NOAA Technical Memorandum NMFS F/NWC-200

Status Review for Snake River Spring and Summer Chinook Salmon

by
Gene M. Matthews
and
Robin S. Waples

June 1991

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

STATUS REVIEW FOR SNAKE RIVER SPRING AND SUMMER CHINOOK SALMON

by

Gene M. Matthews

and

Robin S. Waples

National Marine Fisheries Service
Northwest Fisheries Center
Coastal Zone and Estuarine Studies Division
2725 Montlake Boulevard East
Seattle, WA 98112

June 1991

This document is available to the public through:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

CONTENTS

SUMMARY

To be considered for protection under the U.S. Endangered Species Act (ESA), a group of organisms must first qualify as a "species" as defined by the ESA. To be considered a "species," the group must represent an evolutionarily significant unit (ESU) of the biological species (Waples 1991). If this requirement is met, the status of the ESU is evaluated in terms of its qualifications for a listing as threatened or endangered.

The National Marine Fisheries Service (NMFS) Species Definition Paper (Waples 1991) provides a guide for evaluating the petitions for the three forms (spring-, summer-, and fall-run) of Snake River chinook salmon (*Oncorhynchus tshawytscha*). Those groups that are reproductively isolated from groups with different run-times should be considered separately under the ESA; fish of different run-times for which reproductive isolation cannot be established should be considered as a unit. In the Snake River, there is compelling evidence that fall chinook salmon are reproductively isolated from the other two forms. However, the key information necessary to understand the reproductive and evolutionary relationship between spring- and summer-run fish is lacking. Because the possibility of substantial gene flow exists between the two forms in streams where they co-occur, it is inappropriate at this time for ESA evaluations to assume the two forms represent independent evolutionary lineages. Therefore, NMFS will consider fall chinook salmon separately and spring and summer chinook salmon together in ESA evaluations.

To be considered an ESU under the ESA, a population (or group of populations) must be reproductively isolated from conspecific populations, and must contribute substantially to the ecological/genetic diversity of the species (Waples 1991). Snake River spring and summer chinook salmon as a group meet both

criteria. Although there are some indications that more than one ESU may exist within the Snake River Basin, the data presently available are not sufficient to clearly demonstrate the existence of multiple ESUs or to define their boundaries. Therefore, at present, the NMFS Northwest Region Biological Review Team concludes that the Snake River spring and summer chinook salmon are a single ESU.

There is no official NMFS policy regarding thresholds for determining threatened or endangered threshold status. Therefore, a variety of factors were used to evaluate the status of the population: historical, current, and projected abundance; trends in abundance; and the spatial and temporal distribution of fish. In addition, the stochastic extinction model of Dennis et al. (1991) was employed to gain some insight into the likely persistence of the ESU in the future if corrective actions are not taken. Collectively, the information suggests Snake River spring and summer chinook salmon are in jeopardy, but not in imminent danger of extinction throughout a significant portion of their range. However, they are likely to become endangered in the near future if corrective measures are not taken.

ACKNOWLEDGMENTS

The status review for Snake River spring and summer chinook salmon was conducted by the NMFS Northwest Region Biological Review Team (BRT). The extensive public record developed pursuant to this petition and discussions of that record by the ESA Technical Committee formed the basis for the review. Members of the BRT for spring and summer chinook salmon were: Brian Beckman, David Damkaer, Thomas Flagg, Elizabeth Garr, Orlay Johnson, Robert Jones, Conrad Mahnken, Gene Matthews, Desmond Maynard, George Milner, Gerald Monan, Ben Sandford, Michael Schiewe, George Swan, Grant Thompson, Merritt Tuttle, William Waknitz, Robin Waples, John Williams, Gary Winans, and Waldo Zaugg.

INTRODUCTION

Spring, summer, and fall chinook salmon (*Oncorhynchus tshawytscha*) are native to the Snake River, the largest tributary of the Columbia River. Historically, these fish were abundant throughout most of this large, complex drainage. From the latter 1800s until the present, a variety of factors (including overfishing, irrigation diversions, logging, mining, grazing, obstacles to migration, hydropower development, and questionable management practices and decisions) have led to the current depressed status of these populations. This situation led Oregon Trout, Oregon Natural Resources Council, Northwest Environmental Defense Center, the Idaho and Oregon Chapters of the American Fisheries Society, and American Rivers to petition the National Marine Fisheries Service (NMFS) to list all three forms of Snake River chinook salmon as threatened or endangered "species" under the Endangered Species Act (ESA). This report summarizes the review of the status of Snake River spring and summer chinook salmon conducted by the NMFS Northwest Region Biological Review Team (BRT). For reasons that will be explained below, the Snake River spring and summer chinook salmon petitions are considered together in this report.

KEY QUESTIONS IN ESA EVALUATIONS

Two key questions must be addressed in determining whether a listing under the ESA is warranted:

1) Is the entity in question a "species" as defined by the ESA?

2) If so, is the "species" threatened or endangered?

The "Species" Question

The ESA of 1973, as amended in 1978, allows listing of "distinct population segments" of vertebrates as well as named species and subspecies. However, the Act provides no guidance for determining what constitutes a distinct population, and the resulting ambiguity has led to a variety of criteria being used in listing decisions over the past decade. To clarify the issue for Pacific salmon, NMFS published an interim policy describing how the definition of "species" in the Act will be applied to anadromous salmonid species (Federal Register Docket No. 910248-1048; 13 March 1991). A more detailed description of this topic appears in the NMFS "Definition of Species" paper (Waples 1991).

The NMFS policy stipulates that a salmon population will be considered "distinct" for purposes of the Act if it represents an evolutionarily significant unit (ESU) of the biological species. To qualify as an ESU, a population (or group of populations) must be a) reproductively isolated from conspecific populations and b) represent an important component in the evolutionary legacy of the species. Types of information that can be useful in determining the degree of reproductive isolation include incidence of straying, rates of recolonization, degree of genetic differentiation, and the existence of barriers to migration. Insight into evolutionary significance can be provided by data on phenotype, protein, or DNA characters; life history characteristics; habitat differences; and the effects of stock transfers or supplementation efforts.

For the spring and summer chinook salmon ESA evaluations, it is also necessary to consider races of fish that have traditionally been differentiated on the basis of run-timing. Following the framework of the "Definition of Species" paper, it first must be determined whether spring-, summer-, and fall-run chinook salmon in the Snake River are separate, reproductively isolated groups. Those groups that are reproductively isolated from groups with other run-times should be considered separately for ESA purposes; fish of different run-times for which reproductive isolation cannot be established should be considered as a unit.

Thresholds for Threatened or Endangered Status

There is no official NMFS policy regarding thresholds for considering ESA "species" as threatened or endangered. An unofficial policy paper on this topic, drafted in 1980, is being revised. Written comments on that document and extensive discussions in ESA Technical Committee meetings stressed the importance of incorporating the concepts of Population Vulnerability Analysis (PVA) into threshold considerations. Although such a procedure exists, the concept is rapidly evolving and a definitive policy position on this issue is not expected in the near future. Furthermore, most of the PVA models developed to date require substantial amounts of life-history information that often will not be available for Pacific salmon stocks.

Accordingly, our approach was to consider a variety of information to determine threatened or endangered status. Important factors included absolute numbers of fish and their spatial and temporal distribution; current abundance in relation to historical abundance and current carrying capacity of the habitat; trends in abundance, based on indices such as dam or redd counts or on estimates of spawner-recruit ratios; natural and human-influenced factors that cause variability in survival and abundance; possible threats to genetic integrity (e.g., from strays or outplants from hatchery programs); and recent events (e.g., a drought or improvements in main-stem passage) that have predictable short-term consequences for abundance of the "species" in question. Because a more comprehensive PVA model is not now available for Pacific salmon, we used the stochastic extinction model of Dennis et al. (1991) to provide some idea of the likely distribution of outcomes (population abundance over time) for petitioned stocks. This model is useful for identifying outcomes that are most likely if no protective measures are taken because it assumes that future fluctuations in population abundance are determined by parameters of the population measured in the recent past.

Threshold determinations will focus on threats to the ESU, which are defined in terms of wild fish[1] in the "Definition of Species" paper. The focus on wild fish is consistent with the mandate of the Act to conserve threatened and endangered species in their native ecosystems.

SUMMARY OF BIOLOGICAL INFORMATION

Distribution and Abundance

Historically, spring and/or summer chinook salmon spawned in virtually all accessible and suitable habitat in the Snake River upstream from its confluence with the Columbia River (Evermann 1896; Fulton 1968). Evermann (1896) observed spring-run salmon spawning as far upstream as Rock Creek, a tributary of the Snake River just downstream from Auger Falls and more than 1,442 km from the sea.

Human activities have substantially reduced the amount of suitable spawning habitat in the Snake River (Fig. 1). Even prior to hydroelectric development, many small tributary habitats were lost or severely damaged by construction and operation of irrigation dams and diversions; inundation of spawning areas by impoundments; and siltation and pollution from sewage, farming, logging, and mining (Fulton 1968). More recently, the construction of hydroelectric and water storage dams without adequate provisions for adult and juvenile passage in the

[1]Wild fish as defined by Waples (1991) include all fish that are progeny of naturally-spawning fish.

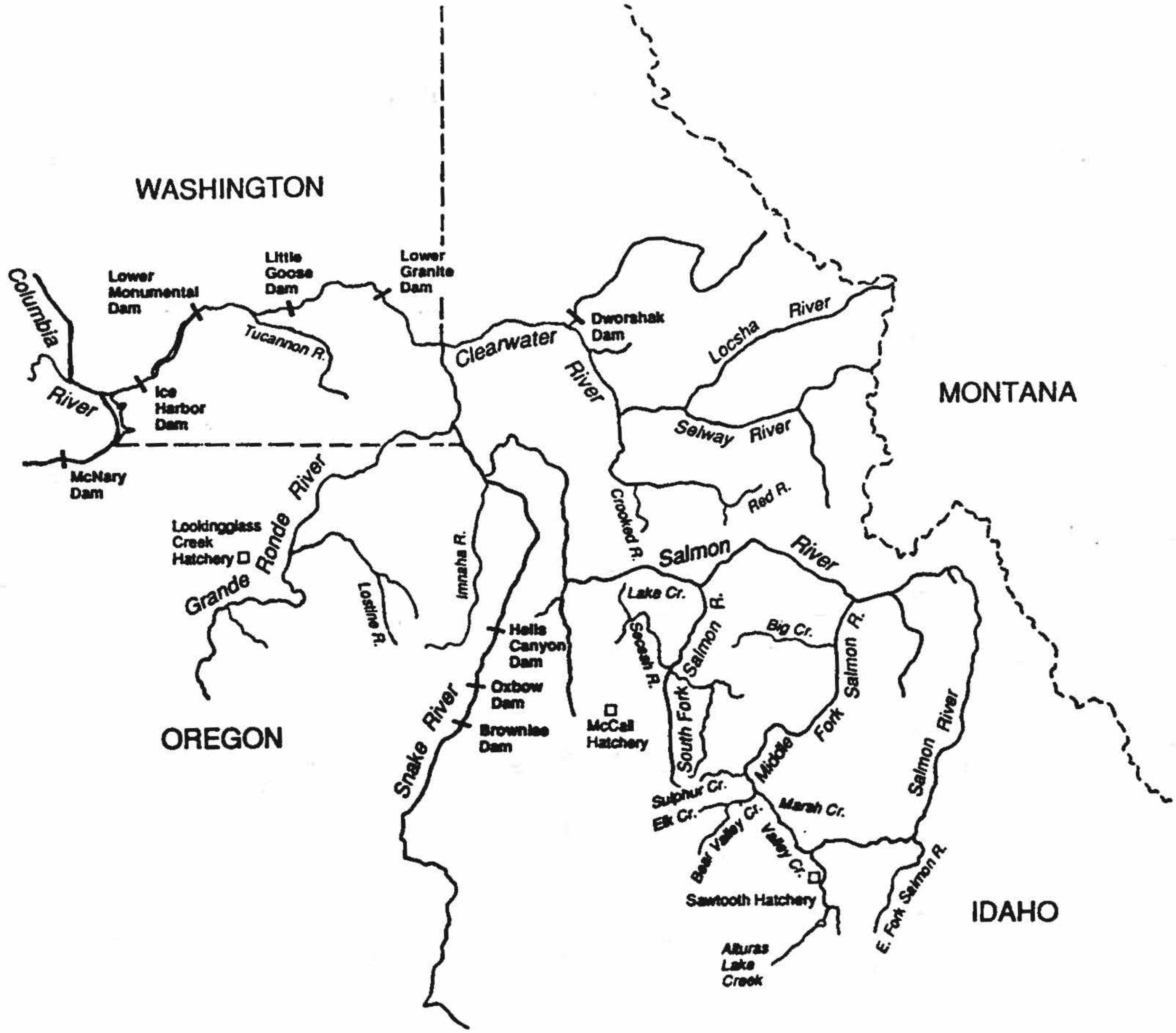

Figure 1.--Map of the Snake River drainage.

upper Snake River has precluded the use of all spawning areas upstream from Hells Canyon Dam.

The Snake River contains five principal subbasins that produce spring- and/or summer-run chinook salmon (CBFWA 1990) (Fig. 2). Three of the five subbasins (Clearwater, Grande Ronde, and Salmon Rivers) are large, complex systems composed of several smaller tributaries which are further composed of many small streams. For example, the Middle Fork of the Salmon River is a tributary of the Salmon River subbasin that is 171 km long and contains 28 streams that produce spring- and/or summer-run chinook salmon (Mallet 1974). In contrast, the two other principal subbasins (Tucannon and Imnaha Rivers) are small systems in which the majority of salmon production is in the main rivers themselves. In addition to the five major subbasins, three small streams (Asotin, Granite, and Sheep Creeks) that enter the Snake River between Lower Granite and Hells Canyon Dams provide small spawning and rearing areas (CBFWA 1990).

The historical size of the Snake River spring and summer chinook salmon population is difficult to estimate. Chapman (1986) provided estimates of chinook salmon abundance for the entire Columbia River during the late 1800s but did not attempt to partition the Snake River runs. For the years 1881 to 1895, Chapman estimated a combined return of 2.5 to 3.0 million adult fish for spring and summer chinook salmon runs in the Columbia River. Historically, it is estimated that the Salmon River alone produced 39 and 45% of the Columbia River spring and summer chinook salmon adults, respectively (CBFWA 1990). Fulton (1968) estimated that 44% of all Columbia River spring and summer chinook salmon entered the Salmon River. By combining the above estimates and considering other production areas in addition to the Salmon River, the total production of the Snake River was probably in excess of 1.5 million spring and summer chinook salmon for some years during the late 1800s.

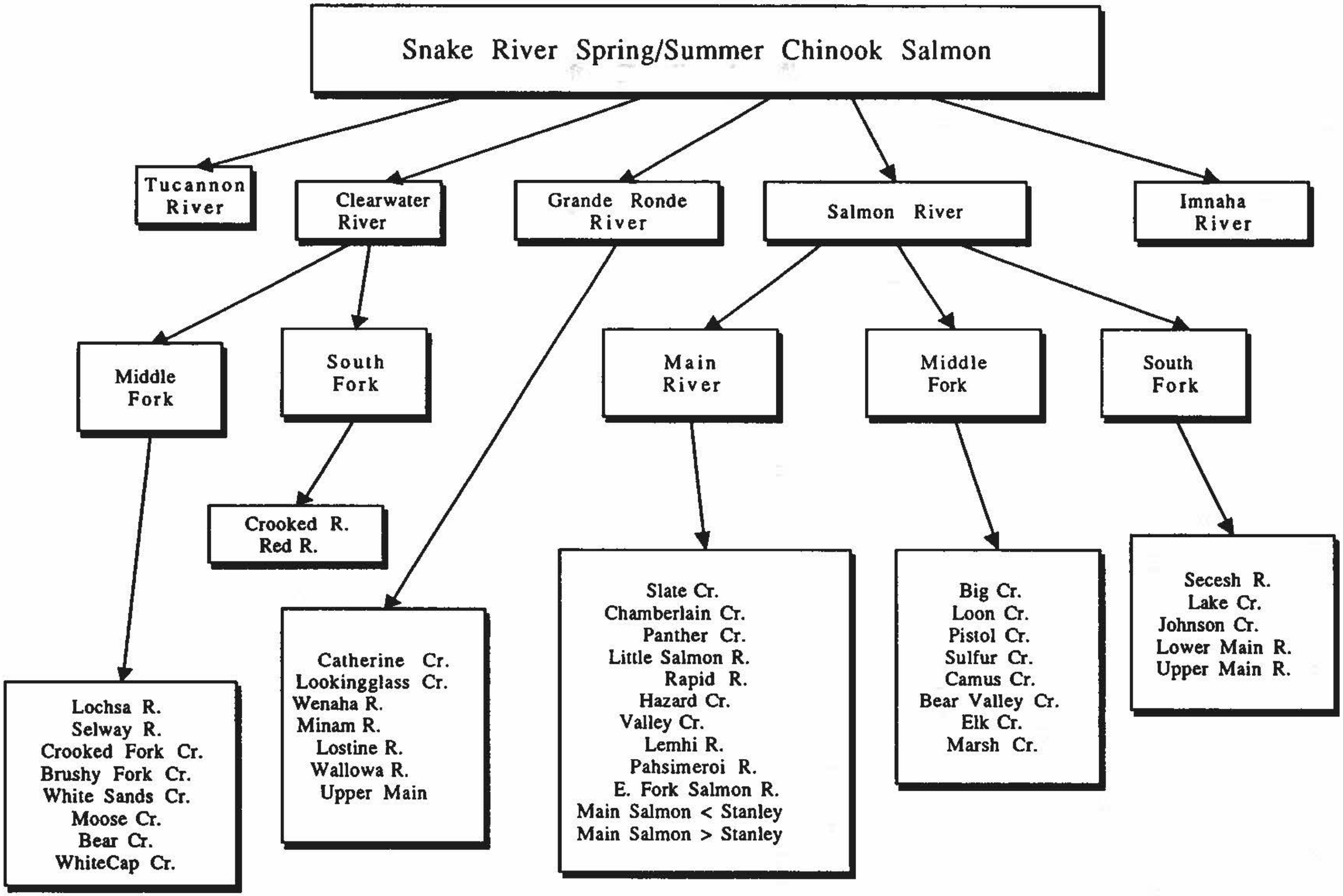

Figure 2.--Schematic of the major subbasins of the Snake River that produce spring/summer chinook salmon.

By the mid-1900s, the abundance of adult spring and summer chinook salmon had greatly declined. Fulton (1968) estimated an average of 125,000 adults per year entered Snake River tributaries from 1950 through 1960. Raymond (1988) estimated that the combined annual returns averaged 100,000 wild fish from 1964 through 1968, adjusting for fish removed by the river fisheries below McNary Dam in Zones 1-6. In another analysis, the average run of Snake River fish over McNary Dam from 1954 through 1961 and over Ice Harbor Dam from 1962 through 1969 was reported to be 90,919 fish (CBFWA 1990).

Since the 1960s, counts of spring and summer chinook salmon adults have declined considerably at Snake River dams (USACE 1989). Counts at Ice Harbor Dam declined steadily from an average of 58,798 fish in 1962 through 1970 to a low of 11,855 fish in 1979. Over the next 9 years, counts gradually increased and reached a peak of 42,184 fish in 1988. In 1989 and 1990, counts dropped sharply again to 21,244 and 26,524 fish, respectively. These counts, although illustrative of population trends for all fish, are not indicative of the abundance of wild fish in the population, because adult counts at dams have been confounded by hatchery-reared fish since 1967. Unfortunately, counts at dams cannot be reliably separated into hatchery and wild components.

The annual abundance of wild fish passing the uppermost dam on the lower Snake River since 1967 can be estimated by two methods, both of which are subject to bias. The first method is to subtract the returns to all hatcheries from the count at the dam. This method is appealing in its simplicity, but it does not account for potentially large differential mortalities after dam passage. The second method entails establishing an expansion factor based on the relationship between adult counts at the uppermost dam on the lower Snake River and redd counts in index areas prior to hatchery influence (J. Williams)[2] . The annual abundance at the uppermost dam can then be estimated after 1967 by multiplying the annual redd counts by the expansion factor. The weakness of this method is that there are only 6 years (1962-67) of dam counts when only wild fish were present to establish the relationship. Also, 5 of the 6 years represent relatively high dam and redd counts. This calls into question the accuracy of extrapolating to situations in which abundance is low. Even so, this method would likely provide the better estimate of the number of wild fish passing the uppermost dam because the dam and redd count indexes used would be temporally consistent.

The expansion factor (EF) is given by:

$$EF = \bar{x}_D / \bar{x}_R = 7.9411$$

where

$\bar{x}_D$ = 52,426 = mean Ice Harbor Dam count from 1962 to 1967

$\bar{x}_R$ = 6,601 = mean redd count from 1962 to 1967, excluding the Grande Ronde and Clearwater River subbasins for reasons described below.

Using this method, the estimated number of wild adult spring and summer chinook salmon passing over Lower Granite Dam averaged 9,674 fish from 1980 through 1990 with a low count of 3,343 fish in 1980 and a high count of 21,870 fish in 1988.

Redd counts in index areas provide the best indicator of trends and status of the population of wild spring and summer chinook salmon in the Snake River Basin; counts used in this review are detailed by subbasin in the Appendix 1 Table (White and Cochnauer 1989; CBFWA 1990; M. White[3]; K. Peterson[4]). Redd counts are

---

[2]John Williams, National Marine Fisheries Service, 2725 Montlake Blvd. East, Seattle, WA 98112. Pers. commun., March 1991.

[3]Marsha White, Idaho Department of Fish and Game, P.O. Box 25, Boise, ID 87307. Pers. commun., January 1991.

available since 1957 from all areas except the Grande Ronde River, for which enumeration began in 1964. Therefore, we provide two perspectives of the abundance of redds over time--one beginning in 1957 excluding the Grande Ronde River and the other beginning in 1964 including the Grande Ronde River. Redd counts in the Clearwater River were excluded from all analyses because the current population was derived from hatchery outplantings of nonindigenous fish (see Stock Histories section).

Trends in abundance of redds are similar for both time series (Fig. 3). Redd counts have declined sharply over the last 33 years. In 1957, over 13,000 redds were counted in index areas excluding the Grande Ronde River (Fig. 4). By 1964 and including the Grande Ronde River, the annual count in index areas was 8,542 redds. Over the next 16 years, annual counts in all areas declined steadily, reaching a minimum of 620 redds in 1980. Annual counts increased gradually over the next 8 years, reaching a peak of 3,395 redds in 1988. In 1989 and 1990, counts dropped again to 1,008 and 1,224 redds, respectively.

The abundance of wild Snake River spring and summer chinook salmon has declined more at the mouth of the Columbia River than the redd trends indicate (Chapman et al. 1991). Prior to curtailment in the mid-1970s, the in-river fisheries in the Columbia River below McNary Dam harvested 20 to 88% of these fish annually (Raymond 1988). Therefore, any analysis of population decline using redd counts provides a conservative approximation of the actual decline in abundance of adults.

In the near term, we are pessimistic concerning the expected abundance of Snake River spring and summer chinook salmon. Based upon the lowest return on

---

[4]Kris Peterson, Washington Department of Fisheries, P.O. Box 313, Dayton, WA 99382. Pers. commun., February 1991.

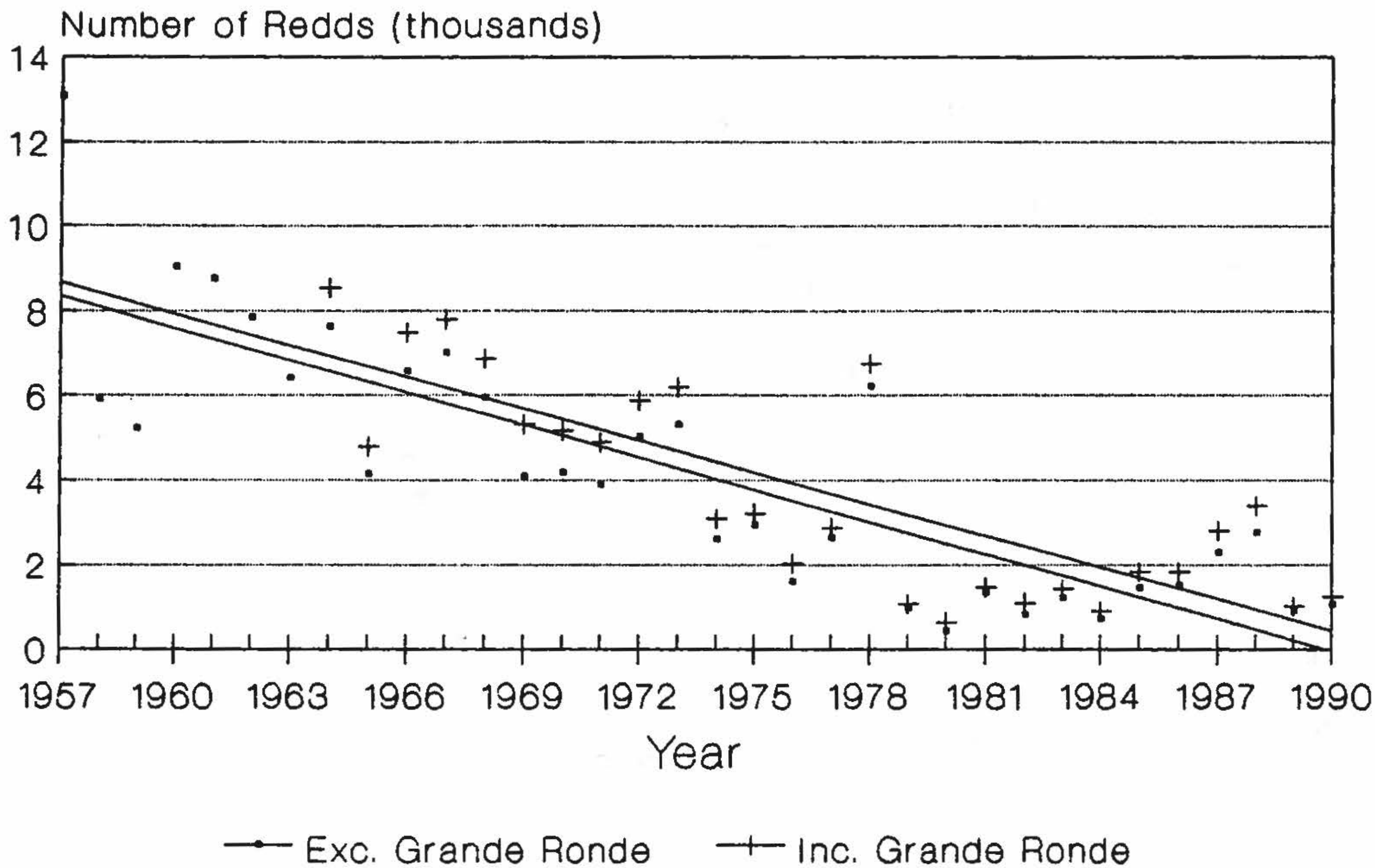

Figure 3.--Trends in abundance of spring and summer chinook salmon redds in index areas of the Snake River from 1957 through 1990.

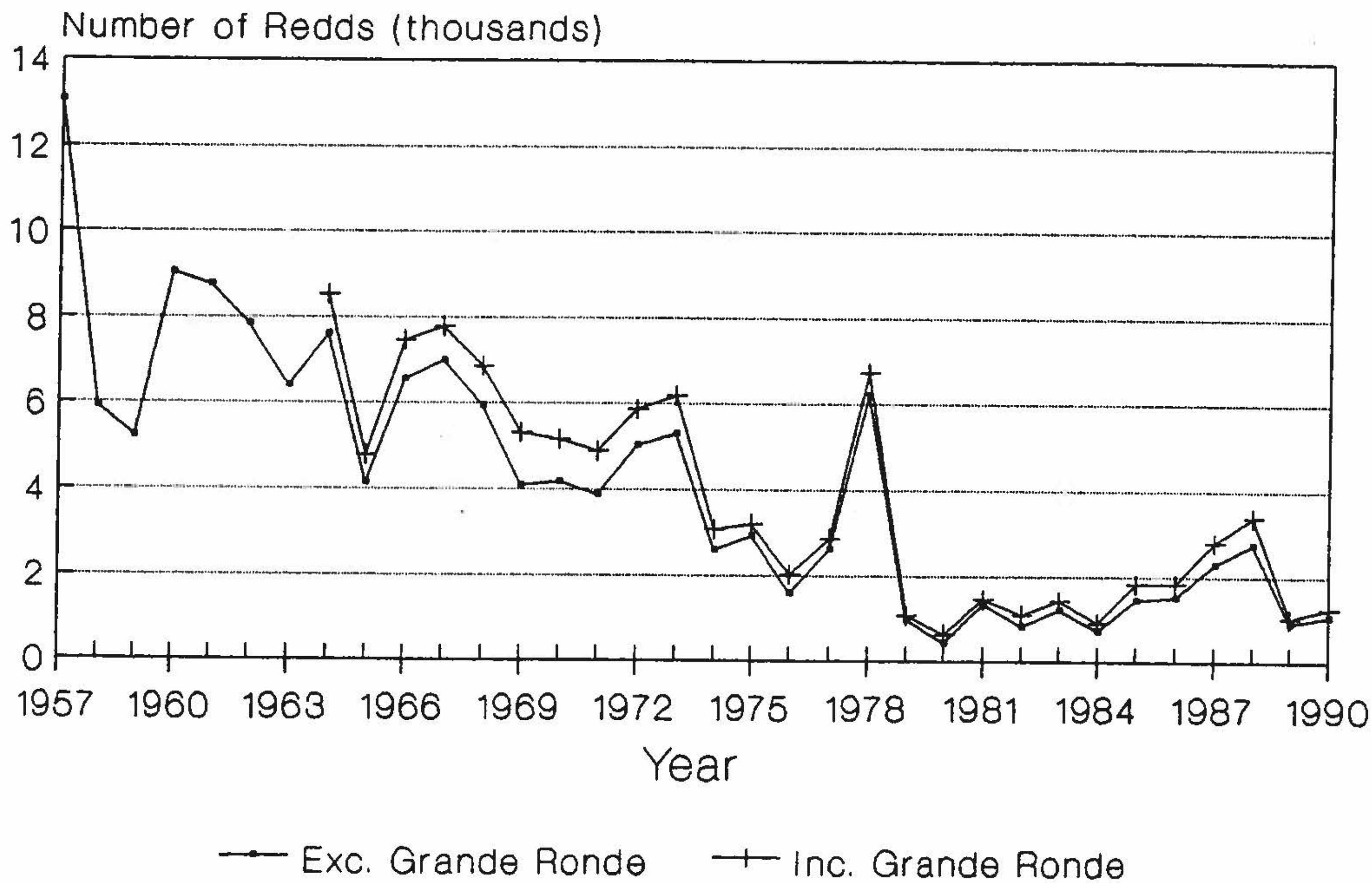

Figure 4.--Number of spring and summer chinook salmon redds in index areas of the Snake River from 1957 through 1990.

record of jack (precocious male salmon that return after 1 year of ocean residence) spring and summer chinook salmon to Lower Granite Dam in 1990 (357 compared to 2,451 in 1989), we expect adult and redd counts to drop considerably over the next 2 years. There is a strong possibility that, over the next few years, we may witness record low returns of wild spring and summer chinook salmon adults to the Snake River.

Life History Characteristics

Run-timing

Adult chinook salmon migrating upstream past Bonneville Dam from March through May, June through July, and August through October are categorized as spring-, summer-, and fall-run fish, respectively (Burner 1951). In general, the habitats utilized for spawning and early juvenile rearing are different among the three forms (Chapman et al. 1991). In both rivers, spring chinook salmon tend to use small, higher elevation streams (headwaters), and fall chinook salmon tend to use large, lower elevation streams or main-stem areas. Summer chinook salmon are more variable in their spawning habitats; in the Snake River, they inhabit small, high elevation tributaries typical of spring chinook salmon habitat, whereas in the upper[5] Columbia River they spawn in larger, lower elevation streams more characteristic of fall chinook salmon habitat. Differences are also evident in juvenile outmigration behavior. In both rivers, spring chinook salmon migrate swiftly to sea as yearling smolts, and fall chinook salmon move seaward slowly as subyearlings. Summer chinook salmon in the Snake River resemble spring-run fish in migrating as yearlings, but migrate as subyearlings in the upper Columbia River (Schreck et al. 1986).

---

[5]In this document, lower, mid-, and upper Columbia River refer to areas of the river below Bonneville Dam, between Bonneville Dam and the confluence of the Snake River, and above the confluence of the Snake River, respectively.

Gilbert (1912) first categorized the two behavioral types and referred to those juveniles that migrate seaward as subyearlings as "ocean-type" chinook and those that migrate seaward as yearlings as "stream-type" chinook. A strong tendency toward one or the other types is found within most streams, with ocean-types dominating in the southern range from California through the coastal streams of Oregon and Washington and stream-types dominating in the northern range from British Columbia (excluding Vancouver Island) through Alaska and in the Yukon River (Taylor 1989). The Columbia River is located in the middle of the range and produces chinook salmon populations with the highest diversity in juvenile migrational behavior and timing. Some tributaries or areas produce only ocean-type juveniles (main-stem areas of the Columbia and Snake Rivers), some produce only stream-type juveniles (upper tributaries of the Columbia and Snake Rivers), and some produce both types (many tributaries of the Columbia River below the confluence of the Snake River). In both the Columbia and Snake Rivers, spring- and fall-run adults produce stream-type and ocean-type juveniles, respectively; however, in the upper Columbia River, summer-run adults produce ocean-type juveniles, whereas in the Snake River, they produce stream-type juveniles.

Life history information thus clearly indicates a strong affinity between summer- and fall-run fish in the upper Columbia River, and between spring- and summer-run fish in the Snake River. Genetic data (discussed below) support the hypothesis that these affinities correspond to ancestral relationships.

The relationship between Snake River spring and summer chinook salmon is more complex. Some streams in the Snake River are considered to have only spring-run fish (e.g., those in the Grande Ronde River), some only summer-run fish (e.g., those in the Imnaha and the South Fork of the Salmon Rivers), and some both forms (e.g., many streams in the Middle Fork of the Salmon River and upper reaches of the Salmon River). These designations persist in spite of the observation that some fish returning to "spring" chinook salmon streams may not pass Bonneville Dam until early June; conversely, some fish from streams having populations recognized as "summer" chinook salmon may pass upstream in late May (at Bonneville Dam, chinook salmon are called spring-run until 1 June and summer-run until 1 August). This has led to confusing appellations such as "late spring" or "early summer" fish.

Elevation appears to be the key factor influencing run/spawn timing. In most cases, spring chinook salmon spawn earlier and at higher elevations than summer chinook salmon. This is generally true whether spring and summer runs from the same stream or different streams are compared. Where the two forms co-exist, spring-run fish spawn earlier and in the upper ends of the tributaries, whereas summer-run fish spawn later and farther downstream. Spawning fish in both groups tend to use the upstream portions of their respective spawning areas first and the downstream portions last.

An obvious connection to elevation is water temperature, with higher elevations generally characterized by lower annual temperatures. Brannon (1987) showed that spawning times for Fraser River sockeye salmon were progressively earlier as the mean temperature of the incubation period decreased. Presumably this is an adaptive behavior, because post-spawning embryo development is retarded in cooler water, requiring more incubation time.

Two hypotheses can explain the presence of both spring and summer chinook salmon in some streams. The first hypothesis is that the two forms arose from a single colonization event by one of the forms. Subsequently, a slight shift in run-timing of some individuals in the population might have allowed expansion into habitat that could not be utilized by the original colonists. The result of this expansion might be a single population, with a cline in the frequency of genes controlling run-timing associated with the cline in stream elevation and incubation temperature. Alternatively, some degree of reproductive isolation between the two forms might develop following expansion into the new area.

The second hypothesis is that spring- and summer-run fish are two independent evolutionary units, and the reason both forms are sometimes found in the same stream is that two colonization events occurred. Under this hypothesis, habitat suitable for summer-run fish is unlikely to be adequate for spring-run fish (and vice versa); therefore, such habitat can only be colonized by fish of the appropriate run-time from another area.

Both hypotheses are consistent with the idea that environmental factors are important in determining time of spawning and, therefore, time of entry into fresh water. That is, "spring" chinook salmon return early and spawn early because the streams they spawn in are colder and the eggs require longer incubation time; furthermore, adverse weather conditions may reduce the success of individuals that spawn too late in the season. In this view, "summer" fish can afford to migrate upriver and spawn later in the season because their spawning locations, being typically at somewhat lower elevation, present less exacting requirements for spawn timing and embryo development. The two hypotheses differ in their predictions regarding the evolutionary relationships between the two forms. According to the first hypothesis, spring- and summer-run fish from the same stream would be more closely related to each other than either is to fish of the same run-time from other streams, whereas the second hypothesis leads to the opposite prediction. At present, there is insufficient information to determine which of these hypotheses is true. (It is also possible that the first hypothesis is true in some cases and the second hypothesis in others.)

Other Life History Characteristics

Detailed life history data (age at spawning, sex ratios, etc.) are plentiful for hatchery populations, but limited and inconsistent for wild populations. More data are also available for some subbasins and streams than others, and different types of data are available for different streams at different times. Moreover, most of this information was gathered during the past 30 years--after man's activities may have disrupted the structure of the populations. The expression of these characteristics by populations can be influenced by short- and long-term population disturbances, stochastic processes, and various sources of sampling error (e.g., sampling only certain segments of a population). The Columbia Basin Fish and Wildlife Authority identified this type of life history data in their "critical data gaps" sections of most of their subbasin production plans (CBFWA 1990). Nevertheless, limited information for seven important life history characteristics of wild fish are available and summarized in Appendix 1 List A.

Age at spawning and associated fecundity differ between the adults returning to the Middle Fork and main Salmon Rivers and all other areas where information is available. In these two areas, 3-ocean adults (especially females) with higher fecundity predominate, whereas 2-ocean adults with lower fecundity predominate in other areas. This is in spite of the fact that spring- and summer-run chinook salmon inhabit parts of both areas. This suggests that geography or other enviromental factors are more influential in determining age at return than run-timing.

In contrast, the outmigration timing of smolts at dams strongly aligns with adult run-timing. Recent studies by NMFS have shown that, in two consecutive years, smolts from summer-run only streams (Imnaha and South Fork of the Salmon

Rivers) arrived at Lower Granite Dam much earlier than smolts from spring-run only or mixed streams (Matthews et al. 1990).

No apparent patterns or relationships were found in any of the other life history characteristics examined. Additional data of this kind will be critical to more precisely define the evolutionary relationship between Snake River spring and summer chinook salmon in the future.

Phenotypic Characteristics

Schreck et al. (1986) compared 29 phenotypic characters (meristic, body shape, size of fins, etc.) of wild and hatchery stocks of spring, summer, and fall chinook salmon in the Columbia River. There were significant differences among the stocks of chinook salmon for each of the characters. Between-year variation did not account for the differences among stocks of chinook salmon. Characteristics of geographically proximal stocks tended to be similar, regardless of time of freshwater entry. Based on phenotypic and genetic characteristics, these researchers found that spring chinook salmon stocks are more similar to stocks with different run-timing that originate on the same side of the Cascade Range than to other spring chinook salmon from the other side of the range. Spring chinook salmon from west of the Cascade Range were more similar to fall chinook salmon from the same or nearby streams; spring chinook salmon from the Salmon River had stronger affinities to summer chinook salmon from the same river than to spring chinook salmon from west of the Cascade Range. Similarly, two groups of summer chinook salmon were identified. Populations in the upper Columbia River aligned with fall chinook salmon stocks of the middle and lower Columbia River, whereas populations from the Salmon River aligned with spring chinook salmon stocks in Idaho. These affinities parallel the similarities between these groups in juvenile migration behavior and timing discussed above.

Stock Histories

Stock transfers from within or introductions from outside the Snake River were unreported prior to the mid-1900s. Since then, transfers have been extensive. Here, we briefly review the history of artificial propagation and summarize the outplantings of spring and summer chinook salmon in the Snake River.

Chapman et al. (1991) listed 24 facilities in the Snake River that have produced, held, or released various life stages of spring or summer chinook salmon since the early 1960s. Currently, major hatcheries producing spring or summer chinook salmon in the Snake River include Sawtooth, McCall, Rapid River, Pahsimeroi, Dworshak, Kooskia, Lyons Ferry, and Lookingglass. Satellite facilities for brood-stock capture, juvenile rearing or conditioning, and juvenile release are associated with most of the hatcheries. Two additional hatcheries, the Clearwater and Nez Perce Tribal Hatcheries, are planned for construction in the near future.

Stocks used in most hatcheries were derived from various exotic lineages, mixtures of exotic lineages, or mixtures of exotic and native lineages (Howell et al. 1985; CBFWA 1990; Chapman et al. 1991). However, the Tucannon River stock raised at Lyons Ferry Hatchery and the Imnaha River stock raised at Lookingglass Hatchery have had minimal exotic influence. Both stocks are released from the hatcheries back into their native streams. Stocks nonindigenous to the Snake River that were released from hatcheries or outplanted into various streams in the Snake River include Carson, South Santiam, Little White Salmon, Marion, Willamette, Klickitat, Cowlitz, and Leavenworth. Stocks that originated in the Snake River but were released into nonnative streams within the Basin include Rapid River, McCall, Sawtooth, Lookingglass, Pahsimeroi, Hayden Creek, and Imnaha.

Many millions of eggs, fry, or smolts as well as many adults have been released directly from hatcheries or placed into other streams or drainages over the last 30-40 years. These outplantings are summarized in Appendix 1 List B. A brief report for each principal subbasin follows.

The Tucannon River subbasin received only two small plantings of nonnative fish: 16,000 Klickitat stock and 10,500 Willamette stock spring chinook salmon fry, in 1962 and 1964, respectively.

The native runs of chinook salmon in the Clearwater River subbasin were nearly, if not totally, eliminated by hydropower development. In 1927, Island Power and Light Company built a dam on the river near its mouth at Lewiston, Idaho. From 1927 through 1940, inadequate adult fish passage in the dam's fish ladder virtually eliminated salmon runs into the basin (CBFWA 1990). Fulton (1968) stated the dam "prevented passage" during the 14-year period, but the area above the dam was subsequently made available to salmon by improvements to the fishway in 1940. He further stated that chinook salmon returning since then were from "re-stocking." Holmes (1961) provided a detailed record of fish passage at the dam. Spring and summer chinook salmon were observed during only 3 years prior to 1950, after which counts were conducted annually. Counts of 311 and 102 spring and/or summer chinook salmon were reported in 1928 and 1929, respectively. In 1938, only two fish were counted. When counting resumed in 1950, seven chinook salmon were observed passing the dam during the time period typical for spring- or summer-run fish. Some or all of these fish could have been from either restocking or straying (Chapman et al. 1991) (see discussion below). The dam was removed in 1973. Harpster Dam on the South Fork of the Clearwater River blocked chinook salmon runs into this tributary (CBFWA 1990). Finally, the construction of

Dworshak Dam on the North Fork of the Clearwater River in the early 1970s eliminated this tributary from use by anadromous salmonids.

The first efforts at re-stocking the Clearwater River occurred from 1947 through 1953, with annual introductions of 100,000 eyed eggs from the headwaters of the Middle Fork of the Salmon River. Since then, millions of salmon of mixed and pure exotic lineages were released into various areas of the subbasin. Even if a few native salmon survived the hydropower dams, the massive outplantings of nonindigenous stocks presumably substantially altered, if not eliminated, the original gene pool. One member of the NMFS Technical Committee suggested that a remnant, indigenous stock may exist in one tributary of the Lochsa River. Recent electrophoretic data for this stock were inconclusive (see Genetics section below).

Hatchery influence began relatively recently in the Grande Ronde River subbasin, with the first release of smolts from Lookingglass Hatchery into Lookingglass Creek in 1980. Since then, four other streams (Big Canyon and Catherine Creeks and the main and upper Grande Ronde River areas) have received various outplantings from the hatchery in addition to annual releases into Lookingglass Creek. Principal stocks used were Lookingglass, Carson, and Rapid River. All streams contained some native fish before the outplantings, as indicated by the presence of redds (CBFWA 1990). Redd counts, which did not increase dramatically in any of the streams after the releases, suggest that, in general, the outplantings did not lead to large increases in the populations inhabiting the streams.

The Salmon River sub-basin can be divided into the South Fork of the Salmon River; the Middle Fork of the Salmon River; the main river below Stanley, Idaho; and the main river above Stanley. We treat each of these areas separately.

The South Fork of the Salmon River is a native summer-run chinook salmon stream. Hatchery influence began in 1976 with the first planting of smolts from

McCall Hatchery into the main river above the adult trapping facility near Cabin Creek. Since then, hatchery fish were outplanted as smolts in this area annually and as fry or smolts in other tributaries during some recent years. The McCall Hatchery stock was originally established from adults trapped at Little Goose and Lower Granite Dams during the mid- to late 1970s. The original gene pool was likely made up of native South Fork stock, with heavy influence from other summer-run streams and, perhaps, a small infusion of spring chinook salmon genes (Chapman et al. 1991). Since 1980, only adults returning to the trapping facility were used as brood stock.

The Middle Fork of the Salmon River received a single, small outplanting of nonindigenous fish. In 1975, 22,000 spring chinook salmon fry from Rapid River Hatchery were outplanted in Capehorn Creek, a small tributary of Marsh Creek at the upper end of the Middle Fork.

The initial outplanting of nonindigenous fish in the main Salmon River system below Stanley occurred in 1966 with the first smolt release from Rapid River Hatchery into Rapid River. Rapid River stock originated from mid-Snake River stocks above Hells Canyon, including the Weiser and Powder Rivers and Eagle Creek. Since 1966, millions of fry or smolts and many adults of various lineages were outplanted into 14 tributaries or areas of the main Salmon River. Numbers and time periods of outplantings varied by stream. Many of the outplants were into streams that contained relatively healthy populations of (or at least some) native fish, as indicated by previous redd counts. Stocks outplanted include, but were not limited to, Rapid River, Sawtooth, McCall, and Pahsimeroi.

The main Salmon River above Stanley contains seven streams or areas that have received hatchery outplants since 1968. Since then, the main river itself received over 10 million spring chinook salmon outplants of either fry or smolts. As with the lower main river, many of the releases were into areas that harbored relatively healthy populations of native fish. Stocks released were primarily Rapid River and Sawtooth.

Only two small releases of nonindigenous fish have occurred in the Imnaha River subbasin. In 1966, 119 adult spring chinook salmon were transferred into the river from the adult trap at Hells Canyon Dam. In 1984, the river received 4,258 spring chinook salmon smolts from Lookingglass Hatchery.

Straying

Natural straying (fish spawning in a nonnatal stream) of anadromous salmonids appears to be minimal for most species. "Wandering" as described by Chapman et al. (1991) can occur when conditions in home streams are detrimental or inhospitable to returning adults or when adults miss their home stream and are trapped above obstacles that preclude their return.

Two recent studies examined straying rates for hatchery-reared spring or summer chinook salmon in the Columbia River drainage. Fulton and Pearson (1981) documented a straying rate of 0.5% in an extensive experiment involving 12 separate releases of spring and summer chinook salmon in the mid-Columbia River. Quinn and Fresh (1984) examined straying of four brood years (1974-77) of spring chinook salmon in the Cowlitz River. Of those recovered, only 1.4% were found outside the Cowlitz River and only 0.2% actually spawned in a nonnatal river. The other fish returned to nonnatal hatcheries, but could have been either strays or "wanderers." Furthermore, the analysis showed that straying correlated positively with age at return and negatively with the number of returning salmon. Straying may be higher in older fish and when numbers returning are few.

Chapman et al. (1991) extensively reviewed coded-wire-tag recoveries from wild spring chinook salmon streams in Washington and wild spring and summer chinook salmon streams in Idaho. Although millions of tagged hatchery fish were released from nearby hatcheries over many years, no tags were found during carcass checks on any of the wild streams[6]. Moreover, tagged fish from one hatchery rarely appeared at another hatchery, except where traps prevented possible wandering adults from leaving a hatchery once they entered. The only exceptions occurred in the Grande Ronde River during 1986 and 1987. About 60% of the releases of Lookingglass/Carson stock released into the main Grande Ronde River were recovered in wild fish areas of the Minam and Wenaha Rivers. The reasons for this apparent anomaly are unknown.

Studies of straying of wild spring/summer chinook salmon have not been conducted. However, we have no reason to believe they would be any higher (and, more likely, they would be lower) than for hatchery-reared fish.

Genetics

Protein electrophoresis has been effectively used to study population structure in anadromous Pacific salmon since the early 1970s, and allele frequency information for Snake River spring chinook salmon has been available for over a decade (Milner et al. 1981). A number of more recent studies (Schreck et al. 1986; Utter et al. 1989; Winans 1989; Waples et al. 1991) have considerably expanded the geographic coverage, and development of additional genetic markers has increased the sensitivity of the technique. Significant findings of these genetic studies can be summarized as follows:

1) On a broad scale, Columbia River populations can be grouped into three clusters (Fig. 5): a) spring- and summer-run fish from the Snake River and spring-run fish from the mid- to upper-Columbia River, b) spring chinook salmon from the Willamette River, and c) fall chinook salmon. The third cluster also includes some

---

[6]NMFS personnel recently recovered on the Secesh River one adult that was tagged as a juvenile at Rapid River Hatchery.

hatchery stocks of spring chinook salmon from the lower Columbia River and some upper Columbia River summer-run fish with life history patterns similar to fall-run fish.

2) Fall chinook salmon are distinct genetically from spring-run fish in both the Snake and upper Columbia Rivers.

3) Summer chinook salmon in the Snake River are genetically very similar to spring chinook salmon in that river. However, summer chinook salmon in the upper Columbia River are genetically very similar to fall chinook salmon in that river.

4) As a group, Snake River spring and summer chinook salmon are characterized by relatively low levels of genetic variation. Winans (1989) found that heterozygosity values in Snake River spring and summer chinook salmon were about half as large as those in lower river stocks of similar run-timing. It has been suggested (Utter et al. 1989; Winans 1989) that these relatively low levels of genetic variation may reflect past bottlenecks in population size; however, other explanations cannot be ruled out. A more recent study (Waples et al. 1991) using more gene loci suggests that the difference in level of genetic variability between Snake River and lower Columbia River stocks may not be as great as previously thought.

5) As a group, Snake River spring and summer chinook salmon also have been shown to be genetically distinct from other chinook salmon populations in North America, with two exceptions. One group is spring chinook salmon from the upper Columbia River. In recent genetic studies, this group is primarily represented by samples from hatcheries using Carson stock fish. This similarity may be due to the origin of the Carson stock, which was initiated to mitigate losses to upper Columbia River populations eradicated by construction of Grand Coulee Dam. Founding brood stock was collected at Bonneville Dam (Mullan 1987) and likely

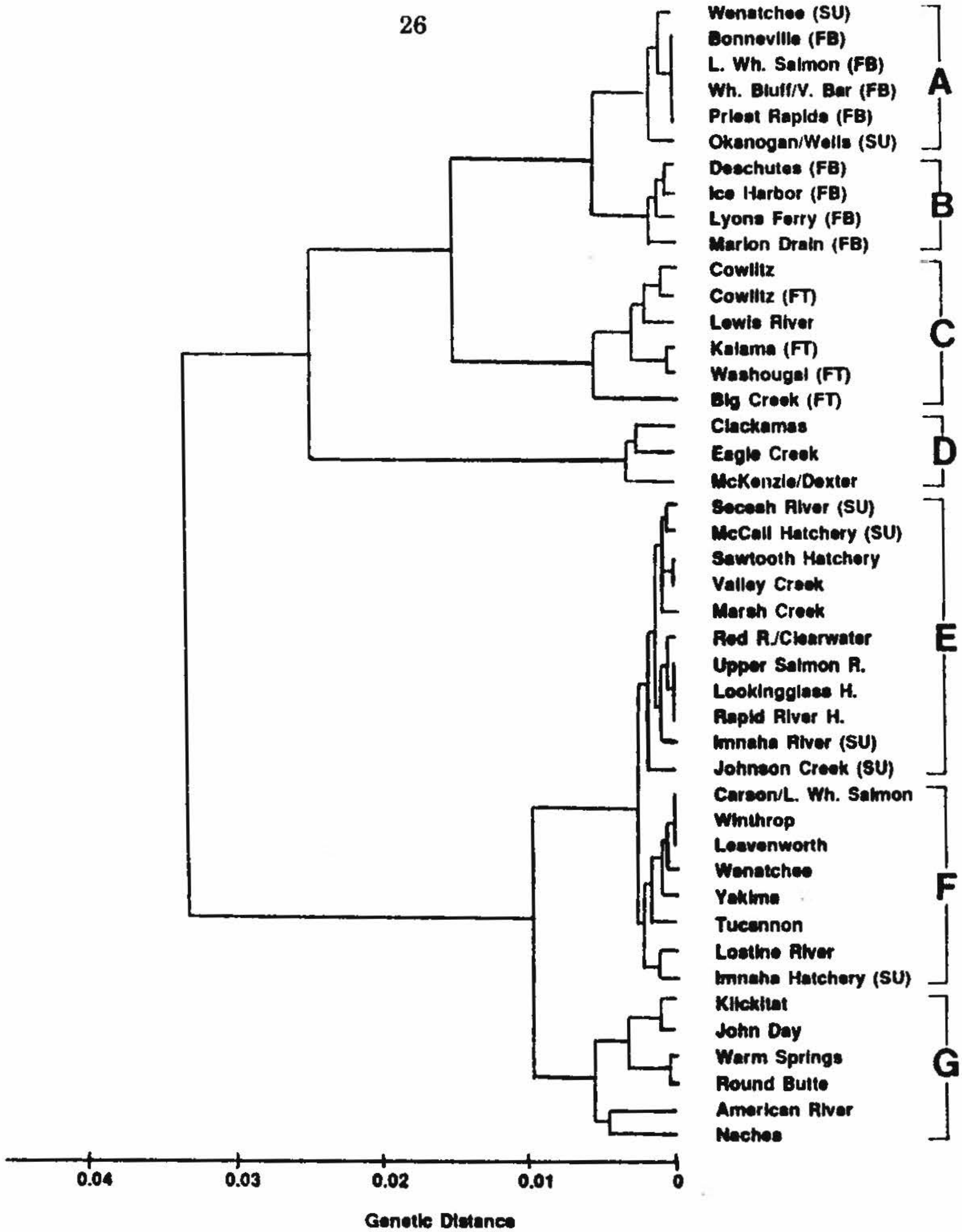

Figure 5.--Dendrogram showing clustering of pairwise genetic distance values (Nei 1978) computed for 21 polymorphic gene loci in chinook salmon from the Columbia River Basin. Modified from Waples et al. (1991), and based on published and unpublished data from the National Marine Fisheries Service and the Washington Department of Fisheries. Run-time designations in parentheses are SU for summer-run, FB for fall-run "Upriver bright," and FT for fall-run "tule;" others are spring-run stocks. In general, clusters can be characterized by geography and run-timing; A--upper Columbia summer- and fall-run; B--Snake River fall-run; C--lower Columbia River fall-run; D--Willamette River spring-run; E--Snake River spring- and summer-run; F--upper Columbia River spring-run; G--mid-Columbia River spring-run.

included some and possibly many Snake River fish. Subsequently, Carson stock has been extensively outplanted in the Columbia and Snake River Basins (Howell et al. 1985). According to Mullan (1987), the Wenatchee, Entiat, and Methow Rivers are the last remaining drainages in the upper Columbia River Basin with "wild" runs of spring chinook salmon, and over a million smolts of Carson stock hatchery fish are released annually into each of these rivers.

Utter et al. (1989) also found an unexpectedly high level of genetic similarity between Snake River spring and summer chinook salmon and samples from the Klamath River in California. The authors speculated that the apparent similarity was largely an artifact that would disappear as more genetic data became available. This has proved to be the case. Data collected more recently (NMFS and University of California at Davis, unpublished data) indicate that substantial allele frequency differences exist between the two groups at several gene loci not examined in the earlier studies.

Although early genetic studies demonstrated that fall chinook salmon in the Snake River are distinct from spring- and summer-run fish, relatively little was known until recently about relationships between the latter two forms. The study of Utter et al. (1989) included two samples each (one hatchery and one wild) of Snake River spring and summer chinook salmon. They found nonsignificant allele frequency differences between the two spring-run samples (Valley Creek and Rapid River Hatchery), as well as between the two summer-run samples (Johnson Creek and McCall Hatchery). Modest (but statistically significant) frequency differences were found between the combined spring- and combined summer-run samples. In a more recent study using substantially more gene loci, Waples et al. (1991) found highly significant allele frequency differences for every pairwise comparison of samples from 11 spring and summer chinook salmon populations in the Snake River Basin, including the four populations examined by Utter et al. (1989). This result presumably reflects the greater sensitivity in the latter analysis provided by the increased number of genetic characters examined.

The results obtained by Waples et al. (1991) demonstrate that some population subdivisions can occur at the level of individual streams. That is, the authors were able to reject the hypothesis that all samples (or any pair) were drawn from a single, random mating population. For example, in the South Fork of the Salmon River, the frequency of the variant ("83") allele at the gene locus ADA-1 was 0.154 in the Secesh River but only 0.015 in nearby Johnson Creek (Waples et al. 1991). It is highly improbable ($P < 0.001$) that both samples could have been drawn from the same population; furthermore, the two samples also differed significantly at 10 other gene loci. Thus, although the mouths of Johnson Creek and the Secesh River are close to each other in the same drainage, there is genetic evidence for restricted gene flow between the two populations.

For perspective, it should be noted that it is not inevitable, even using a large number of loci, that significant genetic differences will be found between samples. For example, allele frequency differences between spring chinook salmon from Carson, Leavenworth, and Little White Salmon Hatcheries are so minor that they can be attributed to random error in drawing the samples (NMFS and WDF, unpublished data). This result presumably reflects the frequent transfers of fish or eggs between these facilities. Nonsignificant tests comparing allele frequencies over all gene loci are also commonly found in comparisons of temporally-spaced samples from the same population. Waples et al. (1991) reported such a result for two samples from Rapid River Hatchery and two from McCall Hatchery.

In their study, Waples et al. (1991) found general agreement between groupings based on genetics and run-timing. For example, the Salmon River spring chinook salmon samples (Marsh Creek, Valley Creek, upper Salmon River, and Sawtooth Hatchery) shared a relatively high degree of genetic similarity, as did summer-run samples from the South Fork Salmon River (Johnson Creek, Secesh River, and McCall Hatchery) and the Imnaha River (a wild and a hatchery sample). However, these clusters also conform largely to geographic patterns, and in some cases substantial differences were found between fish of similar run-timing from different areas (e.g., between spring-run samples from the Salmon and Grande Ronde Rivers). Thus, it cannot be determined from available data whether geography or run-timing is more important to the genetic structure of Snake River spring and summer chinook salmon. Such a determination will require analysis of samples of spring and summer chinook salmon from streams where both forms occur.

Recent (unpublished) electrophoretic data gathered by the NMFS ongoing genetic monitoring program for Snake River chinook salmon and steelhead provide some additional insight into population structuring in the Grande Ronde Basin. This area is of interest because the Lostine River, a Grande Ronde tributary, was a relative outlier in the Waples et al. (1991) study, which was based on samples collected in 1989. Preliminary data show that a 1990 sample from the Minam River (a wild population) is genetically distinct from the 1989 samples, including the Lostine River. In contrast, a 1990 sample from Catherine Creek, another Grande Ronde tributary, is genetically more similar to samples from Carson Hatchery than it is to the Minam River or any of the other 1989 NMFS samples. This latter result presumably reflects the effects of repeated releases of fish from Carson stock and elsewhere into Catherine Creek in the last decade (see Stock Histories section).

Relatively little genetic information is available for chinook salmon from the Clearwater Basin. Waples (1990) found that Kooskia Hatchery, which has received fish from a variety of stocks, is genetically closest to samples from Carson stock spring chinook salmon hatcheries. In contrast, Red River, which has been heavily supplemented with Rapid River stock, is very similar genetically to spring chinook salmon samples from Rapid River Hatchery and the upper Salmon River. In 1989, William Miller of the U.S. Fish and Wildlife Service at Dworshak Hatchery provided NMFS with 11 adult and 19 juvenile chinook salmon taken from the White Sands Creek area of the upper Lochsa River. He suggested that genetic analysis might help resolve speculation that a remnant population of spring chinook salmon persists in the stream. Results of that analysis were inconclusive (Waples 1989). The possibility that genetic characteristics of the White Sands fish differ somewhat from those of other Snake River chinook salmon could not be ruled out, but such differences could not be convincingly demonstrated given the small number of individuals available for analysis.

DISCUSSION AND CONCLUSIONS

Differences in Run-timing

Schreck et al. (1986) and Utter et al. (1989) suggested that neither spring-, summer-, nor fall-run chinook salmon represent monophyletic lineages in the Pacific Northwest. Both reports state that, in general, geographic proximity was a more important factor than run-timing in predicting similarities between stocks. Thus, fish with different run-times from the same area were typically more similar than were fish from different areas with the same run-timing. This pattern suggests that run-time differences may have evolved independently a number of times following colonization of a new area by one form. Foote et al. (1989) concluded that a similar phenomenon--derivation of freshwater kokanee from anadromous sockeye salmon (*Oncorhynchus nerka)*--has occurred numerous times within the species *O. nerka*.

However, in spite of this general pattern, substantial differences are found between some populations having different run-times in the same geographic area. Striking examples of this are the pronounced genetic and life history differences between spring/summer and fall chinook salmon in the Snake River. Therefore, because of compelling evidence that fall chinook salmon are reproductively isolated from other chinook salmon in the Snake River, they are being considered separately in evaluating the ESA petitions for Snake River chinook salmon (see NMFS Status Review Report for Snake River Fall Chinook Salmon).

The relationship between spring- and summer-run fish in the Snake River is not so clear. The demarcation of the two forms based on time of adult passage at Bonneville Dam does separate some spring- and some summer-run populations that appear to be substantially reproductively isolated. However, this isolation may be due to geographical separation as much as to temporal differences in spawning time. Furthermore, as noted above, even in streams assumed to have only one of the forms, some fish may pass Bonneville Dam on the "wrong" side of the 1 June demarcation line. Thus, there is some overlap in migration timing of spring and summer chinook salmon in the Snake River.

The key to understanding the evolutionary significance of spring/summer run-timing is the relationship between the two forms in streams where they co-occur. As noted above, there is insufficient evidence at present to determine the nature of this relationship. Because we cannot rule out the possibility of substantial levels of gene flow between the two forms in at least some localities, it is inappropriate in ESA evaluations to treat the two forms as independent evolutionary lineages. Therefore, NMFS will consider the two forms as a unit in determining whether they are an ESU. This decision, however, does not imply that the two forms are not both important. Clearly, the presence of fish with a spectrum of run- and spawn-timing is crucial to the long-term health and viability of Snake River chinook salmon.

Distinct Population Segments

We next address the question whether Snake River spring and summer chinook salmon are represented by one or more ESUs. If they are not an ESU, then presumably they are part of a larger ESU that would have to be defined. To be considered an ESU, and hence a "species" under the ESA, a population (or group of populations) must satisfy two criteria: it must be reproductively isolated, and it must contribute substantially to the ecological/genetic diversity of the biological species.

Reproductive Isolation

The most compelling evidence in support of reproductive isolation in anadromous salmonid populations is their ability to return with high fidelity to their natal streams to reproduce. This is particularly true for upriver populations such as Snake River spring and summer chinook salmon (Chapman et al. 1991). The great distances that these fish travel to return to their natal streams tend to reduce the likelihood of straying from other major river systems outside the Snake River. All available tagging evidence supports the notion that virtually no straying of Columbia

River fish occurs into areas occupied by Snake River spring and summer chinook salmon.

Several recent studies examined the genetic relationships among chinook salmon stocks from the Columbia River Basin. The studies differed in the populations sampled and the number of gene loci used, but they were consistent in finding substantial differences between Snake River spring- and summer-run fish and a) spring chinook salmon from the lower and mid-Columbia regions and b) summer chinook salmon from the upper Columbia River Basin. These data are consistent with the premise that there is at present little, if any, genetic exchange between Snake River spring and summer chinook salmon and these other groups. Differences between the Snake River fish and spring chinook salmon in the upper Columbia River are smaller, a result that may reflect the mixed origins of the Carson Hatchery stock.

The recent Snake River data also show significant allele frequency differences between streams in the same drainage, as well as between streams from different drainages. These differences do not suggest complete isolation of individual spawning units, but they do show that levels of genetic exchange, even between nearby populations, can be small enough for some level of differentiation to occur. Again, tagging data are consistent with the concept of, at most, a low level of straying between drainages within the Snake River Basin.

Ecological/Genetic Diversity

Phenotypic, life history, and genetic data support the conclusion that Snake River chinook salmon are distinct in an ecological/genetic sense. In a cluster analysis of environmental data (stream gradient, precipitation, elevation, vegetation type, etc.), Schreck et al. (1986) demonstrated two distinct groups of Snake River localities, with one group including those from the Imnaha and Grande Ronde Rivers and the other including those from the Salmon River. Both groups were quite distinct from other localities in the Columbia River Basin. Phenotypic data also indicate that the populations are structured geographically. The fact that juvenile migration behavior is the same for spring and summer chinook salmon in the Snake River, but different for these two forms in the upper Columbia River, strongly implies ecological/genetic differences between the regions. The precision required to migrate great distances from different natal streams and tributaries and return with high fidelity and exact timing to start the next generation 1 to 3 years later speaks of biological entities that are highly adapted to their particular environments. The differences detected by protein electrophoresis between Snake River spring/summer chinook salmon and chinook salmon in the lower and mid-Columbia River Basin may be an indication of adaptive genetic differences at parts of the genome not sampled by protein electrophoresis. By comparison, the genetic differences found between different spring and summer chinook salmon populations within the Snake River are rather modest.

The habitat occupied by spring/summer chinook salmon in the Snake River appears to be unique to the biological species. In contrast to coastal mountains and the Cascade Range, the Snake River drainage is typified by older, eroded mountains with high plateaus containing many small streams meandering through long meadows. Much of the area is composed of batholithic granite that is prone to erosion, creating relatively turbid water with higher alkalinity and pH in comparison to the Columbia River (Sylvester 1959). The region is arid with warm summers, resulting in higher annual temperatures than in many other salmon production areas in the Pacific Northwest. These characteristics combine to produce a highly productive habitat for these fish. As previously mentioned, the Salmon River alone once produced nearly half of the spring and summer chinook salmon returning to the Columbia River.

Chapman et al. (1991) described 10 geologic provinces in the Snake River Basin. Each is unique to some degree in the type of habitat it provides for anadromous salmonids in terms of both geology and climate. Together, these areas form an aquatic ecosystem for chinook salmon that is unique in the Columbia River Basin and, probably, the world. It seems likely that the anadromous salmonid populations that inhabit this ecosystem are unique also.

Species Determination

Snake River spring and summer chinook salmon as a group meet both criteria to be considered a "species" under the ESA; they are strongly isolated reproductively from other conspecific population units, and they contribute substantially to the ecological/genetic diversity of the biological species. There are indications that more than one ESU may exist within the Snake River Basin. However, we do not feel that available data are sufficient to clearly demonstrate the existence of multiple ESUs or to define their boundaries. At present, therefore, we conclude that the Snake River spring and summer chinook salmon should be a single ESU of the biological species *O. tshawytscha.*

This conclusion is consistent with the NMFS policy, which states that ESUs in general should correspond to more comprehensive units in the absence of clear evidence for evolutionarily important differences between smaller population segments (Waples 1991). Nevertheless, we acknowledge the geographical and ecological complexity of an area as extensive as that occupied by Snake River spring/summer chinook salmon. In recognition of evidence for important differences between some population segments within the Snake River Basin, we emphasize that the viability of the proposed ESU is strongly dependent on the continued existence of healthy populations throughout its area. This latter provision is also consistent with published agency policy.

In determining the nature and extent of the ESU for Snake River spring and summer chinook salmon, it is also necessary to consider the effects of artificial propagation and stock transfers. In general, introduced salmon populations will not be considered for protection under the ESA (Waples 1991, Section IIIG), and changes caused by artificial propagation or hybridization may also erode qualities by which a population is recognized as distinct (Waples 1991, Section IIIC).

As discussed above and documented in more detail in the Appendix, there is a long history of human efforts to enhance production of chinook salmon in the Snake River Basin through supplementation and stock transfers. Less well understood is the extent to which these efforts have altered the genetic makeup of indigenous populations. In a recent review of studies assessing the success of efforts to supplement salmonid populations, Hindar et al. (in press) found evidence in some cases that hatchery-reared fish had interbred with native fish, but they also found cases in which repeated supplementation has had no detectable genetic effect on the indigenous population.

Considering Snake River spring and summer chinook salmon in this light, there are a number of streams in most basins without any recorded history of outplanting, and others (e.g., the Tucannon and Imnaha Rivers and Capehorn Creek in the Middle Fork of the Salmon River) that have been planted with only a minimal number of nonindigenous fish. Presumably, genetic characteristics of fish in these areas have been essentially unchanged by artificial propagation.

Conversely, some streams (e.g., Catherine Creek in the Grande Ronde River drainage) have been planted with large numbers of nonindigenous hatchery fish. In many cases the hatchery stocks themselves were from mixed origins. The genetic makeup of fish in these streams may have been substantially altered by the plantings. However, more research will be necessary to conclusively demonstrate the effects of the plantings.

One area for which the evidence of stock transfers and hybridization is overwhelming is the Clearwater River. Indigenous chinook salmon populations were virtually or totally eliminated by Lewiston Dam (1927-40). Subsequent efforts to restore the runs included transfer of eggs from the Salmon River and massive outplants of juveniles from hatcheries throughout the Columbia River Basin. Descendants of these fish of mixed, nonnative origin are not considered part of the ESU for Snake River spring and summer chinook salmon. However, the habitat should be considered as part of the range of the ESU because some wild fish may persist, and the habitat contained spring and summer chinook salmon that were historically a part of the ESU as currently defined.

Status of the Evolutionarily Significant Unit

We have concluded that, at this time, Snake River spring/summer chinook salmon are a single ESU for purposes of the ESA. As more data become available, smaller units may be defined. The next step, then, is to determine the level of risk faced by the ESU. As noted previously, factors relevant to this determination include historical and current abundance, population trends, the distribution of fish in space and time, and other information indicative of the health of the population.

During this century, man's activities have resulted in a severe and continued decline of the once robust runs of Snake River spring and summer chinook salmon. Nearly 95% of the total reduction in estimated abundance occurred prior to the mid-1900s. Over the last 30-40 years, the remaining population was further reduced nearly tenfold to about 0.5% of the estimated historical abundance. Over the last 26 years, redd counts in all index areas combined (excluding the Clearwater River) have also shown a steady decline. This is in spite of the fact that all in-river fisheries have been severely limited since the mid-1970s (Chapman et al. 1991). The 1990 redd count represented only 14.3% of the 1964 count.

To obtain insight into the likely persistence times of the ESU given present conditions, we applied the stochastic extinction model of Dennis et al. (1991) to a 33-year record of redds counted in index areas. The 33-year period is the longest possible, as redd counting in the Snake River began in 1957. We examined both sets of redd counts described previously: a 33-year series excluding the Grande Ronde River and a 26-year series that began with the first count of redds in the Grand Ronde River in 1964. We feel it is prudent to include the Grande Ronde River in at least part of the analysis because it has contributed between 10 and 20% of the total number of redds in the Snake River since 1964. Five-year running sums of redd counts (hereafter referred to as the "index value") were used to approximate the number of redds in single generations. These index values were the input data for the Dennis model; output was the probability that the index value would fall below a threshold value in a given time. An "endangered" threshold was defined as the index value at which the probability of reaching extinction (index value ≤ 1) within the next 100 years is 5%; a "threatened" threshold was defined as the index value at which the probability of reaching the "endangered" threshold within the next 10 years is 50%.

Results of the analyses are shown in Table 1. For the 33-year time series (excluding the Grande Ronde River), the current index value of 8,456 redds is well below the threatened index value of 15,474 redds and only slightly above the endangered index value of 7,065 redds. According to the model, the probability of extinction in 100 years is 0.032, and the probability of reaching the endangered threshold in 10 years is 0.943. For the 26-year time series (including the Grande Ronde River), the current index value of 10,258 redds is somewhat above the threatened index value of 7,730 redds. According to the model, the probability of extinction in 100 years is <0.001, and the probability of reaching the endangered threshold in 10 years is 0.270. The different results are primarily attributable to the fact that the initial index value was higher and the current index value lower in the former analysis. As previously discussed, the use of redd counts means that results of the model provide a conservative perspective of the rate of decline in abundance of adult salmon; hence, the model predictions are also conservative.

The results from the Dennis model should be regarded as rough approximations, given that the model's simplicity undoubtedly fails to consider all of the factors that can affect population viability. In particular, the model does not consider compensatory or depensatory effects that may be important at small population sizes. Nevertheless, considered together, results of the two analyses suggest that the ESU is at risk of extinction.

Table 1.--Extinction statistics for Snake River spring/summer chinook salmon based on redd counts in index areas excluding the Grande Ronde River from 1957 to 1990 and including the Grande Ronde River from 1964 to 1990. Results are based on the model of Dennis et al. (1991).

	1957 to 1990	1964 to 1990
Mean	-0.06199	-0.05486
Variance	0.02649	0.02765
N_q	8,456	10,258
N_e	7,065	3,720
N_t	15,474	7,730
P_1 (100)	0.032	<0.001
P_e (10)	0.943	0.270

Mean = infinitesimal mean.
Variance = infinitesimal variance.
N_q = current index value.
N_e = "endangered" threshold (the index value at which the probability of of reaching extinction within the next 100 years is 5%).
N_t = "threatened" threshold (the index value at which the probability of reaching the "endangered" threshold within the next 10 years is 50%).
P_1 (100) = probability of reaching N = 1 within the next 100 years.
P_e (10) = probability of reaching N = N_e within the next 10 years.

Other factors besides total abundance are also relevant to a threshold determination. Although the most recent data suggest that several thousand wild spring and summer chinook salmon currently return to the Snake River each year, these fish are thinly spread over a large and complex river system. In many local areas, the number of spawners in some recent years has been low. For example, in the small index area of upper Valley Creek, redd counts averaged 215 (range 83 to 350) from 1960 through 1970 (White and Cochnauer 1989). However, from 1980 through 1990, redd counts averaged only 10 (range 1 to 31) (M. White)[7]. Similarly, in the large index area of the entire Middle Fork of the Salmon River, redd counts averaged 1,603 (range 1,026 to 2,180) from 1960 through 1970 but only 283 (range 38 to 972) from 1980 through 1990. If significant population subdivision occurs within the Snake River Basin (as evidence discussed above suggests may be the case), the size of some local populations may have declined to levels at which risks associated with inbreeding or other random factors become important considerations. As numbers decline, fish returning to spawn may also have difficulty finding mates if they are widely distributed in space and time of spawning.

Short-term projections for spring and summer chinook salmon in the Snake River are not optimistic. The recent series of drought years undoubtedly impacted the number of outmigrating juveniles that will produce returning adults in the next few years. The very low number of jacks returning over Lower Granite Dam in 1990 provides additional reason for concern for the ESU.

Collectively, these data indicate that spring and summer chinook salmon in the Snake River are in jeopardy: Present abundance is a small fraction of historical abundance, the Dennis model provides evidence that the ESU is at risk, threats to

---

[7]Marsha White, Idaho Department of Fish and Game, P.O. Box 25, Boise, ID 87307. Pers. commun., January 1991.

individual subpopulations may be greater still, and the short-term projections indicate a continuation of the downward trend in abundance. We do not feel the evidence suggests that the ESU is in imminent danger of extinction throughout a significant portion of its range; however, we do feel it is likely to become endangered in the near future if corrective measures are not taken.

CITATIONS

Aebersold, P. B., G. A. Winans, D. J. Teel, G. B. Milner, and F. M. Utter. 1987. Manual for starch gel electrophoreses: A method for the detection of genetic variation. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 61, 19 p.

Brannon, E. L. 1987. Mechanisms stabilizing salmonid fry emergence timing, p. 120-124. *In* H. D. Smith, L. Margolis, and C. C. Wood (editors), Sockeye salmon, *Oncorhynchus nerka*, population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

Bugert, R., P. LaRiviere, D. Marbach, S. Martin, L. Ross, and D. Geist. 1990. Lower Snake River compensation plan salmon hatchery evaluation program 1989 annual report. Report to the U.S. Fish and Wildlife Service, Cooperative Agreement 14-16-0001-89525, 145 p. Available U.S. Fish and Wildlife Service, 4696 Overland Road, Room 560, Boise, ID 83702.

Burner, C. J. 1951. Characteristics of spawning nests of Columbia River salmon. Fish. Bull. 61:1-50.

Carmichael, R. W., and R. T. Messmer. 1985. Evaluation of lower Snake River compensation plan facilities in Oregon. Oregon Department of Fish and Wildlife, Research Project FRI/LSR-86-07, Annual Progress Report, 47 p. Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.

CBFWA (Columbia River Fish and Wildlife Authority). 1990. Integrated system plan for salmon and steelhead production in the Columbia River Basin, 449 p.; Clearwater River subbasin salmon and steelhead production plan, 238 p.; Grande Ronde River subbasin salmon and steelhead production plan, 163 p.; Imnaha River subbasin salmon and steelhead production plan, 89 p.; Salmon River subbasin salmon and steelhead production plan, 383 p.; Snake River subbasin (mainstem from mouth to Hell's Canyon Dam) salmon and steelhead production plan, 81 p.; Tucannon River subbasin salmon and steelhead production plan, 98 p. Available Northwest Power Planning Council, 851 S.W. Sixth, Suite 1100, Portland, OR 97204-1348.

Chapman, D. W. 1986. Salmon and steelhead abundance in the Columbia River in the nineteenth century. Trans. Am. Fish. Soc. 115:662-670.

Chapman, D., A. Giorgi, M. Hill, A. Maule, S. McCutcheon, D. Park, W. Platts, K. Pratt, J. Seeb, L. Seeb, and F. Utter. 1991. Status of Snake River chinook salmon. Report to the Pacific Northwest Utilities Conference Committee, 531 p. plus Appendix.

Dennis, B., P. L. Munholland, and J. M. Scott. 1991. Estimation of growth and extinction parameters for endangered species. Ecol. Mon. 61:115-144.

Evermann, B. W. 1896. A preliminary report upon salmon investigations in Idaho in 1894. U.S. Fish Comm., Bull. 15:253-284.

Foote, C. J., C. C. Wood, and R. E. Withler. 1989. Biochemical genetic comparison of sockeye salmon and kokanee, the anadromous and nonanadromous forms of *Oncorhynchus nerka*. Can. J. Fish. Aquat. Sci. 46:149-158.

Fulton, L. A. 1968. Spawning areas and abundance of chinook salmon, *Oncorhynchus tshawytscha*, in the Columbia River Basin--Past and present. U.S. Fish. Wildl. Serv. Spec. Sci. Rep.--Fish. 571, 26 p.

Fulton, L. A., and R. E. Pearson. 1981. Transplantation and homing experiments on salmon, *Oncorhynchus* spp., and steelhead trout, *Salmo gairdneri,* in the Columbia River system: Fish of the 1939-44 broods. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-12, 97 p.

Gilbert, C. H. 1912. Age at maturity of the Pacific coast salmon of the genus Oncorhynchus. U.S. Bur. Fish., Bull. 32:1-22 + plates.

Hindar, K., N. Ryman, and F. Utter. In press. Genetic effects of cultured fish on natural fish populations. Can. J. Fish. Aquat. Sci.

Holmes, H. B. 1961. A study of fish passage at Lewiston Dam, Clearwater River, Idaho, with recommendations for improvement in fish-passage facilities. Report to the State of Idaho Department of Fish and Game, Contract 14-19-001-431, 41 p.

Howell, P., K. Jones, D. Scarnecchia, L. LaVoy, W. Kendra, D. Ortmann, C. Neff, C. Petrosky, and R. Thurow. 1985. Stock assessment of Columbia River anadromous salmonids. Volume I: Chinook, coho, chum, and sockeye stock summaries. Report to U.S. Dep. Energy, Contract DE-A179-84BP12737, project 83-335, 585 p. Available Bonneville Power Administration, P.O. Box 3621, Portland, OR 97208.

Mallet, J. 1974. Inventory of salmon and steelhead resources, habitats, use and demands. Job Performance Report, Project F-58-R-1, 25 p. Idaho Department of Fish and Game, P.O. Box 25, Boise, ID 87307.

Matthews, G. M., J. R. Harmon, S. Achord, O. W. Johnson, and L. A. Kubin. 1990. Evaluation of transportation of juvenile salmonids and related research on the Columbia and Snake Rivers, 1989. Report to U.S. Army Corps of Engineers, Contract DACW68-84-H0034, 60 p. Available Northwest Fisheries Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.

Milner, G. B., D. J. Teel, F. M. Utter, and C. L. Burley. 1981. Columbia River stock identification study: Validation of genetic method. Final report to Bonneville Power Adm., Contract DE-A179-80BP18488, 51 p. Available Northwest Fisheries Center, 2725 Montlake Blvd. East, Seattle, WA 98112.

Mullan, J. W. 1987. Status and propagation of chinook salmon in the mid-Columbia River through 1985. U.S. Fish Wildl. Serv. Biol. Rep. 87(3):1-111.

Nei, M. 1978. Estimation of average heterozygosity and genetic distance from a small number of individuals. Genetics 89:583-590.

Quinn, T. P., and K. Fresh. 1984. Homing and straying in chinook salmon, *Oncorhynchus tshawytscha*, from Cowlitz River Hatchery, Washington. Can. J. Fish. Aquat. Sci. 41:1078-1082.

Raymond, H. L. 1979. Effects of dams and impoundments on migrations of chinook salmon and steelhead from the Snake River, 1966 to 1975. Trans. Am. Fish. Soc. 108:505-529.

Raymond, H. L. 1988. Effects of hydroelectric development and fisheries enhancement on spring and summer chinook salmon and steelhead in the Columbia River Basin. N. Amer. J. Fish. Manage. 8(1):1-23.

Schreck, C. B., H. W. Li, C. S. Sharpe, K. P. Currens, P. L. Hulett, S. L. Stone, and S. B. Yamada. 1986. Stock identification of Columbia River chinook salmon and steelhead trout. Report to U.S. Dep. Energy, Contract DE-A179-83BP13499, Project 83-451, 184 p. Available Bonneville Power Administration, P.O. Box 351, Portland, OR 97208.

Sylvester, R. O. 1959. Water quality study of Wenatchee and Middle Columbia Rivers before dam construction. U.S. Fish Wild. Serv. Spec. Sci. Rep. Fish. 290:1-116.

Taylor, E. B. 1989. Adaptive diversification of juvnile life histories in the chinook salmon, *Oncorhynchus tshawytscha* (Walbaum). Ph.D. Thesis, University of British Columbia, Vancouver, 283 p.

USACE (U.S. Army Corps of Engineers). 1989. Annual fish passage report--1989. Columbia/Snake River projects, North Pacific Division. Available U.S. Army Corps of Engineers, P.O. Box 2946, Portland, OR 97208.

Utter, F., P. Aebersold, and G. Winans. 1987. Interpreting genetic variation detected by electrophoresis, p. 21-45. *In* N. Ryman and F. Utter (editors), Population Genetics and Fishery Management. University of Washington Press, Seattle.

Utter, F. M., G. B. Milner, G. Stahl, and D. J. Teel. 1989. Genetic population structure of chinook salmon, *Oncorhynchus tshawytscha*, in the Pacific Northwest. Fish. Bull., U.S. 87:239-264.

Waples, R. S. 1989. Letter to William Miller, U. S. Fish and Wildlife Service, Ahsahka, ID, December 1989. Submitted to ESA Administrative Record for chinook salmon. Available Environmental and Technical Services Division, NMFS, 911 N.E. 11th Ave., Room 620, Portland, OR 97232.

Waples, R. S. 1990. Stock structure and gene conservation in Columbia River spring chinook salmon, p. 14-21. *In* D. L. Park (convener), Status and future of spring chinook salmon in the Columbia River Basin--Conservation and enhancement. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-187.

Waples, R. S. 1991. Definition of "species" under the Endangered Species Act: Application to Pacific salmon. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-194, 29 p.

Waples, R. S., D. J. Teel, and P. B. Aebersold. 1991. A genetic monitoring and evaluation program for supplemented populations of salmon and steelhead in the Upper Columbia River Basin. Draft summary report to Bonneville Power Administration, 37 p. Submitted to ESA Administrative Record for chinook salmon. Available Environmental and Technical Services Division, NMFS, 911 N.E. 11th Ave., Room 620, Portland, OR 97232.

White, M., and T. Cochnauer. 1989. Salmon spawning ground surveys. Idaho Department of Fish and Game, Lower Snake River Compensation Plan Fish Hatchery Evaluation Contract 14-16-0001-89501, 47 p. Available Idaho Department of Fish and Game, P.O. Box 25, Boise, ID 87307.

Winans, G. A. 1989. Low levels of genetic variability in spring-run chinook salmon of the Snake River. N. Amer. J. Fish. Manage. 9:47-52.

APPENDIX 1

Data Summaries

Appendix 1 Table.--Spring and summer chinook salmon redd counts and areas indexed in the Snake River, 1957-90.

Year	Tucannon River	Grande Ronde	S. Fork Salmon	M. Fork Salmon	Salmon River	Imnaha River	Total
1990	24	184	497	203	273	43	1,224
1989	22	122	357	142	325	40	1,008
1988	25	641	1,010	977	607	135	3,395
1987	66	532	945	471	678	112	2,804
1986	43	323	457	383	494	127	1,827
1985	82	393	503	378	318	145	1,819
1984	-	187	203	188	188	121	887
1983	52	220	346	169	533	95	1,415
1982	46	265	213	121	304	129	1,078
1981	75	122	224	205	722	99	1,447
1980	46	199	160	47	128	40	620
1979	-	100	171	195	536	52	1,054
1978	-	546	455	850	4,389	514	6,754
1977	19	247	334	389	1,742	143	2,874
1976	13	435	326	252	876	127	2,029
1975	37	275	317	744	1,695	149	3,217
1974	18	489	346	540	1,416	277	3,086
1973	24	912	931	1,426	2,385	520	6,198
1972	23	840	884	1,026	2,755	336	5,864
1971	6	996	684	731	2,108	366	4,891
1970	62	990	720	1,296	1,922	176	5,166
1969	61	1,205	1,013	1,278	1,571	176	5,304
1968	18	915	700	1,890	3,043	302	6,868
1967	40	781	1,328	1,812	3,616	215	7,792
1966	65	932	1,230	1,783	3,269	223	7,502
1965	24	637	906	1,192	1,835	189	4,783
1964	61	918	1,615	2,219	3,479	250	8,542
1963	21	-	1,486	2,260	2,513	133	6,413
1962	52	-	2,176	1,812	3,559	248	7,847
1961	102	-	1,463	2,311	4,667	221	8,764
1960	42	-	3,347	1,620	3,697	323	9,029
1959	27	-	1,884	1,284	1,899	115	5,209
1958	54	-	1,983	1,477	2,266	129	5,909
1957	127	-	3,505	2,686	6,015	747	13,080

Index areas:

Tucannon River--main river between River Kms 76 and 69.

Grande Ronde River--Bear Creek, Hurricane Creek, Wallowa River, South Fork Wenaha River, Spring Creek, Lostine River, Lookingglass Creek, Indian Creek, Catherine Creek, North Fork Catherine Creek, South Fork Catherine Creek, Grande Ronde River, Sheep Creek, lower and upper Minam River, Little Minam River.

South Fork Salmon River--Johnson Creek, South Fork Salmon River, Secesh River/Lake Creek.

Middle Fork Salmon River--Loon Creek, Bear Valley Creek, Elk Creek, Marsh Creek drainage, Sulphur Creek, Upper Big Creek.

Salmon River--Lower Salmon River, lower and upper Valley Creek, Lower and upper East Fork Salmon River, Alturas Lake Creek, Lemhi River, Upper Salmon River, Upper Yankee Fork.

Imnaha River--main river between Mac's Mine and the Blue Hole.

Appendix 1 List A

Summary of Life History Characteristics for Wild Spring and Summer Chinook Salmon of the Snake River Excluding the Clearwater River

1. Age at spawning
   a. Tucannon River: data limited; mostly 2-ocean adults (Howell et al. 1985).
   b. Grande Ronde River: varies by stream, but 2-ocean adults tend to predominate (Howell et al. 1985).
   c. South Fork Salmon River: extremely variable; 2-ocean adult returns were always higher than 3-ocean adult returns from 1960 to 1967 (Howell et al. 1985); jacks (1-ocean males) predominated during two of those years.
   d. Middle Fork Salmon River: 2-ocean male and 3-ocean female adults predominate (Howell et al. 1985); tend to return as 3-ocean adults (CBFWA 1990).
   e. Upper Salmon River: 3-ocean adults predominated during the early 1960s, especially in females (Howell et al. 1985).
   f. Imnaha River: from 1961 through 1976, adult returns averaged 5% jacks, 44% 2-ocean, and 50% 3-ocean (Howell et al. 1985); in 1984, only 37% of sampled fish were 3-ocean (Carmichael and Messmer 1985).
2. Sex ratio
   a. Tucannon River: female/male 1:1 in 1986 and 1.2:1 in 1987 (CBFWA 1990).
   b. Grande Ronde River: information limited and questionable due to recovery techniques (trapping only portions of runs). In 1982 and 1983, female/male 1.2:1 and 1.9:1, respectively (Howell et al. 1985).

Appendix 1 List A--Continued.

c. South Fork Salmon River: from 1964 through 1967, female/male averaged 0.5:1 (Howell et al. 1985).

d. Middle Fork Salmon River: female/male ranged from 1:1 to 1.3:1 from 1961 through 1964 (Howell et al. 1985).

e. Upper Salmon River: female/male averaged 1:1 from 1961 through 1964 (Howell et al. 1985).

f. Imnaha River: from 1961 through 1974, female/male averaged 0.6:1 (CBFWA 1990).

3. Fecundity

a. Tucannon River: mean of 3,916 and 4,095 eggs/female in 1986 and 1987, respectively (CBFWA 1990).

b. Grande Ronde River: mean of 3,715 and 3,462 eggs/female in 1983 and 1984, respectively (Howell et al. 1985).

c. South Fork Salmon River: mean of 3,685 to 4,412 eggs/female from 1980 through 1984 (Howell et al. 1985).

d. Middle Fork Salmon River: mean of 5,511 and 5,839 eggs/female in 1963 and 1964, respectively, for Bear Valley and Elk Creeks only (Howell et al. 1985).

e. Upper Salmon River: mean of 5,894 eggs/female from 1981 through 1984 (Howell et al. 1985).

f. Imnaha River: mean of 5,286 and 4,709 eggs/female in 1983 and 1984, respectively (Howell et al. 1985).

Appendix 1 List A--Continued.

4. Egg to smolt survival

    a. Tucannon River: 13% for 1985 brood year (CBFWA 1990); 14% for 1987 brood year (Bugert et al. 1990).

    b. Grande Ronde River: varied from 6 to 19% from 1965 through 1969 (Howell et al. 1985).

    c. South Fork Salmon River: no information.

    d. Middle Fork Salmon River: no information.

    e. Upper Salmon River: from 1965 through 1974, averaged 9.7% for Lemhi River (CBFWA 1990).

    f. Imnaha River: no information.

5. Smolt to adult survival

    No data are available for individual streams or drainages. However, Raymond (1979) estimated 4-5% smolt-to-adult survival for wild smolts arriving at Ice Harbor Dam from 1966 to 1968. From 1969 to 1975, survival ranged from 0.4 to 3.5%. These estimates do not take into account any smolt mortality between rearing areas and the first dams.

6. Smolt migration timing at dams

    a. Tucannon River: no information.

    b. Grande Ronde River: in 1989, smolts at Lower Granite Dam between early May and late June, peaking about 9 June (Matthews et al. 1990).

    c. South Fork Salmon River: in 1989, smolts at Lower Granite Dam from early April through June, with peaks on 25 April and 10 May (Matthews et al.

Appendix 1 List A--Continued.

1990); in 1990, at the dam from early April through mid-May, peaking about 14 April (preliminary NMFS data).

d. Middle Fork Salmon River: no information for 1989; in 1990, smolts at Lower Granite Dam from early April through June, peaking in late April and again in late May (preliminary NMFS data).

e. Upper Salmon River: in 1989, smolts at Lower Granite Dam from early April through mid-June, peaking in early May (Matthews et al. 1990); in 1990, smolts from early April through mid-June, peaking twice on 19 April and 31 May (preliminary NMFS data).

f. Imnaha River: in 1989, smolts at Lower Granite Dam from early April through May, peaking the first week of May (Matthews et al. 1990); in 1990, smolts at the dam from early April through early May, peaking in early April (preliminary NMFS data).

7. Adult run-timing

a. Tucannon River: exact timing unknown, but expected to be similar to other upriver spring chinook salmon stocks where adult freshwater entry occurs from mid-March through April (Howell et al. 1985).

b. Grande Ronde River: most adults destined for this river pass Bonneville Dam in April and May (Howell et al. 1985).

c. South Fork Salmon River: adults enter Columbia River in June and July (CBFWA 1990).

d. Middle Fork Salmon River: exact timing of adults over Bonneville Dam unknown; for spring chinook salmon, expected to be from mid-March through

Appendix 1 List A--Continued.

May and for summer chinook salmon, expected to be from June through July (CBFWA 1990).

e. Upper Salmon River: same as for Middle Fork Salmon River (CBFWA 1990).

f. Imnaha River: adults pass Bonneville Dam from mid-April through July (Howell et al. 1985).

Appendix 1 List B

Summary of Outplantings of Spring and Summer Chinook Salmon in the Snake River

Tucannon River System

Tucannon River -- 10,500 spring chinook from Willamette in 1964
-- 16,000 spring chinook from Klickitat in 1962

Clearwater River System
(1961-1989)

Lochsa River System

Big Flat Creek -- 117,482 spring chinook from Rapid River from 1988 to 1989

Boulder Creek -- 441,731 spring chinook from Rapid River (68.2%) and Sawtooth (31.8%) from 1986 to 1989

Brushy Creek -- no outplants since 1978
-- 1.1 million spring chinook from Mullan (94.5%) and Rapid River (5.5%) from 1972 and 1976-1978

Brushy Fork -- 1.1 million spring chinook from Hayden Creek (51.7%) and Rapid River (48.3%) from 1981, 1986, and 1988-89

Crooked Fork -- 1.3 million spring chinook mainly from Rapid River (61%) and Mullan (35%), of which 745,044 (57%) were released from 1986 to 1989

Hopeful Creek -- 102,308 spring chinook from Rapid River from 1988 to 1989

Lochsa River -- 154 adults were released from returns to the Running Creek Channel in 1989
-- 2 million spring chinook from seven different stocks from 1971 to 1979

Pappose Creek -- no outplants since 1972
-- 14,900 spring chinook from Rapid River in 1972

Post Office Creek -- no outplants since 1973
-- 49,900 spring chinook from Sandpoint (70.1%) and Rapid River (29.9%) from 1972 to 1973

Appendix 1 List B--Continued.

Squaw Creek -- no outplants since 1978
-- 191,000 spring chinook from Mullan in 1978
-- 74,700 spring chinook from Rapid River (59.8%) and Sandpoint (40.2%) from 1972 to 1973

Warm Spring Creek -- no outplants since 1962
-- 250,800 fall chinook from Oxbow in 1962

Wendover -- no outplants since 1970
-- 7,000 spring chinook from Rapid River/Sweetwater in 1970

White Sands Creek -- 2.45 million spring chinook from five stocks, of which 2.2 million (91.1%) were released from 1986 to 1989

Selway River System

Bear Creek -- no outplants since 1969
-- 2 million spring chinook from Carson from 1963 to 1969

-- 390,985 spring/summer chinook from Sweetwater/Salmon stock in 1962

Deep Creek -- no outplants since 1980
-- 1.5 million spring chinook mainly from Indian Creek (64.7%) and Carson (31.2%) were released prior to 1981

Goat Creek -- no outplants since 1969
-- 50,688 spring chinook from Carson in 1969

Indian Creek -- no outplants since 1975
-- 9.6 million spring chinook from six stocks prior to 1976

Moose Creek -- no outplants since 1973
-- 316,465 spring chinook mainly from Carson (82.7%) prior to 1974

Running Creek -- no outplants since 1970
-- 2.1 million spring chinook from four stocks from 1965 to 1970
-- 570,162 spring/summer chinook from Salmon stock in 1964

Selway River -- no outplants since 1980
-- 11 million spring chinook from 7 stocks from 1969 to 1980
-- 501,134 fall chinook from Spring Creek in 1961

Appendix 1 List B.--Continued.

Selway River (Lower) -- 1.4 million fall chinook from Spring Creek (71.4%) and Oxbow (28.6%) from 1962 to 1963
-- 1.5 million spring chinook from Spring Creek in 1966

Selway River (Upper) -- 1.2 million spring chinook and 1.8 million spring/summer chinook from four stocks were released prior to 1969

Whitecap Creek -- no outplants since 1980
-- 2.2 million spring chinook from three stocks were released prior to 1981

South Fork of the Clearwater River

American River -- 346,071 spring chinook from Rapid River (76.4%) and Dworshak (23.6%) from 1988 to 1989
-- 143,472 spring chinook Rapid River (54.7%) and Kooskia (45.3%) from 1972 to 1973

Crooked River -- 1.4 million spring chinook from three stocks from 1986 to 1989
-- 6.6 million spring chinook from three stocks prior to 1978

Meadow Creek -- 139,263 spring chinook from Rapid River from 1988 to 1989

Newsome -- 399,776 spring chinook mainly from Rapid River (78.8%) from 1986 to 1989
-- 503,022 spring chinook from four stocks prior to 1979

Red River -- 7.3 million spring chinook from nine stocks from 1970 to 1989

South Fork of the Clearwater -- no outplants since 1979
-- 573,519 spring chinook from Rapid River from 1973 to 1979

Ten Mile Creek -- 400,093 spring chinook from Rapid River from 1986 and 1988 to 1989
-- 336,030 spring chinook from Rapid River (68.3%) and Mullan (31.7%) prior to 1980

West Fork of Newsome Creek -- 100,097 spring chinook from Rapid River in 1989

Appendix 1 List B.--Continued.

Main Stem of the Clearwater River

Clear Creek -- 5.5 million spring chinook mainly from Kooskia (94.4%) between 1978 and 1989
-- 833,186 spring chinook from Kooskia prior to 1977

Clearwater River -- no outplants since 1987
-- 3.0 million spring chinook mainly from Dworshak (75.3%) from 1983 to 1987
-- 73,234 spring chinook from Kooskia in 1978

Eldorado Creek -- 717,275 spring chinook from three stocks from 1986 to 1989

Elk Creek -- no outplants since 1968
-- 56,960 spring chinook from Carson in 1968

Lolo Creek -- 444,489 spring chinook from three stocks from 1986 to 1989
-- 104,500 spring chinook in 1977

Middle Fork of the Clearwater -- no outplants since 1981
-- 4.75 million spring chinook from Kooskia from 1974 to 1979
-- 373,450 fall chinook from Mullan in 1967

North Fork of the Clearwater -- 8.1 million spring chinook from Dworshak from 1982 to 1989

Grande Ronde River System
(1980-88)

Big Canyon Creek -- 542,288 spring chinook from Carson (65.5%) and Lookingglass/Carson (34.4%) from 1984 to 1988

Catherine Creek -- 1.1 million spring chinook mainly from Carson from 1982 to 1988

Lookingglass Creek -- 7.1 million spring chinook mainly from Carson (64.9%) and Rapid River (22.7%) from 1980 to 1988
-- 123,530 summer chinook from Imnaha (with Erythrocytic Inclusion Body Syndrome) in 1987

Grande Ronde River -- 379,450 spring chinook from Carson in 1986

Upper Grande Ronde River -- 111,711 spring chinook from Lookingglass/Carson in 1987
-- 502,642 spring chinook from Carson in 1984

Appendix 1 List B.--Continued.

Salmon River System
(1961-19)

<u>South Fork of the Salmon River</u>

Cabin Creek -- 1 million summer chinook from South Fork stock in 1988

East Fork of the South Fork -- 402,100 summer chinook from South Fork stock from 1988 to 1989

Johnson Creek -- 1.2 million summer chinook from South Fork stock from 1985 to 1989

Rock Creek -- 6,178 summer chinook from South Fork stock in 1987

Sand Creek -- 215,046 summer chinook from South Fork stock from 1987 to 1989

South Fork -- 6.3 million summer chinook from South Fork stock from 1976 to 1989, of which 4.3 million (68.9%) were from 1985 to 1989

Summit Creek (Secesh River) -- 57 adults of unknown stock in 1968

<u>Middle Fork of the Salmon River</u>

Capehorn Creek -- 22,000 spring chinook from Rapid River in 1975

<u>Main Salmon River--below Stanley</u>

East Fork (SR) -- 946,457 (90.4% of all outplants) spring chinook from Sawtooth from 1986 to 1989
-- 167 of these were adults released in 1987 and 1989

Hayden Creek -- there has been no outplanting since 1986
-- 2.89 million spring chinook mainly (98.7%) from Hayden Creek stock from 1970 to 1982
-- 552 spring chinook from Pahsimeroi, including 24 adults, were released in 1986

Indian Creek -- 50,400 spring chinook from the Hayden Creek Exp. Hatchery in 1978

Lemhi River -- Except for 35 spring chinook adults from Pahsimeroi released in 1989, all 3.5 million outplants were prior to 1979 [stocks were Hayden Creek (31.6%), Kooskia (0.8%), Rapid River (64.0%), and Sweetwater/Salmon River (3.6%)]

Appendix 1 List B.--Continued.

Little Salmon River -- 302,140 (99.6%) spring chinook from Rapid River from 1988 to 1989

North Fork -- 45,360 spring chinook from Rapid River in 1977

Pahsimeroi River -- 1983-89--4 million (61.0%) outplants of which 52.4% were spring chinook and 47.6% were summer chinook; 1984-86--the stock was Pahsimeroi; 1983,87-89--the stock was a mixture of Pahsimeroi and South Fork

-- 2.6 million were released from 1970 to 1978 of which 10.3% were spring chinook and 89.7% were summer chinook and all were Pahsimeroi stock

Pahsimeroi River (William Creek) -- 72,090 spring chinook from Pahsimeroi in 1979

Panther Creek -- two outplantings--46,305 spring chinook from Rapid River in 1977
-- 3,383 spring chinook adults from Pahsimeroi in 1986

Rapid River -- 53.6 million spring chinook from Rapid River from 1966 to 1989, of which 15 million (28.2%) from 1984 to 1989

Salmon River (Idaho County) -- 8,371 spring chinook from U.S. Hagerman (81.5%) and Rapid River (18.5%) stocks from 1973 to 1974

Valley Creek -- 102,934 spring chinook from Salmon River stock in 1978

West Fork (SR) -- 618,120 spring chinook from Rapid River from 1977 to 1978

Yankee Fork -- 1.7 million spring chinook mainly from Sawtooth (70.1%) and Pahsimeroi (22.6%) stocks from 1978 to 1989, of which 1.65 million (95.6%) were from 1985 to 1989

Main Salmon River--above Stanley

Alturas Lake Creek -- 51,000 spring chinook from Sawtooth in 1989

Beaver Creek -- 10,447 spring chinook from Rapid River in 1974
-- 19 adults from Sawtooth released in 1985
-- 27,800 spring chinook eggs from Sawtooth in 1987

Frenchman Creek -- 44 spring chinook adults from Sawtooth from 1987 to 1988

Pole Creek -- 95,500 spring chinook from Sawtooth from 1988 to 1989
-- 32 adults from Sawtooth were released in 1988

Appendix 1 List B.--Continued.

Red Fish Lake Creek/Beaver Creek -- no outplants since 1987
-- 2.35 million (69.9%) spring chinook from Salmon River (34.8%) and Sawtooth (65.2%) stocks from 1983 to 1987

Salmon River (Custer County) -- 5.0 million (48.6%) spring chinook from Sawtooth from 1987 to 1989
-- 5.3 million (51.4%) spring chinook prior to 1987 (beginning in 1968)

Smiley Creek -- 95,500 spring chinook from Sawtooth from 1988 to 1989

Imnaha River System

Imnaha River -- 4,258 spring chinook from Lookingglass in 1984
-- 119 adult spring chinook from Hell's Canyon Trap in 1966

Upper Snake River
(1962-89)

Boise River -- 2,000 fall chinook from Eagle-Oxbow in 1962

Snake River -- Fall chinook--3.4 million prior to 1984-62 from Eagle-Oxbow (0.5%)--1964 from Hagerman Nat'l (7.3%) and Oxbow Dam (14.5%)--1965-67 from Oxbow (75.4%)--1983 from U.S. Hagerman (2.3%)
-- Spring chinook--3.8 million from 1981-89--3.3 million from Rapid River (88.2%)--444,700 (11.8%) from Pahsimeroi in 1987

APPENDIX 2

Glossary

GLOSSARY

Ageing

A fish that is less than 1 year old (counted from time of spawning by its parents) is considered a **subyearling**, or **zero-age**. A **yearling** fish is more than 1 year and less than 2 years old. Adult ages are also reckoned from time of egg deposition and are typically based on counts of annual rings on scales or otoliths (a calcareous "earstone" found in the internal ear of fishes). The age of an adult is sometimes estimated by length.

Adult Fish Counts

A fish-viewing window is at the upstream end of most fish ladders. Observers count the number of fish, by species and size, passing the window for 50 minutes of every hour for 16 hours per day. Extrapolations are made for the hours and minutes not counted to provide an estimate of daily adult fish passage for each dam. In general, separate counts are made for adults and **jacks** (precocious males that can be identified by their smaller size).

Adult Fish Ladders

The main-stem hydroelectric dams on the Columbia and lower Snake Rivers have fish ladders that allow adults to pass the dams on their upstream spawning migration. Entrances for fish ladders are placed on shorelines. For fish attracted to turbine discharge flows, a collection channel built across the downstream face of the dams provides a conduit to move fish toward the fish ladders. Fish ladders that are in compliance with established performance guidelines effectively pass most fish that enter them; however, a small percentage of fish at each dam may not find the entrances to the ladders.

Batholith

A large mass of igneous rock bounded by irregular, cross-cutting surfaces or planes, believed to have crystallized at a considerable depth below the earth's surface.

Bypass Systems

Juvenile salmonid bypass systems consist of moving screens lowered into turbine intakes to divert fish away from turbines at hydroelectric dams. Fish move into a channel that transports them safely around the dam. Bypassed fish are then typically returned directly to the river below the dam, although some Columbia River Basin dams have facilities to load bypassed fish into barges or trucks for transport to a release site downstream from all the dams.

PIT-tag detectors (see below) interrogate all PIT-tagged fish passing through the bypass system. In addition, the systems are equipped with subsampling capabilities that allow hands-on enumeration and examination of a portion of the collection for coded-wire tags (CWT), brands, species composition, injuries, etc. Recovery information at bypass systems is used to develop survival estimates, travel time estimates, and run timing; to identify problem areas within the bypass system; and as the basis for flow management decisions during the juvenile migrations.

Coded-Wire Tags

Coded-wire tags (CWT) are tiny pieces of wire which are implanted in the cartilage in snouts of juvenile salmon. Each tag is notched with a binary code that identifies the fish with a particular release group. CWTs are inserted into the snout using a tagging machine. A head mold, which is sized for the fish being tagged, ensures proper placement of the tag to avoid injury to the fish. Large groups of fish can be coded-wire tagged quickly and inexpensively without altering the behavior of the fish.

Fish that have been coded-wire tagged are identified by an external mark (generally, removal of the adipose fin). This enables fish samplers to later identify tagged fish for recovery of the tag. Coded-wire tags are usually retrieved from dead fish by using a core sampler and a magnetic detector; the code is then read under a microscope.

Electrophoresis

Electrophoresis refers to the movement of charged particles in an electric field. It has proven to be a very useful analytical tool for biochemical characters because molecules can be separated on the basis of differences in size or net charge. Protein electrophoresis, which measures differences in the amino acid composition of proteins from different individuals, has been used for over 2 decades to study natural populations, including all species of anadromous Pacific salmonids. Because the amino acid sequence of proteins is coded for by DNA, data provided by protein electrophoresis provide insight into levels of genetic variability within populations and the extent of genetic differentiation between them. Utter et al. (1987) provide a review of the method using examples from Pacific salmon, and the laboratory manual of Aebersold et al. (1987) provides detailed descriptions of analytical procedures. Genetic techniques that focus directly on variation in DNA also routinely use electrophoresis to separate fragments of DNA of different lengths.

Other genetic terms used in this document include **allele** (an alternate form of a gene); **dendrogram** (a branching diagram, sometimes resembling a tree, that provides one way of visualizing similarities between different groups or samples); **gene** (the basic unit of heredity passed from parent to offspring); **gene locus** (pl. **loci**; the site on a chromosome where a gene is found); **genetic distance** (a quantitative measure of genetic differences between a pair of samples); and **introgression** (introduction of genes from one population or species into another).

Fecundity

Fecundity is the reproductive potential of an individual and is equal to its capacity to produce eggs and sperm. In salmon, it generally refers to the number of eggs produced by a female.

Hatchery

Salmon hatcheries use artificial procedures to spawn adults and raise the resulting progeny in fresh water for release into the natural environment, either directly from the hatchery or by transfer into another area. In some cases, fertilized eggs are outplanted, but it is more common to release **fry** (young juveniles) or **smolts** (juveniles that are physiologically prepared to undergo the migration into salt water).

The brood stock of some hatcheries is based on the adults that return to the hatchery each year; others rely on fish or eggs from other hatcheries, or capture adults in the wild each year.

PIT Tags

Passive integrated transponder (PIT) tags have been developed to monitor the movements of anadromous salmonids primarily through juvenile bypass systems or adult fish ladders at dams. In contrast to radio tags, which have a battery that eventually will cease to function, PIT tags contain a small computer chip that transmits its code only when induced by an external energy source. Using current technology, the PIT tag can only be detected at a distance of up to 18 cm in water. Although this limits some applications of PIT tags, bypass facilities at hydroelectric dams provide excellent opportunities for monitoring movements of juvenile and adult fish.

Each PIT tag is 12.0 mm long by 2.1 mm in diameter and is coded with one of 34 billion unique codes. Tags are inserted into the body cavity with nearly 100% tag retention and high fish survival. The tag is interrogated at 400 kHz and transmits a return signal at 40 to 50 kHz. In specially designed facilities at hydroelectric dams, computerized systems automatically detect, decode, and record individual PIT tag codes, thereby providing time, date, and location of detection and eliminating the need to anesthetize, handle, or restrain fish during data retrieval. The information collected daily at each dam is automatically transferred from the monitor system to a central data base for storage and processing.

Although only developed in the mid-1980s by NMFS scientists, PIT tags have already provided a wealth of information about the distributions, migration timing, migration rates, and survival of juvenile salmonids.

Phenotype

The phenotype is the appearance of an organism resulting from the interaction of the genotype and the environment.

Population viability analysis (PVA)

PVA provides a means of quantifying future risks faced by a population due to demographic, environmental, and genetic factors. PVA methods can be used to identify the minimum viable population size (MVP)--that is, the smallest number of individuals that will allow the population to persist for a specified amount of time (t) with a specified degree of certainty (P). There is no purely scientific way of choosing optimal values for t and P, but combinations most commonly suggested in the literature are t = 100 years and P = 95% probability or, more conservatively, t = 1,000 years and P = 99% probability.

Some detailed PVA models have been described in the literature, but they generally require types of data [e.g., means and variances (over a number of years) of sex ratio, fecundity, and age-specific survival rates] not typically available for Pacific salmon. In the current ESA evaluations, the BRT used the stochastic extinction model of Dennis et al. (1991) to provide some idea of the likely status of the population in the future. A major advantage of the **Dennis model** is its simplicity, requiring as input only a time series of abundance data. Predictions are obtained by taking the current state of the population and projecting it into the future, based on the assumption that future fluctuations in population abundance are determined by parameters of the population measured in the recent past. However, the simplicity of the model also means that it may fail to capture some important aspects of population dynamics. In particular, it does not take density-dependent factors into consideration. Nevertheless, the model is useful for identifying outcomes that are likely if no protective measures are taken.

The Dennis model can be used to identify "extinction" and "threatened" thresholds to compare with the current abundance of a population. In this evaluation, the BRT identified an "endangered" threshold as the abundance at which the population was estimated to have a P = 95% chance of surviving for t = 100 years. Populations whose current abundance was above the "endangered" threshold were evaluated with respect to a "threatened" threshold, which was defined as the abundance at which the population was estimated to have a 50% chance of falling below the "endangered" threshold within 10 years.

Redd Counts

A spawning female salmon prepares a series of nests, called a redd, in suitable areas of streams by turning onto her side and beating her caudal fin up and down. Primary factors affecting suitability of spawning habitat include the size of rocks in the substrate and stream flow (high enough to provide adequate aeration for the eggs; low enough to prevent erosion of the nest). A completed redd is a shallow depression in the stream bottom with a rim extending to the downstream end. During spawning, the female continuously digs upstream, covering previously deposited eggs with gravel. Most redds occur in predictable areas and are easily identified by an experienced observer by their shape, size, and color (lighter than surrounding areas because silt has been cleaned away).

Redd counts are conducted annually in certain heavy use areas of streams called index streams, which are usually surveyed repeatedly through the spawning season. Colored flags are sometimes placed on nearby trees to identify redds so that they will not be counted repetitively. Annual redd counts are used to compare the relative magnitude of spawning activity between years.