin as provided below.

7.4.1 Snohomish River

1. **Acquire and/or re-establish hydraulic connection between flood plain, side channels, and main stem river.**

   Implementation: Nothing of this sort has been done to date; however, the Snohomish fish habitat subcommittee, which is part of a larger water rights process, has identified general areas where this can occur.

2. **Restore coho habitat through artificial and natural replacement of large woody debris throughout the system.**

   Implementation: The U.S. Forest Service (USFS), as well as King and Snohomish County Surface Water Management (KCSCSWM), have been involved in projects within the basin.

   The Tolt Habitat Restoration Group (THRG) has accomplished some large woody debris (LWD) placement within the Lynch Creek sub-basin of the Tolt River. The Tolt is a tributary to the Snoqualmie. LWD placement occurred in 1994, and is currently being monitored to determine the benefits gained.

3. **Develop regulatory standards to minimize future erosion from sensitive geologic areas.**

   Implementation: No regulatory standards have been put in place; however, Washington state watershed analysis does identify the hazard potential for mass wasting. In addition, it also identifies road and surface erosion issues within a watershed. State watershed analysis has been preformed on 4 watersheds within the Snohomish, three in the Snoqualmie basin and one in the Skykomish basin.

4. **Establish an inventory and monitoring process within the river, including those areas outside USFS ownership.**

   Implementation: There is no coordinated effort to do this; however, the tribes, as well as several other agencies, including the KCSCSWM, do actively collect and monitor data.

5. **Establish watershed habitat management plan or management coordinating body.**

   Implementation: The Snohomish Fish Habitat Subcommittee has gathered anecdotal and written information, and produced a series of maps regarding fish use and distribution throughout the river basin. The group's activity, however, is limited to only this effort.

7.4.2 Stillaguamish River

1. **Establish and secure minimum instream flows for the Stillaguamish River System.**

   Implementation: Although a study was completed in 1983 by the USGS and Stillaguamish Tribe, nothing has been implemented.

2. **Acquire and/or re-establish hydraulic connection between flood plain, side channels, and main stem river.**

   Implementation: Nothing of this sort has been done to date; however, the restoration subcommittee of the Stillaguamish Implementation Review Committee (SIRC) has been working in 1995 to identify and prioritize restoration actions.

3. **Restore coho habitat through artificial and natural replacement of large woody debris throughout the system.**

Implementation: Snohomish County Surface Water Management , WDFW, Washington Department of Ecology (WDOE), and the tribes have been involved in projects within the basin.

4. **Develop regulatory standards to minimize future erosion from sensitive geologic areas.**

   Implementation: No regulatory standards have been put in place; however, Washington state watershed analysis does identify the hazard potential for mass wasting. In addition, it also identifies road and surface erosion issues within a watershed. State watershed analysis has been performed on two watersheds within the Stillaguamish, while the USFS has completed one watershed analysis.

5. **Establish an inventory and monitoring process within the river, including those areas outside USFS ownership.**

   Implementation: There is no coordinated effort to do this; however, the tribes actively collect and monitor data.

6. **Establish watershed habitat management plan or management coordinating body.**

   The Stillaguamish watershed management plan was established in 1989, and the Stillaguamish Implementation Review Committee (SIRC) restoration subcommittee has been working in 1995 to identify and prioritize restoration actions.

7.4.3 Skagit River

1. **Establish inventory and monitoring process within the river system.**

   Implementation: Through a PSC-funded chinook study, mainstem and estuarine habitat types have been measured, and aerial photos are being used to chart changes in stream width and habitat types over time.

2. **Acquire and/or re-establish hydraulic connection between flood plain, side channels, and main stem river.**

   Implementation: Efforts are underway to do this. One project, at Barnaby Slough, has been completed. In 1995, the Bureau of Indian Affairs (BIA) funded a SSC investigation of potential hydraulic connections on Fir Island. Plans to reconnect Deepwater Slough are under final review by WDFW and SSC.

3. **Develop regulatory standards to minimize future erosion from sensitive geologic areas.**

   Implementation: No standards are in place.

4. **Establish and secure minimum instream flows for the Skagit System, especially in agricultural and urban areas.**

   Implementation: A memorandum of understanding with local utilities is close to completion.

5. **Improve downstream passage at Baker Lake facilities.**

   Implementation: The lead nets on the gulper (the downstream smolt passage trap) at Baker Dam were extended from shore-to-shore in 1988 and from surface-to-bottom in 1992. Since then, estimated passage efficiencies for coho have varied from 27% (in 1993) to 73% (in 1994). While there has been no discernible increasing trend in passage efficiencies since 1988, there has been a vast improvement over the efficiencies observed prior to 1988. In addition, the number of emigrating sockeye smolts has increased by approximately an order of magnitude since 1992, and there has been a smaller increase in the coho emigration numbers.

6. **Reduce incidence of landslide activities as a result of timber harvest activities.**

Implementation: Efforts to deal with this problem have consisted of on-going timber fish and wildlife activities; completion or scheduled completion of watershed analyses on Hansen Creek, Cascade River, and Sauk River; and a reduction in timber harvests on USFS land.

8.0 CURRENT RECOMMENDATIONS

The review group provided the Council with interim recommendations for the 1996 salmon season at the Council's March 1996 meeting in Portland, Oregon. These recommendations, which follow, were not fully implemented in the 1996 cycle and should be implemented beginning with the 1997 cycle.

- **The Salmon Technical Team (STT) should include stock-specific projections of fishery impacts and spawning escapements for all chinook stocks, identified by the Council as overfished, in summaries of model results.**

- **The STT should include projections of harvest rates, fishery impacts and spawning escapements for Strait of Juan de Fuca wild coho, identified by the Council as overfished, in summaries of model results.**

8.1 FRESHWATER HABITAT

The Council should consider that past and present habitat conditions in Puget Sound and SJF watersheds is a significant factor in the cause of declining chinook and coho stocks. Protection of *existing habitat* is necessary to maintain the currently depressed population levels, and *restoration of habitat* is necessary to allow for the recovery of these stocks.

- **Local, tribal, state and federal governments should develop a comprehensive coordinated approach to habitat protection and restoration on a river basin scale. The Council should encourage and support river basin managers to develop river basin approaches to salmon habitat protection and restoration.**

  Although local efforts have occurred (e.g., memorandum of understanding between WDFW and the Skagit tribes), no comprehensive effort has been undertaken. Such an effort can help focus protection, restoration, and research efforts on the same scale harvest management is developed. This would reduce redundancy of habitat efforts, reduce overall costs, and increase the efficiency of habitat protection, restoration, and research implementation.

- **Tribal and state fisheries management agencies should develop stock specific river basin plans for determining appropriate habitat protection and restoration actions.**

  Plans need to identify specific life history types and factors limiting production of discrete life stages. An overall goal should be to improve our knowledge regarding the quantitative relationship between watershed processes, land use, habitat condition, and fish production.

  Similar to the limiting factors efforts that have or are taking place for coho (Beechie *et al.* 1994; Lestelle *et al.* 1993), life history types for different salmonids in different river basins need to be identified. Chinook life history types are being identified for the Skagit by the Skagit tribes (Hayman *et al.* 1996). Other basins where such work is of critical importance include the Stillaguamish, Strait of Juan De Fuca (SJF), and the Snohomish. Identification of life history types helps to focus data collection and analysis efforts on fish populations and watershed processes and conditions. More importantly, it can help identify what specific habitats, or combination of habitat, salmonid life history types may depend upon.

  For example, protection and restoration efforts linked to life history types are important because a lack of protection on a key life history aspect, or restoration focused on a life history aspect that is not truly limiting, can lead to lost opportunity for more significant restoration work. Loss of a particular life history strategy may hinder salmonid production for an entire system. Success or failure of restoration projects may rest upon an understanding of key life history strategies. An understanding of life history strategy can also allow restoration efforts to incorporate larger scale concepts that may be important, such as habitat fragmentation.

- **The Council should support the efforts of local, tribal, state and federal governments to identify, protect and restore critical habitat.**

  The agencies and Council must focus, prioritize and coordinate their efforts. Addressing the following areas are likely to result in the most benefit from the least cost:

  - Road projects that may result in fish passage barriers such as culverts
  - Flood control projects such as diking, dredging, and flood control reservoirs
  - Growth management act regulation and policy development
  - Grazing and agricultural lands
  - Forest practices on state and federally regulated lands
  - Hydroelectric facility permitting

  Identifying the combination of limiting factors, habitat loss and life history information can help the Council support management entities in their pursuit of protecting and restoring habitat. Fish blockages such as culverts should be systematically addressed to help maintain and reconnect habitat that is currently not being utilized. General statements and focus, such as the use of more natural materials (e.g., large woody debris [LWD]) to help in bank protection efforts, can then be linked to fish use.

- **The Council should identify research needs related to the protection and restoration of the essential fish habitat defined and described in the Council's salmon management plan.**

  As an example, current data suggest that research efforts may need to focus on the hypothesis that elevated peak flow events can reduce survival from the egg to migrant fry stage.

- **The Council should support implementation of a chinook restoration plan for the Skagit River Basin which is based upon life history strategies and the use of the limiting factors concept.**

  The restoration plan should outline the testing of life history and life stage related hypotheses, as well as hypotheses related to the causes of habitat degradation in the Skagit River Basin. Specific protection and restoration actions in the Skagit Basin would be implemented according to hypotheses generated from the chinook plan. For example, the Skagit tribes' data suggest that restoration in the estuary should focus first on the transition zone and second on the forested/tidal zone. In streams where production is limited due to lack of suitable spawning area, restoration should focus on creating and maintaining forced pool-riffle channels that have deep holding pools and on maintaining LWD recruitment from riparian zones.

- **The Council should support development of a chinook restoration plan for the Stillaguamish and Snohomish River Basins which are based upon life history strategies and the use of the limiting factors concept.**

  For instance, recovery of chinook populations in the North Fork Stillaguamish River Basin will, in part, depend upon the maintenance and increase in large holding pool areas over time. Plan development should focus on: 1) protecting the existing riparian zone to help maintain LWD over time; 2) limiting land-use activity on sediment source areas which are prone to landslides and surface erosion and 3) accelerate the maintenance and creation of holding pools through LWD restoration projects that create such habitat.

- **The Council should support implementation of systematic habitat restoration efforts throughout the SJF freshwater systems. This would include removal of the Elwha Dam and restoration of over-wintering habitat.**

  Removal of the Elwha Dam can result in a potential increase between 36% to 65% of the total potential coho smolt production in the SJF. Streams with the highest production potential should be given the highest priority for habitat restoration efforts. These include the Elwha, Hoko, Dungeness, Pysht, Clallam, Deep, Sekiu and Twin watersheds. Efforts should focus on activities that address over-wintering habitat.

8.2 CHINOOK HARVEST MANAGEMENT

The review team makes the following recommendations with regard to harvest management of the identified Puget Sound chinook stocks.

- **Develop and implement a management plan for Puget Sound chinook.**

  If rebuilding of the north Puget Sound wild stocks discussed in this report is a goal of the management plan, the fishery regimes affecting these stocks should initially be premised upon continued low productivity. Under these conditions, exploitation rates should be reduced, at a minimum, to the replacement rates for the 1986-1988 broods. The plan should contain provisions to permit increased exploitation rates if survival rates increase and the rate of stock rebuilding is acceptable.

- **The North of Falcon Forum should be used to assess the consistency of proposed troll, sport and net fisheries in Council and Puget Sound waters with the objectives of the chinook management plan.**

  In the absence of a completed management plan, exploitation rates on these stocks should be adjusted, at a minimum, to assure that the replacement rates for the 1986-1988 broods are not exceeded.

- **Utilize a consistent analytic tool for addressing the impacts of all fisheries upon Puget Sound stocks of chinook.**

  The Puget Sound component of the Fishery Regulation and Analysis Model (FRAM) has undergone significant development and review during the last year by representatives of the western Washington tribes and WDFW (the Model Evaluation Subcommittee). It is anticipated that reports describing model calibration and validation will be completed in 1997.

- **Develop and annually conduct a postseason assessment of Puget Sound stocks that provides estimates of catch, exploitation rates and brood survival rates.**

  As one component of the validation of FRAM, the Model Evaluation Subcommittee has developed a preliminary database of statistics for Puget Sound stocks. Funding for completion of the database has been sought through the U.S. Section of the Pacific Salmon Commission. Support of this proposal by the Council would increase the likelihood of obtaining funding.

8.3 STRAIT OF JUAN DE FUCA COHO

8.3.1 General

- **Simulation models, used by the Council during preseason planning, should be modified to enable the STT and the Council to evaluate the stock status and stock-specific impacts to SJF wild coho salmon, by fishery.**

- **The Council's framework salmon plan should establish specific criteria for the stabilization and rebuilding of SJF wild coho salmon.**

- **State and tribal management agencies should ensure that hatchery CWT's are adequate to assess wild coho in this region.**

  Current abundance assessments are hampered by limited coded-wire tagging (CWT) information.

8.3.2 Forecasts

- **State and tribal agencies, and the Council's Scientific and Statistical Committee should conduct further review and analysis of factors contributing to statistical bias in the preseason forecasts of SJF wild coho salmon.**

- **State and tribal agencies should base abundance forecasts of SJF wild coho salmon on region-specific data.**

  This procedure is necessary because of the unique habitat characteristics of the SJF (See: Weitkamp *et al.* 1995).

- **Preseason forecasts should be provided separately for "primary" wild coho runs, artificially enhanced (hatchery) runs, and wild coho runs which are not managed for a specific harvest rate or escapement goal.**

8.3.3 Escapement

- **State and tribal agencies, and the Council's Scientific and Statistical Committee should conduct further review, analysis, and possible revision of historical escapement estimates and their utility, as well as "base year" estimates.**

  These analyses are needed because:

  - In the western SJF, the reliability of estimates prior to 1985 may be, at best, questionable.

  - In the eastern SJF, the historical apportionment of the sub-regional estimate is probably incorrect because it does not take into account inriver harvests in the Dungeness and Elwha Rivers. Furthermore, the continuing reliance on Snow Creek information, in more recent years, may have been inappropriate because of habitat-related losses unique to that system.

- **State and tribal agencies should undertake a re-assessment of the escapement goals for SJF wild coho salmon.**

  These re-assessments are necessary because:

  - The originally established goals have been (in some cases) drawn from "best guess" estimates and were further adjusted to match then current escapement levels. These goals may be too low, too high, or simply misapportioned.

  - In 1983, the U.S. District Court's Fisheries Advisory Board recommended reassessment.

- **In view of the currently extremely depressed status and continuing trend of declining escapements of SJF wild coho salmon, a range of escapement target levels should be established to facilitate run stabilization and rebuilding in lieu of a single-point escapement goal.**

- **The Council should assess whether annual management plans provide for stabilization and rebuilding of the SJF wild coho salmon.**

8.3.4 Enhancement

- **If the State and tribal agencies determine that instream supplementation efforts are required to achieve the rebuilding of the stocks, it is recommended that such effort be undertaken only after specific supplementation guidelines have been developed, and then, using only native wild broodstock.**

- **Current programs which call for instream releases of fry-fingerling coho should be terminated, unless a supplementation program (as referenced in the preceding recommendation) has been developed.**

  Over the past fifteen years, instream releases of coho salmon have been either ineffective (fry-fingerling), or had no lasting effect on rebuilding (yearling). Additionally, evidence from neighboring coastal systems indicates that fry-fingerling releases may be simply displacing native coho fry (Haymes and Tierney 1996).

- **Enhancement and supplementation with appropriately selected yearling coho should not proceed unless it is based on adequate available habitat to sustain the rebuilding effort.**

  Increasing escapements from such yearling supplementation, as has occurred in Chimacum Creek, will not benefit natural productivity if adequate habitat is not available.

8.3.5 Harvest

- **The Council (in U.S. ocean fisheries) and the pertinent state and tribal management agencies (in Puget Sound fisheries) should evaluate annual management plans from the standpoint of halting the decline and facilitating rebuilding of the SJF coho.**

  Most of the harvest-related impacts to SJF wild coho salmon occur in the Canadian fishery. This fact tends to limit the ability of U.S. management agencies, including the Council, to effect major modifications in this stock's harvest regime. The review group concludes that harvest management measures for U.S. fisheries may only provide limited relief toward halting the decline and stabilizing the population, unless relief is sought from further habitat degradation and Canadian fishery impacts.

- **Given the present low abundance of this stock, the Council and state and tribal agencies should adopt exploitation rate target schedules for this stock rather than rely on fixed numeric escapement goals which cannot presently be met. Deviations from such schedules should only be considered under specific guidelines, adopted by the Council, states, and treaty tribes.**

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