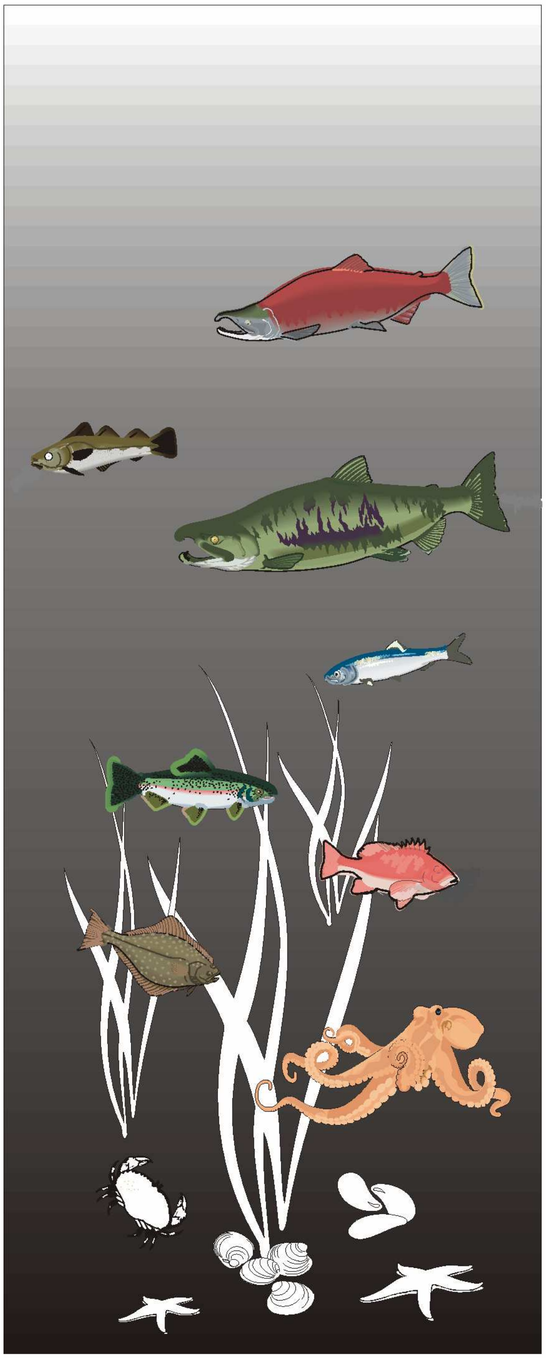
Northwest Fishery Resource Bulletin



Dungeness River Chinook Salmon Rebuilding Project Progress Report 1992-1993

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Project Report Series No. 3

Northwest Fishery Resource Bulletin

Project Report Series

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Dungeness River Chinook Salmon Rebuilding Project
Progress Report 1992-1993

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ABSTRACT

Because the estimated annual returns of chinook salmon (*Oncorhynchus tshawytscha*) to the Dungeness River have declined to an average of 200/year in recent years, a cooperative rebuilding program was developed and initiated to address the restoration of this stock. Success of the rebuilding program relies upon implementation of three major strategic components: salmonid enhancement, habitat restoration, and harvest management.

This report focuses on the development of the enhancement component. The enhancement component relies upon a captive broodstock program to increase recruitment to the native population while allowing continuation of wild stock production in the Dungeness River. Broodstock collection in the Dungeness River drainage during 1993 yielded 3,853 chinook salmon from the 1992 brood for the captive population at Hurd Creek Hatchery. This total was composed of 2,588 pre-emergent fry collected using a hydraulic sampler, 71 free-swimming fry collected with beach seines, and 1,194 free-swimming fry collected with backpack electroshockers. The captive population size and the number of known families included in the population are both below the goals of the program. All fry were segregated based upon collection time and area. “Families” were reared separately until marked with group-specific tags.

Plans for the rebuilding program include rearing the fry to maturity in a captive broodstock setting. After marking, half of each family will be kept in a freshwater captive broodstock program at the Hurd Creek Hatchery operated by the Washington Department of Fish and Wildlife, and half will be transferred to a saltwater captive brood site. Two different captive broodstock programs were used to lessen the inherent risk of loss and to allow a biological and economic comparison of the two techniques. The progeny of the captive broodstock will be tagged and released into the Dungeness River. The planned duration of captive broodstock production is eight years. Overall success of the rebuilding program will also require identification and correction of limiting habitat and/or harvest constraints as well as a successful out-planting strategy.

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INTRODUCTION

Carol J. Smith and Brad Sele

Program Formation

The Dungeness River Chinook Salmon Rebuilding Project was officially founded in December of 1991 with the signing of a Memorandum of Understanding between Long Live The Kings, National Marine Fisheries Service (NMFS), Point No Point Treaty Council, U.S. Fish and Wildlife Service (USFWS), and Washington Department of Fish and Wildlife (WDFW). The rebuilding program has been developed and implemented by the Dungeness River Wild Chinook Restoration Steering Committee, which has representation from the above federal and state agencies, tribal government, and Long Live The Kings. Several regional enhancement groups and sportsmen's associations have also participated in the rebuilding program.

Background

In the mid-1980s, elected officials of Clallam County grew concerned about the decline in abundance of chinook salmon (*Oncorhynchus tshawytscha*) in the Dungeness River and appointed a Dungeness River Management Team to address this decline as well as other river-related problems. An outgrowth of this effort resulted in extensive in-river spawner escapement surveys consisting of snorkel surveys by the USFWS and redd monitoring by WDFW. The snorkel surveys were conducted in 1981, 1982, 1986, and 1987, while the redd monitoring was begun in 1986 and continues to date. Information from these surveys has led to a "critical" classification for the Dungeness River stock of chinook salmon based upon chronically depressed levels of spawners (WDF et al. 1993). This classification is reserved for stocks in jeopardy of a significant loss of within-stock diversity or at risk of extinction. Concern for the long-term future of this stock is heightened by the unstable ecological conditions in the Dungeness River. The depressed and vulnerable status of this stock led to the establishment of the Dungeness River Chinook Salmon Rebuilding Project.

Goal

The overall goal of the project is: to provide a self-sustaining, natural population that maintains the genetic characteristics of the existing chinook salmon stock and meets the agreed-to escapement goal in three out of every four years by the year 2008. The current agreed-to escapement goal is 925 fish per year.

The goal of the rebuilding program is to provide a healthy, self-sustaining population that maintains the genetic characteristics of the existing chinook salmon stock. The intent is to achieve a population size compatible with the Dungeness River basin, that will maintain an adequate effective population size, and that can withstand moderately adverse ecological impacts. It is recognized that the long-term success of the rebuilding program is dependent upon significant restoration of chinook salmon habitat in the Dungeness River and correcting other factors that limit production. The key procedure selected for rebuilding the chinook salmon population in the Dungeness River is development of, and expansion from, a captive broodstock. It should be recognized that the use of captive broodstock methodology for wild stock restoration is experimental and is undertaken with some level of risk to genetic integrity and the long-term health of the stock(s).

Objectives

In order to achieve the goal, we have defined the following objectives.

Genetic Objectives:

1. Collect a representative sample of the total population to found the broodstock program and lessen the risk of genetic bottlenecks. Sample 25 chinook salmon families throughout the Dungeness River watershed each year for eight consecutive years.

2. Develop and follow a captive broodstock spawning protocol, including:
   a. Identify individual spawners by reading tags prior to spawning,
   b. Avoid full-sibling matings,
   c. Use 1:1 spawning techniques,
   d. Record all spawning crosses.

3. To lessen the risk of domestication effects, conduct the captive broodstock program for no more than two consecutive generations (eight years). After that time, evaluate the program before deciding whether or not to continue.

Natural Production:

1. Allow natural production to continue concurrent to the captive broodstock program by limiting the removal of pre-emergent fry from each redd and monitoring the post-emergent fry collection adjacent to each redd.

2. Design and implement experiments to estimate the level of mortality on the natural population caused by the sampling technique used to collect chinook salmon fry for the production objectives (below).

3. Modify the sampling technique if collection-induced mortality exceeds 25%.

Production Objectives:

1. Obtain 5,000 pre-emergent and post-emergent chinook salmon fry each year; 2,500 for a freshwater captive broodstock program and 2,500 for a saltwater captive broodstock program.

2. Collect 200 chinook salmon fry from each family from a minimum of 25 families per year. If additional families are available, samples should be collected from as many families as possible and the numbers collected per family reduced proportionally until a grand total of 5,000 fry has been collected. Excess fry should be returned to their respective collection site in the river as fed fry once pre-emergent and post-emergent fry collection activities have ceased. Production shortfalls within any given year should be made up in succeeding years.

3. Maintain family integrity throughout the project by using differential rearing units or fish mark/tagging techniques.

4. Rear fry to spawning adults with a total mortality of 50% or less in each family.

5. Release progeny back into the river in a manner that mimics the natural life history characteristics of the stock, has a high likelihood of success, and can be monitored and evaluated.

6. Compare the saltwater and freshwater captive broodstock programs for operational and technical effectiveness. Report the findings in a technical or progress report.

Monitoring and Evaluation:

1. Coded-wire tag a statistically valid proportion of each release strategy.

2. Support a sampling rate of at least 20% in fisheries to which this stock contributes. Evaluate coded-wire tag recoveries to assess marine survival, stock distribution, and fishery contribution rates. Recommend harvest adjustments if the exploitation rate exceeds 60%.

3. Continue to conduct spawner surveys to:
    a. Estimate escapement and recover coded-wire tags,
    b. Sample at least 20% of the escapement for the presence of tags,
    c. Evaluate recoveries to assess spawner success from different release strategies.

CHAPTER 2 - STOCK ASSESSMENT

Carol J. Smith and Brad Sele

Stock Status

The Dungeness chinook salmon population consists of a wild chinook salmon stock that is considered to be native in origin and is listed as "critical" in the 1992 Washington State Salmon and Steelhead Stock Inventory (SASSI) (WDF et al. 1993). The Dungeness River Wild Chinook Restoration Committee and the SASSI participants have reviewed the available information and concluded it is likely there is a single chinook salmon stock in the Dungeness River basin. However, the possible existence of multiple stocks cannot be completely ruled out by this information. Furthermore, uncertainty exists regarding the impact from past releases of non-native chinook salmon stocks into the Dungeness River (Table 1). The effects of human-induced impacts, including non-native stock introductions and ecological changes, have not been quantified but can be characterized as negative.

Abundance

Historic levels of chinook salmon escapement to the Dungeness River are difficult to assess due to inconsistent survey methods and sporadic observations. One of the better existing records, for comparative purposes, is the number of chinook salmon enumerated at the Dungeness Hatchery rack (located at river mile [RM] 10.8) or removed for broodstock by WDFW personnel at the Dungeness Hatchery (Figure 1). The numbers recorded are considered partial estimates of spawner abundance, as natural spawning above and below the rack was not quantified during those years. The rack and broodstock collection estimates ranged from 600-850 fish/year in the 1930s, then declined to about 300 fish/year in the mid 1940s-1950s. In 1959, returns peaked at 1,305 fish but dropped in the following years and remained at low levels from 1973 to 1981. Low spawner numbers led to the demise of the Dungeness chinook salmon hatchery program in 1981 (C. Johnson, WDFW, personal communication). The rack was removed in 1982.

Intensive spawner escapement surveys for chinook salmon were initiated in 1986 and continue today. The average adult spawning escapement from 1986-1993 was 179 with a range of 43-335 fish/year (Table 2). These estimates were generated by multiplying the annual cumulative redd count (spanning the entire spawning range) by 2.5. This expansion factor is the estimated average number of adults each redd represents and was developed from a study performed on the Skagit River (Orrell 1976). Each river section was surveyed weekly during the expected spawning time (based upon previous surveys), and each chinook salmon redd was flagged and monitored during the season. The spawning range included the lower 18.7 miles of the Dungeness River mainstem as well as the lower four miles of the Gray Wolf River. Cascades slightly upstream from Dungeness, at RM 18.7, prevent further up-river passage. Chinook salmon were seldom seen during surveys of the spawning grounds (neither live nor dead fish). When fish were encountered, their numbers were recorded but not used to derive the escapement estimate.

Table 1. Releases of non-native chinook salmon into the Dungeness River watershed (WDFW salmon planting records).

Brood Year	Brood Stock Source	Release Type	Size at Release	Number Released
1966	Green River	Fingerling	178/lb	811,680
1967	Issaquah	Fall release	185/lb	416,892
1969	Hood Canal	Fall release	125/lb	128,500
1970	Minter Creek	Fingerling	165/lb	457,700
1970	Minter Creek	Fingerling	112/lb	171,994
1972	Hood Canal	Yearling	9/lb	167,207

Table 2. Chinook salmon escapement estimates for the Dungeness River (WDFW chinook salmon escapement estimation records).

Return Year	Escapement
1986	238
1987	100
1988	335
1989	88
1990	310
1991	163
1992	153
1993	43
Average	179

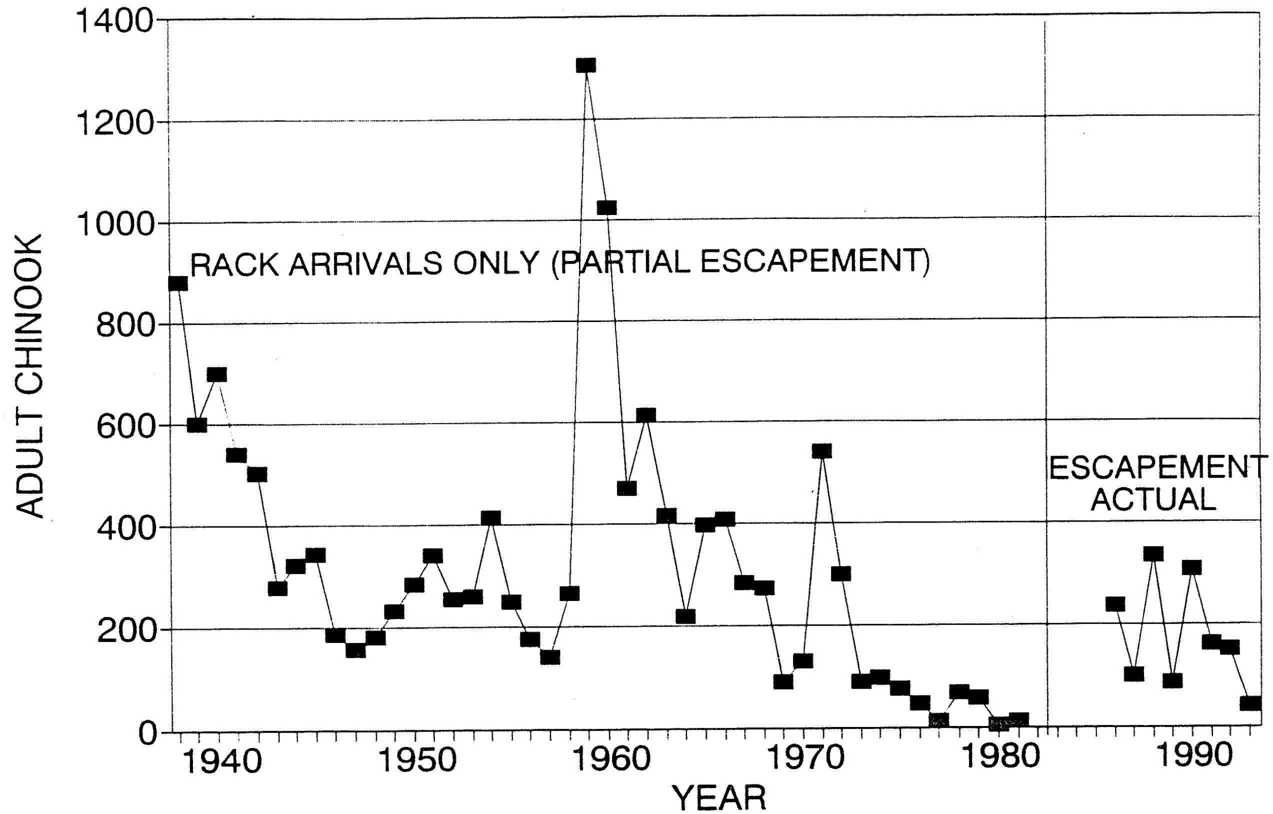

Figure 1. Estimated number of chinook salmon returning to the rack at the Dungeness River Hatchery (1938-1979) or estimated escapement to the river (1986-1992).

Number of Stocks

One of the underlying principles of the Dungeness River Chinook Salmon Rebuilding Project is to preserve the genetic characteristics of the chinook salmon population presently inhabiting the river (see Chapter 4). To develop appropriate genetic guidelines for the rebuilding project, the rebuilding committee first examined available data to assess whether or not more than one chinook salmon stock currently spawns in the Dungeness River and its tributaries.

Historically, Dungeness chinook salmon have been referred to as "spring chinook", alluding to the springtime initiation of returns to the river. However, there is a lack of data to compare historic and current Dungeness chinook salmon run or spawn timing. Presently, the spawn timing extends from mid-August to early October. River entry time is still uncertain, but probably begins one to two months earlier than spawning. Spawning in late September and October is more characteristic of a summer/fall chinook salmon stock than a spring chinook salmon stock. This has led to concerns that a non-native summer/fall stock introduction may have contributed genetically to the native chinook salmon stock, resulting in a later segment of the run, or in a separate, second stock of chinook salmon in the river. Another possibility is that ecological and human-induced influences have skewed the run timing of the indigenous chinook salmon stock to a later date. Much of the human-induced influence may be due to extensive native stock releases into the Dungeness River (Table 3), which may have transferred domestication effects from hatchery-reared fish to the native stock. Also, the presence of the hatchery rack prevented upriver access to spawners and likely altered spawner distribution. Without solid historic data regarding run timing, genetic composition, and a complete record of non-native introductions, the number of stocks may never be known. It is further complicated by overlap in timing between the spring, summer, and fall chinook salmon stocks in Puget Sound, and the lack of common definitions for these races between the co-managers (WDFW and the Tribes) in the State of Washington. The definitions have harvest and data management implications.

The State-operated hatchery on the Dungeness River (RM 10.8) produced chinook salmon for on-station releases from the late 1930s to the early 1980s. Most of the recorded hatchery releases of chinook salmon into the Dungeness River are of native stock, but six releases of non-native chinook salmon stocks into the watershed are known (Table 1). The available data range from brood years 1951 through 1981. There were six separate releases of non-native fall chinook salmon into the Dungeness River watershed during this 30-year period. If these data are accurate, stock interactions may be assumed to be minimal. The non-native impact occurred from 1966-1972; the total number of non-native fish released during this time period roughly equaled the number of native fish released from the Dungeness Hatchery during the same time frame.

Table 3. Hatchery releases of native chinook salmon into the Dungeness River (WDFW salmon planting records).

Year	Release Type	Number Released
1951	Yearling	151,948
1952	Fingerling	277,745
1952	Fall	182,274
1952	Fingerling	30,375
1952	Yearling	90,199
1953	Fall	171,621
1953	Yearling	133,705
1954	Fingerling	9,000
1954	Fall	49,800
1954	Yearling	327,886
1955	Fall	82,625
1955	Yearling	225,320
1956	Yearling	337,310
1957	Fall	6,900
1957	Yearling	229,470
1958	Fall	452,320
1958	Yearling	237,829
1959	Fingerling	778,050
1959	Fall	389,100
1959	Yearling	670,365
1960	Fall	161,423
1960	Yearling	655,123
1961	Fingerling	913,256
1961	Fall	182,900
1961	Yearling	342,060
1962	Fingerling	673,664
1962	Fall	53,405
1962	Yearling	294,823
1963	Yearling	491,836
1964	Yearling	62,789
1965	Yearling	255,672
1966	Fall	123,124
1966	Yearling	558,912
1967	Fingerling	34,572
1967	Yearling	256,824
1968	Yearling	309,410
1969	Yearling	154,144
1970	Fall	36,026
1970	Yearling	194,531
1971	Fall	191,760
1971	Yearling	166,170
1972	Yearling	30,381
1973	Yearling	82,733
1974	Yearling	91,059
1975	Yearling via Soleduck	160,370
1976	Yearling via Soelduck	26,390
1976	Yearling	67,998
1977	Yearling	11,800
1978	Fall	22,768
1979	Yearling	64,249
1980	Fall	3,891
1981	Fall	26,600

The timing of redd deposition and geographical distribution of redds were analyzed for significant differences and plotted to look for evidence of a bimodal distribution, which would support the theory that more than one chinook salmon stock presently exists in the Dungeness River. Survey data from 1986 to 1991 were organized according to one of three geographical regions of the river. These regions were: the lower river from RM 0.0 to 6.4, characterized by a low gradient; mid river from RM 6.4 to 10.8, characterized by a moderate gradient; and upper river from RM 10.8 to 18.7 plus the Gray Wolf River, both of which are characterized by a steep gradient.

The geographical and temporal distributions of new redds constructed by chinook salmon in the Dungeness River exhibit much annual variability (Figures 2, 3, 4, 5, 6, and 7). Spawning ground surveys began one or two weeks prior to the earliest redd sighting each year and ended after one or two weeks of surveys with no new redds sighted in a given area. The data do not clearly indicate a bimodal pattern that would suggest the presence of two stocks.

For each river section, the time of start, peak, and end of redd deposition was examined from data collected in 1986-1991. Average peak spawning time ranged from mid-August to the first of September. Analysis of variance followed by Tukey's test did not find a significant difference ($P > 0.05$) among the sections of the river in the time of peak redd deposition. A significant difference ($P < 0.05$) was evident between redd deposition start time in the lower river compared to either the upper or mid river sections, but start time did not differ between the mid and upper river sections. Also, a significant difference in the end time of redd deposition was found between the upper river and either the lower or mid river sections, but no difference was found between the lower or mid river sections. Because of the inconsistent differences in the start and end of redd deposition, the data could not be pooled into two groups (lower and upper) and the results do not clearly support the theory of more than one stock based upon spawning time and geographical distribution. In addition, the spawning duration of seven weeks is similar to other single stocks.

Based upon the above analyses, the Restoration Committee agreed to proceed with the Dungeness River Chinook Salmon Rebuilding Project under the assumption that one chinook salmon stock exists in the river. It was further agreed that genetic stock identification studies (GSI) would be performed as soon as possible on Dungeness chinook salmon to provide additional information regarding this issue. If more than one stock is identified within the next four years, the genetic and captive brood spawning protocols of the rebuilding program will be revisited.

Run Timing

Data are lacking to document the run timing of Dungeness chinook salmon in marine areas or the timing of river entry. The only information that provides insight on run timing of the stock is the historical daily rack returns to the Dungeness Hatchery. Records of arrival time to the Dungeness Hatchery rack indicate that, generally, the first chinook salmon appeared at the rack in mid-August while the last appeared around 9 September (Table 4). These data are consistent

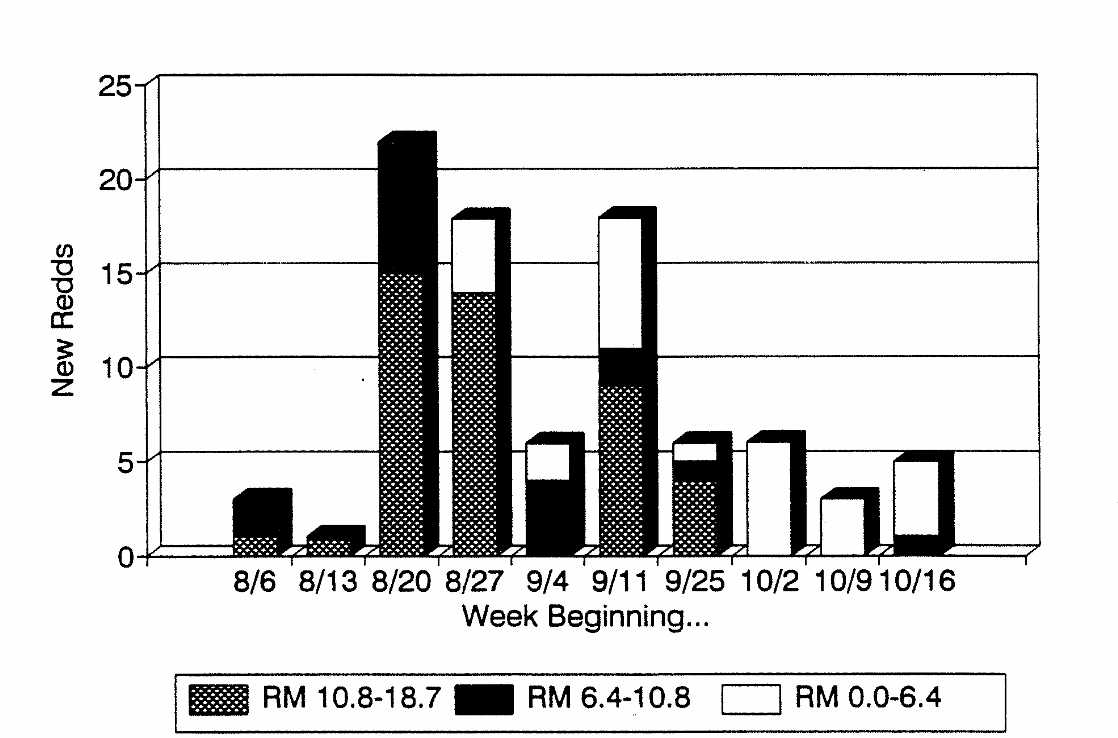

Figure 2. The number of new chinook salmon redds counted in the Dungeness River, summarized by week and area, for 1986.

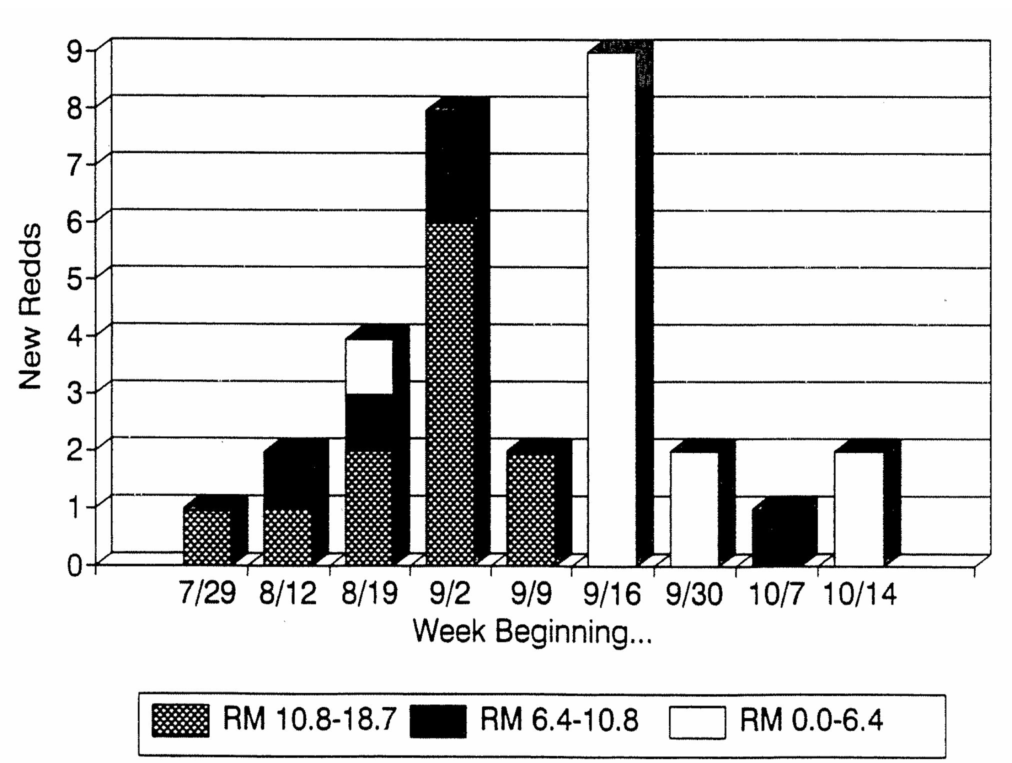

Figure 3. The number of new chinook salmon redds counted in the Dungeness River, summarized by week and area, for 1987.

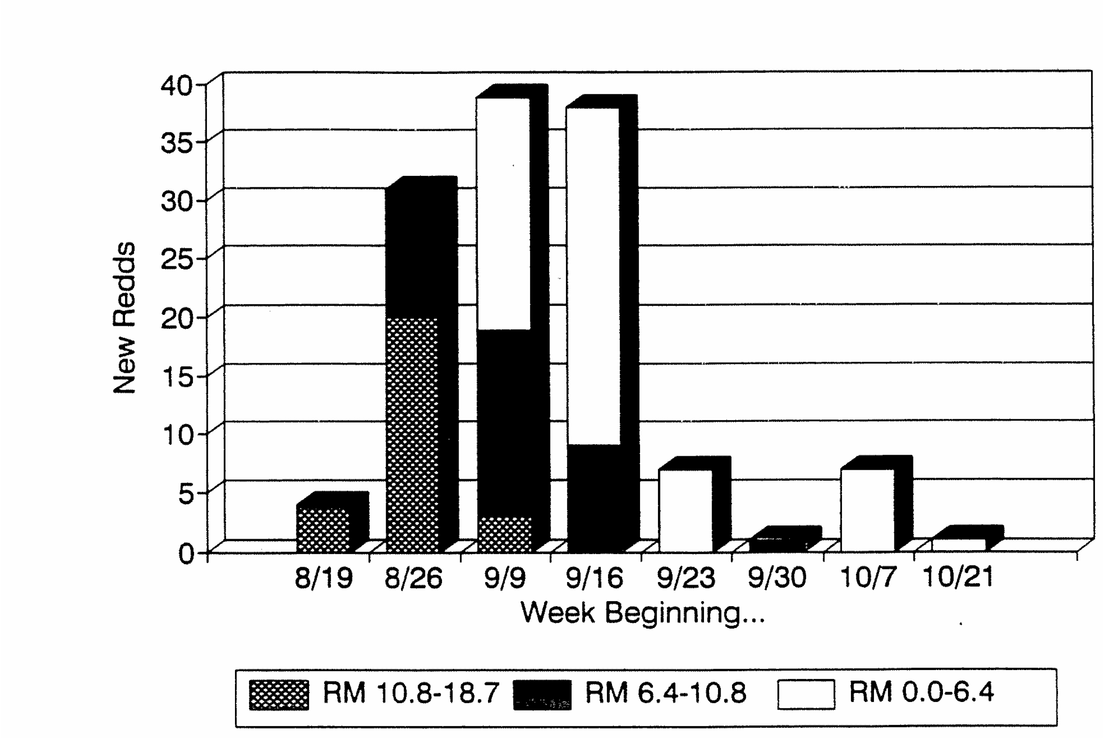

Figure 4. The number of new chinook salmon redds counted in the Dungeness River, summarized by week and area, for 1988.

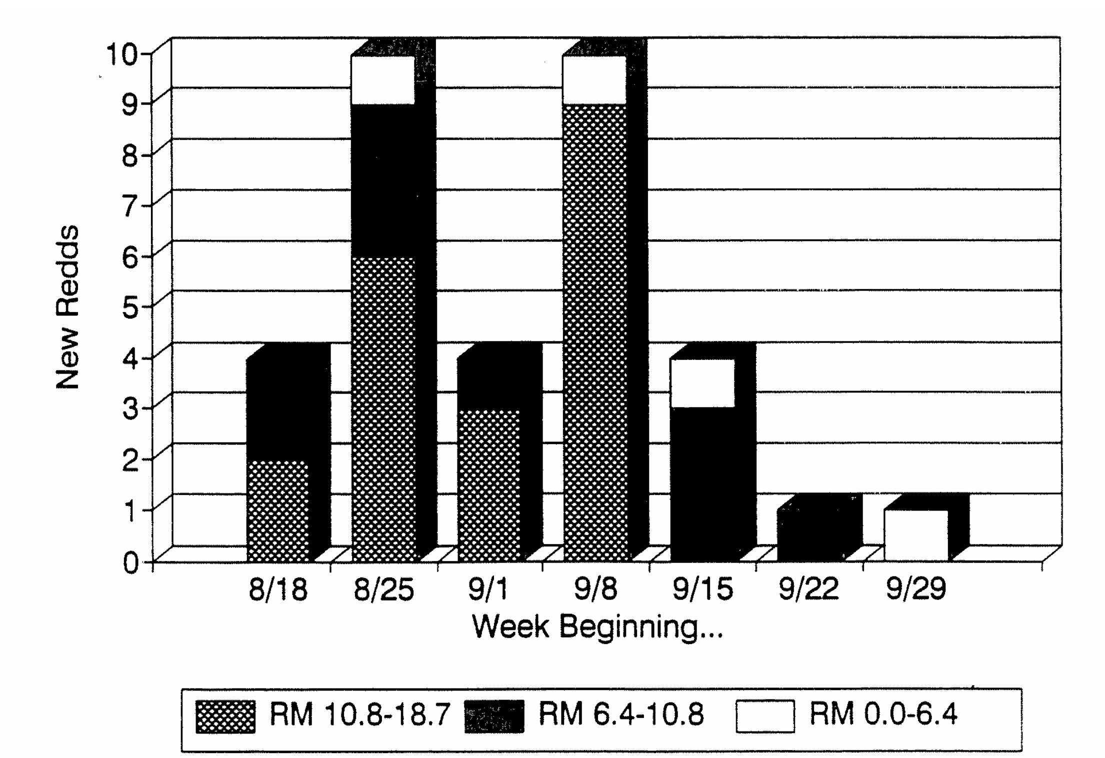

Figure 5. The number of new chinook salmon redds counted in the Dungeness River, summarized by week and area, for 1989.

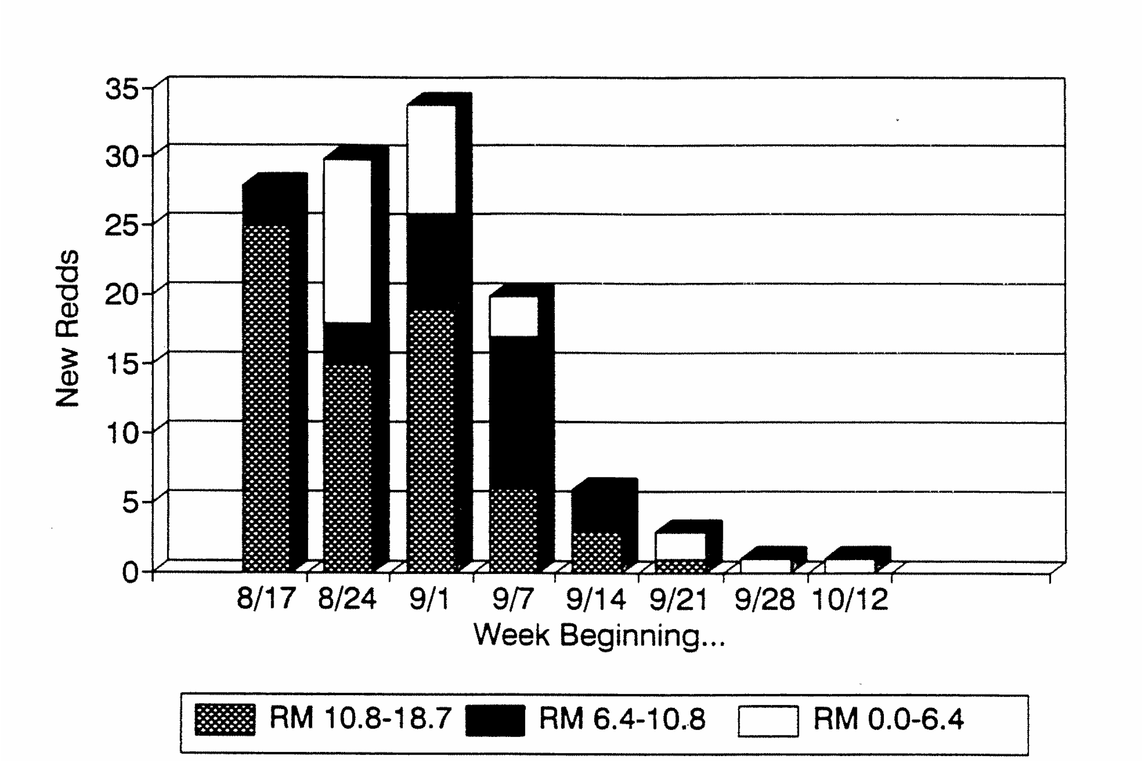

Figure 6. The number of new chinook salmon redds counted in the Dungeness River, summarized by week and area, for 1990.

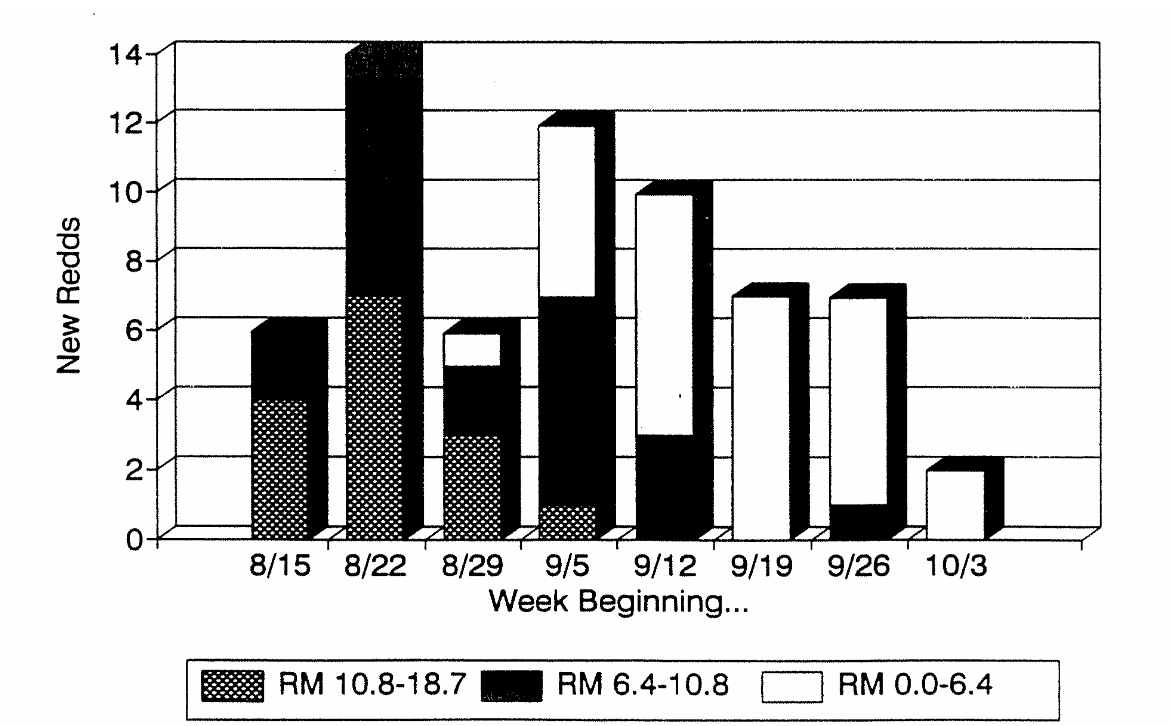

Figure 7. The number of new chinook salmon redds counted in the Dungeness River, summarized by week and area, for 1991.

Table 4. Arrival time of chinook salmon at the Dungeness Hatchery rack (WDFW salmon planting records).

Return Year	Date of First Arrival	Date of Last Arrival
1938	8-13	9-10
1939	8-12	9-09
1940	8-10	9-14
1941	8-16	9-20
1942	7-31	9-19
1943	8-21	9-04
1944	8-12	9-09
1945	8-18	9-01
1946	8-17	8-31
1947	8-16	8-30
1948	8-21	9-04
1949	8-13	9-03
1950	8-12	9-02
1951	8-18	9-15
1952	8-16	9-06
1953	8-15	9-05
1954	8-14	8-28
1955	8-13	9-17
1956	8-18	9-15
1957	8-10	9-14
1958	8-16	9-13
1959	8-15	9-05
1960	8-13	9-10
1961	8-19	8-30
1962	8-18	9-08
1963	8-17	9-07
1964	8-15	9-05
1965	8-14	9-11
1966	8-13	9-10
1967	8-19	9-09
1968	8-17	9-07
1969	8-16	9-06
1970	8-15	9-12
1971	8-14	9-18
1972	7-21	9-02
1973	7-14	9-30
1974	8-17	9-07
1975	8-09	9-06
1976	8-14	9-18
1977	8-31	9-17
1978	8-18	9-09
1979	8-18	9-08
1980	8-30	No data
1981	8-29	9-12
Average	**8-15**	**9-9**
Standard Deviation	**8.4**	**6.8**

with the timing of the current chinook salmon stock in the Dungeness River. The 1986-1992 average start of redd deposition in the middle section (hatchery location) of the river (RM 6.4-10.8) was 18 August (SD=8 d) while the average ending time was 1 October (SD=12 d) (Table 5). Considering that arrival time would likely proceed redd deposition time, the arrival times recorded from the 1930s through 1970s are remarkably similar to the current timing. This evidence does not support the theory that an overall shift in run timing of the indigenous stock has occurred, at least since the 1930s. A shift in run timing could have occurred in the 30 years prior to 1930 as unscreened irrigation ditches impacted the chinook salmon population.

Harvest Impacts

Without adequate coded-wire tagged releases of chinook salmon from the Dungeness River we cannot monitor harvest impacts specific to this stock. Only one release of chinook salmon from the Dungeness Hatchery has been coded-wire tagged and those fish were reared to yearling size prior to release. We cannot assume that harvest impacts indicted by the recoveries from this release are representative of naturally-produced Dungeness chinook salmon because of the yearling type of release. The type of release (fingerling or yearling) greatly influences the harvest distribution of the same chinook salmon stock released from the same site (A. Appleby, WDFW, personal communication). The yearling type of release is probably not representative of the current out-migration pattern of most native Dungeness chinook salmon fry as nearly all Dungeness chinook salmon scales examined to-date indicate outmigration in the first year (J. Sneva, WDFW, personal communication).

Generic spring and summer chinook salmon management periods have been used to approximate the timing of adult returns to the Dungeness River and provide a timing guideline to manage terminal fisheries that may affect this stock. No chinook salmon fisheries are presently allowed in the Dungeness River, and there is a 30″ maximum size limit in the Strait of Juan de Fuca recreational fishery from 15 April through 15 June.

Three additional terminal area protective measures have been proposed to begin in 1994. The in-river fishery for coho salmon (*O. kisutch*) will be delayed until 15 October (after chinook salmon spawning has ceased). A second proposal expands the Dungeness Bay recreational fishery closure. The old boundary was a line running from the Dungeness Spit lighthouse to Kulakala Point. The new line runs from the Dungeness Spit lighthouse to the number 2 red buoy, then from the number 2 red buoy to the Port Williams boat ramp. In addition, the fishery for steelhead (*O. mykiss*) will be closed during August and September to reduce impacts on chinook and pink salmon (*O. gorbuscha*) in the Dungeness River.

Table 5. Average redd deposition timing of Dungeness River chinook salmon, 1986-1992 (WDFW spawner survey records).

River Section	Starting Date	Peak Date	Ending Date
Upper (River Mile 10.8-18.7)	8-15 SD[a]=8	8-30 SD=6	9-14 SD=8
Mid (River Mile 6.4-10.8)	8-18 SD=8	8-31 SD=8	10-1 SD=12
Lower (River Mile 0.0-6.4)	9-1 SD=5	9-13 SD=9	10-13 SD=9

[a] SD = standard deviation.

CHAPTER 3 - ENVIRONMENTAL OVERVIEW

Brad Sele

Physical Description

The Dungeness River basin drains 198 square mi of the northeastern part of the Olympic Peninsula (Figure 1). The main stem extends 31.9 mi and its primary tributary, the Gray Wolf River, adds another 17.4 mi (Williams et al. 1975). In addition, there are another 256.2 mi of tributaries in the basin (Williams et al. 1975) and 97 mi of irrigation ditches (PSCRBT 1991). The headwaters of the Dungeness and the Gray Wolf rivers originate at an altitude of about 4,000′ in the Olympic Mountain Range. The river flows from south to north, first through steep gradients, then progresses to the foothills, and finally opens onto an alluvial fan in the lower 10 mi of the river. The lowest five miles have a relatively flat gradient before entering the sea (Lichatowich 1992).

Water Flows

Water flows have been recorded at RM 11 in the Dungeness River by the U. S. Geological Survey since 1923. This location is above the irrigation diversions but does not include some of the lower river tributaries. Table 1 summarizes average monthly flows in the Dungeness River; flows range from 175 cu ft per sec (cfs) in September to 706 cfs in June. A monthly total of 579 cfs of water from the Dungeness River has been allocated by the Washington Dept. of Ecology for agricultural and domestic use, causing a severe conflict in water use with fish production during the critical low flow periods of August through October (Hiss 1993). Only during the month of June does this total water allocation not exceed the average monthly flow in the river. The low flow period also corresponds to the time of migration and spawning for adult chinook salmon returning to the Dungeness River.

Peak flows are also likely to have an effect on chinook salmon production, particularly during incubation. Peak flows (greater than 4,000 cfs) have been more numerous from 1976 to the present compared to the period of 1962-1975 (Lichatowich 1992). Preliminary data from scour monitors placed in the lower 10 miles of the Dungeness River in 1993 indicate that scour is significant in the lower river and that scour is occurring in the same areas that redds are constructed (S. Ralph, Natural Resources Consultants, personal communication).

A complex irrigation system was constructed in the Dungeness River valley at the turn of the century to support agricultural development. Initially, the irrigation system was not designed to protect the fishery resources in the river. Significant adverse impacts occurred, and modifications were eventually made to prevent diversion of juvenile and adult salmonids into the irrigation distribution channels. Today, five irrigation diversions between RM 6.8 and 11.0 remove as much as 60% of the natural flow during critical low flow periods (A. Seiter, Jamestown S'Klallam Tribe, personal communication). The irrigation season runs from 15 April

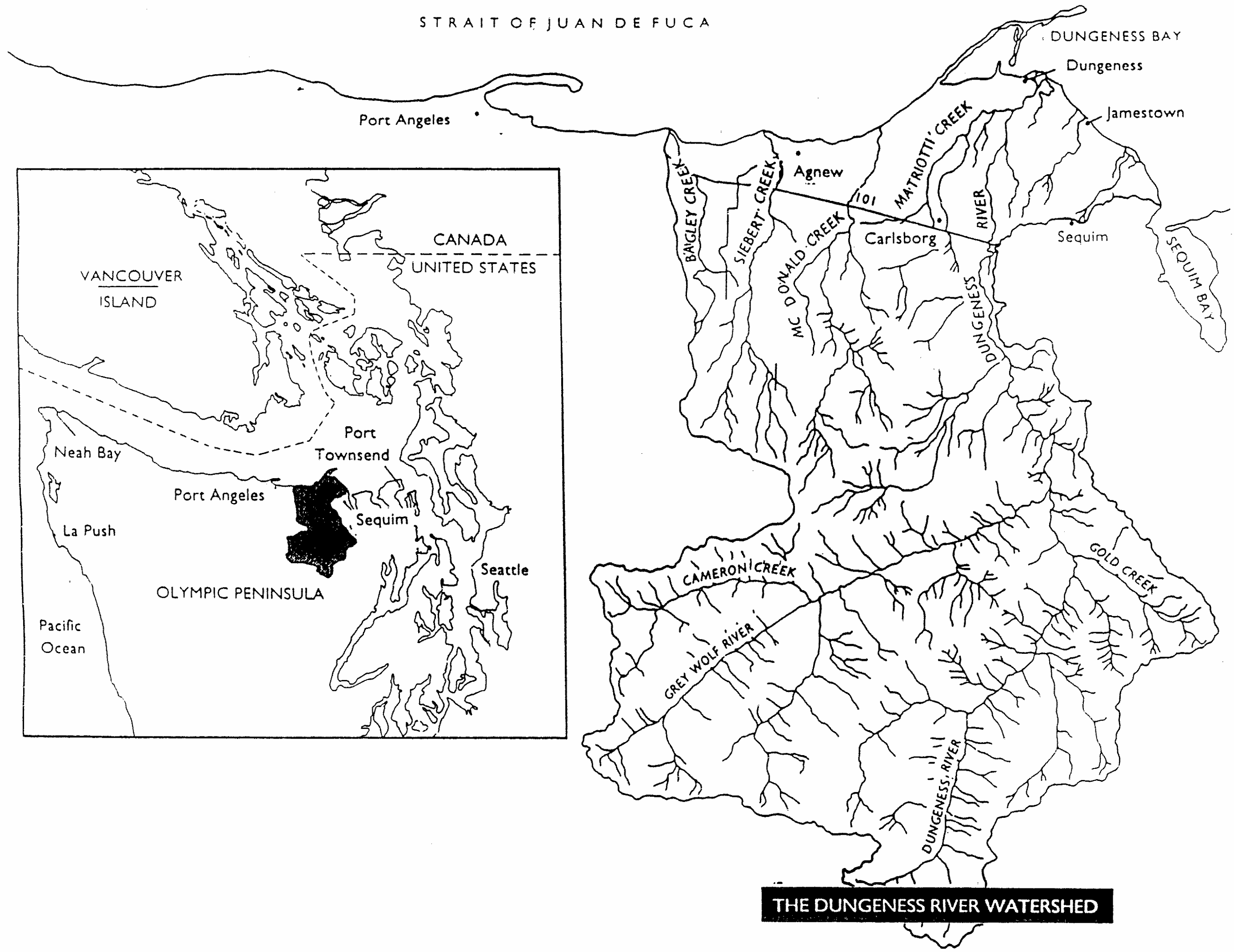

Figure 1. Map of the Dungeness River watershed.

Table 1. Average monthly flows in the Dungeness River, 1923-1991.

Month	Amount of flow (cfs)
January	386
February	380
March	283
April	322
May	564
June	706
July	496
August	265
September	175
October	215
November	345
December	425

to 15 September each year, though smaller water withdrawals for livestock are made throughout the year. It is unknown whether well water withdrawal also affects instream flows.

The 1990 Chelan Agreement has led to the formation of the Dungeness-Quilcene Water Resources Pilot Project. This is a cooperative water management model planning effort involving local and state government officials, treaty tribes (Jamestown and Port Gamble S'Klallam), and private citizens. One of its primary efforts is to address the Dungeness River water withdrawal issue, as well as related issues such as water conservation, the relationship between surface and ground water supplies, and community water needs versus maintenance of fish habitat.

Salmonid Habitat

Human factors that have impacted fisheries habitat in the Dungeness River in the last century include forest practices in the upper watershed, destabilization of the riparian corridor by urban development in the lower river, channelization and diking of the river for flood control, water withdrawals for irrigation and domestic use, and pollution from agricultural and urban run-off. Sedimentation has become a primary problem in the Dungeness River. Sediment deposition is a natural process. However, when the amount of sediment deposited exceeds the river's ability to transport it, the river channel changes in ways that are detrimental to salmon habitat (Lichatowich 1992). High levels of aggradation destroy juvenile rearing habitat, create impediments to both upstream and downstream migration of anadromous salmonids, and the unstable shifting gravel kills incubating salmon eggs during high flows (Nawa et al. 1988).

During the summer of 1994, fish habitat surveys will be conducted on the Dungeness River as part of a cost-sharing program between the Jamestown S'Klallam Tribe and the U. S. Forest Service. The surveys will assess the available fish habitat in the river, particularly for chinook and pink salmon. Recognizing the importance of the lower nine miles of the Dungeness River to the life histories of these two anadromous species, an ancillary study will be funded by the Jamestown S'Klallam Tribe and the North Olympic Salmon Coalition to assess the river channel morphology and water temperature of selected stations to determine stability with regards to fish production. From the information collected by these two studies, a fish habitat restoration plan will be developed which will cite specific activities to improve chinook and pink salmon spawning and rearing habitat in the Dungeness River. Implementation of these chinook and pink salmon habitat restoration activities will commence once financial resources are identified and obtained.

During the past several years, gravel traps have been constructed in the river downstream of the Dungeness Hatchery (RM 10.8). The primary purpose of the traps is to stabilize the river channel by acting as catch basins for the moving gravel and sand during peak flow events. The short- and long-term impacts on the salmon populations are unknown. Limited visual observation indicates that the chum, pink, and chinook salmon are preferentially selecting spawning sites in, or adjacent to, gravel traps. These redds are likely to be destroyed in a peak flow event when gravel is filling the trap. Although the traps may create holding areas for returning adults, chinook salmon juvenile rearing habitat may be destroyed in the process of constructing the trap. To address these problems, traps constructed in the future may be dug after spawning season and in areas where spawning did not occur. In addition, if traps are not dug extensively in the lower river, adequate juvenile rearing habitat can be balanced with the gravel trap placement.

CHAPTER 4 - CONSERVATION GENETIC ISSUES AND CAPTIVE BROODSTOCK PROGRAM DESIGN

James B. Shaklee and Christopher Marlowe

Background and Justification

Conservation Genetics:

As the number of individuals in a population decreases, the probability of the population's extinction due to random genetic, demographic, or environmental events increases. There is general agreement that, in the short-term (fewer than five generations), an effective population size (N_e) of at least 50 per generation is necessary to avoid substantial reductions in fitness due to inbreeding depression (Franklin 1980; Frankel and Soule 1981; Nelson and Soule 1987) and, more generally, loss of variation from genetic drift. For medium- (5-20 generations) and long-term (greater than 20 generations) situations, genetic drift (the fluctuation of allele frequencies due to random sampling events during reproduction) is a major determinant of the genetic characteristics of populations. Based on theoretical considerations, both Franklin (1980) and Lande and Barrowclough (1987) have determined that genetic drift should have a negligible effect on the genetic characteristics of populations provided that N_e is about 500 or more. The latter authors also conclude, assuming weak or no selection, that populations with an N_e of 500 or more can maintain nearly as much genetic variance in typical quantitative traits as an infinitely large population.

Waples (1990) has shown the effective population size per generation for Pacific salmon to be approximately equivalent to the effective number of breeders (N_b) per year times the average generation length (age at reproduction) for the population. Thus, for a chinook salmon population with an average adult return age of four years, the N_e of the population would be four times the harmonic mean of the number of breeders in four successive years.

While the above considerations regarding a stock's genetic vulnerability to small population size are based on specific values of N_e, this parameter is difficult or impossible to estimate with confidence for most natural populations. Population biologists believe that the N_e of natural populations is almost always significantly smaller than the census size. Indeed, Nelson and Soule (1987) and others have suggested that N_e for salmonid fishes may be substantially less than the census population size (N) due to a failure by some of the returning adults to spawn successfully, skewed sex ratios, and variance in lifetime family size. Recent work on a large number ($N >> 1,000$) of outbred Drosophila stocks indicates that N_e may be an order of magnitude lower than N.

To maintain the genetic characteristics of the existing wild population, the minimum number of parents used for augmenting production should be 25 pairs per year in each of four successive years, for a minimum total of 100 males and 100 females. This approach, if coupled with 1:1 spawning, would be expected to yield an effective number of breeders (N_b) of approximately 50 in each year (25♀ x 25♂) resulting in an N_e of about 200 over a single generation (four years).

However, 50-100 pairs per year (totals of 200-400 pairs) would be preferable from a genetic perspective. Such sample sizes should accomplish three important objectives:

1. Ensure minimal inbreeding in the resulting generation(s).

2. Yield a population that mirrors the wild stock with regard to the general pattern and amount of genetic variability (i.e., has similar frequencies for all of the more common alleles at all loci).

3. Yield a population that has a reasonable probability of possessing the majority of the rarer alleles (frequencies of 0.005-0.050) present in the existing wild stock (Figure 1).

Dungeness Chinook Salmon Stock Status:

The numbers of adult chinook salmon returning to the Dungeness River each year to spawn have decreased to fewer than 350 in recent years, with the 1986-1993 average return equal to 179 fish (Chapter 2). The current critical status of the Dungeness chinook salmon run threatens the long-term fitness and survival of this population. We assume the Dungeness chinook salmon population represents a unique stock of fish although direct genetic evidence supporting this presumption does not currently exist. The low population numbers place this stock at risk from negative environmental or ecological impacts and from a genetic bottleneck. Because of the low population numbers and the trend of declining abundance of this stock, we recommend that vigorous steps be taken to increase the number of Dungeness chinook salmon without subjecting the existing population to unnecessary risks.

Nature of the Dungeness River Chinook Salmon Rebuilding Project

Participants in the Dungeness River Chinook Salmon Rebuilding Project reviewed the characteristics and status of this population and considered many different alternatives for rehabilitating the stock (see below and Chapter 5). The goal of rapidly increasing the number of fish while maintaining the genetic integrity of the stock (in order to minimize deleterious genetic effects of a bottleneck) was our primary criterion in evaluating and prioritizing the different approaches. Our initial focus was on increasing spawner abundance by rapidly increasing fry or smolt production, rather than decreasing harvest or improving habitat, because we believed that the population numbers of this stock were dangerously low and that increased spawner abundance was most likely to result in a quick increase in population size. However, habitat and harvest-related issues will eventually be addressed as rebuilding proceeds. Some of the factors considered in our evaluation of the various options included: (1) extent of natural production loss, (2) genetic consequences, (3) disease concerns, and (4) logistical and operational problems.

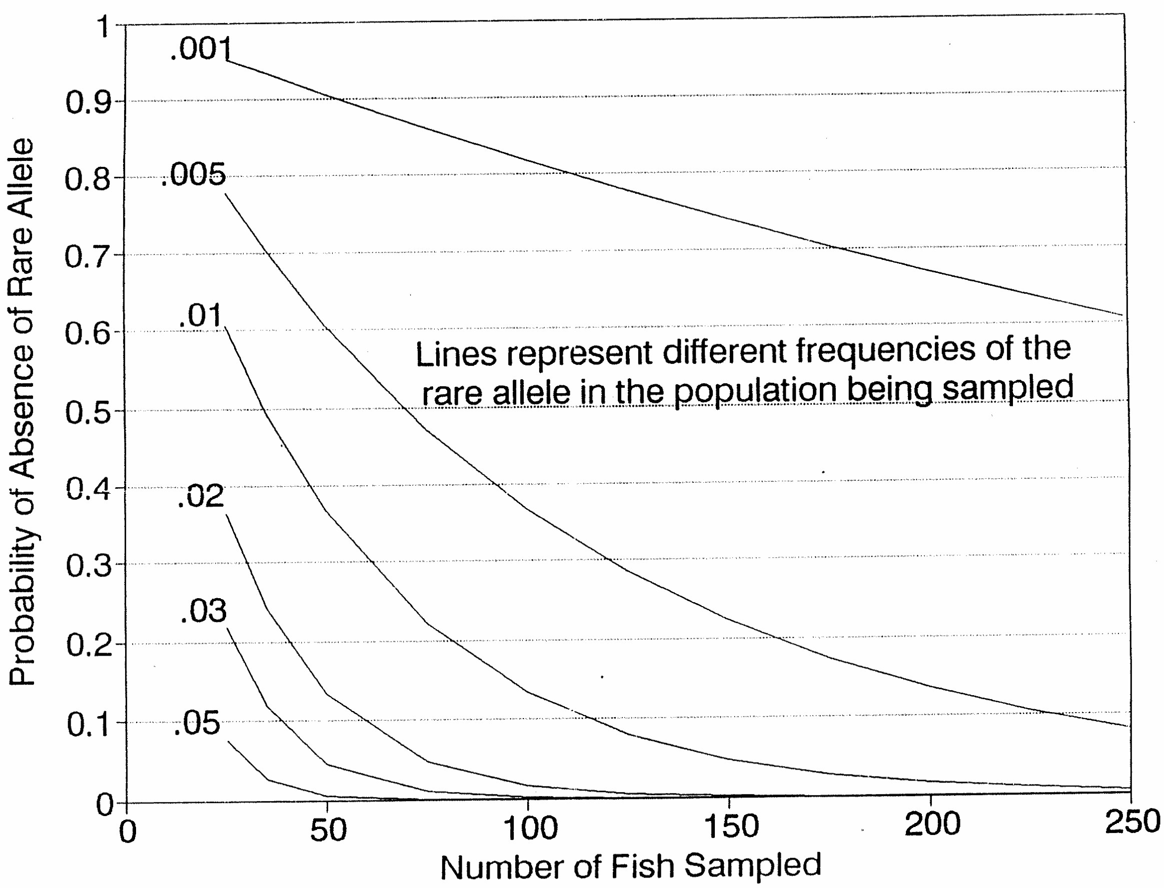

Figure 1. Probability of "missing" a rare allele when sampling a population.

After considering all identified alternatives, the rebuilding committee concluded that implementation of a captive broodstock program was the best approach to achieve a rapid increase in fish numbers with a minimum impact on the numbers of natural spawners. The group established a goal of starting the first year's captive brood program with 5,000 fry based on considerations of: (1) the reproductive potential of a chinook salmon captive broodstock program, (2) a general understanding of the current/historic carrying capacity of the Dungeness watershed to support chinook salmon (adult pre-spawning holding and spawning, incubation, and juvenile rearing), (3) the estimated mortality rate for the captive broodstock, and (4) the capacities of available hatchery and freshwater broodstock rearing facilities.

We decided that to obtain a representative genetic cross-section of the natural population, fry collections from the Dungeness River (as opposed to capturing and spawning adults, see Chapter 5) would be the most desirable source of fish for founding the captive broodstock. Genetic considerations (outlined above) dictated that fry from at least 25 families (progeny of 25 ♀♀ and 25 ♂♂) per year be used to found the broodstock to avoid problems of excessive inbreeding and genetic drift. We chose to utilize collections of both pre-emergent and post-emergent fry to maximize the likelihood of obtaining our goal of 5,000 fry from 25 or more families.

We also decided to initiate two parallel captive broodstock programs - one freshwater and one saltwater (see below). This provides redundancy that reduces the risk of complete program failure (both broodstock programs would have to fail) and it allows evaluation of the relative merits of freshwater and saltwater captive broodstocks using the same stock of fish.

Pre-Emergent Fry Collection:

This approach requires the collection of pre-emergent fry from each of approximately 25 redds by hydraulic sampling (see Chapter 6). Because a genetic goal of the program is to retain the genetic character of the natural stock in the captive population, the intent is to obtain a relatively small number of fry from a large number of redds. In order to meet the identified numeric goal for initiating the captive broodstock program with 5,000 fry, 200 fry must be obtained from each of 25 redds. If we are successful in collecting fry from more than 25 redds we will need fewer than 200 fry from each redd. Each of the resulting "families" will be reared separately until the fish are large enough to mark with family-specific tags. Eventually, the resulting adults will be spawned in such a way that full-sib matings (crossing ♀♀ and ♂♂ from the same family) are avoided.

Advantages of this approach include: knowledge of the number of families contributing fish to the captive broodstocks, an ability to avoid full-sib crosses (brother-sister matings) at spawning, and ability to monitor family-specific survival and performance throughout the project.

We identified several disadvantages of pre-emergent fry collection. One possible risk is that the resulting captive broodstock(s) will be based on progeny from only the fraction of the natural population that is sampled (approximately 25% using the recent average escapement and projected redd sampling numbers presented above). Thus, although the use of 25 pairs/year should theoretically provide a good genetic cross-section of the natural spawning population, there is a risk that the genetic characteristics of the resulting captive broodstock may not be representative of the whole population.

Another weakness is the uncertainty of the redd sampling. The goal is to obtain 200 viable chinook salmon fry from each of 25 redds, but hydraulic sampling of redds is an unproven, experimental stock collection procedure with a risk of damage to the fry remaining in the redd after sampling. Furthermore, redd sampling is very labor intensive.

A third disadvantage is that fish sampled as pre-emergent fry cannot be taken to another facility outside of the river basin of origin without violating the existing Salmonid Disease Control Policy agreed to by WDFW and the tribes unless all effluent waters from that facility are sterilized.

Post-Emergent Fry Collection:

The broodstock will also be established using 1,000-3,000 post-emergent fry collected by electroshocking (and/or seining). The actual numeric goal for post-emergent fry will be adjusted according to the success in obtaining pre-emergent fry to address the total broodstock goal of 5,000 fry. Sampling will occur throughout the river over a period of several weeks (late March to June) to maximize the likelihood of obtaining fry from as many different families as possible and maximizing the genetic diversity of the resulting population.

We identified four advantages to post-emergent fry collection. There is a potential to represent 100% of the spawners in the total Dungeness population in the captive broodstock. The success of seining for chinook salmon fry in other river systems, and of a small pilot seining project in the Dungeness River in 1992, indicated that this approach will likely yield adequate numbers of fry, at least in the lower river. Also, this strategy will provide one or more collections of fry that can be sub-sampled for electrophoretic characterization of the natural Dungeness chinook salmon stock. This seems the only practical way to accomplish genetic characterization of this stock in the near term because of the extreme difficulty of obtaining an adequate sample of spawned-out adults for a GSI characterization. The resulting genetic characterization could also provide some insight regarding the number of parents contributing to the post-emergent fry collection(s). Lastly, because collecting at this later developmental stage allows natural selection greater opportunity to act on the population during the earliest life stages (when mortality is usually high) the potential for genetic change due to the captive broodstock program may be decreased. However, if unnaturally high levels of bedload movement and scour are causing elevated mortality of pre-emergent fry, much of the mortality at this time could be considered to be the result of unnatural selection.

Potential disadvantages to post-emergent fry collection include: no direct information regarding the actual number of families (spawners) sampled; possible poor representation of the wild population genetically; it will not allow the complete elimination of full-sib spawnings; and because considerable natural mortality will have likely occurred by this later developmental stage, a proportionately larger fraction of the population will have to be collected to meet the numeric goal of the program (thus decreasing natural production).

Two-Source Captive Broodstock:

While both hydraulic redd sampling and electroshocking/seining appear to be attractive ways of initiating a captive broodstock program, using both approaches has two additional advantages: possibly yielding a more representative broodstock by utilization of two somewhat independent sources of fish from which to establish the captive broodstock and providing insurance in case one sampling approach is partially or completely unsuccessful.

In summary, the strengths of the two-source broodstock collection being used for restoration of the Dungeness chinook salmon are:

1. There is no impact on the adult spawning population.

2. There is a reasonable expectation that the required number of fry can be captured and the fry will be a genetically adequate source for founding the captive broodstock.

3. It is reasonable to expect a large increase in fish numbers within a single generation using a captive broodstock approach. For example, starting with 5,000 fry/captive brood, and assuming a smolt to spawning survival rate of 40% (Keown and Eltrich 1992), 2,000 spawning adults would be expected. These adults could provide over 2 million eggs (assuming an average fecundity of 2,650 eggs/female and a population composition of 40% females). About 1,375,000 fry would be expected in the next generation based upon White River spring chinook salmon captive broodstock results (Keown and Eltrich 1992).

4. Natural selection processes can still occur on the fry remaining in the river.

Disadvantages and Uncertainties of the Two-Source Collection:

1. There will be uncertainty regarding the parentage and genetic characteristics of the post-emergent fry used to establish the captive broodstock and whether or not the fry adequately represent the genetic profile of the wild population.

2. Even if apparently healthy, no fish obtained from the Dungeness River by fry collections could be moved to other facilities outside the Dungeness watershed (e.g., Lilliwaup) without violating disease control policies, unless the effluent water from the other facility were disinfected. Such treatment would increase the cost of the operation substantially.

3. There is some uncertainty about the amount and pattern of mortality that may be encountered in getting the wild fry to accept artificial food and otherwise adapt to the hatchery environment. Mortality may also be non-random or so high as to compromise the size or genetic diversity of the resulting broodstock population.

4. The natural chinook salmon population in the Dungeness River (and their progeny) would be largely unprotected from the effects of environmental catastrophes (e.g., severe flooding) in the river, because only a relatively small number of fish would be included in the two

captive broodstocks. This potential effect would most affect the portion of the population spawning in areas prone to bedload movement and scour.

5. The captive broodstock program, like other artificial propagation programs, carries a risk of changing the genetic characteristics of the natural stock through domestication selection.

Establishment of Captive Broodstock Programs

We consider the use of captive broodstock for restoring depleted wild stocks of salmon to be unverified and, therefore, experimental. While there are theoretical advantages of this approach and a few seemingly successful examples, there have also been a number of unsuccessful or at least poorly documented attempts as well (see Chapter 5). The considerable uncertainty of this approach led us to conclude that the prudent approach was to pursue parallel saltwater and freshwater broodstock rearing programs, both to reduce the risk of failure and to conduct a rigorous side-by-side comparison of the two approaches using the same stock of fish. The intent is to conduct initial rearing of all fish in freshwater. At about the time of smolting, each family/group will be split in half. One half of each family will be maintained in freshwater until they reach maturity and can be spawned. The other half will be transferred to saltwater net pens and maintained there until maturity. Then this latter group will be returned to freshwater for spawning. The present intent is to establish the freshwater captive broodstock at the WDFW Hurd Creek Hatchery and eventually establish the marine captive broodstock in salt water net pens in Port Angeles Bay.

The freshwater component of the captive broodstock was chosen to minimize the dominant threat to successful broodstock maturation, disease. If the rearing water is from a pathogen-free (subterranean) source at an acceptable water temperature, many of the sources of mortality in the sea-pen option are eliminated. Chinook salmon have been grown to maturity in freshwater and produced gametes (T. Flagg, NMFS, personal communication).

However, many risks are involved with captive broodstocks (see Chapter 5). Perhaps of greatest significance is the absence of specific results. There is no basis for estimating mortalities, offspring fitness, or identifying optimal culture methods. The lack of documented results for freshwater captive broodstock programs emphasizes the experimental nature of this approach. Mechanical failure of equipment such as pumps and other vulnerabilities such as vandalism add additional risk factors to this culture option.

In contrast, the White River spring chinook salmon captive broodstock program in Puget Sound provides a decade of experiences and results. While saltwater rearing at the NMFS Manchester site in the initial years of this program was only marginally successful, rearing in recent years at the Squaxin Island facility has been very successful (A. Appleby, WDFW, personal communication). Additionally, the successes of, and information from, the private salmon sea-pen culture industry suggest that saltwater rearing is a viable approach.

One potential disadvantage of sea-pen rearing is that success may be highly site specific (possibly due to geographic variation in pathogen levels). Additionally, sea-pen facilities are at risk from storms, pinniped and avian predation, vandalism, red tides, and pollution.

We believe the use of both freshwater and saltwater rearing programs will substantially reduce the risk of overall program failure (by separating the fish into two basically independent groups that will be maintained in distinct environments with different characteristics and stresses). It will also provide needed information on the relative merits of freshwater versus saltwater captive rearing. Thus, we see the proposed experimental use of two captive broodstocks as both a safer vehicle for rehabilitating the Dungeness chinook salmon population and a means of increasing our knowledge and understanding of the suitability of using captive broodstocks for preserving threatened salmon stocks.

Limited Duration of the Captive Broodstock Program

Although the captive broodstock program was seen as a way to increase the population size rapidly so that subsequent long-term rebuilding would proceed quickly, once the primary factors currently limiting the population had been identified and corrected, it is important to emphasize that the captive broodstock approach is (and should always be considered) a short-term emergency approach to help a stock past a brief population bottleneck and not a long-term solution to population problems facing “wild” salmon.

In one sense, a captive broodstock program can be viewed as the most extreme type of hatchery propagation. The fish in a captive broodstock program are held for their entire life cycle in an artificial manner where they are fed an artificial diet. This exempts them from many of the normal effects of natural selection, and might induce considerable genetic change in the stock it was implemented to save. For this reason, captive broodstock programs should not last any longer than absolutely necessary to get the depressed stock past a population bottleneck.

The Dungeness chinook salmon captive broodstock program is intended to be implemented as only a two-generation program (eight years). Because captive broodstock programs for chinook salmon are still experimental, it may be unrealistic to expect adequate success in a single cycle (four years). Additionally, it will likely take more than four years to identify and correct the major fish habitat or harvest management problems impacting the Dungeness stock. Continuation of a captive broodstock program for two cycles will also provide a convenient and cost-effective (but not the only) way to apply the necessary tags to these fish. It will not be possible to evaluate the overall success of the total rebuilding effort, or even of the captive broodstock program, at the end of four years because adult returns from the captive brood fish will not begin until approximately seven years after the program is initiated. Thus termination of the complete rebuilding project after four or even eight years would precede comprehensive evaluation - an undesirable situation. Because any captive broodstock program can have undesirable genetic or other impacts on a stock, restricting the duration of captive broodstock collection and production should be a basic intent of all such programs. For these reasons, we believe that the initial Dungeness chinook salmon captive broodstock operations should be stopped after eight years. The accompanying evaluation program should be focused on the identification and estimation of spawner returns, harvest impacts, and survival, and should be conducted from the years 2000-2008. Subsequent re-initiation of captive broodstock operations should be dependent upon the results of a thorough evaluation of the performance and fates of broods produced during the captive broodstock program's initial operation and upon an assessment of how effectively we have begun to deal with long-term limiting factors.

Requirement for Other, Complementary Restoration Activities

In order to return this or any other depleted stock to a healthy, self-sustaining status, it is imperative that environmental, harvest, and/or other factor(s) that contributed to its decline be corrected. Unless this is accomplished, resources and energy directed at captive broodstock programs will not succeed in stock rebuilding per se, they will only serve to maintain the genetic character of the target stocks. Thus, while a captive broodstock program affords a technology that can substantially increase fish numbers in the short term, it will not, by itself, address the underlying causes for the problem(s). We must identify the factor(s) limiting production and/or survival and correct these in order to accomplish long-term stock restoration.

CHAPTER 5 - ALTERNATIVES CONSIDERED FOR RESTORATION OF DUNGENESS CHINOOK SALMON

Christopher Marlowe and James B. Shaklee

Out-planting or Traditional Hatchery Program

We identified and evaluated a number of approaches other than the chosen strategy described in Chapter 4. The traditional hatchery strategy could utilize either a native or a non-native chinook salmon stock for release into the Dungeness River. The use of a non-native stock was rejected because it was inconsistent with the goal of rehabilitating the stock of chinook salmon native to the Dungeness River and it was inconsistent with WDFW's stock transfer guidelines. Furthermore, enhancement using a non-native stock may adversely affect the native stock through competition and predation (Fresh et al. 1984), as well as by interbreeding.

Using the native stock in a traditional hatchery program would require capture of returning adults, collection of gametes, and production of yearling-type smolts for release. This strategy has been successful in other chinook salmon programs. Adults could be trapped or gaffed in the river. This approach would allow considerable flexibility in selecting sites for rearing of the captive broodstock because adults could be tested for pathogens and, if negative for disease, their progeny could be transferred out of the Dungeness watershed without violating existing disease control policy. However, to provide a genetic representation of the population, 17%-50% (25 pairs of adults, Chapter 4) of the spawning population would be removed from the river. This approach would be expected to yield approximately 100,000 eggs (25 females x 3,900 eggs/female) which would lead to about 650-900 spawning adults (based upon White River and Nooksack spring chinook salmon return rates for fingerling release and four year old return). However, this could increase the vulnerability of the wild stock to ecological and genetic bottleneck problems. An unforeseen failure of the hatchery operation would jeopardize the natural population because it would eliminate 17%-50% of at least one brood's production.

Specific problems involved in trapping adults include: the lack of a weir in the river, concern that building a weir could harm the chinook salmon population by impeding passage and increasing the vulnerability to poaching, and concern regarding pre-spawning mortality during holding of the adults.

Gaffing the desired number of reproductive adults on the spawning grounds in the Dungeness River may be impossible with the current population status as chinook salmon, especially males, are rarely seen during stream surveys. Also, it is presently unclear how to deal with the existing uncertainty of adult sampling. Once adults are gaffed they must be spawned almost immediately. If fish of one sex but not the other are collected on a given day, their contribution may be lost from the population. If several fish of one sex are obtained but a smaller number of fish of the other sex are captured, there would be concerns regarding minimizing the negative genetic effects of the skewed sex ratio of the potential parents. Finally, and perhaps most importantly, is the difficulty of successfully collecting 25 females and 25 males.

An additional concern regarding a traditional hatchery program or progeny released from captive brood is the effect release-type might have on naturally-produced chinook salmon as well as other salmonid species in the river. Yearling release (early April) would coincide with the presence of much smaller, younger, newly-emergent chinook salmon fry produced by natural spawning in the river. If these two broods co-occur in the same areas of the river, the hatchery yearlings could negatively impact the naturally produced fry directly through predation or indirectly through competition (Fresh et al. 1984). The larger chinook salmon might also prey on pink salmon fry. Two pink salmon stocks occur in the Dungeness River, one is listed as "critical" and the other "depressed" in the SASSI report (WDF et al. 1993).

Captive Broodstock

The use of returning adults to seed a captive broodstock program was rejected for the reasons mentioned above. We also considered the removal of residual eggs from spawned-out females on the spawning grounds (and milt from males). This approach was not pursued because of concerns there would be too few eggs in each spawned-out carcass, too few female carcasses, or too few males to fertilize the eggs in a genetically appropriate way.

Eyed eggs hydraulically pumped from redds could provide another source of fish to use to initiate a captive broodstock. This approach was not pursued because of the uncertainty regarding the potential destabilization of redds caused by hydraulic sampling, especially when it is done at this early developmental stage that occurs before the period of high flows. Nevertheless, this approach was recognized as having several potential advantages, including the likely greater success in locating and sampling the relatively recently created redds and the protection from catastrophic events in the river if fish were moved to a hatchery environment early in their development.

Trapping outmigrating smolts was rejected based upon the high mortalities experienced by chinook salmon smolts trapped in other systems and the belief that smolts would be difficult or impossible to convert to the artificial hatchery environment and diet.

Captive Broodstock Culture Strategies Considered

The most extensively attempted captive broodstock technology for chinook salmon has been to rear fry in fresh water (usually until yearlings) then move them to sea pens or a pumped sea water facility until maturation, followed by spawning at a freshwater facility. While this strategy best mimics the natural life history, success has been mixed and is partially dependent upon location. Although high mortalities (up to 100% in some pens) were experienced by White River spring chinook salmon at Manchester, Washington, the same stock is currently successfully reared in sea pens at Squaxin Island, Washington (A. Appleby, WDFW, personal communication). The program at Squaxin Island has been providing large numbers of eggs for the rebuilding program. Survival from smolt to maturity has averaged 50% with an additional loss of 20% from maturity to spawning, yielding a net 40% survival from smolt to spawning (Keown and Eltrich 1992). Egg viability is about 65%, with fecundity around 3,200 eggs per four-year old female (74% of females) and 2,300 eggs per three-year old female (12% of females).

In California, saprophytic parasitic infestations have marred success in the freshwater broodstock culture of winter chinook salmon. After initial freshwater rearing at Coleman National Fish Hatchery, the chinook salmon are now reared in two different pumped sea water environments, the Steinhart Aquarium and Bodega Marine Laboratory. Both facilities have substantial disease control abilities such as ozone and ultraviolet sterilization of water. In general, pathogen problems encountered in this strategy have been bacterial kidney disease in fresh and saltwater, marine fungal pathogens and infectious anemia in saltwater adults, and furunculosis when adults are returned to freshwater.

Other disadvantages to saltwater pen rearing of chinook salmon include size, maturation, fecundity, and egg viability differences compared to hatchery fish released prior to smoltification. Captive broodstock fish mature younger and at a smaller size and produce smaller eggs and fry than anadromous fish, although juvenile fish size is not different after six months (Keown and Eltrich 1992; Joyce et al. 1993). Males mature more as two- and three- year olds (95%) and females as four- and five- year olds (88%) (Keown and Eltrich 1992). Fecundities average about 50%-68% of anadromous fish fecundities and 65% egg viability is typical for captive broodstock chinook salmon (Keown and Eltrich 1992).

A variation on saltwater captive broodstock rearing is to keep fish in saltwater net pens until spawning. This reduces handling of the fish during maturation and reduces costs because a freshwater facility is not needed for spawning. Nevertheless, gamete viability is significantly reduced when maturation occurs in higher salinities (Joyce et al. 1993). A unique approach to curb the effect of high salinity on chinook salmon gamete viability was used at Little Port Walter, Alaska. Workers improved gamete and fry viability by keeping fish in saltwater net pens until spawning, then providing a freshwater lens and a special broodstock diet during maturation (Joyce et al. 1993). Requirements include a special site and sea pen construction to accommodate the freshwater lens.

Another type of captive broodstock technique for chinook salmon is to rear fish in a freshwater facility throughout their entire life cycle. A few freshwater life cycles exist for chinook salmon in nature (Lake Chelan and Lake Cushman, Washington and the North American Great Lakes). Furthermore, a good water source with constant temperature can provide a more disease-free environment. This technique is experimental with few documented examples and no known examples with long-term results. Mayr Bros. (Grays Harbor, WA) has experimented with a small number of fish that voluntarily remained at the hatchery, but it is premature to estimate gamete and fry viabilities (T. Balzell, Long Live the Kings, personal communication). Poor egg and sperm viabilities and subsequent low egg fertilization rates have been encountered with coho salmon raised in freshwater captive broodstock programs (G. Graves, Sea Springs Inc., personal communication). In the Snake River fall chinook salmon program, fish were placed into freshwater and saltwater components. The saltwater component died quickly, but the freshwater component reared to maturity (T. Flagg, NMFS, personal communication). Unfortunately, funding ended and spawning was not assessed.

Other potential freshwater captive broodstock problems include a possible elevated level of precocious males, at least with coho salmon (A. Appleby, WDFW, personal communication). In the winter chinook salmon program for the Sacramento River, the freshwater broodstock component was abandoned after freshwater fungal infections at smolting and maturation were experienced. Also, no information is available concerning any special dietary needs for maturation of viable gametes in a completely freshwater life cycle.

Other Fish Culture Options

The traditional hatchery program rears and then releases fish into streams to attempt to increase anadromous returns. This type of program existed for chinook salmon in the Dungeness River for at least three decades and coincided with a decrease, rather than an increase, of returning adults (Chapter 2).

Another variation of the traditional hatchery approach was used in the spring chinook salmon program at White River in which fish have been reared to smolting and released into an environmentally "safe" stream (Minter Creek) for anadromous return. Similarly, Snake River fall chinook salmon have been reared to smolts and released at the Kalama River Hatchery which is downstream of the dams on the Columbia River. While this strategy has shown success in maintaining population numbers of other chinook salmon stocks, there is an assumption that selection will not occur of a degree to hamper the successful re-introduction of the stock to its native habitat. Also, there is the risk that salmonids introduced into non-native streams may have poor survival. Tribal/WDFW fish health policy prohibits transfers among streams unless strict, expensive health regimes are followed.

Combinations of fish culture technologies offer a diversity of rearing strategies thereby lowering the probability of catastrophic loss of the entire program. Examples of combination strategies include the White River spring chinook salmon program, the Snake River fall chinook salmon program, and the Redfish Lake sockeye salmon ESA recovery efforts. The White River spring chinook salmon program utilizes saltwater net pens in combination with anadromous returns to a facility on a non-native stream (Minter Creek) and the native stream (White River Hatchery). Some of the smolts in the Snake River fall chinook salmon program were taken to Manchester for sea-pen rearing, and some taken to Kalama River hatchery for rearing and anadromous release below the Columbia River dams. The Redfish Lake sockeye salmon program is utilizing a combination of freshwater and saltwater captive broodstock strategy.

Other potential options include supplementing captive-brood adults with wild-capture adults for breeding. While combination approaches offer a lower risk for the entire program and an ability to compare strategies directly, the primary disadvantages are increased cost and the potential of not maximizing total possible yield as would occur if all assets were applied to the most successful technology.

CHAPTER 6 - TECHNIQUES OF HYDRAULIC REDD SAMPLING, SEINING, AND ELECTROSHOCKING

Sewall Young and Christopher Marlowe

Hydraulic Redd Sampling

Equipment:

Extraction of pre-emergent fry was accomplished with a modified version of the hydraulic redd sampler first described by McNeil (1964). This apparatus consists of a portable, gasoline-powered, four-horsepower, two-cycle engine driving a centrifugal pump with flexible 2″ suction and discharge hoses of 8′ and 15′ lengths. The discharge hose has a 4.3′ long venturi-probe apparatus attached (Figure 1). The end of the probe injects aerated water into the fry pocket of the redd. Rising air bubbles remove pre-emergent fry for capture by a netted basket placed around the probed area.

The hydraulic redd sampler used for the Dungeness Chinook Salmon Rebuilding Project was modified in two significant ways (Figure 1). First, instead of using the cone assembly that McNeil described, our probe had a simple set of drilled holes with a splash jacket secured over the top of the holes. The flow of pumped water past the holes draws in air, providing an air/water mixture to lift fry and small substrate particles out of the gravel and allow their capture in the netted basket. Secondly, we modified the sampling probe by connecting the probe section to the venturi section with cam-lock fittings. This modification allowed the probing operation to be interrupted, the basket checked for fry and, if needed, fry could be removed without moving the location of the probe orifice. This modification helped in managing some of the difficulties and time requirements of locating fry. Once fry were located, the probe could be disconnected and remain in the gravel during net cleaning or fry removal. The probe could then be reconnected and pumping resumed without the need to relocate the precise pocket where fry had been found.

The cam-lock fittings between the probe and the venturi section also greatly facilitated the systematic search for fry by allowing accurate marking of previously probed areas. After the area within the capture basket had been thoroughly probed, the fittings were disconnected and a PVC marker was dropped down the probe. When the probe was pulled out of the gravel the PVC pipe remained to mark the sampled area. These markers helped us avoid re-sampling unproductive areas. This proved important due to the intensive searching within a redd required to obtain fry.

Chinook salmon fry flushed from the gravel were collected in a nylon net (0.012″ mesh) attached to a cylindrical, open ended, 0.236″ wire mesh-covered basket. The basket stood about 20″ high and had a 19″ diameter.

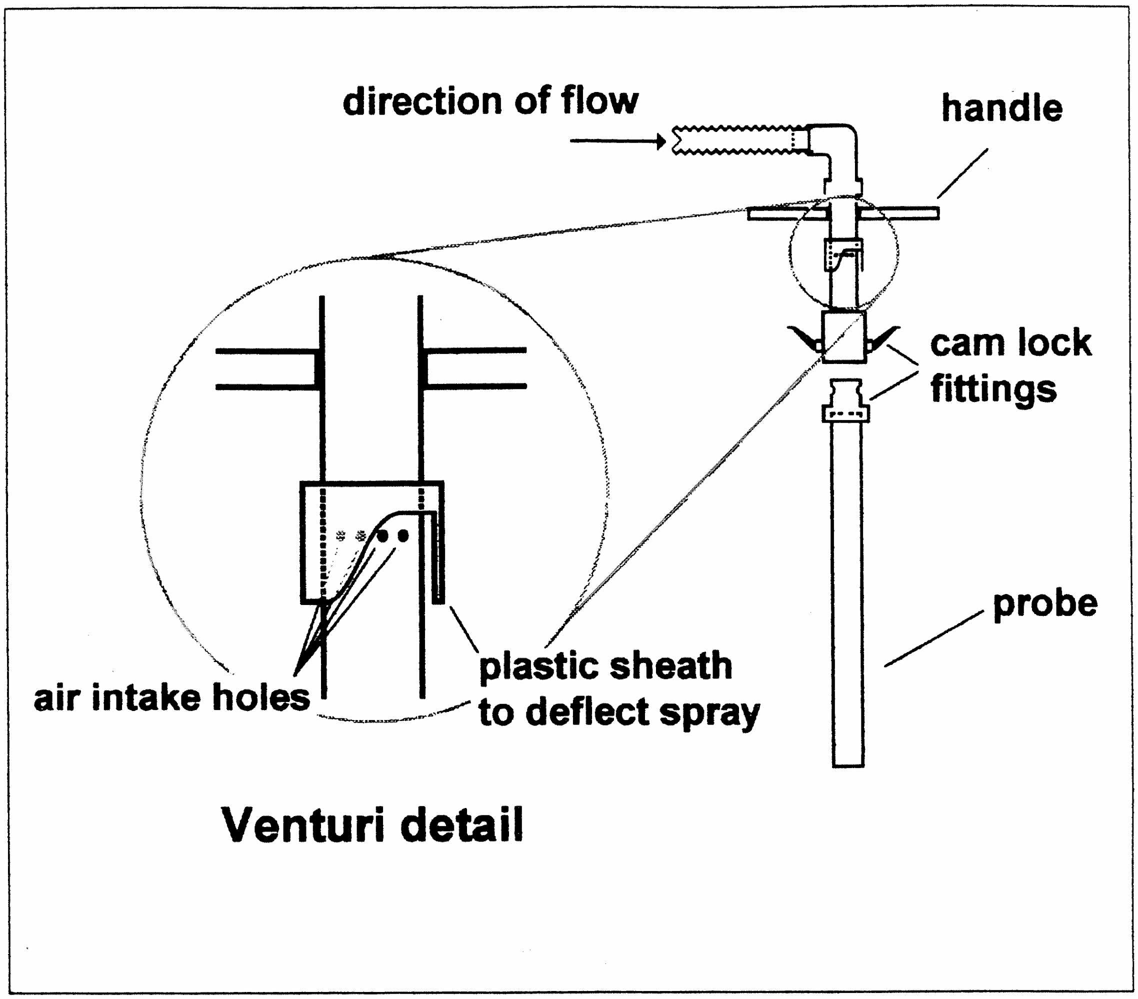

Figure 1. Hydraulic sampling probe with cam-lock fittings that make disconnecting the tip easy. This modification enables users to leave the probe in place in the gravel while checking the collecting net for captured fry. It also allows users to anchor markers in the gravel easily by inserting them through the throat of the disconnected probe.

Ontogenic Stage and Redd Sampling:

In the spring of 1992, we conducted a limited test of hydraulic sampling on a single chinook salmon redd in the Satsop River. We visited the redd on two occasions, once about one month prior to the onset of emergence and again three weeks later. We noticed hematomas around the yolk sacs on about one-third of the 32 fry captured on the first visit, and eight of those died within a week of delivery to the hatchery. The 80 fry taken on the second visit had almost completed yolk-sac resorption and suffered no mortality after their removal from the redd. We have no direct indication of the status of the fry that remained in the redd after either sampling event. However, we assume that fry flushed from the gravel into the net were among the most severely jostled. These observations suggest that about one month prior to emergence hydraulic sampling harmed chinook salmon fry, but fry could be removed from the gravel with minimal mortality two to three weeks prior to emergence.

At the onset of broodstock collection, the time of emergence for Dungeness chinook salmon fry was unknown but Chiwawa River spring chinook salmon, an upper Columbia River stock adapted to a similar water temperature range, showed yolk-sac resorption after accumulating approximately 1,650 temperature units (TU) (H. Fuss, WDFW, personal communication). The only known temperature measurements recently recorded in the Dungeness River were near the Dungeness Hatchery at RM 10.8. Since TU are cumulative, redds built in different areas probably accrue TU out of phase with each other and the temperature profile near the hatchery serves only to calibrate our estimate of the onset of emergence in other parts of the watershed.

Initially, we considered sampling eyed-eggs because of the suspected destruction of redds during floods in the Dungeness River. Early sampling before high water events, rather than later in incubation, probably would enable more precise probing and result in shorter search times and higher success rates due to the presence of topographical features that define the redd. Early removal of individuals from redds might enable inclusion in the captive broodstock of family groups that later would be decimated during winter high flows. Even in redds that survive the winter flows, mortality in the gravel reduces the size of many families. Sampling eyed-eggs would precede the portion of intra-gravel mortality that occurs between hatching and emergence so that the effect of taking 200 eyed-eggs from a family would be less than the effect of taking 200 “buttoned” fry.

Eyed-egg sampling also entails risks. Some members of the planning group were concerned that hydraulic sampling at the eyed-egg stage might destroy the interstitial redd structure and either deleteriously alter the flow of oxygenated water through the egg pockets or predispose the redds to scour during high river flows. Some also expressed concern about the lack of motility eyed-eggs have compared to fry, and that eggs displaced by the sampler to shallower positions within the gravel would be unable to reposition themselves and might be more vulnerable to gravel scouring or predation than motile fry. In addition, sampling at the pre-emergent fry stage allows for more natural selection to occur which lessens the domestication effect.

Equipment Operation:

The process of hydraulic redd sampling required: precise location of redd sites (even after erosion of characteristic river bottom contours); transport to the redd site of necessary equipment for capture and removal of fry; setup of the pumping equipment; searching for fry within the redd; separation of fry from other material collected in the net; and timely delivery of captured, pre-emergent fry to the Hurd Creek Hatchery for rearing.

Because of the amount and weight of equipment associated with hydraulic sampling, and because some redd locations were distant from the nearest road access, crew size was usually five or six people. Generally, only two redds per day per crew could be sampled unless redds were close enough that equipment did not need to be disassembled and transported to another location. During the peak effort (March) two pumping crews were active each work day.

Approximate redd location was determined from redd flags that had been placed by WDFW survey crews during their regular spawning ground surveys (August to October, 1992). These flags were tied to branches of a tree or a bush in the vicinity of the redd, with the date of first sighting of the redd, and the estimated distance from the flag to the redd pocket recorded on each flag. The proximity of the flags to the redd pockets varied. A few were as much as 100′ away. In almost all cases, traces of the redd in the river gravel were obscured by the time of sampling, therefore the flags provided the only clues to redd locations.

In the fall of 1992, more precise marking was done for 28 of the 63 redds marked. The additional marking included: (1) dropping a flat, red-painted rock into the river at the location of the redd pocket; (2) driving a 2′ length of construction rebar into the riverbank adjacent to the redd and recording the distance from the redd pocket to the rebar; and (3) drawing a detailed map of the area which showed stream bank shapes, rebar location, and distances from rebar to redd pockets. These maps were then used by the hydraulic sampling crews in February and March.

Using these approximate redd locations, the sampling teams probed the redd area searching for pre-emergent fry. The capture basket was held in place on the river bottom while the end of the probe was forced into the gravel as far as possible. Material lifted from the gravel by the bubbles rising around the probe collected in the net attached to the basket. After the area within the basket had been thoroughly searched the probe was reinserted into the gravel within the basket. Then the pump was turned off and the excurrent hose and venturi were disconnected from the probe at the cam-lock fittings, leaving the probe in the gravel. A 3′ length of 0.6″ diameter PVC pipe was dropped down the probe and was embedded in the substrate as the probe was withdrawn. The capture basket was then cleaned and moved one basket width away from its original location into an unprobed area and the process repeated. This was continued until either sufficient fry were captured or until no further fry recovery was thought possible from that redd. The process of probing the area within a basket and moving the basket to an adjacent area was done up to 20 times at a given redd location and took up to 2.5 h per redd site.

Names of crew members, a redd identification code, number of basket areas sampled, numbers of eggs recovered, numbers of dead or live fry recovered, and general observations for each redd were recorded on field data sheets.

Seine Haul Method of Fry Collection

We used a 39′ long seine with lead line and 0.24″ cotton mesh to collect post-emergent chinook salmon fry in suitable mainstem habitat. In narrow side channels, we used 6.6′ to 16.4′ long stick seines with 0.24″ mesh. Current, water depth, and substrate size limited the number of suitable seining sites. Sampling location, names of crew members, length of seine haul along the bank, and numbers and species of fish captured were recorded on field data sheets.

Electroshocking Method of Fry Collection

Equipment:

Two different Smith-Root electroshockers were used for broodstock collection, one identified as Type VII and the other as Model 12.

Equipment Operation:

We found post-emergent fry typically hiding in crevices between cobbles in the very near shore areas having little or no apparent water velocity. These areas typically had shallow water (0.75″ to 3.5″) over 4-6″ diameter rocks and were located on the margins and gravel bars of the mainstem river or within small side channels. We captured stunned fry using small nets, measured their fork length, and then placed them in a bucket of river water for recovery and transport to the hatchery.

In most cases a crew consisted of three people: one person operated the shocker; one netted stunned fry; and one measured fork lengths, recorded data, and carried the bucket of captured fish. We recorded sampling location, names of the crew members, description of habitat, and numbers and fork lengths of fry captured.

CHAPTER 7 - 1993 BROODSTOCK COLLECTION

Christopher Marlowe and Sewall Young

Sampling Yield

Broodstock collection in the Dungeness River drainage during 1993 yielded 3,853 chinook salmon from the 1992 brood for the captive population at Hurd Creek Hatchery (Table 1). This total was composed of 2,588 pre-emergent fry collected from fourteen redds, 71 free-swimming fry collected with beach seines, and 1,194 free-swimming fry collected with backpack electroshockers. The captive population size and the number of known families included in the population are both below the goals of the program (Chapter 4).

Redd Sampling

1992 Chinook Salmon Redd Counts and Locations:

Spawning ground survey data collected by WDFW Stock Assessment (SA) personnel during late summer and fall of 1992 served as the basis of our redd location information. Spawning ground surveys covered the Dungeness River between the mouth (RM 0) and Gold Creek (RM 18.7) and the lower six miles of the Gray Wolf River. These areas covered the entire known spawning range of chinook salmon in the Dungeness River. WDFW Genetics Unit personnel visited Dungeness River spawning areas during fall 1992, after spawning ground surveys were completed, to place redundant redd location markers (rebar on the stream bank and painted rocks in the redd pockets) and draw detailed area maps.

WDFW Stock Assessment identified 63 probable chinook salmon redds in the Dungeness River drainage in 1992. Information developed after completion of the spawning ground surveys suggests that some chinook salmon spawning occurred after the surveys were completed and that two redds marked as chinook salmon redds contained other species' spawn. Hydraulic redd sampling at redd D 56 (Figure 1 and Table 2) yielded only chum salmon fry; the sample taken from redd GW 2 (Figure 4 and Table 2) contained sockeye salmon fry and coho salmon eggs. We found no evidence of chinook salmon spawning at either D 56 or GW 2. The Genetic Unit's redd location marking effort included one site not noted by SA that may have been deposited by a late spawning (after cessation of spawning ground surveys) chinook salmon (redd D 31, Table 2) near Dungeness Hatchery. However, hydraulic sampling on 9 March 1993 yielded no evidence of chinook salmon spawning at that site. Hydraulic sampling around redd D 40 (Table 1) yielded chinook salmon fry that seemed immature for the initial redd identification date. The final hydraulic sampling visit at that site six weeks after the initial sampling yielded fry that still had visible yolk sacs. The late development of those fry suggests that the eggs could have been spawned later than 23 September 1992, the initial identification date of redd D 40, so the Genetics Unit infers an additional redd at that site (D 41, Table 2). These observations led us

Table 1. Broodstock capture, mortality, and yield summary for the Dungeness River Chinook Salmon Restoration Project, 1992 brood year.

Capture Method / Trough	Fry Collected (live+dead) [a]	Mortalities: Intra-gravel [b]	Mortalities: Sampling [c]	Mortalities: Post-delivery [d]	Outplants [e]	Yield (@ 7/30/93) [f = a-(b+c+d+e)]	Mortality Rates: Sampling [c/(a-b)]	Mortality Rates: Post-delivery [d/f]
Redd Sampling								
12A	245	0	13	10	0	222	0.05	0.04
12B	161	17	13	8	0	123	0.09	0.06
11A	345	0	14	20	100	211	0.04	0.06
11B	281	0	4	11	60	206	0.01	0.04
10A	208	0	7	6	0	195	0.03	0.03
10B	247	0	4	10	0	233	0.02	0.04
9A	289	7	5	1	70	206	0.02	0.00
9B	225	2	8	2	0	213	0.04	0.01
8A	863	0	27	10	610	216	0.03	0.01
8B	195	0	7	8	0	180	0.04	0.04
7A	142	14	4	7	0	117	0.03	0.06
7B	140	71	0	19	0	50	0.00	0.28
6B	228	0	4	8	0	216	0.02	0.04
6C	223	10	12	1	0	200	0.06	0.00
Sub- totals	3,792	121	122	121	840	2.588	0.03	0.03
Seining								
5B*	1	NA	0	0*	0	1	0.00	0.00*
4A*	45	NA	0	0*	0	45	0.00	0.00*
5A	25	NA	0	0	0	25	0.00	0.00
Sub-totals	71	NA	0	0	0	71	0.00	0.00
Electrofishing								
7C	208	NA	23	20	0	165	0.11	0.11
6A	101	NA	1	13	0	87	0.01	0.13
5B *	330	NA	19	122*	0	189	0.06	0.64*
4A *	69	NA	0	30*	0	39	0.00	0.36*
4B	84	NA	4	16	0	64	0.05	0.20
4C	152	NA	7	33	0	112	0.05	0.23
4D	52	NA	3	18	0	31	0.06	0.37
3B	162	NA	19	4	0	139	0.12	0.03
3C	110	NA	26	20	0	64	0.24	0.24
3D	69	NA	12	3	0	54	0.17	0.05
2A	52	NA	1	7	0	44	0.02	0.14
2B	68	NA	5	4	0	59	0.07	0.06
2C	100	NA	7	6	0	87	0.07	0.06
1A	32	NA	4	1	0	27	0.13	0.04
1C	33	NA	0	0	0	33	0.00	0.00
Sub-totals	1,622	NA	131	297	0	1,194	0.08	0.20
Grand Totals	**5,485**	**121**	**253**	**418**	**840**	**3,853**	**0.05**	**0.08**

*Troughs 5A and 4B received fry caught by seine and electrofishing. Mortalities in those troughs are presented in the electrofishing section.

Table 2. Approximate locations and timing of chinook salmon redds in the Dungeness River drainage and redd sampling dates, fry yield, and initial distribution of captured pre-emergent fry within Hurd Creek Hatchery. The sequential redd numbers were assigned retrospectively from top to bottom of the Dungeness and Gray Wolf Rivers to simplify references to them.

Sequential Redd #		River Mile	Date of Initial Redd Identification	Date of Initial Redd Sampling	Rearing Trough	Number of Chinook Fry Delivered	Notes
D	1	18.5	08/26/92	02/16/93		0	
D	2	18.2	08/18/92	02/12/93		0	
D	3	18.2	08/26/92	02/12/93		0	
D	4	17.6	08/26/92	02/12/93	12B	131	Also sampled on 3/1/93
D	5	17.6	08/26/92	02/12/93	11A	331	
D	6	17.5	08/26/92	02/08/93		0	
D	7	17.5	08/26/92	02/08/93		0	
D	8	17.5	08/26/92	02/08/93		0	
D	9	17.5	08/18/92	02/08/93		0	
D	10	17.5	09/01/92	02/08/93		0	
D	11	17.4	08/26/92	02/16/93	11B	277	
D	12	17.3	08/26/92	02/24/93		0	
D	13	17.2	09/01/92				
D	14	17.2	08/26/92	03/01/93		0	
D	15	16.3	09/01/92				Date and location indefinite
D	16	16.3	09/11/92				Date and location indefinite
D	17	15.9	08/26/92	02/24/93	8A	836	
D	18	15.7	08/26/92	02/24/93	8B	188	
D	19	15.2	09/01/92	03/11/93	6C	201	Flag missing; flag date guessed
D	20	15.2					Flag missing; location approximate
D	21	14.9					Flag missing; location approximate
D	22	14.8					Flag missing; location approximate
D	23	14.8					Flag missing; location approximate
D	24	13.5					Flag missing; location approximate
D	25	13.3					Flag missing; location approximate
D	26	13.0	09/01/92	02/26/92		0	Flag missing; flag date unknown
D	27	13.0	08/27/92	02/26/93		0	
D	28	12.0					Flag missing; location approximate
D	29	12.0					Flag missing; location approximate
D	30	10.9	09/10/92	02/22/93	10B	243	
D	31	10.6		03/09/93		0	Flagged by WDF Genetics Unit 10/30/92
D	32	10.4	09/02/92	02/26/93	7B	69	Also recovered 71 intra-gravel mortalities.
D	33	10.4	09/02/92	02/08/93		0	
D	34	10.4	08/19/92	02/08/93		0	
D	35	10.4	09/02/92				Conterminous with redds 33 and 34

- continued -

Table 2. Approximate locations and timing of chinook salmon redds in the Dungeness River drainage and redd sampling dates, fry yield, and initial distribution of captured pre-emergent fry within Hurd Creek Hatchery (continued).

Sequential Redd #		River Mile	Date of Initial Redd Identification	Date of Initial Redd Sampling	Rearing Trough	Number of Chinook Fry Delivered	Notes
D	36	9.6	09/02/92	02/19/93		0	
D	37	9.6	08/19/92	02/19/93		0	
D	38	9.5	09/02/92	02/02/93	12A	232	Sample completed 2/19/93
D	39	9.0	09/16/92	02/26/93		0	
D	40	9.0	09/23/92	02/26/93		0	
D	41	9.0		02/26/93	7A	124	Redd deduced from immaturity of fry for D40's date. Also sampled on 3/11 and 4/5/93.
D	42						Redd counted by WDF Stock Assessment. Date and location are unknown.
D	43	6.2	09/16/92	02/22/93	9A	277	
D	44	5.8	09/16/92			0	Not sampled - high water
D	45	5.7					Flag missing; location approximate
D	46	4.3	09/16/92	02/22/93		0	
D	47	4.3	09/03/92	02/19/93	10A	201	
D	48	4.2	09/16/92	02/22/93	9B	215	
D	49	4.2	10/09/92	03/09/93	6B	224	
D	50	4.0	09/10/92	02/19/93		0	
D	51	3.7	09/23/92	03/01/93		0	
D	52	3.4		03/05/93		0	Flag missing; location approximate
D	53	3.3					Conterminous with redd 54
D	54	3.3	09/03/92	03/01/93		0	
D	55	3.3	10/01/92	03/05/93		0	
D	56	3.2	09/23/92	03/01/93		0	Two distinct developmental stages of chum salmon recovered. We infer 2 chum salmon redds.
D	57	3.1	09/23/92	03/01/93		0	
D	58	2.8		03/05/93		0	
D	59	2.6					Flag missing; location approximate
D	60	2.1					Flag missing; location approximate
D	61	2.1					Flag missing; location approximate
D	62	1.8	10/01/92	03/03/93		0	
D	63	1.8	10/01/92	03/03/93		0	
Gray Wolf River							
GW	1	2.6	08/25/92			0	Flag missing; electrofishing yielded Dolly Varden fry
GW	2	1.6	09/09/92	03/11/93		0	Sockeye fry and coho eggs
Grand Total						3,549	

to add two redds to the redd accounting, and to note that at least two of the redds that were presumed to be chinook salmon redds when first identified were likely made by other species. Table 2 details the locations of 65 potential redds, 63 of which the Genetics Unit has listed as chinook salmon redds. Two of these redds were not included in the 1992 escapement estimate because of the possibility that site-specific colder temperatures could have resulted in the slower development seen in redd D 41 and because the site at D 31 was not verified and no chinook salmon were extracted from it.

Because hydraulic sampling commenced more than five months after the onset of chinook salmon spawning and few sites retained the contours that allowed redd identification during the spawning season, we rarely recovered pre-emergent fry at sites lacking redd location markers placed while the redds were still visible. The redd marker flags placed by WDFW Stock Assessment during fall 1992 were missing from 16 of the 63 surveyed redds (25%) when hydraulic sampling crews attempted to locate the redds in February and March 1993. Two redds that had received redundant marking (rebar and painted stones) were missing all markers.

Redundant redd marking was associated with a slightly higher sampling success rate (8 out of 28 redds or 29%) compared to redds that had only been flagged in the traditional way (8 out of 35 or 23%). We cannot determine whether the increased success rate was due to chance or to the redundant location markers that we placed. Clearly, successful redd sampling requires precise location of fry pockets within redds and the redd marking techniques employed in 1992 were inadequate to meet the program goals.

Pre-Emergent Fry Captures:

We attempted to collect fry from 45 of the 65 redds (69%) identified in the drainage (Table 2, Figures 1, 2, 3, and 4) and delivered to Hurd Creek Hatchery 3,549 live, pre-emergent chinook salmon fry from 14 redds. We did not sample the other 20 redds either because of poor access, imprecise recording of their locations, or unsafe river conditions at the sites. All redds that yielded fry did so on our first visit to the site. We captured fewer than our 200 fry/redd goal from three redds and substantially more than our goal from five redds (Table 2).

After all broodstock collecting ceased, we released the surplus fry from the over-sampled redds in the vicinity of the redds from which they were taken which reduced those captive family sizes to 220 (Table 1). We scheduled the returns to the river after all other sampling attempts were completed to avoid recapture of those returned fry. We released the surplus fry at dusk to minimize predation on them while they re-acclimated to river conditions.

Initiation of Hydraulic Redd Sampling:

Temperature records taken in the Dungeness River near Dungeness Hatchery from 1989 to 1991 suggest that the first chinook salmon redds in the river near the hatchery accrued 1,650 temperature units by 30 January in 1990 and 1992, and 14 February in 1991.

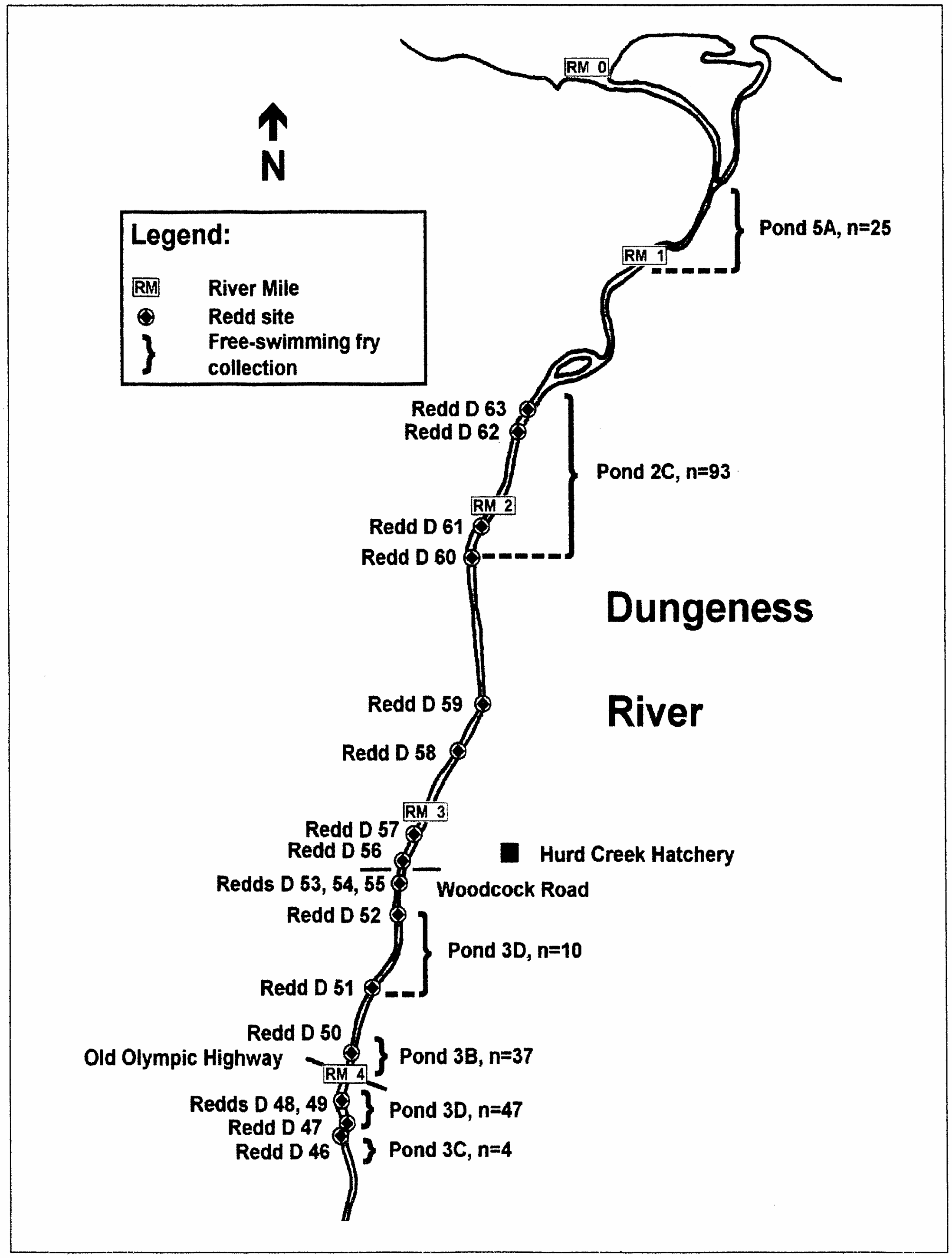

Figure 1. Chinook salmon spawning sites in 1992, and free-swimming chinook salmon fry collection areas in 1993, in the lower four miles of the Dungeness River. Pond designations refer to the indoor troughs at Hurd Creek Hatchery in which initial rearing occurred.

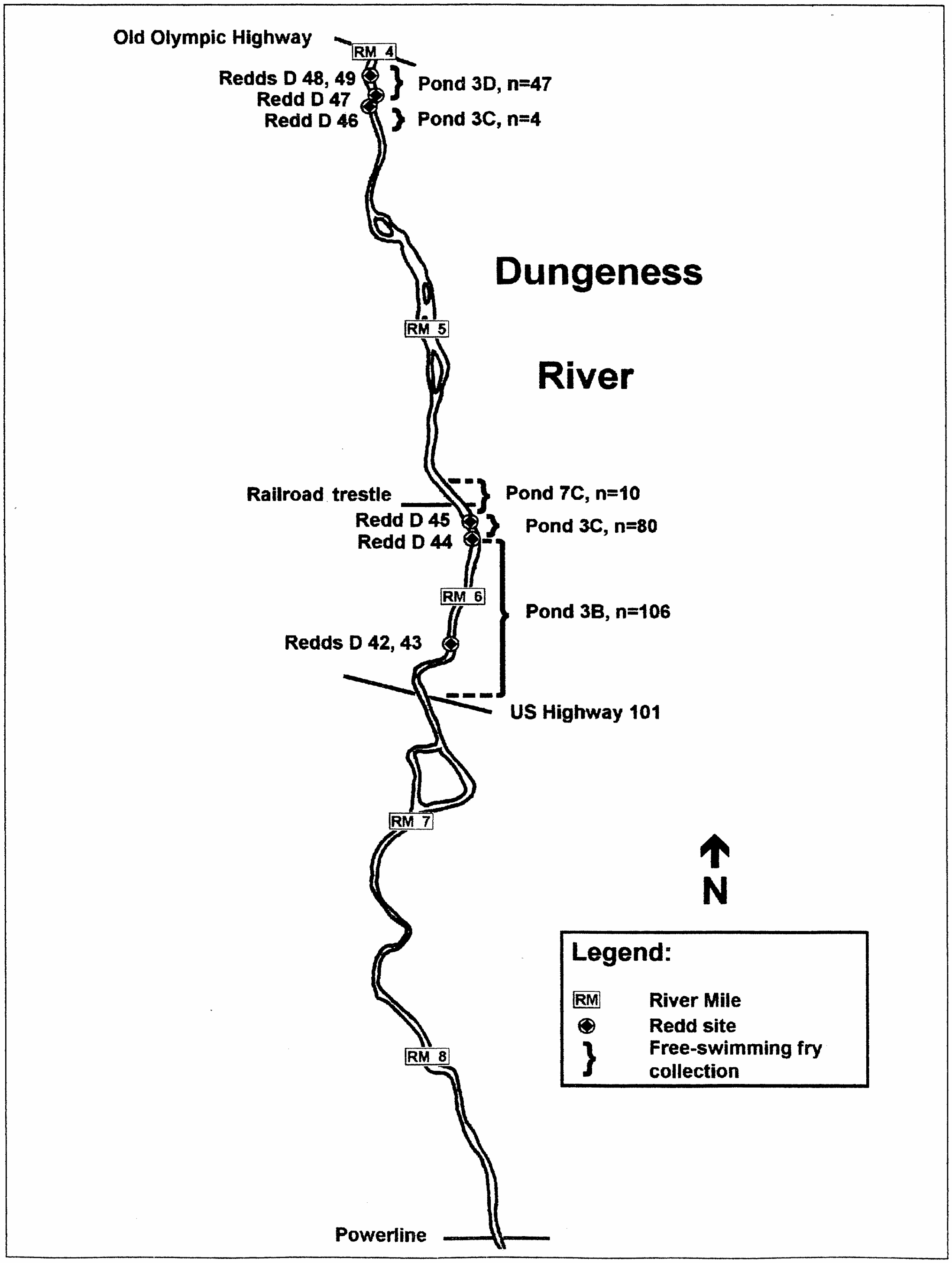

Figure 2. Chinook salmon spawning sites in 1992, and free-swimming chinook salmon fry collection areas in 1993, between river miles 4 and 9 of the Dungeness River. Pond designations refer to the indoor troughs at Hurd Creek Hatchery in which initial rearing occurred.

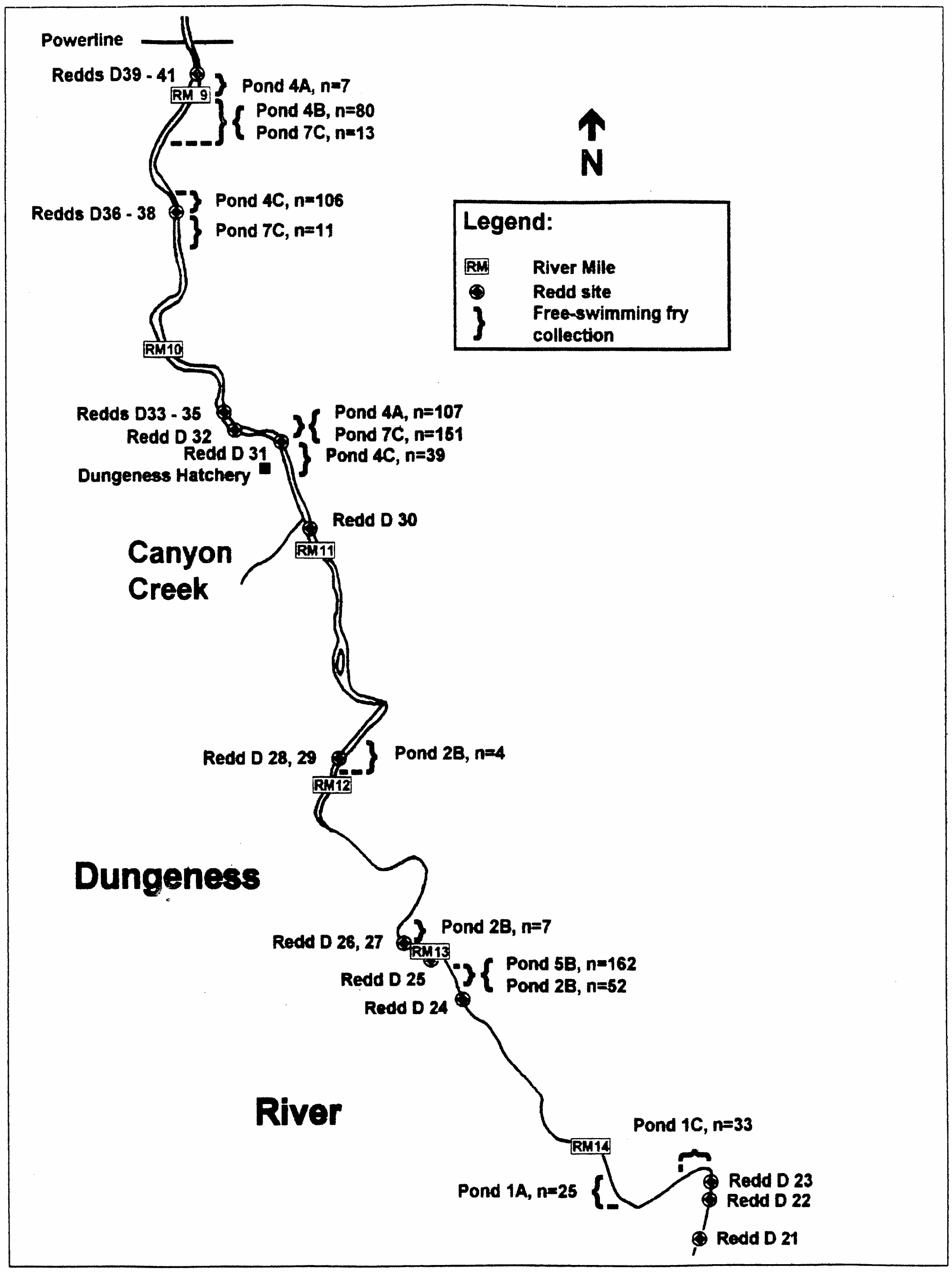

Figure 3. Chinook salmon spawning sites in 1992, and free-swimming chinook salmon fry collection areas in 1993, between river miles 9 and 14.5 of the Dungeness River. Pond designations refer to the indoor troughs at Hurd Creek Hatchery in which initial rearing occurred.

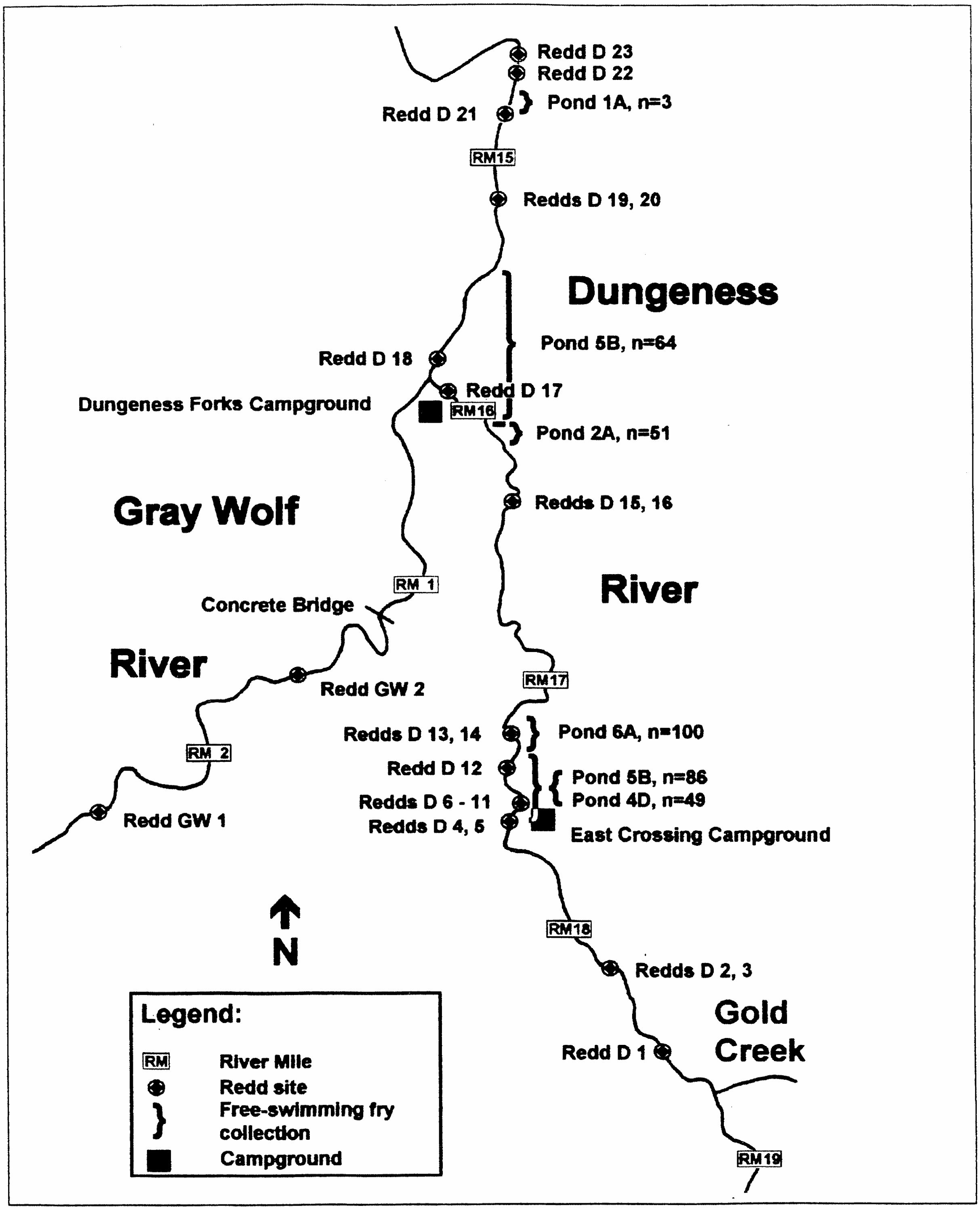

Figure 4. Chinook salmon spawning sites in 1992, and free-swimming chinook salmon fry collection areas in 1993, in the upper Dungeness River. Pond designations refer to the indoor troughs at Hurd Creek Hatchery in which initial rearing occurred.

Dungeness River temperatures in the winter of 1992-1993 were colder than usual, leading us to expect unusually late chinook salmon fry emergence. By 30 January 1993, the temperature units had reached 1,473 which was lower than the 1,580-1,650 TU accrued by that date in the previous years. Guessing that emergence could be as early as mid-February, and seeking fry two or three weeks prior to emergence, on 2 February 1993 we sampled a redd that was first identified in early September 1992 (D 38 in Table 2). Pre-emergent fry taken during that initial effort retained more yolk than we considered acceptable. We delivered those fry to Hurd Creek Hatchery for inclusion in the captive broodstock but deferred further sampling at that site for two weeks. The fry development we observed suggested, however, that fry conceived in mid-August might have developed enough to survive hydraulic sampling. On 12 February 1993 we collected fry from two redds (D 4 and D 5 in Figure 1) in the East Crossing area at about RM 17.6. Stock Assessment survey crews first identified those redds on 26 August 1992 (Table 2). Fry collected from those redds retained little yolk and they were transported to the hatchery for rearing.

Mortalities:

We divided the pre-emergent fry mortalities that we encountered during the 1993 collection of Dungeness River chinook salmon broodstock (1992 brood) into two classes: (1) sampling mortality - freshly killed fry recovered during hydraulic sampling; and (2) intra-gravel mortality - fry that appeared to have died prior to their removal from the gravel (Table 1). We judged that 121 fry (3.2% of all fry collected) were intra-gravel mortalities and 122 fry (3.3% of the fry collected after subtracting the intra-gravel mortalities) were killed during sampling. We recovered 71 of the intra-gravel mortalities from a single redd (D 32, Figure 2). Eight of the 14 chinook salmon redds from which we recovered fry had no intra-gravel mortalities in the sample.

Observations by the field crews suggest there may be unquantified mortality associated with hydraulic sampling. We sampled four redds where fry were collected on more than one occasion. We recovered dead fry, which might have been the result of previous sampling, from three of the four resampled redds. At two of those resampled redds the fry were first sampled while in the yolk-sac stage of development. These observations are similar to our experience on the Satsop River in 1992 (Chapter 6) and suggest that intra-redd mortality may result from hydraulic sampling at some developmental stages. This possibility requires further investigation.

Effects of Hydraulic Sampling on Other Species:

We recovered coho salmon eggs at four redds while probing for chinook salmon fry. We attempted to rebury those eggs but many of them washed downstream. No estimates of the losses were made. Fry that we collected from two presumed chinook salmon redds were later identified as chum and sockeye salmon fry. We returned those fry to the area from which they were taken but we have no way of assessing their survival.

It is noteworthy that pink salmon spawn in the Dungeness and Gray Wolf Rivers in odd years in many of the areas that chinook salmon commonly use. The concurrent use by chinook and pink salmon in odd years will exacerbate the problems we encountered in distinguishing chinook salmon redds from those of other species.

Hydraulic Sampling Observations and Problems:

Pre-emergent chinook salmon fry tended to be in clusters within the gravel. Fry recovery from redds five or more months after redd deposition is difficult even when redd locations are well marked. The pre-emergent fry that we collected (from 16 of 45 redds attempted, including recoveries from two non-chinook salmon redds) were almost always clustered in pockets within redds rather than evenly or randomly dispersed in the area within or around the original redd. With no redd contours to guide the sampling crews, finding those pockets was difficult. In some cases, moving the probe laterally 20″ from a non-productive insertion resulted in the capture of more than 50 fry. At all sites where we failed to recover pre-emergent fry at least 20 recovery basket areas, sampling an area of approximately 40 square feet, were probed.

Hydraulic sampling in below freezing conditions will require precautions to prevent ice formation in the sampling apparatus, the aerated excurrent stream, and in the fry transport vessels. On two occasions when the air temperature was below 32°F, the mixture of freezing air with near-freezing water caused the discharge water from the hydraulic sampler to emerge as an ice slurry. The capture net filled with a ball of granular ice which encased the fry. We consider subjecting the fry to such conditions to be unnecessarily risky. However, we were able to thaw the ice in the sunlight and did not detect damage to the fry.

Throughout the redd sampling period we were unsure of the overall progress of intra-gravel development and emergence. This uncertainty made it difficult to decide when to switch from redd sampling for pre-emergent fry to post-emergent fry collecting. Our observations of the early rearing habits of newly emerged fry suggest that concurrent use of electroshocking or seining and hydraulic redd pumping would have allowed us to monitor emergence from redds.

Personnel Requirements:

Hydraulic sampling crews were in the field on 15 days between 2 February and 5 April, 1993. We had two crews working on eight of those days. This effort represented 122 person days with a crew size of five or six people. In addition, one person inspected potential collection sites prior to sampling to assess water conditions and access problems. This accounted for 15 more sampler days.

Seine Collection of Post-Emergent Fry

1992 Trial Results:

In May 1992, we made trial sets with a 100′, small-mesh seine and with a stick seine in the Dungeness River to attempt to capture post-emergent chinook salmon fry. We were successful on that preliminary trip near Schoolhouse Bridge (RM 1-2) but were unable to find suitable sites for seining in the upper watershed on that trip. Based on that success in the lower river in 1992, we planned to augment the pre-emergent fry collections with post-emergent fry taken with seines (see Chapter 4 for a discussion of using a two-source broodstock).

1993 Capture Results:

On 29 March 1993, we seined on the same gravel bars sampled in 1992 and captured about 200 live fry. Later, Hurd Creek Hatchery personnel determined that only 25 of those were chinook salmon and the remainder were chum salmon. We released the chum salmon from Hurd Creek Hatchery. The 25 chinook salmon fry now constitute the lower river, early-period capture group (Tables 1 and 3, Trough 5A).

We also used the seine in late March at the confluence of the Dungeness and Gray Wolf Rivers (RM 15.8) where we caught a single chinook salmon fry (Table 1, Trough 5B). Seining in the adult holding pond of the Dungeness Hatchery and the hatchery intake settling pond captured 16 chinook salmon fry. Seine sets in side channels close to RM 9 captured a few additional fry. On 21 April and 10 May, beach seining at RM 1 caught chum and coho salmon fry but no chinook salmon fry. On 14 June, we seined the same area and caught three chinook salmon fry that were as large as any of those captured in the river by electroshocking (2.8″-2.9″ in length) and which had the silvery coloration characteristic of smolting fry. These three captured chinook salmon fry were released. High water flows increased the difficulty of seining. There were no known sampling mortalities among the 71 fry taken in the seine.

Seining Observations and Problems:

The greatest problem associated with seining was the lack of suitable habitat conducive to seining. Seining was inadequate for collecting early, post-emergent chinook salmon fry from the Dungeness River: seining accounted for only 71 of the live 5,111 fry (1%) collected in 1993.

Our limited observations can be interpreted to suggest that a small component of the chinook salmon population in the Dungeness River migrated downstream soon after emergence from the gravel. We captured 25 chinook salmon fry on 29 March 1993 at Dungeness RM 1. Subsequent seining efforts (21 April and 10 May) between RM 0 and RM 1 captured no chinook salmon fry until 14 June, when larger, silvering chinook salmon fry were captured at the same site. The significance of these results is unclear, but they suggest a possible early post-emergence dispersal of a portion of the chinook salmon fry. WDFW biologists using scoop traps have found chinook salmon fry in the lower Skagit River on their first night of operations in early April (S. Wolthausen, WDFW, personal communication). This suggests a component of the chinook salmon population which moves directly from emergence into the lower river and possibly into the estuary. If such a component exists in the Dungeness River watershed it would not have been represented in the electroshocking collections, but might be represented by the 25 individuals caught on 29 March 1993. This scenario would explain the late March presence of chinook salmon fry at School House Bridge, their absence on 21 April and 10 May, and their reappearance on 14 June. A definitive study of chinook salmon life history strategies in the Dungeness River would help clarify these results (see Chapter 9).

The fry captured on 14 June 1993 were not included in the broodstock collection because they appeared to be migrating and we had adopted a protocol to link captured fry to a region of the river where we assumed they were produced. The reasoning that led to their exclusion from the captive broodstock also suggests that the 25 fry caught in the area on 29 March should be excluded from the captive broodstock. These lower river captures suggest emigration from the river may begin at a threshold size of around 2.7″.

Seine Collection of Larger Fish:

Work in the Chehalis and Humptulips drainages (S. Wright, WDFW, personal communication) suggests that when chinook salmon fry attain sizes larger than 2.25″ to 2.75″ they may occupy glide areas above pools where they can be captured by larger seines. After they leave those areas they probably move toward the estuary. It was beyond the scope of this effort to determine when different life history components of chinook salmon might occupy various habitats in the Dungeness River, but the 14 June seine captures at RM 1 suggest a beginning of the emigration. Until the life history strategies of Dungeness River chinook salmon are studied thoroughly uncertainty will remain. Scale analysis from 91 samples of returning adults collected in the Dungeness River from 1987 to 1991 revealed no yearling outmigrant scale patterns (J. Sneva, WDFW, personal communication).

Electroshocking Collection of Post-Emergent Fry

Fry Capture:

We used backpack electroshockers to capture free-swimming fry on 24 days between 2 April and 14 June, 1993. Two crews were used on 2 April and one crew on all subsequent days. Crew size was usually three people. We captured 1,491 live chinook salmon fry by electroshocking and transported them to the hatchery (Figures 1, 2, 3, and 4; Tables 1 and 3).

Figures 1-4 show the regions of the river where fry were captured by electroshocking, the relation of those areas to known redd sites, the numbers of fish captured, and the dates of capture. These figures do not show river reaches sampled unsuccessfully for post-emergent fry. Table 3 summarizes the river reaches where captures occurred, the numbers of live fry delivered to the hatchery, and the initial hatchery trough to which each collection was assigned.

Except on 2 April, we recorded the fork lengths of most electroshocked fish at the time of capture since they were already stunned. No analysis or summary of these measurement data is available for this report.

Table 3. Number, source (stream segment), and destination (initial rearing trough) of free-swimming chinook salmon fry collected in the Dungeness River for captive broodstock in 1993.

Stream Segment			Initial rearing trough															
From	To		7C	6A	5A	5B	4A	4B	4C	4D	3B	3C	3D	2A	2B	2C	1A	1C
RM (Redd)	RM (Redd)	Totals	185	100	25	312	114	80	145	49	143	84	57	51	63	93	28	33
18.5 (D1)	17.5 (D6)	0																
17.5 (D6)	17.3 (D12)	101				52				49								
17.3 (D12)	17.1 (D15)	134		100		34												
16.3 (D15)	15.9 (D17)	51												51				
15.9 (D17)	15.7 (D21)	64				64												
14.9 (D21)	14.8 (D22)	3															3	
14.8 (D22)	14.7 (D24)	33																33
14.6 (D23)	13.5 (D24)	25															25	
13.5 (D24)	13.0 (D27)	221				162									59			
13.0 (D27)	12.0 (D28)	4													4			
12.0 (D28)	10.9 (D30)	0																
10.9 (D30)	10.6 (D31)	39							39									
10.6 (D31)	9.6 (D36)	258	151				107											
9.6 (D36)	9.5 (D38)	11	11															
9.5 (D38)	9.0 (D41)	206	13				7	80	106									
6.4 (D41)	6.2 (D43)	74									74							
6.2 (D43)	5.8 (D44)	32									32							
5.8 (D44)	5.7 (D45)	80										80						
5.6 (D45)	4.3 (D46)	14	10									4						
4.3 (D46)	4.1 (D47)	20											20					
4.3 (D47)	4.2 (D49)	27											27					
4.0 (D49)	3.9 (D50)	37									37							
4.0 (D50)	2.1 (D60)	10											10					
2.1 (D60)	1.8 (D63)	93														93		
1.8 (D63)	0.0 (D0)	25			25													
Grand Total		1,562																

Electroshocking Mortality:

We captured 1,622 chinook salmon fry with 131 (8.1%) sampling-related mortalities (Table 1). We cannot partition those deaths between stunning by electroshock and other handling in the field. The electroshocking occurred in shallow water (often less than 4″ in depth) and, to collect the stunned fish, we sometimes had to scoop them off the bottom or move rocks in order to reach fry that darted for cover.

Post-Delivery Mortality in Hatchery

Most collection groups were maintained separately in Hurd Creek Hatchery and their mortality in the hatchery reveals interesting trends. The seine groups (Troughs 4A, 5A, and 5B, Table 1) were combined with electroshocked groups from the same stream segment so we are unable to compare post-delivery mortalities between the seine-caught groups and the electroshocked groups.

Post-emergent fry collected in 1993 suffered a higher mortality rate shortly after capture than the pre-emergent fry. Sixty-nine percent of the live fish delivered to Hurd Creek Hatchery were collected by hydraulic redd sampling (Table 1) and were introduced into the hatchery as unfed fry. This portion of the captive population suffered 29% of the post-delivery mortality through 30 July 1993. Free-swimming fry captured by seining and electroshocking comprised 31% of the fish delivered to the hatchery but they suffered 71% of the post-delivery mortality through 30 July 1993. Almost half of the post-delivery loss in the free-swimming fry groups occurred between 17 June and 23 July, 1993, when 108 of the 1,714 fry (7.6%) died. Fifty-four of those 108 dead fry were taken before 16 April in the upper watershed. Hurd Creek Hatchery personnel noted that this post-emergent fry group was composed of a mixture of large and small fish and subsequently separated those fish into two lots according to size. After that subdivision mortalities decreased within the group. This suggests a negative interaction of small fish with larger ones perhaps due to competition for food. During the same period, the fry taken from redds by hydraulic sampling experienced 0.8% mortality. Hatchery mortality after 30 July 1993 is discussed in Chapter 8.

Pooling of Captured Fry Groups:

We observed high densities of chinook salmon fry just downstream from some redd sites and very low densities in areas with apparently suitable habitat that were just above or distant downstream from known redds. This suggests that chinook salmon fry generally emerged from the gravel and headed immediately to the channel margins adjacent to their redds where they reared in quiet water among the cobbles for several months. Where we observed low fry density above a redd and high fry density adjacent to, and just below, we treated fry captured in the area of high density as production from the nearby redd and representative of an individual family.

We do not suggest that those groups should have the same stature in the breeding protocol as the groups taken as pre-emergent fry. Rather, we assumed that recently emerged chinook salmon fry did not move substantial distances upstream and fry collected in those channel margin clusters were not produced in redds downstream of the collection site. Fry captured in the channel margin clusters therefore may be crossed with fry taken from all downstream redds with high confidence that no full sibling crosses will result. This treatment will increase our breeding options and help us achieve our genetic goals. Unexplained pockets of fish could be due to juveniles migrating away from redds in search of good rearing habitat. In areas just below multiple redds we were unable to detect substantial fluctuations in fry density between neighboring redds. We treated fry taken from such areas as an aggregate superfamily. Those groups provide the same breeding opportunities with pre-emergent fry collected downstream as the presumed single redd free-swimming fry clusters.

We used a more general protocol for pooling post-emergent fry during the early phase of our post-emergent fry collections (troughs 3B and 5B) when we anticipated organizing fry into nine groups defined by time (early, middle and late) and area (lower river, mid river, and upper river) strata. Trough 7C fits neither protocol due to accidental inclusion of lower watershed fish in a group taken mostly above Taylor Cutoff (RM 10.5, Figure 3). Fry in 12 of the 15 ponds are from discrete river reaches associated with redds or groups of redds (Table 2).

Relative Distribution of Redds and Captured Post-Emergent Fry:

After dividing the chinook salmon spawning range in the Dungeness River (RM 0 to 18.5) into quarters, 38% of the redds fell within the most upstream quarter, 22% fell within the next downstream quarter, 13% fell within the third downstream quarter, and 27% fell within the lowest quarter in 1992. The collection locales of fry remaining in the hatchery as of 24 July 1993 were distributed similarly with 36%, 26%, 17%, and 21% of the fry coming from the upper, upper middle, lower middle, and lower quarters, respectively. In general, the fry in the hatchery reflected the distribution of the known chinook salmon redds in the river.

<u>Discussion</u>

Differential Mortality Rates Between Capture Methods:

The estimated capture mortality rate of fry collected using an electroshocker was 2.5 times greater than that experienced by fry collected by hydraulic sampling, assuming hydraulic sampling causes no intra-gravel mortality. The electroshocked fry also suffered much higher mortality in the hatchery than the hydraulically-sampled fry: as of 30 July 1993, 297 of the 418 (71%) in-hatchery mortalities were electroshocked fry. A portion of the high mortality associated with electroshocking in this work may be due in part to a lack of formal training in the use of electroshocking gear among crew members.

Under-utilized Early Rearing Habitat:

Stock Assessment personnel identified two presumed chinook salmon redds in the Gray Wolf River in 1992. During two days of hydraulic sampling and three days of electroshocking in the lower two miles of the Gray Wolf River we failed to collect any chinook salmon fry, either from the redds as pre-emergent fry or from apparently suitable habitat along the channel margins below the redds. This suggested that there was no successful chinook salmon spawning in the Gray Wolf River in 1992. In the Dungeness River, there were no free-swimming fry in suitable habitat above redd D 4 (RM 17.6) at East Crossing, suggesting that redds D 1 through D 3 were unproductive. There were also substantial areas in the mainstem Dungeness River that contained suitable-looking rearing habitat but which were virtually barren of fry. This under-stocking of rearing habitat for early chinook salmon suggests that chinook salmon production in the Dungeness River is limited by something other than the availability of early rearing habitat.

Effect of Removal on Local Post-Emergent Fry Densities:

We electroshocked some areas more than once. In most of those areas, the density of fry encountered decreased substantially between samples. This suggests that electroshocking significantly decreased the abundance of fry from those areas and the areas were not re-colonized by chinook salmon fry between sampling efforts. This observation supports our supposition that fry caught in channel margins constitute rearing clusters and are not transients.

The numbers of post-emergent fry captured in the area between redds D 4 and D 15 (RM 17.1 to RM 17.5) suggest that there were more successful redds in the East Crossing area than the three from which we had collected pre-emergent fry (D 4, D 5, and D 11). In spite of substantial effort during the hydraulic redd sampling phase only these three redds yielded fry. It is interesting to note that we electroshocked that area twice and did not notice a drop in abundance between sampling times suggesting extended recruitment from some or all of the redds in the area (redds D 4 through D 15). Similarly, in the lower river no redds were successfully sampled below RM 6, yet 303 post-emergent fry were collected between there and School House Bridge. This suggested that either the redds were productive but were not successfully hydraulically sampled or that the redds in this lower portion had been non-productive and some component of fry from upstream redds moved downstream for residence.

Early Post-Emergent Chinook Rearing and Gravel Traps:

Electroshocking below Woodcock Bridge (RM 3.3) near gravel traps produced no chinook salmon fry. However, we collected fry from nearby shallow shoreline and side channel areas. Our experience strongly suggests that chinook salmon fry prefer to rear in very shallow, quiet areas with rock cover for several months after emergence. In contrast, gravel traps are very steep-sided, deep pools, inhabited by larger trout and sculpins which are potential predators on chinook salmon fry.

Recommendations

We should re-evaluate our decision not to collect eyed eggs by hydraulic sampling. We suspect that some redds from which we collected no pre-emergent fry may have been lost to scouring during winter high flows. Other redds from which we failed to collect fry were poorly marked or unmarked and the redd topography that allows identification in the fall had flattened. In both situations, sampling eyed eggs might have allowed collection from the affected redds. In future years, we should evaluate temperature data from the river near Dungeness Hatchery (RM 10.8) at bi-weekly intervals starting in November to determine when to start hydraulic sampling.

We should conduct an experiment, or experiments, to assess the effects of hydraulic sampling on fry that remain in the gravel. These experiments should include the effects of hydraulic sampling at the eyed-egg and pre-emergent stages of development. We suspect that hydraulic sampling can injure fry still in the yolk-sac stage but the effects of sampling on the fry which remain in the gravel after probing and fry removal is unknown and could well affect the decisions of when, or even if, to hydraulically sample.

Hatchery and field personnel need objective guidelines regarding grouping of post-emergent fry delivered to the hatchery. A consistent field protocol is needed to reduce confusion when delivering fry to the hatchery for final enumeration into categories such as: live, killed by collection, and dead before collection.

CHAPTER 8 - EARLY HATCHERY REARING CONDITIONS AND RESULTS

Chuck Johnson, Dan Witczak, Brian Russell, and Carol J. Smith

<u>Rearing Environment</u>

The 1992 brood was reared in older, deep, concrete troughs at the Hurd Creek Hatchery in Sequim, Washington. Each trough consisted of two sections. The smaller sections were 35″ long by 19″ wide with a water depth of 12″. The larger sections were 97″ long by 19″ wide with a water depth of 11″. Trough sections were divided by perforated aluminum screens. A cover was provided over approximately half of each trough section. It was thought that the covers would provide a safe haven for fry and lead to earlier and better feeding. Later trials without the cover showed no visible difference between covered and uncovered groups. It is noteworthy, however, that while no behavior differences were seen with or without trough covers, fish in uncovered tanks started feeding later and did not feed as well as fish in covered tanks. Fry collected in later broods were transferred directly from collection buckets to circular tanks and were not kept in the deep troughs.

The deep troughs had poor flow patterns which caused a fast accumulation of fecal matter and food particles. Cleaning (vacuuming) of troughs was performed using a suction hose which discharged into a screened bucket that was resting inside a five-gallon bucket. Pathogen-free water was supplied from the hatchery's wells at a mean temperature of 47°F which was nearly constant throughout the year.

Installation of 30 circular tanks was completed in July 1993. Each tank was 4′ wide with 22″ of water depth creating 22 cu ft of rearing capacity. The tanks were arranged in four rows and each tank was assigned a letter and number designation. The letter denoted the row; the number denoted the position of the tank within the row. "Families" that were collected from different areas in the river were reared separately in these tanks until tagging. Mortality was estimated for each tank separately and the tank designation was linked to a database specifying the geographical origin of the fish. These estimates are discussed later in this chapter. Tank water temperature varied slightly with ambient air temperature but remained in a range of 47°-50°F.

The circular tanks had excellent flow patterns and were virtually self-cleaning. Two sizes of sumps were built for each tank. Fry (≤ 1.5″) were started with the small-screened sump. This mesh excluded fry while allowing enough space for feces and feed passage. As the fry (≈ 3″) and feed size became larger, a wide slotted sump was installed for more efficient effluent discharge.

Each tank was covered with a small mesh net to prevent jumping. Half of the top was covered with black plastic which provided a less stressful environment. Feed was presented to fry without crew presence being detected resulting in very good initial feed acceptance.

Installation of four, 20′ circular tanks was completed in December 1993. These tanks were 5′ tall with a water depth of 4′ and had a capacity of 1,256 cu ft. These tanks had a dual sump system consisting of an external (out of pond) control sump, which controls the water depth, and a center tank slotted outlet sump. The sumps' action provided a self-cleaning circular flow pattern. Tank cleaning was done on an as-needed basis depending on algae growth. The 20′ tanks were covered with 1.5″ stretch, knotless webbing. One-half of the top was covered with camouflage netting to provide protective covering. It is thought that the cover reduced stress.

Four more 20′ circular tanks were installed in November 1994 to provide space for future broods as well as to maintain lower densities for the 1992 brood as growth continued. One continuous span of grip-strut walkway straddled each row of four tanks. Observation of fish from the walkway was excellent.

Fish Growth and Mortality

The 1992 brood was founded with a total of 4,271 fry: 2,709 fry from hydraulic sampling, 71 fry from seining, and 1,491 fry from electroshocking. Fry were received from the field in three or five gallon buckets. Buckets were placed in the trough and initial water temperature was equalized to within 2°F of trough temperature. Each bucket of fry was poured into a screened box where live and dead fry could be separated from the gravel and debris. During the first five fry collections mortalities were simply classified as "initial loss". On subsequent collections, we attempted to classify mortalities into two categories, "sampling loss" (mortalities that appeared to have been caused by equipment and techniques used in capture) and "intra-gravel loss" (mortalities that obviously occurred prior to capture). All losses that occurred within five days of arrival at the hatchery were classified as "sampling losses". Loss occurring after five days was classified as "delayed loss". Initial, sampling, and intra-gravel losses were summarized in Chapter 7.

Fry pumped from separate redds, or electroshocked from different river areas, were maintained in separate trough sections. Starter feed was presented to each group the day after capture. Direct observations of feeding by fry were difficult in the deep troughs due to fry wariness. However, from a distance some surface pecking was observed indicating initial food acceptance. As expected, groups that were more developed began to feed sooner after capture (some within the first 24 h). The most delayed group began feeding between seven to ten days after capture. All fry fed well at ten days post-capture.

Certain generalities regarding fry feeding behavior were noted and are summarized below.

1. Larger groups of fry exhibited positive feeding behavior earlier than smaller groups of fry.

2. Smaller groups of fry fed better when confined to shorter (smaller) trough sections.

3. Electroshocked fry did not feed as well as hydraulically-sampled fry. This might have been due to the smaller group size of the former or that fry captured after emergence have already begun feeding on natural prey.

4. Electroshocked fry groups showed a wider range of individual sizes than did hydraulically-sampled groups and they generally had a larger number of mortalities. Mortalities may have resulted from the inability of smaller fry to compete successfully for food.

5. Previous work has demonstrated that larger fish are more readily injured by electroshocking (McMichael 1993). However, one electroshocked fry group had a high number of mortalities even though there were few large individuals in the group.

On 30 July 1993, 3,853 fry were moved from indoor troughs to the outdoor 4′ circular tanks. Total mortality from delivery to this date was estimated at about 8% (Chapter 7, Table 1). In mid-December 1993, 3,694 fry were tagged. Mortality from 30 July to mid-December totaled 4%. Sixteen additional fish died during tagging. After tagging, the population was divided in half and placed into two, 20′ tanks.

Ten fish died with spinal damage during June and July, 1994. Symptoms began in June when large (300-450 g) fish began to lie on their side and swim with a partial paralysis. These fish showed no other symptoms and appeared to be free from disease. Afflicted fish were transferred into a 4′ circular tank but did not improve. Upon their death the fish were examined by a pathologist and found to have broken backs and bubbles in the gill plates. Further histology found gas bubbles in the injured spinal column.

A saturometer was used to record nitrogen levels in the tanks. Levels of nitrogen were supersaturated and ranged from 101% to 104% saturation. To decrease the nitrogen levels, pack columns with bio rings were installed to provide more exposure of the water to air. Nitrogen levels dropped to a range of 100.3%-100.5% and no additional mortalities have been linked to ruptured spines.

Beginning in August 1994, a total of 619 jacks (two-year old precocious males) were sorted out of the 1992 brood population. The percentage of jacks (16%) was less than the average percentage (24%) reported for the spring chinook salmon in the saltwater captive broodstock program for the White River (Appleby and Keown 1994). Sperm was cryogenically preserved from the jack population for future use, if necessary; 24 out of a total of 30 families are represented in these samples.

After the jacks were separated from the population, the 1992 brood was divided into four groups and placed into four, 20′ tanks. At this time, the population numbered 3,083 fish (excluding 586 jacks initially removed) for 0.3% mortality during the period from tagging (December 1993) to spawning season (August 1994). During this time period, the average size of the fish in the freshwater captive brood increased from 14 fish/pound to 2 fish/pound. In September 1994, ten fish in one tank died because of fungus. A daily treatment with one-hour baths of 125 parts per million (ppm) hydrogen peroxide was applied for ten days. Treatment was stopped after nine treatments because mortality began to occur. Mortality in that tank was 266 fish in October and 38 fish in November. During this same time period fungus was treated in a second tank. The second tank was treated with 125 ppm hydrogen peroxide for one-hour on one day. Treatment was skipped the next day because losses were occurring in the first tank. On the third day, treatment in the second tank resumed for one hour at a level of 75 ppm hydrogen peroxide. Only one fish died in the second tank.

At the end of February 1995, there were 2,703 fish remaining from the 1992 brood (not including the 619 jacks that had been removed in August 1994) (Table 1). Total mortality in the 1992 brood from delivery (spring 1993) to the end of February 1995 is estimated as 22%. Mortalities were classified into groups based upon suspected causes and are summarized in Table 2. On 1 March 1995, 92 fish were sampled for size. The average weight was 763 g and the average fork length was 14.6″.

As fry grew to about 3″ in length, deformities became visually apparent in the groups collected by electroshocking. The deformities generally consisted of reduced growth from the dorsal fin to the tail or consisted of a distinct bend along the back of the fish. The deformed fish would inevitably die. Damage from electroshocking accounted for an estimated 21% of the total mortality in the hatchery. In addition, fish size varied to a greater degree in the electroshocked groups which created a difficult feeding scheme. Up to three different sizes of feed were blended to ensure adequate feeding opportunities for all sizes of fish in the group.

Marking the Captive Broodstock

We recognized the need to preserve family identity of fry collected from specific redds and decided upon an external marking strategy for the captive broodstock. An external mark would also allow us to track mortality and select spawning crosses with ease. Requirements of the selected mark included low mortality, reliable external identification, and sufficient combinations to provide a different code for each family or collection group.

We considered a variety of marking strategies including fin clips, visual implants (VI), passive integrated transponder (PIT) tags, and laser marks. Current information indicates that laser marks do not last throughout the life of the fish (R. Olson, NWIFC, personal communication). Fin clips have the disadvantages of a limited number of combinations and potentially increased mortality. PIT tags involve the insertion of a small radio transponder into the abdomen. Each fish would have its own code and the codes could be read with a hand-held transceiver wand and sorted with software. This method would provide the ease of identification but the cost is three to five dollars per tag, not including the required equipment. Also, tag loss from mature females might be high due to the tags exiting the body cavity during egg maturation (G. Schurman, WDFW, personal communication). Visual implant marking entails the insertion of a silicone or film-like material in the adipose issue behind the eye and overcomes these disadvantages (Haw et al. 1990, Blankenship and Tipping 1993). Mortality from visual implants is similar to mortality caused by coded-wire tagging and a large number of different tag combinations are available for identification (L. Blankenship, WDFW, personal communication).

Table 1. Growth and mortality of Dungeness chinook salmon in the hatchery.

Trough	**Tank**	**Sample Date - 7/30/93** Census	**Sample Date - 7/30/93** g/fish	**Sample Date - 2/21/95** Census
12A	D1	222	7.3	136
12B	C5	123	8.1	60
11A	D2	211	8.6	139
11B	D3	206	7.9	133
10A	D4	195	11.0	131
10B	D5	233	6.5	148
9A	D6	206	10.6	130
9B	D7	213	8.5	147
8A	D8	216	11.7	149
8B	C4	180	6.7	156
7A	C8	117	7.0	85
7B	B1	50	9.2	37
7C	C6	165	3.5	128
6A	B3	87	2.6	65
6B	C1	216	6.4	142
6C	C2	200	4.8	178
5A	A7	25	9.4	16
5B	C3	190	2.8	138
4A	B4	84	5.7	59
4B	A1	64	3.1	49
4C	B2	112	3.3	83
4D	A3	31	2.0	27
3B	C7	139	5.1	90
3C	B5	64	3.9	57
3D	A4	54	5.4	33
2A	A2	44	3.0	35
2B	B7	59	2.1	47
2C	B6	87	6.9	58
1A	A6	27	3.8	22
1C	A5	33	3.1	25
TOTALS		3,853		2,703

Table 2. Suspected mortality causes during freshwater captivity of chinook salmon from the Dungeness River raised at Hurd Creek Hatchery, 1993-1994.

Suspected Cause of Mortality	**Number of Fish**	**Percent of Total Mortalities**
Toxic Reaction to a Treatment	184	20%
Fungus Due to Handling	126	14%
Pin Heads	51	5%
Tagging Loss	16	2%
Obvious Electroshock Damage	193	21%
Handling and Transfer Loss	29	3%
Unknown	320	35%
TOTALS	919	100%

There are three different types of visual implant tags: fluorescent filament, elastomer, and alpha-numeric. The types have a minimum fish size requirement of 3.5″, 2.8″, and 4.5″, respectively (R. Olson, NWIFC, personal communication). The elastomer type of tag has reduced coding combinations but coding possibilities can be increased by adipose fin clipping half of the fish and left eye, right eye color combinations. The major advantage of this type of tag is the minimum fish size requirement of only 2.8″ so that the fish can be tagged at an earlier age.

Because the alpha-numeric tag offers a greater number of coding possibilities due to the use of black or white letters and numbers on different colored backgrounds, it was the tag chosen by the Dungeness River Chinook Salmon Rebuilding Committee for the 1992 brood. The fish were also coded-wire tagged (CWT) with family-specific codes in the adipose fin and in the snout at the same time as the visual implant marking to provide a backup mark. The adipose fin was chosen as the site for the CWT so that benign removal to read the tag code would be possible. Also, this technique has a tag retention in rainbow trout (*Oncorhynchus mykiss*) of 99% (Oven and Blankenship 1993).

Some fish were too small to VI tag. Each of these fish were tagged with three CWTs: one CWT in each adipose eyelid and a CWT in the snout. The adipose fin was clipped on the fish that were not VI tagged to facilitate recognition of a different tagging protocol. All of the 1992 brood was tagged in the last week of December 1993.

Budget

A summary estimate of direct expenses incurred to-date by this project is presented in Table 3. The greatest percentage of expenses has been hatchery-related, including capital and maintenance. Other expenses are summarized to provide information regarding the cost of salmonid rebuilding programs, but these cost estimates are conservative. Much time has been devoted by technical staff members to plan and implement the program and those costs are not reflected in this budget. Travel costs to and from the Dungeness River are also not reflected in this summary.

Table 3. Summary of the costs, through 30 September 1993, of the program to rebuild the chinook salmon population native to the Dungeness River.

Project	Cost
30 Small Tanks - Materials	$9,601
Small Tank Installation	$12,514
4 Large Tanks - Materials	$43,250
4 Large Tanks - Installation	$20,000
Hatchery Costs - Overhead, Fish Food, Salaries, Etc.	$90,000/year
Netting on Tanks	$9,500
Stream Surveys	100 person days/year
Rebar Redd Marking	16 person days/year
Captive Broodstock Tagging (tagging of progeny will cost much more)	$5,000/year
Broodstock Collection - Redd Sampling	137 person days/year
Broodstock Collection - Seining/Electroshocking	74 person days/year

CHAPTER 9 - FUTURE NEEDS AND PROJECT EVALUATION

Brad Sele and Carol J. Smith

Future Needs

Ideally, a rebuilding program for a depressed salmonid stock would begin with the identification of factors limiting production. Unfortunately, the stock status of Dungeness River chinook salmon is critical, warranting immediate action to maintain the remaining genetic characteristics of the stock and reduce its risk of extinction. For this reason, a captive broodstock program was initiated to perpetuate a segment of the population in a protected environment, concurrent with the identification of limiting factors and habitat restoration.

Identification of limiting factors for Dungeness chinook salmon will require a biological needs assessment of the stock and technical studies of basic life history and habitat utilization. Some of these data needs are listed below. Where possible, these studies should be integrated with other salmon restoration efforts in the Dungeness River, such as a rebuilding program for Dungeness River pink salmon.

Life History and Habitat Studies

1. Factor(s) limiting chinook salmon production in the Dungeness River must be identified.

2. Habitat restoration activities need to be developed and implemented in the Dungeness River within the next three to eight years. These activities should be consistent with the evaluation of life history/habitat relationships and analysis of factors limiting chinook salmon production, and should include identification of potential habitat restoration project sites.

3. Some specific habitat issues that need attention include: an assessment of road and slope failures in the upper watershed; development of restoration projects to reduce the impact of road and slope failures on Dungeness River stability; assessment of scour-type flows, noting frequency and location relative to chinook salmon redds; and resolution of the discrepancy between water flow needs for fish versus allocated water removals for agricultural and urban use.

4. Biological studies are needed to determine the run size, run timing, age composition, freshwater survival, stock distribution, fishery contribution rate, and marine survival of Dungeness River chinook salmon.

In addition to the need for habitat restoration and life history studies, the Committee should continue to develop various aspects of the captive broodstock program and improve broodstock collection techniques. The Committee should also prepare long-term monitoring and evaluation plans to determine the effectiveness of the rebuilding program and improve management of this stock. Specific needs are listed below.

Work Remaining in the Captive Broodstock Program

1. The Dungeness chinook salmon stock should be genetically characterized and its genetic baseline compared to other Puget Sound chinook salmon baselines.

2. Prior to the first spawning from the captive broodstock program (assuming some genetic sampling), the issue of whether the Dungeness chinook salmon population is composed of one or two stocks should be re-addressed.

3. A genetically sound, captive-broodstock spawning protocol needs to be developed and implemented.

4. A plan for planting the progeny of the captive broodstock program into the Dungeness River needs to be developed and implemented. This would include identification of type of release (fingerling or yearling), time and location of release, and development of acclimation sites.

5. A comparative analysis of the freshwater and saltwater captive broodstock programs should be conducted to assess biological success and cost-effectiveness. This analysis should provide practical information to aid the development of future captive broodstock programs for other chinook salmon stocks.

6. A program needs to be developed and implemented to monitor and evaluate genetic changes resulting from the captive broodstock program.

7. Hatchery practices that reduce the potential for genetic change between the captive broodstock and wild fish should be developed and implemented.

8. A formal genetic risk assessment (Busack 1990) of the Dungeness chinook salmon captive broodstock project should be conducted.

Needs for Broodstock Collection Techniques

1. The broodstock collection crew should be trained in electroshocking techniques.

2. Experiments are needed to assess the effects of hydraulic sampling on fry remaining in the gravel.

3. Automated data management tools are needed to track the transfer and survival of specific families of fish from collection, through hatchery rearing, to spawning.

Long-Term Monitoring and Evaluation Program

1. Technical processes should be planned and implemented to monitor and evaluate the rebuilding program and the rebuilding program should be adjusted as necessary. This includes coded-wire tagging hatchery releases and analyzing tag recoveries, as well as stream survey coverage to monitor escapement levels and relative contribution of broodstock-origin chinook salmon to the natural spawning population and success of fish from various types of acclimation regimes.

2. The Dungeness Hatchery chinook salmon program should be evaluated to determine successes, failures, and what impacts, if any, the hatchery program has had on the indigenous chinook salmon stock. The purpose of this analysis would be to guide and direct the rebuilding program from past experiences, both good and bad.

3. Fishery impacts on Dungeness chinook salmon should be estimated and evaluated.

4. Habitat restoration projects should be evaluated in terms of effectiveness, longevity, and productivity.

An additional challenge facing the Dungeness River Wild Chinook Restoration Steering Committee is finding the monetary resources to implement the tasks identified.

Although the primary goal of the program is to rebuild the native chinook salmon stock in the Dungeness River, other valuable results will be produced from this venture. Because the captive broodstock program will consist of both freshwater and saltwater components using equivalent groups of fish from this stock, comparisons can be made to show the relative cost-effectiveness of each program. This information can be used to direct future programs towards the methodology that is more successful based upon results and cost, avoiding unnecessary mortality and expense.

In addition, hydraulic redd sampling has not been used previously for broodstock collection. If this method proves to be successful, without significant damage to fry remaining in the redds, its use can be expanded to other watersheds and species where population numbers are critically low. The key advantage of this technique is the ability to remove a small number of the fish from the river to provide a good genetic representation of the stock while leaving the remaining fry in their natural environment. This allows the perpetuation of the wild stock in its natural setting, subjected to natural selection pressures, while using the necessary artificial rearing techniques to increase the population. However, the Committee strongly suggests that the effects of hydraulic sampling on fry remaining in the redds should be experimentally examined prior to widespread use of this technique.

Another positive outcome will be the link between specific habitat conditions and redd productivity in defined areas of the river. A study that is planned for 1993 involves the installation of gravel scour indicators similar to those described by Lisle and Eads (1991) throughout the lower ten miles of the Dungeness River. The goals of the study are to define the areas of the river in which scour is likely to occur, and to provide an indication of the amount of scour that will lead to a significant loss of fry from nearby redds. This information should increase our general understanding of the effect of scour on egg-to-fry survival. As additional habitat work proceeds, the information should be useful not only for Dungeness chinook salmon but also to help direct similar needs in other basins. Ultimately, all of these efforts must be documented in order to provide the information to other restoration committees.

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