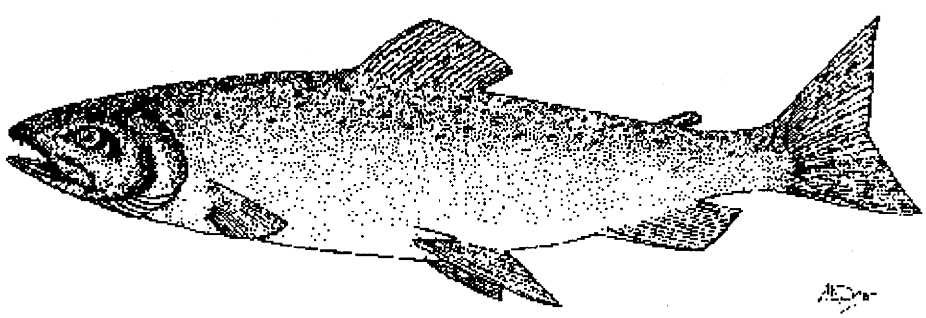
Skagit System Cooperative
P.O. Box 368 LaConner, WA 98257-0368 Ph. (360) 466-3450
Fax: Administration & Enforcement (360) 466-3610
Fisheries/Biology/Environmental Svcs.: (360) 466-4047

FY 1995 SKAGIT RIVER CHINOOK RESTORATION RESEARCH

SKAGIT SYSTEM COOPERATIVE

CHINOOK RESTORATION RESEARCH PROGRESS REPORT NO. 1

BY R. A. HAYMAN, E. M. BEAMER, and R. E. McCLURE



FINAL PROJECT PERFORMANCE REPORT

IN COMPLIANCE IN PART WITH NWIFC CONTRACT # 3311 FOR FY95

AUGUST 1996

TABLE OF CONTENTS

ABSTRACT

In order to develop inputs to a model that would evaluate chinook restoration strategies, the Skagit System Cooperative (SSC) conducted a program to calculate the area of chinook rearing habitat in the Skagit mainstem and estuary, estimate the 1995 rearing populations in each mainstem and estuarine habitat type, and investigate the feasibility of sampling juvenile chinook in Skagit Bay to collect otoliths to determine life history strategies. Otoliths were also collected from returning adults in the test fishery to determine the proportion of the adult return comprised of each life history type.

We estimated the mainstem channel area of the Skagit River basin at almost 4,000 ha, of which 369.5 ha was edge habitat: 53.9 ha was backwater, 86.5 ha was bank, and 229.1 ha was bar habitat. Of this total, about 2,400 ha was in the mainstem Skagit River: 209.2 ha was edge habitat, consisting of 26.7 ha of backwater, 58.7 ha of banks, and 123.8 ha of bar habitat.

We classified the mainstem into 24 reaches, and sampled for juvenile chinook in eight of those reaches between March and June, 1995, with one sampling period in September. Chinook densities were significantly higher in backwater and natural bank habitat than in hydromodified banks and bars. We calculated preference ratios between the different mainstem habitat types, and estimated chinook densities according to both peak counts and fish-weeks. By using peak counts, we estimated 0+ chinook production at 1.78 chinook/m^2 in backwaters, 0.97/m^2 in natural banks, 0.348/m^2 in hydromodified banks, and 0.44/m^2 in bar habitat. Total 0+ chinook production from each habitat type was estimated at 475,000 from backwaters, 430,000 from natural banks, 50,000 from hydromodified banks, and 540,000 from bars. By using fish-weeks, we estimated 0+ chinook production at 1.86 chinook/m^2 in backwaters, 0.91/m^2 in natural banks, 0.282/m^2 in hydromodified banks, and 0.454/m^2 in bar habitat. Total 0+ chinook production from each habitat type was estimated at 500,000 from backwaters, 400,000 from natural banks, 40,000 from hydromodified banks, and 560,000 from bars.

We estimated the total riverine/tidal area of the Skagit estuary at 2,556 ha, of which 1,015 ha were estuarine emergent marsh, 1,000 ha were emergent/forested transition, and 541 ha were forested riverine/tidal zone. We further determined the area of different channel types within each of these zones, and estimated that the estuary was 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. Our estuary sampling, which was conducted from weeks 7 through 33, yielded 3,468 sub-yearling wild chinook, 2 sub-yearling hatchery chinook, and 2 yearling chinook. From these catches, we estimated that approximately 800,000 chinook (age 0+), or about half of the outmigration, reared in small blind channels in all three zones, and in large blind channels within the estuarine emergent marsh in 1995. We estimated 120,000 chinook (age 0+) reared in estuarine emergent marsh large blind channels, 155,000 in estuarine emergent marsh small blind channels, 470,000 in transition small blind channels, and 30,000 in forested riverine/tidal small blind channels. These estimates should be considered very approximate. We did not sample main or subsidiary channels.

Comparison of estuarine smolt densities with total smolt outmigration estimates, for sites where data were available from previous years, indicated that increases in smolt outmigration above 2.5 million did *not* increase rearing densities at two forested riverine/tidal sites, and increases above a lower number did not increase rearing density at one transition zone site. Density increased with smolt outmigration only at an estuarine emergent marsh site on the South Fork. While the data were limited, this may imply that capacity in the forested riverine/tidal and transition zones may be reached at outmigration 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.

Bay sampling indicated that beach seining is a feasible method for collecting juvenile chinook for otolith samples. Pair trawling was unreliable, and the jury is still out on otter trawling, which appeared to be mechanically feasible, but only caught one chinook. Beach seining yielded 377 chinook, of which 344 were retained for otolith extraction. Those otoliths have not been read yet.

Test fishing yielded 161 chinook, of which the heads of 153 were retained for otolith extraction. Those otoliths have also not been read yet.

Analysis of lengths and timing in the river, estuary, and bay, indicated at least three possible life history types: one type consisted of emergent fry that migrated directly to the bay early in the year; a second consisted of fry migrants that emerged from the spawning areas and moved relatively quickly downstream to the estuarine habitats, where they reared for a few weeks before they achieved a length of about 70 mm and moved into more marine areas; and the third consisted of fingerling migrants that emerged from spawning areas, dispersed to rear in freshwater habitat for several months before achieving a length of about 70 mm, and then bypassed the estuary and moved directly into the bay in late spring or summer. Otolith reading should shed further light on these life history types.

I. INTRODUCTION

Background on Restoration Efforts

Skagit spring and summer/fall chinook together comprise the largest natural chinook runs in Puget Sound (Scott *et al.* 1992). Terminal area harvest goals have been defined, in the short term, as 500 springs and 20,000 summer/falls, and, in the long term (10+ years), as 1,000 springs and 30,000 summer/falls (Joint Objectives and Goals Committee 1992). The terminal area catches of Skagit chinook have, however, been declining since at least 1935 (Ward *et al.* 1976), to a low of 458 chinook in 1994 (AFCRS 1994). In 1994 the Joint Chinook Technical Committee of the Pacific Salmon Commission classified both Skagit spring and summer/fall chinook as "Not Rebuilding" (Chinook Technical Committee 1994).

To address this decline, direct restoration actions focused initially on spring chinook, for which the decline in abundance appeared most severe. In 1976, the tribes that fish in the Skagit terminal area, the Swinomish, Upper Skagit, and Sauk-Suiattle, first enacted time/area restrictions to avoid spring chinook, and in 1977 they completely closed their spring chinook fisheries (Sanford *et al.* 1990).

Simultaneously, in 1976[1], the Washington Department of Fisheries (WDF) initiated a broodstock collection program in tributaries to the Suiattle River (a spring chinook spawning area), for the purpose of developing a hatchery run that could be used for supplementation programs in the Suiattle. This program, however, suffered poor returns for many years, and did not begin to achieve adult returns surplus to its own on-station release needs until after improvements were made to the entrance fishway at the Marblemount Hatchery in 1988 and 1989.

In 1993, for the first time, the egg-take of Skagit hatchery springs exceeded the on-station goal of 590,000 eggs. At the same time, the wild spawning escapement in the Suiattle, the original source of the hatchery spring run, reached a near-record low of less than 300 spawners (P. Castle, WDFW, *pers. comm.*). Consequently, WDF and tribal personnel proposed to otolith-mark and release the hatchery surplus, which would be about 750,000 fry, as supplementation in the Suiattle (Hayman 1993). Unexpectedly, however, genetic stock analysis, which was completed by January of 1994, indicated that the allele frequencies of the hatchery springs differed significantly from that of the wild Suiattle baseline at five (out of 27) loci (J. Shaklee, WDFW, *pers. comm.*). These differences may have been caused by genetic drift, due to the low number of spawners in the hatchery population, but there was also strong evidence that hatchery springs had, in earlier generations, been crossbred with other hatchery stocks, including Green River falls and Skagit summers (Baranski and Shaklee, 1994). WDF (now

1. The program actually began in 1974, with the collection of 4 spawners. However, 1976 was the first year that a significant number of broodstock, 41, was collected.

called WDFW) and the tribes then discussed whether there would be worse long-term risk to the productivity of Suiattle springs by planting these genetically dissimilar fry in the Suiattle, or by doing nothing and allowing wild spawning to continue its decline. In the end, it was agreed not to release these fry into the Suiattle[2], provided that alternative positive actions could be proposed and implemented that would lead to restoration of Skagit chinook to optimum levels.

As a first step in developing these alternative positive actions, the Skagit tribes and WDFW created a technical workgroup[3] that was charged with determining:

a) What is known about factors that affect Skagit chinook; and

b) What needs to be accomplished over the next year(s) to design effective supplementation, habitat enhancement, harvest management, enforcement, and other strategies that will restore Skagit chinook to optimum levels (Memorandum of Understanding on Skagit Spring Chinook 1994).

Purpose of Project

Before proposing any restoration actions, the workgroup recognized the need to determine whether the constraint that would be removed by a proposed restoration action was in fact a constraint on chinook adult production. For example, one-time fry-planting assumes that the constraint on adult production is a lack of seeding; if the constraint is actually lack of rearing area or poor incubation survival, then a single fry-plant would actually provide little, if any, long-term benefit.

Identifying constraints on chinook production was, however, complicated by the complexity and variety of chinook life histories (Reimers 1971; Healey 1991) and the lack of studies that identify limiting factors on chinook production, particularly for ocean-type chinook[4]. For coho, for example, restoration actions have usually focused on constraints caused by underseeding (Lestelle *et al.* 1993a; Chitwood 1995), lack of protected overwintering habitat (Jenks *et al.* 1993), or lack of rearing area at summer low flow (Zillges 1977). For chinook, however, limiting factors have been so poorly understood that Puget Sound chinook run size forecasts and escapement goals have usually been expressed only as averages from a period of

---

2. They were released on-station at the Marblemount Hatchery.

3. Participants also included personnel from Seattle City Light, U.S. Fish & Wildlife Service, National Marine Fisheries Service, National Park Service, U.S. Forest Service, National Biological Survey, Marysville Middle School, and Skagit Regional Enhancement Group.

4. "Ocean-type chinook" are runs that typically smolt during their first year (Gilbert 1913, cited in Healey 1991).

years, rather than as functions of biotic or abiotic factors [see, for example, Washington Department of Fisheries *et al.* (1992)].

Because of the complexity and variety of chinook life history types, it was likely that there is no single limiting factor on chinook production, but there may be a variety of constraints that interact to affect different components of the chinook population. Faced with this complexity, the most efficient way to determine whether a proposed restoration action would actually remove a constraint on adult chinook production, and to quantify the likely benefits of that action, would be to use a computer model that simulates the production of each chinook life history type through each stage of its life, from incubation to spawning, and compares the before-and-after benefits of each proposed action. Cheslak and Morhardt (1988) summarized the benefits of using simulation models to guide chinook restoration, as follows:

1) All assumptions are explicitly stated;
2) Hypotheses are independently testable;
3) Gaps in knowledge are identified; and
4) In a complex system, quantitative results of various management alternatives can be explored.

Thus, with such a chinook restoration model, it would be possible to predict how a proposed restoration action, such as planting fry in the Suiattle, or increasing the area of off-channel rearing habitat in the Upper Skagit, might affect adult chinook production; it would also allow testing of the assumptions and inputs that went into the model (for example, if the capacity of off-channel habitat was significantly overestimated, observed smolt production would be well under what the model predicted -- this would be cause for revising the inputs). Implicit in this modelling would be identification of the factors that limit chinook production, and the life stages on which they act.

In order to develop such a model, it was necessary to have information on several input factors, including what the different chinook life history types are, the capacities of different habitat types, and survival rates by life history type. It was the purpose of this project to provide these inputs.

Existing Data

For the Skagit, some data did exist on juvenile chinook rearing densities in freshwater and estuarine habitat. Data on juvenile chinook abundance, distribution, and outmigration timing were collected in Skagit Bay from 1970-1972 (Stober and Salo 1971; Stober *et al.* 1973). These data were also collected in tidally-influenced river areas in 1979, and from 1990-1994 (Congleton *et al.* 1981; Davis 1981; Larsen and Reisenbichler 1993; Beamer and Henderson 1995; Kirby 1995). For freshwater mainstem areas, data on chinook abundance and size were collected from 1974-1978, 1986, and 1993 (Graybill *et al.* 1979; Ladley and Pflug 1986; SSC, unpubl. data; Kirby 1995). In addition, since 1990, WDFW has operated a mainstem scoop trap and screw trap to catch outmigrating smolts (Seiler *et al.* 1995).

While these data were not, by themselves, sufficient to provide estimates of habitat capacity or survival rate that could be used as inputs to a restoration model, they could be used to start a data base that records how the densities of different chinook life history types varied by habitat type over a period of years. With additional data collected over a long enough period of time, this information could be used analytically to estimate the capacities and survival rates that would be used as inputs to a model that evaluates chinook restoration actions (Lestelle *et al.* 1993b).

FY 1995 Project Objectives

For FY 1995, the project objectives were:

1) <u>Mainstem Inventory:</u> Completely survey eight mainstem reaches, quantifying the area of bank, bar, and backwater habitat in each reach.

2) <u>Estuary Survey:</u> Complete the surveys of the tidally-influenced habitat in the Skagit River, quantifying the total area of all salt marsh and transition zone habitat. The remaining tidally-influenced habitat type, the riverine tidal habitat, has previously been quantified.

3) <u>Mainstem Chinook Sampling:</u> Sample chinook in representative bank, bar, and backwater units within each of the eight mainstem reaches, periodically throughout the fingerling migrant period. Calculate habitat preference ratios, and estimate the distribution of smolts among each mainstem habitat type.

4) <u>Estuary Chinook Sampling:</u> Sample chinook at representative Estuarine Emergent Marsh, transition zone, and riverine tidal sites throughout the fingerling residence period. Calculate chinook densities, and estimate the number of smolts produced from each estuary habitat type.

5) <u>Bay Sampling:</u> Test the feasibility of different strategies and time periods for sampling juvenile chinook in Skagit Bay, and collect sufficient numbers of otoliths from these chinook (about 200) to identify the important juvenile life history types, and the average residence time in each estuary habitat type.

6) <u>Test Fishing:</u> Conduct a river test fishery for adults through the chinook management period, and collect sufficient numbers of otoliths (about 100) to identify the proportion comprised of each of the important juvenile life history types.

Although not a direct objective of this study, we also investigated the relationship between mainstem channel types in small rivers (< 50 m bankfull width) and spawner density, in order to develop hypotheses for model inputs for spawning habitat and to examine whether some of the observed variability in juvenile densities between reaches might be attributable to spawner distribution.

In future years, project objectives will include writing the code for the chinook restoration analysis model, and calculating capacity and survival rate values to be used as inputs for this model. However, those were not project objectives in FY 1995.

II. METHODS

Mainstem Inventory

An inventory of river mainstem habitat was necessary to estimate the rearing capacity of these habitats for ocean-type, and, to the extent possible, stream-type juvenile chinook. We focused our inventory only on the habitat in large rivers (> 50 m bankfull width).

Due to cost considerations, we did not survey small rivers (10 - 50 m bankfull width). There are over 400 km of small rivers within the anadromous zone of the Skagit River basin; however, not all of these rivers are currently important for chinook. Habitat and fish use information have been collected for some of the important small chinook rivers (e.g. Illabot, Bacon, Buck, Falls, and Lime Creeks), and we can use this information to answer habitat area and production capacity questions or develop a sampling strategy, if deemed necessary in the future.

Small streams (typically <10 m bankfull width) were adequately surveyed in the mid-1980's by Washington Department of Fisheries (Johnson 1986), and were not included in this inventory.

To do our inventory of large mainstem habitat, we used a classification system with a measured subsample:

1. We defined different mainstem reach types and identified them throughout the river basin;

2. We selected representative reaches of each type;

3. We defined different habitat unit types and identified representative habitat units within the selected sample reaches;

4. We measured the size and physical characteristics of those habitat units in the field. We assumed that the physical characteristics of these units were representative of the unsampled units of that habitat type within that reach;

5. We used aerial photographs to identify the remaining habitat units in the sampled reaches, and we measured the lengths of those units (and the area of the backwater units) from the photographs. This gave us the total length and area of each habitat unit type in the sampled reach.

6. We applied those measurements to the unsampled reaches of the same type.

Reach Identification and Sample Site Selection

For large rivers (Skagit, Sauk, Suiattle, and the lower part of the Cascade River), we defined reaches upstream of the North and South Fork junction (located at river mile 8.1) according to differences in hydromodification and channel pattern, and we also considered differences in channel gradient and width. Channels downstream of the Forks were considered part of the estuarine habitats because they were regularly influenced by the tide (see Estuary Survey, below). We used current 1:12,000 scale orthophotos (1991-92) and USGS 7.5 minute quadrangles to determine open canopy width, current channel pattern (single or multiple), whether the reach was dominated by hydromodification or not (diked), and gradient for all reaches.

To determine channel pattern, we classified a *multiple* channel reach as one in which 50% or more of its main channel length had active side channels[5]. A *single* channel reach had less than 50% of its main channel length in active side channels.

We identified dikes either visually from the photos, or from map symbols on the 7.5 minute quadrangles. Contour lines on the 7.5 minute quadrangles were used to determine gradient from the upstream to the downstream end of a reach.

Once we identified the reach types, we labelled them with reach ID numbers, and randomly selected at least two boat-accessible reaches of each type for measurement.

Habitat unit definition

In large rivers, we classified the wetted habitat area along the river shoreline (edge habitat) into banks, bars, 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 (Fig. 1). Mid-channel habitat units (riffles, glides, or pools) were not inventoried in this study because chinook were not found in those areas during previous studies (SSC unpubl. data). Edge habitat units were distinguished from mid-channel units by current; edge units had lower velocity (Fig. 1). The demarcation line between edge and mid-channel units was generally a visible current shear line between the two units.

---

5. *Active* side channels are secondary channels that regularly receive surface water flow, and are separated from the main channel by a vegetated island. In contrast, *relic* secondary channels are those that do not regularly receive surface water flow, and include oxbow lakes, meadows, and their outlet channels. Riparian areas surrounding relic channels are usually heavily vegetated.

Measurement of Representative Edge Habitat Units

In each sampled reach, we measured representative edge habitat units over a range of flows while conducting mainstem chinook sampling (see Mainstem Chinook Sampling, below). Samplers measured the length and width of each unit from a boat with hipchains and measuring tapes. Edge unit width was measured several times (~30 times) in each unit to obtain mean unit width.

We also classified each measured habitat unit according to water depth, relative surface water velocity, cover type, and substrate type during the process of electrofishing. These data were collected at each grid point that was shocked (~30 per habitat unit). The habitat conditions recorded at each grid point represented the dominant measurement (or average condition, in the case of water depth) within a two meter diameter circle at the site. In order to describe the habitat conditions of the entire unit, we averaged the depth measurements for all grid points within the unit, noted the most common surface velocity condition, and noted the most common and second most common substrate and cover type within each unit.

We measured depth by standing the electroshocking wand vertically on the bottom of the river, and reading previously-marked depth gradations (marked at 10 cm intervals) off it. Surface current was estimated by dropping a chip of wood into the river and clocking the amount of time it took to float the length of the boat. We classified surface as high, medium, or low according to Weigand (1991): high surface current was greater than 45 cm/sec; medium surface current was 15 - 45 cm/sec; and low surface current was less than 15 cm/sec. The definitions used for substrate types, cover types, types of wood cover, and size of wood cover are shown in Table 1.

Inventory from Orthophotos

For each of the sampled reaches, all edge habitat units were delineated on 1991-92 orthophotos (1:12,000 scale). The area of backwater units and the length of bank and bar units were measured using Generic CADD. To estimate the area of bank and bar units that were not measured in the field, we multiplied the estimated length of each unit by the average width of the habitat units of that type that were measured in the field.

Expansion to unsampled reaches

In order to apply the results from the sampled reaches to estimate edge habitat area in the unsampled reaches, we first calculated total channel area (reach length multiplied by channel width) for each reach. We then calculated the percent of the total channel area represented by each edge habitat unit type within a sampled reach, and applied those percentages to the unsampled reaches of the same type. Where more than one reach of the same type was inventoried, the percentages were averaged, and then applied to the unsampled reaches.

We then summed up the area of each habitat type within each reach to determine the total area of each habitat type within the large rivers upstream of the convergence of the North and South forks of the Skagit River.

Estuary Survey

An inventory of estuary habitat was necessary to estimate the rearing capacity of ocean-type juvenile chinook. Objectives for FY 95 were to complete the survey of all estuarine habitat zones in the Skagit.

Estuarine Habitat Zones

We used some of the classification features of Cowardin *et al.* (1979) to define three habitat zones within the study area: estuarine emergent marsh, emergent/forested transition, and forested riverine/tidal. We assumed that the zones were formed primarily by various combinations of elevation, and tidal and river hydrology. Habitat zones were identified by *indicator habitat types*. Indicator habitat types had to dominate an area (not merely be present in an area) for the area to be delineated as the zone associated with that habitat type. Indicator habitat types were primarily vegetative communities that arose from distinctive combinations of hydrology and elevation. The zones were not, however, exclusively composed of their indicator habitat types; we assumed that non-indicator habitats could persist in small patches within zones, due to localized disturbances of the natural processes that created the zone.

The indicator habitats for the *estuarine emergent marsh* (EEM) zone were low and high saltmarsh. Other habitat types commonly occurring within this zone in small patches included: channels (various types), mudflat, estuarine openwater, estuarine scrub shrub, and freshwater emergent marsh.

The *emergent/forested transition* (Transition) zone was a mosaic of tidally-influenced emergent marsh and scrub shrub habitats. This zone encompassed the trend in vegetation from forest-dominated wetlands and uplands to EEM. Other habitat types commonly occurring within this zone in small patches included: channels (various types), wetland forest, upland forest (gallery forests), palustrine openwater, and mudflat.

The indicator habitats for the *forested riverine/tidal* (Forested) zone were palustrine and riverine forests. Other habitat types commonly occurring within this zone in small patches included: channels (various types), mudflat, upland habitats, tidally influenced emergent marsh, and scrub shrub habitats.

Measurement of Habitat Types

Within each zone, we identified three channel types used by juvenile chinook (main, subsidiary, and blind), according to a classification system adapted from Simenstad (1983) (Fig. 2). For this study, we classified blind channels into two categories, based on their size and how they were formed. Large blind channels (typically wider than 20 meters) were historically subsidiary channels that were cut off by diking, which converted them to blind channels. Small blind channels (typically less than 20 meters wide) were primarily formed and maintained naturally by tidal energy. We further classified small blind channels according to channel order (first, second, and third order channels) (Fig. 2).

To estimate the area of main, subsidiary, and large blind channels in each zone, we used Generic CADD (1992) to measure the length of each channel segment from current (1991-92) 1:12,000 scale orthophotos. To determine the average channel width of each channel type, we used CADD to measure the widths of 18 different channels from 1:6000 scale enlarged photos. The area of each segment was then estimated by multiplying the average width of that channel type by the length of that channel segment. The segment areas were then added together to estimate the total area of each channel type within the zone.

Widths of small blind channels could not be measured from aerial photographs. To estimate the area of small blind channels in the EEM zone, we first calculated the average length/ha of first, second, third order blind channels in EEM habitat. Average channel length/ha was estimated by using CADD to measure channel lengths in four different marsh areas of known area in the Skagit estuary. To estimate the average bankfull width of small blind channels by channel order, we measured 21 different small blind channels in the field. We then multiplied the average channel lengths and widths to estimate the average small blind channel area per area of marsh.

Small blind channel areas in the other zones were not estimated directly because, due to vegetation, they were not easily detected on orthophotos. The upper limit of small blind channel area was inferred from the relative difference in channel density observed in the field, compared to the density calculated for the EEM zone (see results section).

We measured the area of marsh, scrub shrub, and forested wetland within each zone by using CADD on current 1:12,000 scale orthophotos. These habitat areas were exposed to regular or periodic flooding caused by tidal or river flow.

Mainstem Chinook Sampling

Our FY 95 objectives for mainstem chinook sampling were to sample chinook in representative bank, bar, and backwater units within each of the eight mainstem reaches throughout fingerling migration, calculate habitat preference ratios, and estimate the distribution of smolts among each mainstem habitat type.

Chinook Sampling

To accomplish these objectives, we selected 24 representative edge habitat units in eight of the nine sampled mainstem reaches, and sampled these to determine the relative densities of juvenile chinook in each habitat type. Each representative edge habitat unit was electrofished from a boat, using a grid point shocking system adapted from Weigand (1991). Grid point spacing ranged from 15 to 30 meters over the entire unit, and 9 to 45 grid points were established in each habitat unit, depending on the unit's size (Fig. 1).

At each grid point, the electroshocker was turned on for 10 seconds, off for 5, and back on for 10 seconds. The stunned fish were retrieved by dipnets. A total of five people were necessary to conduct this sampling: one boat operator, one anode pole operator, one notekeeper, and two people who dip-netted the stunned fish. We sampled every 2 weeks from March through June of 1995 (management weeks 9 - 25), with one additional sample taken in September (management week 36) during the low flow period.

For each grid point, we recorded the catch of all fish by species and age classes, as well as the habitat data referenced under Mainstem Inventory (above). Fork lengths of juvenile chinook were recorded for each habitat unit. We did not electrofish mid-channel units because, as noted under Mainstem Inventory (above), previous pilot-level mainstem shocking in the Skagit River showed juvenile chinook were present only in edge habitats (SSC, unpubl. data).

Habitat Preference

To estimate habitat preference ratios for 0+ chinook, we stratified the backwater, bank, and bar units each into three mainstem groups: upper river, middle river, and lower river. The upper river group included all units in the Skagit River upstream of the Sauk River (reaches SK100 through SK130) (Table 2). The middle river group included units from SK070A through SK090. The lower river group included units from SK030 through SK050. We did not use Sauk River units to estimate juvenile habitat preferences, because sampling in the Sauk was sporadic, and very few chinook were caught.

The relative density data (chinook/grid point) for each habitat type were pooled by mainstem groups (instead of by individual reach) in order to increase the sample size and obtain a rough estimate of the variance in density within each group. The boundaries between the groups were based on the number of chinook stocks likely to be present in the group. Chinook in the upper river group should have consisted primarily of Skagit River summers, because the sampled units were located in the spawning area of this stock. The middle river group was located in the spawning range of Skagit falls, but all chinook stocks of the Skagit must migrate through this area. The lower river group was not located in any spawning range, but all outmigrating chinook had to pass through this area.

Preference coefficients between habitat types were calculated by comparing their relative densities, as follows:

For each sampling period, the 0+ chinook density (chinook/grid point) in habitat unit u (δ_u) was calculated as:

$$\delta_u = \sum_{j=1}^{G} \frac{N_j}{G} \tag{1}$$

where

N_j was the number of 0+ chinook observed at each grid point; and

G was the number of grid points shocked in habitat unit u.

We calculated the mean density for habitat type i ($\overline{\delta_i}$) as:

$$\overline{\delta_i} = \sum_{u=1}^{T} \frac{\delta_u}{T} \tag{2}$$

where T was the number of habitat units in habitat type i.

Because natural banks were the habitat type most frequently sampled, we assigned lower river natural banks a habitat preference coefficient (K_{bank}) of 1.0. Habitat preference coefficients for the other habitat types were calculated as:

$$K_i = \frac{\overline{\delta_i}}{\overline{\delta_{bank}}} \tag{3}$$

where

K_i was the habitat preference coefficient for habitat type i; and

$\overline{\delta}_{bank}$ was the mean 0+ chinook density in lower river natural bank habitat.

The K_i were calculated for two types of δ_i: maximum (peak) mean density observed during all sampling periods (but we only used sampling periods during which all habitat types were sampled); and mean fish-weeks per grid point shocked (the area under the curve of density against week number).

Because we observed a distinct difference in chinook densities between natural banks and hydromodified banks, we split the bank habitat type into these two classifications. Thus, we determined habitat preference coefficients for four habitat types within each mainstem group: natural banks, hydromodified banks, bars, and backwaters. We did not use an electivity index (as used by Bisson et al. 1982) because it was not feasible to sample a reach intensively enough to establish an average density for an entire reach. We assumed chinook 0+ were not present in mainstem habitat until after management week 6 (February 5th) in order to calculate the area under the curve estimates.

We did not sample any backwater units in the lower river or middle river. In order to estimate chinook density in those units, we assumed that the abundance ratio between backwaters and natural banks was the same in the lower and middle river as was observed in the upper river.

Distribution of Smolts Among Habitat Types

In order to calculate the rearing capacity of the Skagit System, it was necessary to estimate the average distribution among habitat types of the population as a whole[6]. We did this by using the habitat preference coefficients calculated above, and the habitat area measurements calculated during the mainstem inventory (see Mainstem Inventory, above), as follows:

WDFW calculated the total 0+ chinook smolt outmigration (N_T) from their mainstem scoop/screw trap (Seiler 1995).

The number of smolts distributed into each habitat type was the chinook density in that habitat type (in chinook/m^2, *not* chinook/grid point) multiplied by the total area (in m^2) of that habitat type within the Skagit. However, chinook/m^2 could not be directly calculated from chinook/grid point. In order to make this conversion, we made use of the fact that:

$$N_T = \sum (A_i K_i d) \qquad (4)$$

where

A_i was the total area (in m^2) of habitat type i within the Skagit System; and

d was the density (in chinook/m^2) of 0+ chinook in natural bank habitat.

---

6. Note that this was an average distribution. It was not meant to imply that each smolt reared in only one habitat type.

By rearranging, we solved for d as:

$$d = \frac{N_T}{\sum (K_i A_i)} \tag{5}$$

Since the density (in chinook/m^2) in each habitat type was then estimated as $K_i d$, the number distributed into each habitat type was calculated as

$$N_i = A_i K_i d \tag{6}$$

where (N_i) was the number of chinook distributed into habitat type i.

<u>Relation Between Channel Type and Spawner Density</u>

In order to examine whether some of the observed variability in juvenile densities between reaches might be attributable to spawner distribution, we identified reaches, in small rivers where chinook are known to spawn, as one of four channel types listed below, following a classification system developed by Montgomery and Buffington (1993).

Pool-riffle channels exhibit regularly spaced alternate bars and pools that are predominantly formed without in-channel obstructions. They are commonly found in low gradients, ranging from ~0.5% to ~2.0%.

Plane-bed channels lack the free-forming bars and pools present in pool-riffle channels, and consist primarily of riffle area. These channels are usually found at moderate gradients, ranging from ~2.0% to ~4.0%.

Forced pool-riffle channels are also found at moderate gradients, but have more than half of their pools and bars formed as a consequence of in-channel obstructions such as LWD or bedrock.

Step-pool channels exhibit channel-spanning steps visible in the low-flow water surface profile. The steps are generally formed by boulders organized into small dams. These channels are found at higher gradients, ranging from ~4.0% to ~8.0%.

We then identified the cumulative number of chinook redds in each type of reach either by using available WDFW redd count data or by surveying the reaches ourselves. The number of chinook redds was standardized (redds/km) for each reach, and descriptive statistics (mean and variance) were calculated for each reach type.

Estuary Chinook Sampling

The 1995 estuary sampling objectives were to sample chinook at representative EEM, Transition , and Forested zone sites throughout the fingerling residence period, calculate chinook densities, and estimate the number of smolts produced from each estuary habitat type.

Site Selection, Description and Location

Six estuary sites, representing each estuary zone, were sampled for juvenile chinook abundance approximately biweekly during 1995, from management weeks 7 through 33 (Fig. 3). The Tom Moore, Ika, and Brown Slough sites represented the EEM zone. The Deepwater Slough and Grain of Sand sites represented the Forested zone, and the Freshwater Pond site represented the Transition zone in the South Fork area of the Skagit River delta. We tried to trap several sites in the Transition zone on the North Fork side of the delta, but could not successfully access and maintain the sampling equipment throughout the tidal cycle.

The primary channel type sampled was small blind channels. The Brown Slough site contained a portion that was large blind channel. All sites had some emergent marsh habitat (salt or freshwater types, depending on the zone) that was inundated at high tide.

Habitat Area of Sampling Sites

The usable habitat area for juvenile chinook at the sampling sites was assumed to be the wetted area. This area varied with tidal magnitude and river flow at each site. In order to estimate the wetted area at different high and low tidal heights, we developed a relationship between wetted habitat area and the water depth, measured from a staff gauge, at that site. To develop this relationship, we used a hipchain to measure the dimensions of the wetted area at several depths, calculated the wetted area from those measurements, and plotted the estimated wetted area against its corresponding water depth, for each measured depth. We connected these points with lines, and used these lines to estimate the wetted area at high and low tide at any subsequently measured water depth. To estimate the average rearing area at high or low tide, we averaged all the area measurements taken at high or low tide at that site.

Fish Sampling

We used fyke traps and beach seines to sample for fish presence and abundance at each site. The fyke trapping methods generally followed those described in Levy and Northcote (1982): a 1/8 inch knotless nylon net with an attached fyke tunnel was set across the outlet channel of a site at high tide; the trap was fished throughout the ebbing tide, and it captured fish that exited the habitat area as it dewatered. Impounded areas that formed at low tide in the Grain of Sand, Deepwater Slough, Freshwater Pond, and Ika sites were beach seined with a 80 ft. long by 10 ft. deep 1/8 inch knotless nylon mesh net. Salmonids caught in the fyke traps and beach seine were identified and enumerated by species and age class. Fork lengths were collected on juvenile chinook.

To estimate juvenile chinook density, we used Levy and Northcote's (1982) mark/recapture technique to calculate the *recovery efficiency* (RE). With this technique, juvenile chinook were seined from nearby sites, marked with partial fin clips, and held for a day in a live box to acclimate to the site. The marked chinook were then planted into the habitat upstream of the fyke trap or in the beach seine area at high tide. The RE was then the proportion of the marked fish recaptured by the fyke trap or beach seine. Since it was likely that RE would not be constant at each site, and may have been affected by either the amount of water flushed out of the site or the amount of water remaining in the site, we estimated RE more than once at each site (except Deepwater Slough) and examined whether the variation in RE could be explained by either the drop in tidal height or by the ending tidal height. If the tests showed no significant difference in RE at a site, we used the mean of the estimated RE's as the RE for that site. If there was a significant difference between RE's that could be explained by either the drop in tidal height or by the ending tidal height, we used a regression between RE and the predictor to estimate RE on each sampling date.

Unmarked juvenile chinook catches were then divided by RE to estimate the site's population at the time the trap was set (high tide). To estimate the low tide population at each site, we subtracted the number of fish which egressed from the site.

Juvenile chinook density was then calculated as population divided by habitat area. Because total estuary habitat was estimated from aerial photos done at low tide, density at the sampling sites was expressed in terms of area at low tide. For three sites (Deepwater Slough, Freshwater Pond, and Grain of Sand), which were complete enclosures under normal tide and river flow conditions, the habitat area was simply the mean wetted area at low tide. The Brown Slough, Tom Moore, and Ika sites contained flooded plains, contiguous with the river, at high tide. Because the fykes, which were set in the channels, trapped only chinook that flushed out through those channels, and in order to be consistent with the aerial photo measurements of area (which did not include flooded plains in the area estimates), we used bankfull channel area of the first, second, and third order channels upstream from the trap as the habitat area for these sites.

Calculation of Smolt Production by Estuary Habitat Type

To estimate total smolt production for each estuary habitat type, we plotted the population density over time for each site, and used CADD to measure the area under this curve. This value was the fish-days/area for that site. When data were lacking, we assumed that chinook were present between weeks 6 and 29, to complete the curves. We then divided the fish-days/area value by average residence time, which was provisionally set at the 25 days estimated by Healy (1980)[7], yielding the annual smolt production/area for that site. We then averaged the smolt production/area values for all sites that represented the same estuary habitat type, and multiplied this average by the total area of that estuary habitat type, to produce our estimate of the total smolt production for each estuary habitat type.

Bay Sampling

As described above in the Introduction, the FY 95 objectives for bay sampling were to test the feasibility of different strategies and time periods for sampling juvenile chinook in Skagit Bay, and collect sufficient numbers of otoliths from these chinook (about 200) to identify the important juvenile life history types, and the average residence time in each estuary habitat type.

Juvenile chinook salmon were sampled from Skagit Bay by using both beach seine and tow net surface trawling, according to the procedures of Stober and Salo (1971). Beach seining was designed to sample fish in the intertidal area while the tow net sampling was designed to collect fish from the areas outside the intertidal range. Inshore (beach seine) sampling was scheduled two days/month, and offshore (surface trawl) sampling one day/month, from April through October.

Surface Trawling

Surface trawling was conducted throughout northern Skagit Bay (Fig. 4). Trawling began in May, utilizing a surface pair-trawl, and was conducted at all tidal stages. The trawl (Fig. 5), which is currently used by WDFW to collect baitfish samples, was designed to capture fish that swim near the surface. This gear has captured juvenile salmon incidentally during WDFW baitfish surveys and was used for collection of juvenile salmon during National Biological Survey (NBS) research in Skagit Bay (Larsen and Reisenbichler 1993). The net, which was borrowed from WDFW, was, however, available for only limited periods due to the pre-existing schedule of the baitfish program. Vessel scheduling conflicts and WDFW commitments for net use necessitated the development of an alternative sampling method.

As an alternative, WDFW provided the use of a small otter-trawl, which could be towed by a single boat, and surface trawling resumed in August. This net, although smaller than the pair-trawl, was considered adequate for testing the utility of the surface trawling technique and for identification of appropriate sampling locations. The trawl net was modified for surface trawling by attaching 18-inch spherical buoys to each trawl door. This allowed the doors to hold the net open while the floats provided enough buoyancy to keep the net at the surface.

---

7. This residence time estimate will be refined in future years by otolith readings.

Beach Seining

Beach seining was conducted at several locations in northern Skagit Bay (Fig. 6), during the period around high slack tide. Sites initially selected represented a variety of geographic and substrate types. Sites where large numbers of chinook were caught were selected as primary sample sites. Additional sites were sampled on each sample day to monitor changes in catch at those sites.

The beach seine used was 100 feet in length, 12 feet in depth at the bunt, and constructed of ⅛ inch knotless mesh throughout. The net was set from a skiff by anchoring on the beach, running out from the beach to the full extent of the net, holding the net against the current for 1-3 minutes as the net was slowly brought back to the beach and closed. The net was then drawn up by hand and all organisms were examined. Salmonids were put into buckets for further examination.

Data Collected

For both the surface trawl and beach seine collections, salmonids were identified to species, enumerated, and measured, and chinook salmon were retained if needed for otolith samples. Only unmarked chinook were kept for otolith sampling. Data collected from each salmon included: species, age[8], fork length, and collection date, time, and site. Information recorded for each site included location, relative slope of bank (steep or level), and substrate type (mud, cobble, etc.). Retained juveniles were preserved in 95% ethanol. Other organisms were identified, enumerated, and released. All field-recorded data were transcribed into electronic format for analysis and storage.

NBS staff recommended, for Skagit Bay, an otolith collection schedule of 20 chinook per sampling day for periods of lower abundance, and 20 chinook per sample site for periods of high abundance. If the total number of juvenile chinook collected from a site was less than five, the fish were generally released and sampling commenced at another site.

Juveniles collected during Skagit Bay sampling were transferred to the NBS for otolith extraction. Otoliths will be read by NBS staff by using the methods of Larsen and Reisenbichler (1993). Specific growth patterns will be identified and matched up with baseline samples taken from different habitat types in the river and estuary. Average residence times will be calculated for chinook that reared in estuarine habitat types.

---

8. A field evaluation of whether the fish was a subyearling or a yearling. Because of their large size in the Bay, particularly during the summer, this determination could not be made in the field for chinook. Otolith reading will be used to age bay chinook.

Test Fishing

The test fishery was conducted from May through August with one drift gillnet skiff at Blake's Drift (RM 1.4 - 2.0 in the North Fork), 1 day/wk for 6 hrs/wk, in two 3-hr periods starting at high tide. The gillnet used was 50 fthm long, 40 mesh deep, 7 to 7½ in monofilament mesh. After each drift, any fish caught were counted and sampled for otoliths, length, sex, scales, and marks. The total catch was weighed at the end of the fishery. All chinook heads, except those of ad-clipped chinook, were removed and sent to the NBS lab for otolith removal; if any chinook were ad-clipped, the snouts of those fish were sent to WDFW for CWT retrieval.

Model Development and Calculation of Inputs

Development of the chinook restoration analysis model, and calculation of habitat capacities and survival rates for different life history stages, were not project objectives in FY 1995. These methods will be described in the FY 1996 annual report.

III. RESULTS

Mainstem Inventory

Reach Identification

We estimated the total length of large mainstem habitat to be 254.9 km (158.4 miles), in which we identified 27 reaches upstream of the Forks (Fig. 7). By stratifying the 27 reaches according to hydromodification and channel pattern, we identified three different reach types: non-hydromodified multi-channel, non-hydromodified single channel, and hydromodified single channel. For habitat unit measurements, we selected two non-hydromodified multi-channel reaches, five non-hydromodified single channel reaches, and two hydromodified single channel reaches (Table 2). These reaches represented 34% of the total length of large mainstem habitat.

Width of Bank and Bar Habitat Units

Mean width for bank and bar units was calculated from 14 bank units and 7 bar units (Table 3). Mean width was 2.6 m for bank habitat and 15.6 m for bar habitat units. No relationship was observed between bank habitat width, and gradient or channel width. For bar habitat, a positive relationship was observed between bar habitat width and mean channel width (Fig. 8).

Area of edge habitat

From aerial photos, we identified and measured 301 edge habitat units in the nine sampled large mainstem reaches, consisting of 38 backwaters, 131 banks, and 132 bars units (Table 4. Edge habitat made up less than 14% of the total channel area within each reach, with the lowest percentage edge habitat occurring in hydromodified reaches (Table 5).

To estimate the area of each edge habitat type in each unsampled reach, we used the mean percentages shown in Table 5 for that reach type. For example, to estimate backwater area in an unsampled non-hydromodified multi-channel reach (e.g., SK060A), we multiplied the total channel area in that reach by 1.8%. This resulted in an estimated total channel area throughout the Skagit (excluding Reach SK140 -- see below) of 3,996.1 ha, of which 53.9 ha were backwater habitat, 86.5 ha were bank habitat, and 229.1 ha were bar habitat (Table 6).

Reach SK140 was the uppermost reach in the mainstem Skagit, located directly below the Gorge Dam. We did not make any habitat area estimates for this reach because: 1) we lacked sufficient aerial photograph coverage to make a reliable channel width estimate; 2) the gradient (steeper) and valley confinement (in a canyon) of this channel was more extreme than all the other reaches, which suggested that SK140 may be a unique reach type; and 3) the flow in this reach was usually bypassed via a tunnel between Gorge Dam and the Gorge Powerhouse (located in Newhalem) -- at least partly because of this bypass, few chinook currently utilize this reach.

Field Verification of Aerial Photo Measurements

To check the accuracy of our aerial photo identifications and measurements, we selected a sample of individual backwater, bank, and bar habitat units, and compared aerial photo measurements to field measurements. In this comparison, the person doing the photo measurements did not know the location of the field-delineated units, but he was very familiar with the mainstem habitat within the vicinity of the sample areas.

Out of ten backwater units identified in the field, all ten were correctly identified as backwater habitat from aerial photographs (100% accuracy). Out of 24 bank units identified in the field, 23 were correctly identified from aerial photographs (~96% accuracy) while one unit was identified as bar habitat. Out of eleven bar units identified in the field, all were correctly identified from aerial photographs as bar habitat units (100% accuracy) (Appendix 1). Therefore, it appeared that identification of edge habitat types from aerial photography was highly accurate.

In terms of the accuracy of area measurements, there were wide deviations for individual units, but these deviations tended to balance out when the measurements were combined across several units. For individual backwater units, air photo measurements deviated by up to 447% from field measurements (Table 7). For individual bank units, air photo measurements deviated by up to 174% from field measurements. And for individual bar units, air photo measurements deviated by up to 348% from the field measurements. However, the sum of air photo area measurements of ten backwater units deviated by <1% from the field measured total (50,559 m^2 from air photos vs. 50,675 m^2 from field measurements). Similarly, the sum of air photo area measurements of 14 bank units deviated 14% from the field measured total (20,330 m^2 vs. 17,862 m^2), and the sum of air photo area measurements of seven bar units deviated 12% from the field measured total (52,706 m^2 vs. 47,206 m^2). For these areas combined, the area measured from air photos was 123,595 m^2, vs. 115,743 m^2 from field measurements, a difference of about 7% (Table 7).

It may have been possible to use regression analysis to develop a correction for total estimated area (Table 8), but this would not have increased the precision of the area measurements for individual habitat units; moreover, the slopes of the regressions were not significantly different from 1 for any habitat type (see Appendix 1 for detailed regression statistics and plots of field measurements against aerial photo measurements). More importantly, a correction was not warranted for our applications because, for the purpose of quantifying habitat area at the basin scale, the accuracy of air photo estimates of total area appeared to be reasonable (Table 7). This was primarily because the number of photo measured habitat units within the sampled mainstem reaches was large (38 backwaters, 131 banks, and 132 bars units).

Other Habitat Characteristics

In addition to area measurements, we recorded the depth, water surface velocity, substrate, and cover within 24 representative edge habitat units up to nine different times between March through July, and once in early September. Notable differences between edge unit types were observed in mean depth, substrate, and cover (Table 9).

Water depth in bar units was consistently shallower than all other edge unit types. Mean water depth for all measured bar units was 0.35 meters, while mean depth for natural bank, hydromodified bank, and backwater units was > 0.60 m.

The substrate in backwaters was dominated by sand and mud, while the other unit types generally had larger substrate particles.

In terms of cover, aquatic plants were most common in backwaters, with wood also generally present. In bar units, cobble cover was most common, while wood was never dominant or subdominant in any single unit. In bank units, cover was usually dominated by wood; however, hydromodified banks had a significant cover component composed of riprap or rubble, while natural banks did not. When wood cover was dominant or subdominant in edge units, debris piles were the most common type of wood cover.

Estuary Survey

We estimated the mean width of main channels, except the North Fork Skagit River, at 124 m. The width of the North Fork Skagit River was 197 m. The mean width of subsidiary channels and large blind channels was 28 m.

Average channel lengths of first, second and third order blind channels were 57, 38, and 5 m/ha of marsh, respectively. Average channel widths for first, second and third order channels were 3, 7, and 15 m respectively.

From these lengths and widths, we estimated the total inventoried estuary area at 2555.7 ha (Table 10). This area runs from the bifurcation of the Skagit River near Mt. Vernon to the large mudflat area in Skagit Bay (Fig. 3). Of these 2,555.7 ha, we estimated that 1,014.6 ha were EEM zone, 1,000.2 ha were Transition zone, and 540.9 ha were Forested zone. Mainstem channel area was greatest in the Forested zone, and least in the emergent marsh zone. Subsidiary and large blind channels comprised over 6% of the EEM zone, but were nearly nonexistent in the Forested zone.

We could not directly estimate the area of small blind channels in the Transition or Forested zones, because vegetation often covered them in the photos. However, our field observations indicated that small blind channel density in the Transition and Forested zones, among the marsh, scrub shrub, and forested habitat, was less than among that habitat type in the EEM zone. Since we could measure, from photos, the area of the marsh, scrub shrub, and forested habitat that concealed the small blind channels in the Transition and Forested zones, we could estimate an upper limit for the small blind channel area in those two zones. Since small blind channel area in the EEM zone was ~5% of the marsh/scrub shrub/forested + small blind channel areas, we estimated that small blind channels in the Transition zone would not exceed 37 ha (5% of 747.6 ha = 37.4 ha), and that small blind channels in the Forested zone would not exceed 11 ha (5% of 222.6 ha = 11.1 ha). From these calculations, we estimated that small blind channel area was greatest in the EEM zone, and made up less than 3.7% of the total estuary habitat (Table 10).

Mainstem Chinook Sampling

Chinook Sampling

We conducted 149 samples of habitat units in FY 1995. This was 38% less than the number planned, primarily because turbid water cancelled some sampling days, low flows prevented boat access to some of the sites (particularly the Sauk River sites), and some equipment failed.

Sampling began in management week 9 in the upper river, with chinook present in all habitat types (Fig. 9). The other mainstem groups, the middle and lower river, were not sampled until weeks 11 and 13 respectively (Figs. 10 and 11]). Peak abundance was between weeks 13 and 15 inclusive, with the highest chinook per grid point recorded in backwater units in the upper river in week 15 (Fig. 9). No juvenile chinook were captured in 14 units sampled at the end of summer (Figs. 9 and 10).

Habitat Preference

Habitat preference coefficients were highest for upper river backwaters, and were generally lowest for bars, although hydromodified banks in the middle river had lower densities than did the middle river bars (Table 11). Complete chinook per grid point data by site and sample week are attached in Appendix 2.

Habitat preference coefficients were calculated both from peak densities, and by summing the area under the curves in Figs. 9,10 and 11. Under either method, the trends in the lower and middle river were similar (Table 11). The preference at the lower river sites was: natural banks (most preferred) > hydromodified banks > bars (least preferred). The preference at the middle river sites was: natural banks > bars > hydromodified banks. No backwater units were sampled in the lower or middle river strata.

For the upper river, however, the preference coefficients for hydromodified banks and bars, calculated according to peak densities, were about half the values calculated from the area under the curves.

Distribution of Smolts Among Habitat Types

From Table 6, we could estimate the total backwater and bar areas within each mainstem section. For banks, however, we noted only whether a reach was predominantly hydromodified or non-hydromodified; we have not yet quantified how much of the bank area within the reach was hydromodified and how much was non-hydromodified. Until this task is completed, in order to generate estimates of smolt distribution among habitat types in 1995, we assumed that banks in hydromodified reaches were 100% hydromodified, and banks in non-hydromodified reaches were 100% natural. While this assumption was clearly inaccurate (for example, some of our upper river sampling sites were hydromodified banks, even though no upper river reach was predominantly hydromodified), these inaccuracies can be corrected when data become available. Until that time, the area estimates we used for each habitat type, in order to estimate smolt distribution, were (in m^2):

	Lower River	Middle River	Upper River	Total
Backwaters	26,000	147,000	94,000	267,000
Natural Banks	25,000	233,000	185,000	443,000
Hydromodified Banks	101,000	43,000	0	144,000
Bars	147,000	723,000	368,000	1,238,000

Seiler (*pers. comm.*) calculated the 1995 0+ wild chinook outmigration from the Skagit at 1.5 million smolts. From the habitat area estimates listed above, and the abundances shown in Table 11, we estimated that of these 1.5 million smolts, the number distributed into the backwater, natural bank, and bar habitat types were all about the same magnitude, about 400,000 to 600,000 in each, and about 50,000 were distributed into hydromodified bank habitat (Table 11). While the average density in bar habitat was low, relative to backwaters and natural banks, there was much more bar habitat area (see above); hence, the number of fish in bar habitat was somewhat more than the number in backwaters and natural banks.

Changes in Length

Mean length in the spawning ground areas remained stable at about 41 mm from weeks 9 through 15, and then increased steadily to a mean length of about 55 mm in week 25 (Fig. 12a). These mean lengths were less than those of chinook farther down river at WDFW's mainstem trap and in the estuary and bay (Fig. 12b). Mean lengths by sample site are listed in Appendix 3.

Relation Between Channel Type and Spawner Density

In the five small rivers examined (Bacon, Buck, Falls, Lime, and Illabott), all streams had at least three of the four possible channel types present in their anadromous zones. Bacon and Buck Creeks had all four channel types present, with Bacon Creek having more than one reach of each type. Bankfull channel widths ranged from 8 to 36 m. Chinook redds/km data by channel type were generated for all five streams in 1994, and in three of the streams (Buck, Falls, and Lime) in 1995. Data for Falls Creek were also available from 1990.

Chinook redd densities by channel type were:

Channel Type	**Mean Density (redds/km)**	**Std. Dev.**	**N**
Pool-riffle	35.3	33.1	4
Forced pool-riffle	28.1	24.7	21
Plane-bed	1.8	3.3	17
Step-pool	0.5	1.5	8

The densities in the pool-riffle and forced pool-riffle channels were not significantly different from each other, while the densities in the plane-bed and step-pool channels were also not significantly different from each other.

Estuary Chinook Sampling

Habitat Area of Sampling Sites

For the complete enclosure sites (Deepwater Slough, Grain of Sand, and Freshwater Pond), we measured wetted area at high and low tide from 18 to 45 times at each site. The mean wetted area at low tide ranged from about 1,000 m^2 (Grain of Sand and Deepwater Slough) to about 2,000 m^2 (Freshwater Pond), and the mean wetted area at high tide ranged from about 1,800 m^2 to over 5,000 m^2 (Table 12). The staff gauge-habitat area relationships used to estimate wetted area at these sites are shown in Appendix 4. For the EEM sites, bankfull channel areas (small blind channels) ranged from about 1,000 m^2 to about 2,400 m^2 (Table 12).

In addition to these sites, we also sampled sporadically at five other sites: two North Fork sites (NF#6 and NF#7), one site at the mouth of the South Fork (SF#4), Cattail Channel (a

Transition zone about ¼ mile from Ika), and Brown Slough upstream of the cross levee. We did not use these sites to estimate chinook density, either because we could not maintain traps throughout the tidal cycle (the North and South Fork sites), or because the sites did not drain sufficiently to allow an estimate of RE. We did not measure the area of these sites.

Fish Sampling

For all sites, including the unmeasured sites, we collected 72 fyke trap samples and 46 beach seine samples. Fyke trap and beach seine sampling started in management week 7, and ended in week 33. Total chinook catch was 3,468 sub-yearling wild chinook, 2 sub-yearling hatchery chinook (all hatchery chinook were ad-clipped), and 2 yearling chinook. Chinook were caught at all three sites sampled in week 7, and peak abundance occurred between weeks 14 and 20, depending on the site. Chinook were absent from all sites by week 29. In addition to chinook, we observed seven other salmonid species (including whitefish) and at least nine non-salmonid species of fish. Daily catches for each sampling site are listed in Appendix 5.

Estimates of Recovery Efficiency (RE)

We estimated RE from one to four times at each measured sampling site, with 0+ chinook release groups that ranged in size from 29 to 100 fish. The estimated RE's ranged from 7% at Grain of Sand to 97% at Brown Slough (Table 13). For Tom Moore, Freshwater Pond, and Grain of Sand, there was a negative correlation between RE and ending gauge level (Fig. 13)[9], while there was a positive correlation between RE and tidal drop for Ika, as well as for Grain of Sand and Freshwater Pond (Fig. 14).

For Deepwater Slough, we estimated RE only once, at 55% (Table 13). We therefore used a RE of 55% for all sample dates at the Deepwater Slough site.

At Brown Slough, the RE was high (> 90%) and varied only from 91% to 97% in two samples at widely different levels of tidal drop and ending gauge level (Table 13). We therefore saw no reason to introduce the complications of a regression equation at Brown Slough, and instead used the average RE of 94% to expand catches at this site for all sampling dates. We used regression equations with either tidal drop or ending gauge level as the independent variable at the other four sites to estimate RE for specific sampling dates at these sites.

At Ika, our two estimates of RE varied by almost a factor of two (Table 13). Because the correlation between RE and ending gauge height was positive (Fig. 13), which was illogical, we used a regression between RE and tidal drop to estimate RE at Ika. For sampling dates

9. Gauge levels were not standardized between sites. It is coincidental that the ending gauge levels appeared to give the same RE's at different sites (Fig. 13).

where tidal drop at the lower gauge at Ika was between 122 and 155 cm, RE was estimated as:

$$RE_{Ika} = 0.00327 * (\text{tidal drop}) - 0.23404$$

When tidal drop was ≤ 122 cm, we used our minimum measurement of RE (16%). When tidal drop was ≥ 155 cm, we used our maximum measured RE (27%).

At Freshwater Pond, our estimates of RE also varied by a factor of almost two (Table 13). At this site, we used a regression between RE and ending gauge level to estimate RE. For sampling dates where the ending gauge level at Freshwater Pond was between 39 and 72 cm, RE was estimated as:

$$RE_{\text{Freshwater Pond}} = -0.0058 * (\text{ending gauge level}) + 0.6562$$

When the ending gauge level was ≤ 39 cm, we used our maximum measured RE (43%). When the ending gauge level was ≥ 72 cm, we used our minimum measured RE (24%).

At Tom Moore, RE's varied widely, and there was a significant negative relationship ($r^2 = 0.99$, $N = 4$, $P = 0.007$) between RE and ending gauge level. We therefore used a regression between RE and ending gauge level to estimate RE. For sampling dates where the ending gauge level at Tom Moore was between 17 and 63 cm, RE was estimated as:

$$RE_{\text{Tom Moore}} = -0.0125 * (\text{ending gauge level}) + 0.9167$$

When the ending gauge level was ≤ 17 cm, we used our maximum estimated RE (74%). When the ending gauge level was ≥ 63 cm, we used our minimum estimated RE (15%).

At Grain of Sand, RE was measured twice when there was relatively little drop in tidal height; not surprisingly, the RE's measured at these times were very low (Table 13). The third measurement coincided with a large drop in tidal height, and the RE was considerably higher. To account for this effect of tidal drop on RE ($r^2 = 0.99$, $N = 3$, $P = 0.059$), we estimated RE from a regression between RE and tidal drop. For sampling dates where the tidal drop at Grain of Sand was between 14 and 124 cm, RE was estimated as:

$$RE_{\text{Grain of Sand}} = 0.00358 * (\text{tidal drop}) + 0.00131$$

When the tidal drop was ≤ 14 cm, we used our minimum estimated RE (7%). When tidal drop was ≥ 124 cm, we used our maximum estimated RE (45%).

Chinook Density by Habitat Type

From these RE's, we calculated the chinook population by week at each sampling site, and divided by area (Table 12) to estimate density by week. These data, together with available data from previous years (SSC, unpubl. data), are listed in Appendix 6.

Density had a bimodal pattern at two of the EEM small blind channel sites, Brown Slough and Ika (Fig. 15). Density peaked at Brown Slough in weeks 12 to 14, and again in week 18, with chinook gone by week 22. At Ika, a distinct peak occurred in week 12, with a secondary peak in week 20. No chinook were observed in week 33, but there was no sampling between weeks 24 and 33, so it is uncertain when chinook vacated that site.

For Tom Moore, another EEM small blind channel site, we had comparative data from 1992 and 1993 (SSC, unpubl. data). Density in 1995 peaked in week 16, and chinook were gone by week 24. Peak density was much lower than observed in 1992 and 1993, and the timing of the peak was somewhat later (Fig. 16).

At Freshwater Slough Pond, our Transition small blind channel site, density peaked in week 21 and chinook were gone by week 29. Observed densities were comparable to those of 1992 (Fig. 17).

In the Forested Riverine Tidal zone, the density at our Deepwater Slough site showed a broad peak from weeks 14 to 20, with chinook gone by week 26. Densities were generally less than in 1993, and considerably less than those of 1992 (Fig. 18). At Grain of Sand, another small blind channel in the Forested Riverine Tidal zone, density peaked in week 14 at the highest density observed at any site in 1995, over 6000/ha. Chinook were gone from this site by week 29. While sampling at Grain of Sand was incomplete in 1992, it appears that densities were considerably higher that year (Fig. 19).

In addition to these sites, density estimates were made at two other sites (Deepwater Slough and Brown Slough) utilizing beach seine data. Deepwater Slough contained separated ponds that did not drain at low tide. The RE test indicated that fish planted into this site did not migrate to the fyke traps that drained the lower parts of this site; thus, the densities in these ponds were independent of those in the lower parts of this site. Because these ponds did not drain, densities were estimated by beach seining (catch/area seined). Densities at this site peaked in weeks 14 and 20 (Fig. 20), the same weeks that density peaked in the lower part of Deepwater Slough (Fig. 18). The Brown Slough data (from Beamer and LaRock ,1995) show that density was high when sampling started in week 15, and was considerably lower when sampling ended in week 19 (Fig. 20). As sampling was discontinued prior to all fish migrating out of this site, we do not know when the site was totally vacated.

Total Smolt Production by Habitat Type

From these curves (Figs. 15 to 20), we estimated the number of fish-days/ha at each site, and divided by residence time (assumed at 25 days) to calculate the number of chinook/ha produced from each site (Table 14). Production was highest at Freshwater Pond, a small blind channel in the Transition zone, at 12,762 chinook/ha, and was lowest at the lower part of Deepwater Slough, a small blind channel in the Forested Riverine Tidal zone, at 524 chinook/ha. There was considerable variation in production within habitat types in the same zone. Production at the three small blind channel sites in the EEM varied more than fourfold, from 1,400 to 6,600 chinook/ha, and in the Forested Riverine Tidal zone, production varied more than tenfold in the small blind channel sites, from 500 to 5,600.

We multiplied these mean production values by total area of that habitat type (Table 10) to estimate the 1995 total chinook smolt production by estuarine habitat type. Because we did not estimate chinook densities in main or subsidiary channels, we did not estimate production for these habitats. Of the habitat types we did sample, the small blind channels in each zone and large blind channels in the EEM, we estimated that 781,991 chinook smolts were produced in these habitats (Table 15). Of these, over 650,000 were produced in small blind channels, and over 120,000 from large blind channels. Because the estimated small blind channel areas in the Transition and Forested Riverine Tidal zones are maxima (Table 10), these estimates of production from small blind channels are also maxima. Since the estimated total chinook smolt production in 1995 was about 1.5 million (D. Seiler, WDFW, *pers. comm.*), this would mean that about half the smolt production reared in small and large blind channels in the Skagit estuary.

Bay Sampling

Surface Trawling

Trawling began in May, later than planned due to problems locating a net and chartering a vessel. The first sampling, which used a pair trawl, was conducted on May 4, 1995 from a chartered stern-gillnet vessel accompanied by a 20' skiff. We were assisted by the WDFW Biologist who had experience with this net and technique to ensure that we were fishing the net correctly. A total of six tows were conducted. Sampling occurred during ebb and slack low tide periods. The areas sampled were over bottom depths of 12ft to 30ft, of unknown substrate type (Fig. 4).

No salmon were collected from these tows; the vertebrate catch was comprised almost entirely of smelt, with one stickleback, one herring, and 3 sandlance included (Table 16). We also caught shrimp, jellyfish, comb jellies, amphipods, and crabs. The details of each tow are presented in Appendix 7.

Mechanically, the pair trawl gear functioned correctly, except that the skiff (equipped with a 200 hp outboard jet drive) had a tendency to 'slip', which sometimes caused the distance between vessels to vary from normal. In addition, when the tow speed of the gillnet vessel increased while towing with the current, the skiff had trouble keeping up.

When the pair trawl became unavailable, we switched to the small otter trawl. In the interim, we missed several planned sampling dates. Surface trawling resumed on August 10, with the otter trawl, and was also conducted on September 1, September 29 and October 20, 1995. Samples on these four dates included a total of 31 tows, throughout northern Skagit Bay (Fig. 4). Catches were composed primarily of herring, with significant catches of gunnels, perch, sandlance, and smelt occurring on different sampling days (Table 16). No salmonids were collected surface trawling[10]. No data on bottom depth was collected during otter trawl sampling because our vessel was not equipped with a depth sounder.

Beach Seining

Catches: Because the equipment was not available in April, beach seining did not begin until May. Seining continued through October, at a rate of two sampling days per month (approximately 2 weeks between samples). Seining was conducted at a total of 30 sites in 8 areas (Fig. 6), and yielded a total catch of 377 chinook, of which 344 were retained for otolith extraction (Table 17). Juvenile chum salmon were the most numerous species in the catch, and there were also high numbers of smelt, herring, perch, sandlance, and flatfish (mostly starry flounder) (Table 18). The second most numerous salmonid in the catch was juvenile sockeye. Hours fished and catch/set data for each sampling date are listed in Appendix 8.

Of the 8 areas where seining was conducted, four areas were fished consistently throughout the season: Hoypus Point, Ala Spit, Lone Tree, and Hope Island Inn. These sites consistently produced good catches of juvenile chinook (Table 17), as well as other species of salmon and baitfish (Appendix 9). All four were similar in that high tidal current, cobble substrate and moderate to steep dropoff to depth existed at each site (Table 19). Other areas yielded considerably lower catches of juvenile salmonids, particularly chinook.

Juvenile chinook abundance at these four areas, in terms of beach seine CPUE, was initially high in May, increased to a peak between mid-June and mid-July, and then declined gradually, until none were caught in October (Fig. 21 and Table 20)). While chinook persisted throughout the summer, the abundance of other salmonids declined rapidly from high initial levels to virtually nothing by the beginning of July (Fig. 22). Baitfish, in contrast, reached their highest abundance later, in August; however, they were present in significant numbers throughout the sampling period (Fig. 23).

---

10. On August 4, 1995, during an initial check-out of the equipment, we did catch one chinook salmon. However, since this was not a sampling cruise, no data were collected from this fish.

The highest beach seine catches of chinook, and of all other salmon, occurred at times near high tide. Other tidal stages were sampled, but catches always increased substantially near high slack tide. No statistical comparison between catch rates at various tidal stages was conducted.

Lengths: Juvenile chinook mean length increased between the first two samples, declined dramatically on the third sample (June) and then increased steadily throughout the remainder of the sample period (except for the final sample of three fish, which declined slightly) (Fig. 24). In early May, mean length of chinook was 87 mm (n = 50), and increased to 95 mm (n = 33) a week later. After the initial two samples were collected, the mean length decreased to 77 mm (n = 84). Analysis of lengths indicated that the decrease in the third week was statistically significant (as was the increase in the second week) (Table 21). Thereafter, mean lengths increased steadily throughout the remainder of the sampling period, to a peak of 122 mm in late August. The increases in mean length, after June 8, were statistically significant between June 16 and June 30, June 30 and July 19, and July 19 and August 18. Details of the statistical analyses are given in Appendix 10.

Comparison of lengths between sample sites, for a specific date, was hampered by low catch numbers; nonetheless, sample sizes sufficient for comparisons between at least two sites were possible for every sampling date except September 18. Comparisons could be made between 4 sites on May 11, between 3 sites on May 19, between 2 sites on June 8, between 3 sites on June 16, between 4 sites on June 30, between 3 sites on July 19, between 2 sites on August 18, and between 2 sites on August 31. Results showed no consistent patterns in either relative size between sites, or in significance of differences between sites. Significant differences in mean length between sites were found on May 19, June 16, July 19, and August 31; there were no significant differences between sites on May 11, June 8, June 30, and August 18 (Table 22). Details of the statistical analyses are given in Appendix 10.

Life History Types: The 1995 otolith samples have not yet been read. Thus, estimates of the percentage of the 1995 bay catch composed of each chinook life history type, and estimates of average residence time in the estuary, are not yet available.

Test Fishing

The chinook test fishery started on May 1, 1995 (week 18), and continued until August 16, 1995 (week 33). A subsequent coho test fishery started September 20, 1995 (week 38), and continued until November 2, 1995 (week 45). A total of 161 chinook were caught in these test fisheries (Table 23). Of these, 147 were caught in the chinook test fishery, and 14 were caught in the subsequent coho test fishery. A total of 153 chinook heads were sent to NBS for otolith removal; 4 chinook were ad-clipped, so their heads were sent to WDFW for CWT extraction; and, due to a miscommunication, the 4 chinook caught in the coho test fishery at Blakes on September 20, 1995 did not have their heads removed (Table 23).

The catch/hr in the test fishery indicated a bimodal run timing pattern, with a peak around week 20 (mid-May), and another peak around week 32 (mid-August) (Fig. 25, top). This bimodal pattern is consistent with the timing of the run during the previous 5 years (Fig. 25, bottom, and Fig. 26).

The chinook test fishery catch was predominantly chinook. In addition to chinook, we caught 6 pink salmon, 1 coho, 10 sockeye, and 21 steelhead (Table 24).

Model Development and Calculation of Inputs

Because development of the chinook restoration analysis model, and calculation of habitat capacities and survival rates for different life history stages, were not project objectives in FY 1995, there are no results to report.

IV. DISCUSSION

Achievement of Project Objectives

Mainstem Inventory

Mainstem inventory objectives were to survey completely eight mainstem reaches, quantifying the area of bank, bar, and backwater habitat in each reach.

These objectives were exceeded. By using orthophotos and some field measurements, we surveyed nine mainstem reaches: Sa010, SK030, SK040, SK050, SK070, SK090, SK100, SK110, and SK120, and used the measurements of bank, bar, and backwater habitat in those reaches to estimate bank, bar, and backwater area for the entire river system. We estimated that, for all mainstems in the river system, there were 53.9 ha of backwater 86.5 ha of bank, and 229.1 ha of bar habitat.

Estuary Inventory

Estuary inventory objectives were to complete the surveys of the tidally-influenced habitat in the Skagit River, quantifying the total area of all EEM and Transition zone habitat.

These objectives were achieved, with the caveat that we could estimate only a maximum area for small blind channels in the Transition zone. Total channel area in the Skagit estuary was estimated at 581.3 ha of mainstem channel; 87.4 ha of subsidiary channels, 24.0 ha of large blind channels, and less than 93.7 ha of small blind channels.

Mainstem Chinook Sampling

Mainstem chinook sampling objectives were to sample chinook in representative bank, bar, and backwater units within each of the eight sampled reaches, periodically throughout the fingerling migrant period, calculate habitat preference ratios, and estimate the total distribution of smolts among each mainstem habitat type.

Our original sampling anticipated bi-weekly sampling from February through June. We were, however, unable to meet this sampling frequency either because of the time required to process samples during peak abundance, or because flows made sampling impractical. We did, however, sample all 22 habitat at least monthly, while 8 habitat units (3 of the 8 reaches) were sampled bi-weekly.

This frequency of sampling was adequate to meet the objectives of this project: preference ratios indicated that backwater and natural banks were preferred over hydromodified banks and bars. In terms of total distribution, backwaters, natural banks, and bars each produced about 400,000 to 600,000 chinook smolts in 1995, while hydromodified banks produced about one-tenth that amount.

Relation Between Channel Type and Spawner Density

We also collected data on the relation between channel type in smaller streams and spawner density. Chinook redd density did appear to be affected by channel type. In the streams sampled, step-pool and plane-bed channels had consistently low or no chinook spawning while pool-riffle and forced pool-riffle channels consistently had a presence of chinook spawning, usually at levels exceeding plane-bed or step-pool channels by an order of magnitude.

This finding is important for several reasons. First, forced pool-riffle and plane-bed are thought to be interrelated, depending on the amount of in-channel LWD (Montgomery and Buffington 1993; 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. Moreover, forest and flood management activities influence the amount and recruitment potential of LWD in streams. Therefore, land management activities could lead to substantial changes in chinook redd potential. Secondly, if chinook spawning potential in small rivers varies by channel type, then chinook fry production may not be evenly dispersed under present habitat conditions. Also, if the stream type can change due to management or mismanagement, then spawning habitat could become a bottleneck on chinook production in local areas. In order to assess chinook restoration options, we will need to monitor these changes (either positive or negative); to address these issues, an inventory of chinook spawning habitat (location and total area of each channel type) would be necessary.

Estuary Chinook Sampling

Estuary sampling objectives were to sample chinook at representative EEM, Transition zone, and Forested Riverine Tidal zone sites throughout the fingerling residence period, calculate chinook densities, and estimate the number of smolts produced from each estuary habitat type.

For the most part, we achieved our sampling objectives, but had to change some of our sampling sites from those originally planned due to high river flows, which prevented crews from setting fyke nets, and changes in the channel pattern in the delta that prevented access to two sites (Deep Slough and Fishtown).

Our sampling objectives, however, were not adequate to estimate smolt production from each estuary habitat type. This was because: 1) after doing the habitat classification and inventory, we discovered that there were additional habitat types used by chinook within each zone -- while we sampled each zone, most of our sites were of the same habitat type (small blind channels); and 2) we had trouble finding a Transition zone site that could be trapped consistently on the North Fork.

Consequently, while we achieved project objectives for small blind channels in each zone, and large blind channels in the EEM, we could not estimate smolt production from main or subsidiary channels. Our calculations indicated that, for small blind channels, and large blind channels in the EEM, production ranged from 500 to 13,000 chinook/ha, and accounted for about half of the smolt outmigration.

Bay Sampling

Bay sampling objectives were to test the feasibility of different strategies and time periods for sampling juvenile chinook in Skagit Bay, and collect sufficient numbers of otoliths from these chinook (about 200) to identify the important juvenile life history types, and the average residence time in each estuary habitat type.

This project did successfully establish a feasible strategy for sampling juvenile chinook in Skagit Bay. Beach seining about twice/month from May to October by itself captured well over the 200 chinook needed for otolith analysis of life history types and residence times.

The feasibility of surface trawling, however, remains unproven. Pair trawling is unreliable; it might be possible to catch chinook with this method (even though we didn't catch any), but we clearly could not rely on having the equipment, which we would have to borrow or charter, available when it was needed. Otter trawling, on the other hand, was logistically and mechanically feasible. While only one chinook was caught in 4 sampling days (and that one in a non-sampling gear test), the timing of the beach seine catches indicates that these sampling days were late in the outmigration period; other researchers have had more favorable results with surface trawling (Larsen and Reisenbichler 1993) and it is possible that we would have caught more chinook if otter trawling had started earlier.

Since beach seining has been shown to be a feasible sampling method in Skagit Bay, it would only be necessary to use surface trawling if the life history composition of chinook that inhabit inshore areas (where we beach seine) is different from that of the chinook that rear in offshore areas (where we would surface trawl). Larsen and Reisenbichler (1993) have not yet completed a comparative analysis of otoliths from their beach seine and tow net samples; mean lengths at two areas that were both seined and tow netted were not significantly different, but mean lengths at all sites that were tow netted during May and July 1991 were significantly greater than the lengths at all the sites beach seined during the same months. Thus, there is a possibility that the life history composition in offshore areas is different from that of the inshore areas.

Life History Types

The reason for collecting otoliths from Skagit Bay was to identify the important juvenile life history types of Skagit River chinook and their proportion in the run. While explicit identification of juvenile life history types will not be available until these otoliths are read, which they haven't been yet, we could still infer juvenile life history information from earlier work and from length and timing information collected from the freshwater, estuarine, and bay sampling done in 1995.

Both ocean-type or sub-yearling smolt, and stream-type or yearling smolt life history patterns are present in Skagit River wild chinook populations. Based on adult scale samples collected from spawning areas, 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 (WDFW, unpublished scale data). The sampling conducted for this study in 1995 collected very few yearling chinook, so we have learned very little about this life history pattern, other than where they don't rear. However, our sampling of sub-yearling chinook abundance and length frequency throughout the river basin from emergence to Skagit Bay provided us with a profile of juvenile chinook use of habitat throughout the outmigration period (Figs. 12a and 12b).

The migration past the WDFW mainstem trap in Burlington (lower river) had multiple peaks (Fig. 12a). 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 there was a decline in upper river abundance; simultaneously, mean lengths in the lower river became larger than in the upper river, in which mean length remained relatively constant through week 20. This reflected a reduced rate of emergence after week 15, outmigration of some fry to estuarine habitats (Fig. 12b), and immigration of other fry to areas in the lower river or off channel habitats. The peak migration of fish leaving off channel habitat (see below) 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 (Fig. 12a). In addition, the mean length of fish leaving the off channel habitat was similar to that of fish in the Brown Slough estuary habitat at the same time (Figs. 12a and 12b).

Through week 14, mean fork lengths of sub-yearling chinook were similar at all estuary and river sites (Figs 12a and 12b). During this time, there was an increase in abundance at the estuary sites and a peak migration past Burlington. Following week 14, mean fork length at estuary sites generally was greater than in the lower river until week 24, when mean fork length in both the estuary and lower river approximated 70 mm. However, when this occurred, very few sub-yearling chinook apparently remained in the estuary (Figs 15 to 20). After week 17, there was a decrease in the sub-yearling chinook population in the estuary, which suggested that fish were moving to the more marine areas of Skagit Bay.

From the length patterns, it appeared that it was the larger fish that were moving out of the estuary first. Following week 17, the rate of increase in mean fork length at Brown Slough declined (Fig. 12b). Because Brown Slough was the estuarine site most distant from the source of juvenile chinook (i.e., the North and South Forks) (Fig. 3), we suspect 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. For this reason, the increase in length at Brown Slough from weeks 14 - 17, may approximate the true growth of juvenile chinook in the estuary. Because mean length did not increase much above 70 mm after week 17, fork lengths of ~70 mm or greater may have been the size at which fish moved to the more marine habitats. Thus, one life history type appeared to be chinook that migrated from spawning areas down to the estuarine river area, where they reared until achieving a mean length of about 70 mm, after which they migrated out to the bay.

A second life history type was suggested by the length pattern in the bay (Fig. 12b). After week 17, there was a distinct decrease in mean length, down to about the length of the Brown Slough fish, that coincided with the outmigration from the estuary. This implies that, prior to this time, there were larger fish present in the bay than were observed either in the river or the estuary. These may have been fish that migrated directly to the bay after emerging, and grew rapidly in the bay environment.

After week 22, only ~10% of the chinook that used the estuary remained in that area, while > 40% of the outmigration had not yet passed Burlington, which is located ~15 miles upstream of the estuary (Fig. 12b). This suggested that many of the fish passing Burlington in the later part of the outmigration (~week 22 and later) were not rearing in the estuary, which implied a third life history type: fish that reared in the river up to the same threshold size (~70 mm or greater), and then migrated directly to the bay without rearing in the estuary.

Taken together, these data indicated at least three distinct juvenile life history types exist within the ocean type chinook of the Skagit River basin. One type consisted of emergent fry that migrated directly to the bay early in the year. A second type consisted of fry migrants that apparently emerged from the spawning areas and moved relatively quickly downstream to the estuarine habitats, where they reared for a period (weeks) before moving to more marine areas. There may have been variations within this pattern, or several "crops" of fry migrants in any broodyear. A third type consisted of fingerling migrants, sometimes referred to as 90 day type, that emerged from the spawning areas, but apparently dispersed to rear in the freshwater environment (some with a possible preference for off-channel and backwater habitat areas -- see below) for several months following emergence, and then bypassed the estuary, moving directly to marine areas in late spring and early summer, at approximately the same size that fry migrants moved from the estuary to marine areas.

Use of Off Channel Habitat

A discussion of life history types would not be complete without a discussion of chinook rearing in off-channel habitat. Off-channel habitat was not trapped as part of this study; however, other agencies did trap chinook in habitat off the main channel, incidentally to other juvenile salmonid trapping projects. Because off-channel use may represent a distinct life history type, their results are summarized here.

During the spring of 1995, two downstream migrant traps were operated by the North Cascades National Park Service (NPS) at the outlets of Park Slough and County Line Ponds, located near Newhalem in mainstem reach Sk130 (Figure 7). WDFW operated one trap at the outlet of Barnaby Slough near Rockport in reach Sk100 (Figure 7). The chinook that emigrated from each of these sites had very similar timing (Fig. 27). Their timing was somewhat later than that found in our mainstem sampling, and their mean fork lengths were generally much greater (Fig. 12a). This suggested that significant growth had occurred while occupying those habitats. Density estimates (total catch / area trapped) were 192 fish/ha at Barnaby, 293 fish/ha at County Line Ponds, and 486 fish/ha at Park Slough. Using this range and Beechie *et. al.*'s (1994) estimate of 46.98 ha for the basin's total off-channel habitat area (side channel sloughs) we estimated that between 9,000 and 23,000 sub-yearling chinook used this habitat type in the spring of 1995.

It was unknown whether the fish emigrating from off-channel habitat were sub-yearling migrants, yearling migrants, or both. However, it did not appear that these fish used off-channel habitat in the Sauk or Suiattle to any significant extent. We examined years of smolt trapping data available for Skagit River basin sloughs, ponds, and tributaries, and observed that the fish that regularly used these areas were consistently using it only along the Skagit River, not the Suiattle or Sauk (Table 25, Fig. 28). This overlapped with the range of Skagit summer and fall chinook, which suggested that the spring stocks of the Suiattle and Sauk Rivers were not actively rearing in off-channel habitat in those areas. Annual variation in the level of use, and the mechanisms (behavioral or environmental) that triggered this use of off-channel habitat is unknown. Some of these issues may be explained by otolith patterns in future years.

Test Fishing

Test fishing objectives were to conduct a river test fishery for adults through the chinook management period, and collect sufficient numbers of otoliths (about 100) to identify the proportion comprised of each of the important juvenile life history types.

We accomplished these objectives, collecting 153 heads for otolith extraction, which exceeded the target number.

Comparison to Previous Studies

Mainstem Sampling

Puget Sound Power and Light captured juvenile chinook during limited beach seine and electrofish sampling conducted at the end of July, 1978, and in August of 1973, 1974, and 1975 (management weeks 30 through 34) in the mainstem reaches Sk050 and Sk060. Annual beach seine catches ranged from 5.0 to 34.5 juvenile chinook per set with mean fork lengths ranging from 78.9 mm to 87.6 mm (Dames and Moore 1978). While we did not sample during this time period, our sampling in the middle and upper river reaches during week 36 (beginning of September) did not produce a single juvenile chinook. There may, however, have been chinook present during weeks 30 to 34, because the lower river mainstem trap was removed in week 28 with juvenile chinook still moving past. This provides an argument for extending the mainstem trap sampling period to determine if there has been a change in the number of chinook rearing in the river in August, since the 1970's.

In February and March of 1993, SSC conducted pilot level sampling of mainstem (> 50m width) habitat. During the large river mainstem sampling, 616 edge habitat unit grid points were electrofished with 1,695 sub-yearling chinook captured. In addition to edge habitat, 212 mid-channel habitat units were shocked, and only 1 sub-yearling chinook was captured. Chinook were captured at 48% of the edge habitat grid points, but at only 1 of the 212 mid-channel habitat points (< 0.5%). Water velocity was also different between edge and mid-channel habitat. Water velocity was 56% low (< 15cm/s), 37% medium (15-45cm/s), and 7% high (>45cm/s) for all edge habitat unit grid points combined. In contrast, water velocity was 0% low, 5% medium, and 95% high for all mid-channel habitat unit grid points combined. Snorkel sampling in small rivers (10-50m width) did, however, find some sub-yearling chinook using mid-channel habitat units.

Other studies indicated that sub-yearling chinook did not rear in higher velocity areas of rivers (e.g., Hillman *et. al.* (1987) for a small river; Murphy *et. al.* (1989) for a large river). While the location of chinook varied within mainstem habitat, water velocities of 20 cm / sec or less were usually necessary for good levels of chinook. Our pilot level sampling in 1993 suggested that water velocities in the preferred range for juvenile chinook did not occur in mid-channel units.

These studies and the pilot level sampling led us to sample only edge habitat units in this study. However, because we now know that the size of juvenile chinook changes dramatically during their freshwater residence, and some studies have seen a change in the habitat selection by sub-yearling chinook related to a change in fish size, we should examine the distribution of sub-yearling chinook in mainstem habitats later in the year to determine whether it is valid to sample only edge habitat throughout sub-yearling chinook freshwater residence.

We also observed that chinook rearing densities in hydromodified banks were generally less than in natural bank units. This was consistent with Swales *et al.* (1986), who observed lower chinook utilization in riprapped sections of a small stream than in the natural sections, and with SSC's 1993 pilot study of hydromodified and natural banks in the same reach, which found that densities in the natural bank units averaged over four times higher than in the hydromodified units (SSC, unpubl. data).

In contrast to our current study, Murphy *et al.* (1989) observed higher chinook density along banks than in backwaters. They assumed no chinook use in main channels, but did not sample them because the current was too swift. Our 1993 pilot study results were similar to those of Murphy (*ibid*) in that within the same reach, chinook density in natural banks was nearly double that found in backwater areas.

Estuary Survey

Congleton *et al.* (1981) estimated the "salt marsh" area of the Skagit in 1977 at about 1250 ha. It is unclear which habitat zones were included in their definition of "salt marsh". If "salt marsh" was analogous to what we called EEM, then, according to our surveys, about 1,000 ha of EEM remained when orthophotos were taken in 1991 and 1992. While it is uncertain whether the difference in our area estimates represents a loss of habitat or a difference in definitions, loss of estuarine habitat has been occurring over a long time period. Beechie *et al.* (1994) documented a loss of 64% of the distributary sloughs since European settlement, and Bortleson *et al.* (1980) reported a loss of 59% of the delta's entire tidal marsh.

Estuary Sampling

Congleton *et al.* (1981) estimated that roughly 3.4 million chinook fry outmigrated from the Skagit in 1979, of which about 1.1 million used "salt marsh channels", rather than migrating directly into the bay. While it is unclear which habitat is included in "salt marsh channels", his estimate of 1.1 million is comparable to our estimate that about 800,000 chinook fry used small blind channels and EEM large blind channels in 1995. It is therefore possible that similar numbers of chinook reared in the estuary in 1979 and 1995.

For more recent years, SSC has previously collected chinook abundance data at four of the sites sampled in 1995 -- Tom Moore, Deepwater Channel, Grain of Sand, and Freshwater Pond (SSC, unpubl. data). Peak counts are available for each site from 1992 and 1993, and from Deepwater Channel and Grain of Sand in 1994. Estimates of fish-days of use over the season, which require more samples than peak counts, are available for each site from 1992, and from Tom Moore and Deepwater Channel in 1993 (Table 26). Where data for both type of abundance measure exist, there is a high correlation between peak counts and fish-days of use (Fig. 29).

When compared to the total smolt outmigration estimates from the mainstem traps (D. Seiler, WDFW, *pers. comm.*), the peak counts indicate that abundance increased with smolt outmigration at the Tom Moore site (a South Fork EEM site), but not at the other three sites (Fig. 30). At the Forested Riverine Tidal sites, Deepwater Channel and Grain of Sand, there appeared to be a dome-shaped relation between smolt outmigration and rearing density, with a decline in density at the higher levels of river outmigration. At the Transition zone site, Freshwater Pond, there was no discernible change in rearing density as the outmigrant population doubled.

The relation between fish-days/ha and smolt outmigration has fewer data points, but shows the same pattern -- rearing density increased with smolt outmigration at the Tom Moore site, but not at Deepwater Channel or Freshwater Pond (there were no fish-day estimates for Grain of Sand for the smolt outmigrations that showed declining density on Fig. 30) (Fig. 31).

Given the low number of data points and the imprecision of the smolt outmigration estimate (see Assumptions, below), it would be premature to draw definitive conclusions from these data. If, however, further data supported the apparent relations shown in Figs. 30 and 31 that might mean that rearing capacity is reached in small blind channels in the Forested Riverine Tidal zone at smolt outmigrations of about 2.5 million, and in the Transition zone at even lower outmigration numbers, but that small blind channels in the EEM do not reach capacity until the smolt outmigration is much higher. This would imply that any work aimed at restoring some of the lost estuary rearing capacity should be aimed first at the Transition zone, and then at the Forested Riverine Tidal zone, before undertaking projects in the EEM. This is, however, only speculative at this point, and any such conclusions should wait until more data are acquired.

Bay Sampling

Surface trawling in Skagit Bay has been done in 1970 and 1971 by Stober and Salo (1971), and in 1991 by Larsen and Reisenbichler (1993). Stober and Salo (*ibid*) made about 2,800 5-minute tows from March to July in 1970, and caught over 2,000 chinook juveniles; in 1971, they made about 1,400 tows between March and May and caught only 89 chinook, a decrease in catch that they attributed to not towing in June and July. Larsen and Reisenbichler (*ibid*) caught 122 chinook on 4 monthly sampling days in 1991, but only 12 of those were caught in August. Except for a pair trawl gear test in May, our trawling didn't start until August, which was later than both of these previous studies; thus, our surface trawling results are not directly comparable.

Our beach seining, was, however, conducted during the same time period as Larsen and Reisenbichler's. It is noteworthy that both studies documented a decrease in mean length from May to June. Since this decrease was statistically significant, and it is unlikely that individual fish were shrinking during this time period, the most likely explanation is that a new influx of smaller fish contributed heavily to the June population. The timing of this influx corresponds to the timing of the emigration of chinook smolts of similar length out of the estuaries and sloughs, presumably into the bay (see Life History Types, above).

Test Fishing

Test fishing catches in 1995 were comparable to the levels caught from 1990 - 1994 (SSC, unpubl. data). The bimodal timing in 1995, which was consistent with that of the earlier years, indicates the persistence of a distinct timing separation between the spring run and the summer run. Interestingly, this separation is more distinct than that shown on the Skagit by Orrell (1976) for runs prior to 1973, and may indicate that the numbers of fish that run in early summer have decreased relative to the numbers that run in the spring and later summer.

Assumptions Required for FY 1995 Analyses

Mainstem Inventory

The primary assumptions required for our mainstem inventory were that habitat units could be accurately identified and measured from orthophotos, and that the unsampled reaches had the same percentage of each habitat type as the sampled reaches.

Comparisons with field measurements indicated that, with nearly 100% accuracy, habitat units were correctly identified from orthophotos. Orthophoto measurements did vary from field measurements for individual units; however, these errors were apparently unbiased, and the cumulative total of the orthophoto measurements did not vary significantly from the field measurements. Thus, it was likely that orthophoto measurements accurately identified and estimated the area of edge habitat units.

There was no independent test of whether the unsampled reaches had the same percentage of edge habitat types as the sampled reaches of the same reach type (same hydromodification and channel pattern). The sampled reaches represented 38% of the total channel area in the entire Skagit basin, and 55% of the channel area in the mainstem Skagit, which was the only place significant numbers of juvenile chinook were found. Thus, if the sampled reaches did not adequately represent unsampled reaches, this error would affect less than half the channel area in the area where the great bulk of the juvenile chinook were found.

Estuary Survey

The estuary survey required the same assumptions as the mainstem survey about the accuracy of orthophoto measurements. In addition, for small blind channels in the EEM, we assumed that bankfull channel area/ha in the four measured marsh areas was the same as in unmeasured marsh areas. For the other zones, we assumed that small blind channel density was less than in the EEM, but did not quantify the degree.

We did not do a field verification of our orthophoto measurements of the estuary, as we did for the mainstem, but the accuracy of the mainstem measurements provided some comfort in the estuary measurements.

Mainstem Chinook Sampling

The primary assumptions required to estimate the average distribution of chinook juveniles in the mainstem were that they did not rear in mid-channel units above the range of tidal influence, that catchability by electroshocking was equal in each habitat type, and that preference coefficients in the sampled habitat were the same as in unsampled habitat. We also assumed that mainstem habitat was measured accurately (see Mainstem Inventory, above), and that the smolt outmigration was accurately measured at the WDFW mainstem trap.

Our assumption about chinook absence from mid-channel units was based on previous studies (SSC, unpubl. data). Mid-channel units, however, were more difficult to shock than edge units, and chinook may still have been present. Nonetheless, we did observe other species in mid-channel units, and because we did not observe chinook, we believe that chinook rearing in mid-channel units, above the range of tidal influence, was not significant (see Comparison to Previous Studies, Mainstem Sampling; above).

Catchability with electroshocking gear is affected primarily by flow and visibility. Because edge habitat units were defined as low-velocity flow areas, differences in catchability due to flow should have been small. We had planned to test for differences in catchability by blocking off some areas and testing mark-recovery efficiency, but did not have the time.

The assumption that preference coefficients were representative was primarily a sampling assumption. Within individual units on a given sampling date, chinook catches were very spotty from grid point to grid point, and the C.V. of chinook/grid point for individual dates was typically greater than 100% (Appendix 2). We did, however, sample many grid points in each unit (about 30/unit), so the standard error of the mean chinook/grid point was usually closer to 50% of the mean. With this much variability within habitat units, it is perhaps not surprising that estimates of mean chinook/grid point varied considerably between habitat units of the same type (Appendix 2). Thus, our estimates of preference coefficients were imprecise, and should probably be interpreted more as general indicators of preference, rather than precise measures. That having been said, it should be noted that there was general consistency in the pattern of preference coefficients in all three regions of the river, particularly between backwaters, natural banks, and other units (hydromodified banks and bars showed some inconsistencies in relation with each other) (Table 11), which may indicate that our estimates of preference coefficients were not entirely exercises in the generation of random numbers.

Regarding our mainstem inventory, one problem that affected our juvenile chinook distribution estimates was that the inventory did not distinguish between natural bank and hydromodified bank area within the bank habitat type. This was because we completed the inventory before realizing that chinook preference was affected by hydromodification in bank units. Lacking these data, we assumed that the banks in hydromodified reaches were 100% hydromodified. As noted in the Results section, there were some obvious errors in this assumption, but these errors can be corrected in future years.

Our final assumption in estimating the mainstem distribution of juvenile chinook was that the total smolt population estimate was accurate. As with the preference coefficients, this estimate was more a general indicator than a precise estimate. Due to problems with estimating daily trapping efficiencies for chinook, its author characterized these estimates as "preliminary, cursory, and crude" (D. Seiler, WDFW, *pers. comm.*), and accurate to within ± 500,000 (Seiler 1994). Because this estimate was used directly in our estimates of total chinook distribution by mainstem habitat type, a similar degree of precision would apply to these estimates.

Estuary Chinook Sampling

As with mainstem chinook sampling, our estimates of smolt production by estuary habitat types assumed that the chinook density in the sampled habitat represented that of unsampled habitat. Unlike the mainstem chinook sampling, it was not necessary to assume equal catchabilities between habitat types (because we calibrated our catches with RE estimates), and the scoop trap smolt outmigration estimate was not used in our estimates of estuary rearing distribution.

For estuary habitat types that were represented by more than one sampling site, chinook densities varied widely between the sites (Table 14). As with mainstem chinook sampling, this would limit the precision that can be assumed for the estimates of smolt production by estuary habitat type.

In addition, there were some indications that the North fork sites were more productive than the South fork sites. In the Forested Riverine Tidal zone, the North fork site (Grain of Sand), was far more productive than the two South fork sites (Deepwater Channel and Deepwater Pond), and in the EEM, the North fork site (Ika) was more productive than the South fork site (Tom Moore), with Brown Slough, which is about dead center between the North and South forks, of intermediate productivity (Table 14). These differences may have had less to do with whether more fish migrated through the North or South forks, than with the location of our sites relative to the forks. The North fork sites were connected almost directly with the North Fork itself, while the South fork sites were some distance from the South fork down a few branched channels. The North fork sites were therefore immediately accessible to fish migrating down the river, while the South fork sites required some searching. If this was the reason why North fork densities were higher than South fork densities, then we may need to consider an additional sampling strata (distance from the river and extent of channel branching) in calculating estuary chinook densities.

Bay Sampling

The purpose of bay sampling was to get an estimate of the percentage of the bay population represented by each chinook life history type. This required us to assume that the different life history types of Skagit chinook could be identified from otoliths, and that our bay sampling adequately represented each type.

Regarding otolith identification, Larsen and Reisenbichler (1993) indicated, in preliminary examinations, that they can reliably distinguish estuary rearing checks from river checks. Since identification of estuary rearing checks is probably the most critical identification needed for this study, it seems likely that otolith identification will be adequate for our purposes. The refinement of the restoration analysis model will be greater if otolith identification can also distinguish between different rearing habitat types in the river and estuary, but the minimum requirement, identification of estuary rearing, will likely be met.

The requirement for representative sampling can certainly be met by greatly expanding the area and scope of the sampling effort, but then cost considerations intrude. Further analysis of otoliths will be needed to determine whether there are significant differences in life history composition between sampling sites or between sampling gears. As noted above (see Achievement of Project Objectives, above), there is some evidence that mean lengths in beach seine and tow net samples collected in the same general vicinity do not differ significantly, but mean lengths in tow net samples throughout the bay may be significantly greater.

It should be noted that our bay sampling assumes that all chinook caught originated from the Skagit River. Some data on the extent to which this assumption is violated could be available from any CWT's that might be recovered. To the extent that fish from other rivers are sampled, and the life history type composition of those rivers differs from that of the Skagit, our estimates of life history composition will be biased. Sensitivity analyses can be done with the restoration model to evaluate the effect that errors in estimates of bay composition might have on our evaluation of restoration actions.

Test Fishing

The purpose of test fishing is to estimate the percentage of the adult run that is composed of each life history type, in order to calculate the marine survival rates of each life history type. This requires the same assumptions about readability of otoliths described above for Bay Sampling.

In addition, it must be assumed that the test fishery randomly samples the life history types in the returning adult run. The chinook test fishery, which uses 7 to 7½ in mesh gillnets, does catch fish that vary widely in size and age; however, simultaneous coho test fisheries, conducted with 5 to 5½ in mesh gillnets in late August, have caught a higher proportion of smaller (younger) chinook (SSC, unpubl. data). This indicates that either the chinook test fishery catch, at least in late August, is biased against younger adults, the coho test is biased towards younger adults, or both.

If there is an age-specific bias, it would affect the estimate of return by life history type only if the juvenile life history type affects the age of maturity of adult chinook (e.g., fish that hold in the river until summer are more likely to mature as 3-yr-olds than fish that rear in the estuary). The effect of juvenile life history type on age of maturity is currently unknown, but this can be investigated by analysis of otoliths.

Recommended Changes in Procedures

Mainstem Surveys

Mainstem surveys have been completed; however, it is recommended that:

1) additional surveys be done to quantify the amount of bank habitat that is composed of natural banks and hydromodified banks in the sampled reaches.

2) In addition, because there appeared to be a relationship between channel width and width of bar units (Fig. 8), it may be advisable to examine other variables that may affect bar width (e.g., gradient, flow), and recalculate the bar areas by using these variables. This would not require additional surveys.

In developing restoration options it would be advisable to review other studies that estimate habitat area and losses from earlier periods in order to focus on options that return habitat to its original condition.

Estuary Surveys

Estuary surveys have been completed. At present, we believe that this inventory is adequate. However, if the trends in estuary density, as a function of outmigration density, continue (Fig. 30), better resolution of small blind channels in Transistion and Forested zones might be necessary to adequately identify and evaluate restoration actions. No changes in procedures are recommended at this time.

In developing restoration options it would be advisable to review other studies that estimate habitat area and losses from earlier periods in order to focus on options that return habitat to its original condition. An analysis specific to Fir Island is currently being conducted, and should be reviewed when completed.

Mainstem Sampling

1) To make mainstem sampling more cost-efficient, it is recommended that the sampling frequency be reduced to only three sampling periods, instead of biweekly or monthly. Since fish density estimates derived from using peak densities did not differ significantly from the estimates derived from cumulative counts (fish-weeks) (Table 11), it should only take about three samples to determine the peak counts. Reducing the number of samples will save on sampling costs, and will also reduce mortalities associated with electroshocking.

2) Test the validity of sampling only edge habitat areas later in the outmigration period when sub-yearling chinook would be larger. This could increase confidence in these data.

3) Test for differences in catchability between edge habitat types.

4) To address the question regarding outmigration rates and dates (see: Comparison to Previous Studies, Mainstem Sampling; above), extend the mainstem trap sampling period to cover the entire outmigration period.

Estuary Sampling

In order to refine further our estimates of smolt production by estuary habitat type, changes recommended for future years' estuary sampling are:

1) Increase the number of times RE is estimated at each site. Our estimates of RE, which had a significant role in calculating the estuary rearing densities, relied on regressions that were based on very few data points. Increasing the number of estimates of RE at each site would improve the precision and accuracy of these estimates. If these additional data change the way RE is calculated, we should be able to revise the 1995 estimates of RE.

2) Insure that sampling sites cover more of the estuary habitat types, including main and subsidiary channels. Ideally, there would also be more sites within each habitat type, in order to reduce the variability in the density estimate, but this would greatly increase the cost of the project. We have not sampled the mudflats, which cover a large area, but these are usually dewatered at low tide, and fish rearing in these areas should be included in our other samples.

Bay Sampling

In order to examine further the extent to which life history composition varies by site, gear, and time, changes recommended for future years' bay sampling are:

1) Begin beach seining in February to ensure collection of juveniles soon after they enter the Bay, and again continue sampling through October. Catches after the month of September were low, but sampling through October should probably be continued for another year to verify that juveniles have left the bay by that time. In addition, beach seining should be limited to high slack tide; while this will limit the effective collection period for beach seining, it is the time of highest salmon catches.

2) Extend the sampling area to include more southerly sample sites, between the current north bay sites and the mouth of the South Fork Skagit, to establish a geographical continuum from the mouth of the Skagit River to Deception Pass. This should better ensure that juveniles representing all life history strategies are sampled throughout their residence in the Bay.

3) Because it is still unclear whether chinook caught surface trawling represent the same life history types as chinook caught beach seining, otter trawling should be conducted for another year, in order to continue to test its feasibility, and to examine the variation in life history types between sampling methods. Otter trawling should start earlier, in February, using a larger net that is suited to both single and dual vessel surface trawling. This new gear is lighter, larger and better suited to the vessels available. Due to the difficulty of scheduling available boats, additional pair trawling is not recommended.

Test Fishing

No modifications in procedures are proposed. In 1996, there will be no pink fishery, so it will be possible to continue the test fishery through late August.

ACKNOWLEDGMENTS

Funding for this project was administered by the Northwest Indian Fisheries Commission (NWIFC), under Northwest Indian Fisheries Commission Contract #3311 FY95. Funding was provided pursuant to a PL-638 contract between the NWIFC and the U.S. Department of the Interior, in order to collect information necessary to meet obligations of the United States under terms of the Pacific Salmon Treaty.

Many people assisted in various ways on this study, and it would not be possible to list all of them. However, special thanks are due to the Skagit System Cooperative biologists and technicians who did much of the field work for this project.

REFERENCES CITED

AFCRS. 1994. Auxiliary Fish Ticket Catch and Reconciliation System (Soft Data System). On-line database maintained on Univ. of Wash. Hardy Computer.

Baranski, C. and J. Shaklee. 1994. Skagit Hatchery spring chinook history. February 15, 1994 memo to Bob Hayman and Eric Beamer. Wash. Dept. Fish. & Wildlife, Olympia, WA. [memo].

Beamer, E.M. and R. Henderson. 1995. Fish and Fish Habitat Information for the Deepwater Slough Restoration Feasibility Study. Skagit System Cooperative. LaConner, Washington.

Beamer, E.M. and R. LaRock. 1995. An evaluation of fish use and water quality associated with a cross levee in the tidally influenced portion of Brown Slough, Skagit River Basin, Washington. Skagit System Cooperative Rept. prepared for Skagit County Diking District No. 22. LaConner, Washington.

Beechie, T., E. Beamer, and L. Wasserman. 1994. Estimating coho salmon rearing habitat and smolt production losses in a large river basin, and implications for habitat restoration. North Am. J. Fish. Mgmt. 14:797-811.

Bisson, P.A., J. L. Nielsen, R. A. Palmason, and L. E. Gore. 1982. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low streamflow. Pgs. 62-73 *in* Armantrout, N. B., ed., *Acquisition and Utilization of Aquatic Habitat Information*, Western Division, American Fisheries Society, Portland, OR., 1982.

Bortleson, G.C., M. J. Chrzastowski, and A. K. Helgerson. 1980. Historical changes of shoreline and wetland at eleven major deltas in the Puget Sound region, Washington. U.S. Geological Survey, Hydrologic Investigations Atlas. Atlas HA-617.

Cheslak, E.F., and J. E. Morhardt. 1988. Use of computer models to affect policy decision-making for San Joaquin Drainage chinook salmon. Pgs 44-47 *in* B.G. Shepard, Chairman, Proceedings of the 1988 Northeast Pacific chinook and coho salmon workshop. Published by North Pacific Int. Chapter of the American Fish. Soc.

Chinook Technical Committee. 1994. Pacific Salmon Commission Joint Chinook Technical Committee 1993 Annual Report. Report TCCHINOOK (94)-1.

Chitwood, S. A. 1995. Wild coho smolt supplementation in the Queets River. Quinault Tribal Type III Project Proposal for FY 1996. Quinault Indian Nation, Taholah, WA. 6 pp.

Congleton, J.L., S.K. Davis, and S.R. Foley. 1981. Distribution, abundance and outmigration timing of chum and chinook salmon fry in the Skagit salt marsh. Pgs. 153-163 *in* E.L. Brannon and E.O. Salo, eds. Proceedings of the Salmon and Trout Migratory Behavior Symposium. School of Fisheries, Univ. of Wash., Seattle, WA.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U. S. Fish and Wildlife Service, Biological Services Program FWS/OBS-79-31.

Dames and Moore. 1978. Skagit Nuclear Power Project Aquatic Ecological Studies. Report prepared for Puget Sound Power and Light Company. 12 pp.

Davis, S.K. 1981. Determination of body composition, condition, and migration timing of juvenile chum and chinook salmon in the lower Skagit River, Washington. M.S. Thesis, Univ. of Wash., Seattle, WA. 97 p.

Generic CADD Version 6.0. 1992. Computer Aided Drafting and Design software; Publ. by Autodesk Retail Products, Bothell, Washington, USA.

Gilbert, C.H. 1913. Age at maturity of the Pacific coast salmon of the genus *Onchorhynchus*. Bull. Bur. Fish. (U.S.) 32:1-22.

Graybill, J.P., R.L. Burgner, J.C. Gislason, P.E. Huffman, K.H. Wyman, R.G. Gibbons, K.W. Kurko, Q.J. Stober, T.W. Fagnan, A.P. Sayman, D.M. Eggers. 1979. Assessment of the reservoir-related effects of the Skagit Project on downstream fishery resources of the Skagit River, Washington. final Report. Prepared for City of Seattle, Department of Lighting. Univ. of Wash., School of Fisheries, Seattle, WA. 602 p.

Hayman, R. A. 1993. Plans for 1993 chinook rack return. August 20, 1993 memo to Lorraine Loomis, Darrein Maloney, Lawrence Joseph, and Bill Ryan. Skagit System Cooperative, La Conner, WA [memo].

Healey, M.C. 1980. Utilization of the Nanaimo River estuary by juvenile chinook salmon, *Onchorynchus tshawytscha*. Fish. Bull. 77:653-668.

Healey, M.C. 1991. Life history of chinook salmon (*Oncorhynchus tshawytscha*). pp. 311-394 *in* C. Groot and L. Margolis, eds. Pacific Salmon Life History. UBC Press, Vancouver, B.C.

Hillman, T. W., J. S. Griffith, and W. S. Platts. 1987. Summer and winter habitat selection by juvenile chinook salmon in a highly sedimented Idaho stream. Tran. Am. Fish. Soc. 116:185-195.

Johnson, R. 1986. Assessment of the Skagit River System's Coho Rearing Potential. State of Washington, Department of Fisheries, Technical Report No. 95. 22pp.

Joint Objectives and Goals Committee. 1992. Chapter 9A: Northern Puget Sound goals and objectives for stocks and fisheries. Pacific Salmon Commission, Vancouver, B.C.

Jenks, S., D. Phinney, and D. King. 1993. Washington Department of Fisheries coho salmon habitat enhancement and protection program. Pages 290-294 *in* L. Berg and P. W. Delaney, eds. Proceedings of the Coho Workshop, Nanaimo, B.C., May 26-28, 1992.

Kirby, G. H. 1995. North Puget sound juvenile chinook salmon tagging feasibility evaluation. Northwest Ind. Fish. Comm. Contract No. FY93-3133, Olympia, WA. [in prep]

Ladley, R. and D.E. Pflug. 1986. Fry recruitment into potholes along the Skagit River in 1986. Final Report. Prepared for R.W. Beck and Associates. 17 p.

Larsen K. A. and R. R. Reisenbichler. 1993. The Importance of Estuarine Habitats of the Skagit River, WA, to Juvenile Chinook Salmon, *Oncorhynchus tshawytsca*. Presentation at the International Symposium of Fish Otolith Research and Application January 23-27, 1993, Hilton Head Island, SC.

Lestelle, L. C., G. R. Blair, and S. A. Chitwood. 1993a. Approaches to supplementing coho salmon in the Queets River, Washington. Pages 104-119 *in* L. Berg and P. W. Delaney, eds. Proceedings of the Coho Workshop, Nanaimo, B.C., May 26-28, 1992.

Lestelle, L., M. L. Rowse, and C. Weller. 1993b. Evaluation of natural stock improvement measures for Hood Canal coho salmon. FY 92 Report. PNPTC Tech. Rept. TR 93-1.

Levy, D.A. and T.G. Northcote. 1982. Juvenile salmon residency in a marsh area of the Fraser River estuary. Can. J. Fish. Aquat. Sci. 39:270-276.

Memorandum of Understanding on Skagit Spring Chinook. 1994. Memorandum of Understanding dated May 13, 1994 between Robert Turner, WDFW, Olympia, WA, and Lorraine Loomis, Skagit System Coop. La Conner Wa. 2 p.

Montgomery, D. R. and J. M. Buffington. 1993. Channel classification, prediction of channel response, and assessment of channel condition. Washington Department of Natural Resources. Report No. TFW-SH10-93-002.

Montgomery, D. R., J. M. Buffington, R. D. Smith, K. M. Schmidt, and G. Pess. 1995. Pool spacing in forest channels. Water Resources Research 31(4):1097-1105.

Murphy, M. L., J. Heifetz, J. F. Thedinga, S. W. Johnson, and K. V. Koski. 1989. Habitat utilization by juvenile Pacific salmon (*Onchorhynchus*) in the glacial Taku River, southeast Alaska. Can. J. Fish. Aquat. Sci. 46:1677-1685.

Orrell, R. 1976. Skagit chinook race differentiation study. Project Completion Report for Project No. 1-98-R, Nat. Mar. Fish. Service Grant-in-Aid Program.

Reimers, P.E. 1971. The length of residence of juvenile fall chinook salmon in Sixes River, Oregon. Ph.D. thesis. Oregon State University, Corvallis, OR. 99 p.

Sanford, B., R. Orrell, R. A. Hayman, P. Castle, and S. Fransen. 1990. Skagit River chinook. Planning support document [draft] attached to Skagit River Chinook Plan [draft] of March 13, 1990. Wash. Dept. Fish., Olympia, WA.

Scott, J., S. Moore, and R. Moore. 1992. Review of the chinook exploitation rate and indicator stock program for the Washington Coast and Puget Sound. Draft report dated May 19, 1992.

Seiler, D. 1994. Estimated Skagit River 0+ chinook production. Memo dated May 25, 1995, from D. Seiler, WDFW, to E. Beamer, SSC. 3 p. [memo]

Seiler, D. 1995. Preliminary Skagit River chinook smolt estimates. Memo dated July 28, 1995, from D. Seiler, WDFW, to B. Tweit, WDFW, and B. Hayman, SSC. 3 p. [memo]

Seiler, D., P. Hanratty, S. Neuhauser, P. Topping, M. Ackley, and L. E. Kishimoto. 1995. Wild salmon production and survival evaluation. Annual Performance Report October 1993 - September 1994. U. S. Fish & Wildlife Serv. Contract No. F-112-R-2. Wash. Dept. Fish & Wildlife Prog. Rept., Olympia, WA.

Simenstad, C. 1983. The ecology of estuarine channels of the Pacific Northwest coast: a community profile. USFWS, FWS/OBS-83/05. 181 p.

Stober, Q.J., and E.O. Salo. 1971. Biological studies of the Kiket Island nuclear power site. Second Ann. Rep., Sept. 1, 1970 to Sept. 30, 1971. Contract with Snohomish County P.U.D. and Seattle City Light. FRI, Coll. Fish., Univ. of Wash., Seattle, WA. 197 p.

Stober, Q.J., S.J. Walden, and D.T. Griggs. 1973. Juvenile salmonid migration through North Skagit Bay. Pgs 35-69 *in* Kiket Island nuclear power site draft EIS. Contract with Snohomish County P.U.D. and Seattle City Light. FRI, Coll. Fish., Univ. of Wash., Seattle, WA.

Swales, S., R. B. Lauzier, and C. D. Levings. 1986. Winter habitat preferences of juvenile salmonids in two interior rivers in British Columbia. Can. J. Zool. 64:1506-1514.

Ward, D., R. S. Robison, and G. Nye. 1976. 1975 fisheries statistical report. Wash. Dept. Fish. State Printing Plant, Olympia, WA. 115 p.

Washington Department of Fisheries, Puget Sound Treaty Indian Tribes, and Northwest Indian Fisheries Commission. 1992. Puget Sound summer/fall chinook forecasts and management recommendations. Olympia, WA.

Weigand, D. 1991. Effect of gravel scalping on salmonid rearing habitats in the Puyallup river. MS. Thesis, School of Fisheries, University of Washington, Seattle, Washington.

Zillges, G. 1977. Methodology for determining Puget Sound coho escapement goals, escapement estimates, 1977 pre-season run size prediction and in-season run assessment. Wash. Dept. Fish. Tech. Rept. 28.