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Status Review for Mid-Columbia River Summer Chinook Salmon

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Status Review for Mid-Columbia River Summer Chinook Salmon

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U.S. DEPARTMENT OF COMMERCE
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SUMMARY

We have concluded that mid-Columbia River summer chinook salmon as petitioned are not a species or Evolutionarily Significant Unit (ESU) as defined by the U.S. Endangered Species Act (ESA). Rather, they are part of a larger ESU that includes all late-run (summer and fall), ocean-type chinook salmon from the mainstem Columbia River and its tributaries (excluding the Snake River) between Chief Joseph and McNary Dams. We have also concluded that at the present time this larger ESU is not likely to become endangered in the foreseeable future and does not warrant listing as a threatened or endangered species.

ACKNOWLEDGMENTS

The Biological Status Review of mid-Columbia River summer chinook salmon was conducted by a team of scientists from the Northwest Fisheries Science Center of the National Marine Fisheries Service. This Biological Review Team relied upon the extensive public record developed pursuant to the petition. Team members included Peggy Busby, Dr. David Damkaer, Robert Emmett, Dr. Stephen Grabowski, Dr. Jeffrey Hard, Dr. Orlay Johnson, Dr. Conrad Mahnken, Gene Matthews, Dr. Michael Schiewe, Lowell Stuehrenberg, Dr. Thomas Wainwright, William Waknitz, Dr. Robin Waples, Laurie Weitkamp, Dr. John Williams, and Dr. Gary Winans. Bill Hevlin from the Northwest Regional Office of the National Marine Fisheries Service also contributed information and participated in discussions.

INTRODUCTION

Chinook salmon (*Oncorhynchus tshawytscha*) are distributed from central California to northern Alaska on the North American coast and are native to the Columbia River Basin (Healey 1991). This species was once extremely abundant throughout most of the basin's large, complex river system (Chapman 1986) and has often been partitioned into three races (spring, summer, and fall) based upon timing of adult entry into fresh water. From the late 19th century until the present, a variety of factors have led to a reduction in many Columbia River chinook salmon populations (Nehlsen et al. 1991).

This situation prompted American Rivers, Northwest Environmental Defense Center, The Sierra Club, Northwest Resource Information Center, Friends of the Earth, Inland Empire Public Lands Council, Washington Wilderness Coalition, North Central Washington Audubon Society, Trout Unlimited, Washington Trout, and Federation of Fly Fishers (NEDC et al. 1993) to petition the National Marine Fisheries Service (NMFS) to list mid-Columbia River[1] summer-run chinook salmon as a threatened or endangered species under the U.S. Endangered Species Act (ESA) of 1973 (U.S.C. 1531 et seq.).

This report summarizes a review of the biological status of mid-Columbia River summer-run chinook salmon. This review was conducted by the NMFS Northwest Fisheries Science Center

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[1] Mid-Columbia was used by the petitioners to refer to the Columbia River Basin between Priest Rapids and Chief Joseph Dams.

Biological Review Team (BRT). Because previous studies have consistently found genetic and life-history similarities between summer- and fall-run chinook salmon in the middle Columbia River above McNary Dam, the BRT also considered information for this larger group. In this review, both summer- and fall-run chinook salmon will be referred to as "late-run" chinook salmon or stocks. Fall-run chinook salmon in the Snake River were listed as threatened in 1992 (NMFS 1992).

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

As amended in 1978, the ESA allows listing of "distinct population segments" of vertebrates as well as named species and subspecies. However, the ESA provided no specific guidance for determining what constitutes a distinct population, and the resulting ambiguity led to the use of a variety of criteria in listing decisions over the past decade. To clarify the issue for Pacific salmon, NMFS published a policy describing how the agency will apply the definition of "species" in the ESA to anadromous salmonid species, including sea-run cutthroat trout and steelhead (NMFS 1991). A more detailed description of this topic appeared in the NMFS "Definition of Species" paper (Waples 1991). The NMFS policy stipulates that a salmon population (or group of populations) will be considered "distinct" for purposes of the ESA if it represents an evolutionarily significant unit (ESU) of the biological species.

An ESU is defined as a population that 1) is substantially reproductively isolated from conspecific populations and 2) represents an important component in the evolutionary legacy of the species (Waples 1991). Information that can be useful in determining the degree of reproductive isolation includes incidence of straying, rates of recolonization, degree of genetic differentiation, and physical or ecological barriers to migration. Insight into evolutionary significance can be provided by data on genetic and life-history characteristics, habitat differences, and the effects of stock transfers or supplementation efforts.

Hatchery Fish and Natural Fish

Because artificial propagation of Pacific salmonids has been widespread for many years, the influence of hatchery fish must be considered in most ESA status reviews. NMFS policy stipulates that in determining whether a population is distinct for purposes of the ESA, attention should focus on "natural" fish, which are defined as the progeny of naturally spawning fish (Waples 1991). This approach directs attention to fish that spend their entire life cycle in natural habitat and is consistent with the mandate of the ESA to conserve threatened and endangered species in their native ecosystems. Implicit in this approach is the recognition that hatcheries are not a substitute for natural ecosystems.

The decision to focus on natural fish is based entirely on ecosystem considerations; the question of the relative merits of hatchery vs. natural fish is a separate issue. Fish are not automatically excluded from ESA consideration because some of their direct ancestors were reared in a hatchery. Conversely, identifying a group of fish as "natural" as defined here does not necessarily mean that they are part of a listed ESU. For a discussion of artificial propagation of Pacific salmon under the ESA, see Hard et al. (1992).

Thresholds for Threatened or Endangered Status

The ESA (sec. 3) defines the term "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range." The term "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." Neither NMFS nor the U.S. Fish and Wildlife Service (USFWS), which share authority for administering the ESA, has an official policy regarding thresholds for considering ESA "species" as threatened or endangered. An information document on this topic published by NMFS suggests that conventional rules of thumb, analytical approaches, and simulations may all be useful in making this determination (Thompson 1991). There is considerable interest in incorporating the concepts of population viability analysis (PVA) into ESA threshold considerations for Pacific salmon. However, available PVA models generally require substantial life-history information that is not available for most Pacific salmon populations, so quantitative PVA is not practical at this time.

Therefore, NMFS considers a variety of information in evaluating the level of risk faced by an ESU. Important factors include 1) absolute numbers of fish and their spatial and temporal distribution; 2) current abundance in relation to historical abundance and carrying capacity of the habitat; 3) trends in abundance, based on indices such as dam or redd counts or on estimates of spawner-recruit ratios; 4) natural and human-influenced factors that cause variability in survival and abundance; 5) possible threats to genetic integrity (e.g., selective fisheries and interactions between hatchery and naturally-produced fish); and 6) recent events (e.g., a drought, a change in management procedure, or improvements in mainstem passage) that have predictable short-term consequences for abundance of the ESU.

In evaluating these factors, the role of artificial propagation is an important issue. Because of the ESA's emphasis on conserving species in their native ecosystems, threshold determinations must focus on the status of natural fish, on the premise that an ESU is not healthy unless a viable population exists in the natural habitat.

Artificial production may have direct or indirect impacts on the status of a population through direct supplementation of numbers, by altering the genetic composition of the population, or through ecological interactions(competition, predation, disease transmission, etc.) between artificially-produced and natural fish. A mixture of artificially-produced and natural fish in a population also complicates assessment of the natural fish: abundance and viability of the natural stock is difficult to estimate unless artificially-produced fish are clearly marked, and abundance trends in the natural stock can be obscured by the infusion of artificially-produced fish and their progeny into the natural population.

SUMMARY OF PETITIONERS' CLAIMS

This section summarizes declarations made in the petition by the Northwest Environmental Defense Center and others (NEDC et al. 1993) to support the designation of mid-Columbia River (MCR) summer-run chinook salmon as an ESU. Information regarding the assertions of the petitioners, as well as additional relevant information, is presented following this section. The petitioners' arguments and other relevant information are evaluated in the Discussion and Conclusions section of this review.

Reproductive Isolation

Geographic Isolation

Homing fidelity--The petitioners stated that MCR summer chinook salmon have a reduced likelihood of straying due to specificity of the homing instinct and the long migration to the spawning grounds (NEDC et al. 1993, p. 7).

Life history--The petitioners described MCR summer chinook salmon as reproductively isolated from Snake River summer chinook salmon by differences in migration, spawning, and rearing times, as well as by geographic separation. They noted that NMFS determined that the two summer chinook salmon stocks were reproductively isolated in 1992 (NEDC et al. 1993, p. 7-8).

Genetics--NEDC et al. (1993, p. 8) cited a protein electrophoretic study by Hershberger et al. (1988) to show that spring-run and summer-run chinook salmon in the MCR were separated into two genetic clusters. The petitioners stated that there is little available genetic information comparing summer and fall chinook salmon populations in the MCR (NEDC et al. 1993, p. 8), and that this lack of scientific data supports keeping these stocks separate.

The petitioners also claimed that fall chinook salmon in the MCR were historically considered "inferior" to summer chinook salmon (NEDC et al. 1993, p. 8). The Okanogan River was said to contain the only documented native stock of summer chinook salmon in the MCR (NEDC et al. 1993, p. 6). According to the petitioners, the legacy of the race of summer chinook salmon that migrated past the site of what is now Grand Coulee Dam was partially preserved by the Grand Coulee Fish Maintenance Project (NEDC et al. 1993, p. 2).

Distinctive Life History and Body Size Characteristics

Time of peak spawning--The petitioners state that MCR summer chinook are distinct because peak spawning occurs during the last 2 weeks in October and continues through November (NEDC et al. 1993, p. 7 and 10).

Age and body size at spawning--The petitioners claimed that MCR summer chinook were referred to as "June hogs" because of their time of migration and size (NEDC et al. 1993, p. 1-2). They claimed that the age at spawning of MCR summer chinook ranges from 2 to 6 years, with 4- and 5-year-old fish making up nearly 80% of the spawning run (NEDC et al. 1993, p. 10). They also claimed that the size range for 4- and 5-year-old fish varied from 78 to 89 cm (NEDC et al. 1993, p. 10).

Smolt age--The petitioners stated that the largest number of MCR summer chinook juveniles emigrate seaward as subyearlings in mid-to-late summer (NEDC et al. 1993, p. 10).

Effects of hatchery fish--The petitioners stated that the Wells Hatchery has recently been contaminating the summer chinook salmon stock with fall chinook salmon, and that this intermixing has changed inriver migration times of chinook salmon in the MCR (NEDC et al. 1993, p. 7). However, they also assert that introgression of hatchery fish with natural MCR summer chinook has been slight in the MCR Basin, and they estimate that 65% of the summer chinook are "natural" (NEDC et al. 1993, p. 8).

Evolutionary Significance

Geographic location--The petitioners claim that summer chinook salmon spawn in two distinct areas: in tributaries of the Snake River and in tributaries of the MCR above Rock Island Dam (NEDC et al. 1993, p. 1-2). The petitioners stated that Methow, Okanogan, and Wenatchee River summer chinook salmon occupy unique ecosystems with often hostile conditions (NEDC et al. 1993, p. 9).

Spawning distribution--The petitioners stated that the original spawning distribution of MCR summer chinook included the Columbia River as far upstream as Lake Windemere in British Columbia (NEDC et al. 1993, p. 1), but that currently, MCR summer chinook salmon spawn only in the Wenatchee, Methow, and Okanogan Rivers (NEDC et al. 1993, p. 6).

Population Trends

Abundance--The petitioners cited early pioneers' stories of millions of salmon, mostly summer chinook, ascending Kettle Falls (NEDC et al. 1993, p. 5). They state that the abundance of Columbia River summer chinook salmon has been declining continuously since 1973, with an adult count over Bonneville Dam of 15,100 adults in 1992, the lowest count on record. Current numbers of MCR summer chinook were reported by the petitioners to be under 9,700 in the Wenatchee, Methow, and Okanogan Rivers (NEDC et al. 1993, p. 11). The population of summer chinook salmon in the Entiat River was said to be so small as to be considered extinct (NEDC et al. 1993, p. 12).

BRT SUMMARY OF BIOLOGICAL INFORMATION

Environmental Features

The Columbia River is the third largest river in North America and drains an area of approximately 668,000 km^2. This area includes British Columbia, Idaho, Washington, Montana, and Oregon, and smaller sections of Wyoming, Nevada, and Utah. It flows through or borders on three physiographic regions of the Pacific Northwest: the Rocky Mountain System, the Intermontane Plateau, and the Pacific Mountain System (Scott et al. 1989). Originating in Lake Windermere, B.C. in the northern Rocky Mountains, the Columbia River flows through British Columbia for over 1,000 km before entering the United States via the Okanogan Highlands. The river flows westerly until it turns south, approximately at its confluence with the Okanogan River (RKm 859), where it forms a boundary between two distinct ecoregions: the Columbia River Basin (part of the Intermontane Plateau) on the east, and the Cascade Mountains (part of the Pacific Mountain System) on the west. Approximately 25 km below its confluence with the Snake River (RKm 522), the Columbia River turns westerly towards the Pacific Ocean. For the purposes of this Biological Status Review, the MCR is defined as the mainstem river and tributaries between McNary Dam (Rkm 470) and Chief Joseph Dam (Rkm 878; Fig. 1). This definition was previously used by Mullan et al. (1992b) and Chapman et al. (1994).

The western side of the MCR is generally mesic, alpine habitat. Rivers originating there drain the eastern slopes of

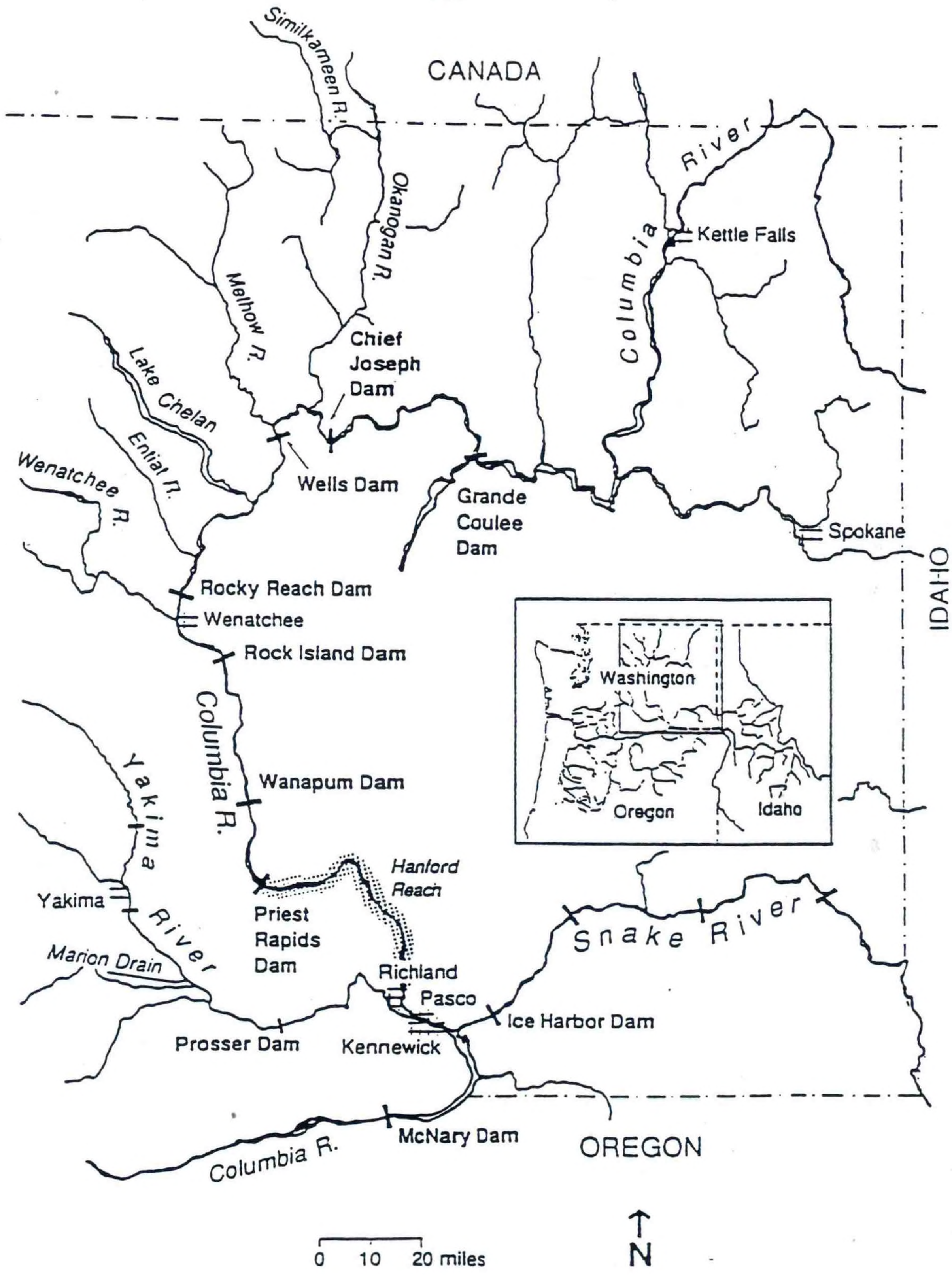

Figure 1. Map of mid-Columbia River Basin, showing principal tributaries and hydroelectric facilities.

the Cascade Mountains as relatively short streams that begin precipitously and make a transition to low gradient streams in the lower reaches. These rivers receive the majority of their runoff from snowmelt in the spring and early summer. The five major east-slope rivers of the Cascade Mountains are the Yakima, Wenatchee, Entiat, Methow, and Okanogan (Fig. 1). General habitat features of these rivers are presented in Table 1 (see also Chapman et al. 1994).

The eastern side of the MCR is a basaltic plateau that reaches 763 m in elevation and is principally xeric, sagebrush-grassland habitat. Between the Grand Coulee Dam and the Snake River, there are no chinook salmon streams entering the MCR from the eastern side.

In general, the five major MCR tributaries are not biologically productive. At certain size-at-age classes, resident trout populations in the Methow, Entiat, and Wenatchee Rivers have standing crop levels among the lowest ever reported (summarized in Mullan et al. 1992b). The habitat quality index score for these three rivers was 47 on a scale of 11 to 113, indicating low overall potential for salmonid spawning and rearing (Mullan et al. 1992b). Among MCR tributaries, the Okanogan River, which flows through four mainstem lakes, is somewhat more fertile. The Yakima River is presently enriched due to agricultural runoff and reservoir storage. Overall water quality in the other petitioned streams is excellent (Mullan et al. 1992b).

Table 1. Habitat characteristics of the mid-Columbia River Basin and tributaries inhabited by ocean-type chinook salmon (from Bryant and Parkhurst 1950; Davidson 1953; CBIC 1957; Mullan et al. 1992b; Chapman et al. 1994).

River:	Okanogan	Methow	Chelan	Entiat	Wenatchee	Yakima	Columbia
Location (RKm)	859	843	810	779	754	540	470-878
Gradient	low	steep/ low	low	steep/ low	steep/ low	med./ low	low
Terrain	grass	alpine/ grass	grass	alpine/ grass	alpine/ grass	alpine/ grass	grass
Runoff	snow/ lakes	snow/ rain	reser-voir	snow/ rain	snow/ rain	reser-voir	reser-voir
Minimum flow (m^2/s)	--[a]	13.9	n/a	3.5	19.8	36.8	2405[b]
Climate	arid	wet/ arid	arid	wet/ arid	wet/ arid	wet/ arid	arid
Productivity	med.	low	low	low	low	high	low/ med.
Temperature	low/ high	low/ high	med.	low/ high	low/ high	med./ high	med./ high

[a] Dash indicates data not available.
[b] At Rock Island Dam.

By the turn of the century, sawmill, hydroelectric, and irrigation dams had already decimated salmon populations in this area. Since then, the condition of spawning habitat has improved greatly (Mullan et al. 1992b). The small dams on tributaries have been removed, irrigation diversions have been screened, and riprap has been placed over eroded stream banks, providing critical summer and winter habitat for juveniles (Chapman 1989). Mullan et al. (1992b) concluded that, with the exception of the Yakima River, degradation of habitat in MCR tributaries does not appear to be a significant cause of run depression. In fact, these authors consider that the area covered by the petition is currently at or near maximum historical smolt production for chinook salmon.

The Yakima River differs somewhat from other MCR tributaries. At its headwaters, the streams are steep and drain mountains about 1,500 to 3,000 m in elevation. The river valleys then flatten out and meander down gentle slopes into the Columbia River. As previously mentioned, the overall bioproductivity of the Yakima River is higher than that of other MCR streams because of agricultural runoff and lake and reservoir storage. However, these factors may also lead to increased water temperature, which inhibits salmonid migration and spawning (Mullan et al. 1992b).

Production of late-run chinook salmon in the Yakima River has also been severely curtailed by unrestrained irrigation practices. These practices include the use of unscreened irrigation diversions and exploitation of river water to an extent that produces low flows, which diminish summer habitat

(Robison 1957). Although some of these irrigation practices have been corrected, no "summer" chinook salmon (i.e., early part of late run) have been observed in the Yakima River Basin since the 1970s, most likely due to the presence of inhospitable thermal conditions for adult chinook in the lower river (Busack 1990).

Life History Characteristics

Detailed life history data (age at spawning, sex ratios, etc.) are plentiful for many hatchery populations of MCR ocean-type chinook salmon, but data are limited and inconsistent for wild populations. Life history characteristics were specifically identified as "critical data gaps" for most subbasins in the production plans of the Columbia Basin Fish and Wildlife Authority (CBFWA 1990). Howell et al. (1985, p. 449) summarized the situation for Columbia River summer-run fish: "Basic juvenile and adult life history information is almost completely unknown for naturally produced summer chinook."

Considering the long history of salmon management by various fisheries entities, the paucity of basic biological information is both surprising and discouraging. In the context of an ESA biological review, this lack of information hampers the identification of distinct population segments or ESUs. Efforts to gather detailed life history information have only recently been initiated.

Juvenile Life History Characters

Chinook salmon populations have been separated into two basic types based on juvenile life history characteristics: those whose juveniles migrate to sea as subyearlings, known as "ocean-type" populations; and those whose juveniles migrate to sea as yearlings, designated as "stream-type" populations (Gilbert 1912, Taylor 1990, Healey 1991). Ocean-type chinook salmon in the MCR Basin spend most of their ocean life in coastal waters, returning to fresh water a few months prior to spawning. Stream-type fish, on the other hand, perform extensive offshore migrations, returning to fresh water many months prior to spawning (Healey 1991).

A strong tendency toward one or the other of these types is also found within most chinook salmon populations outside the MCR. Ocean-type populations dominate the southern range of the species from California through the coastal streams of Oregon and Washington, and stream-type fish dominate the range from approximately 56° N in British Columbia through Alaska (Taylor 1989, Healey 1991). However, in the southern portion of its range, stream-type chinook salmon are relatively common in upstream areas of most large rivers, while small rivers contain primarily ocean-type fish. Stream-type populations also appear to predominate in Asian representatives of the species (Healey 1991).

Variations in stream temperature regimes due to latitude or altitude appear to be the major factor controlling the general distribution of the two types. However, Healey (1983) suggested that other factors, such as distance of the spawning migration, annual river-discharge cycles, and ocean migration patterns may also be important.

In North America, the Columbia River is located near the middle latitudes of the chinook salmon range. The Columbia River is inhabited by populations with high diversity in juvenile migrational behavior and timing: both stream- and ocean-type populations inhabit the basin. As in areas outside the Columbia River, stream temperatures, which vary with elevation, appear to control the distribution of the two types. Mainstem areas and lower tributary streams of the Columbia and Snake Rivers produce only ocean-type juveniles, and upper tributaries of the Columbia and Snake Rivers produce only stream-type juveniles.

However, some tributaries, including the MCR streams listed in the petition, produce both types. In both the mid-Columbia and Snake Rivers, spring-run chinook salmon produce stream-type juveniles, and fall-run chinook salmon produce ocean-type juveniles. However, the so-called "summer-run" adults produce ocean-type juveniles in the MCR above McNary Dam and stream-type juveniles in the Snake River.

In summary, available life history information indicates a strong affinity between fish designated as summer- and fall-run in the MCR, and between spring- and summer-run fish in the Snake River (Matthews and Waples 1991). For example, ocean-type chinook salmon in the mainstem Yakima River exhibit life-history and spawning characteristics similar to those of ocean-type fish in the Hanford Reach of the Columbia River. Genetic data (discussed below) also support the hypothesis that these affinities correspond to ancestral relationships.

Run and Spawn Timing

The temporal distribution of adults as they enter fresh water to spawn is referred to as run timing. Historically, chinook salmon have entered the mouth of the Columbia River almost continuously. Commencing in February, the run peaked in mid-June and ended in late November (Thompson 1951, Mullan 1987). In general, early-returning fish were stream-types destined for upper tributary areas, while late-returning fish were ocean-types destined for mainstem areas (Fulton 1968).

However, during the peak of chinook salmon migration, a large number of both run-types migrated upstream, filling a large portion of the spawning habitat. Thus, the so-called "summer-run" was a mix of chinook salmon composed of late-migrating stream-type fish destined for upper tributaries of the Snake and Columbia Rivers and early-migrating ocean-type fish destined for lower tributary and mainstem areas of the middle Columbia and Snake Rivers.

Since the turn of the century, human activities (i.e., overfishing, dam building, etc.) have severely fragmented or dislocated portions of the ancestral continuum of migrating chinook salmon in the Columbia River, leaving what now appears as noncontinuous or discrete populations. The middle portion was depleted by early commercial harvests, leaving the early (spring-run) and late (fall-run) portions separated as semidiscrete run groups (Thompson 1951, Beiningen 1976).

Because chinook salmon spawning coincides with a declining temperature cycle (Miller and Brannon 1982), temperature variation, controlled primarily by elevation, is thought to be the key factor influencing the run and spawn timing of ocean- and stream-type populations. In most cases, stream-type chinook salmon spawn earlier, at higher elevations, and further upstream than ocean-type chinook salmon.

Spawning fish of both types use the upstream portions of their respective spawning areas first and the downstream portions last, thus providing opportunities for mixing among groups of fish whose spawning activities overlap spatially and temporally (i.e., spring- and summer-run fish in the Snake River and summer- and fall-run fish in the Columbia River). This phenomenon in the MCR is succinctly described by Mullan (1987, p. 3): "This time-space dimension was originally filled by successive waves of chinook salmon spawners."

In the Columbia River, adult chinook salmon migrating upstream past Bonneville Dam from March through May, June through July, and August through October have been categorized as spring-, summer-, and fall-run fish, respectively (Burner 1951). However, run-partitioning dates are progressively later at each dam encountered as adult fish migrate upstream. While annual run-partitioning dates remain static at all dams, adult migration timing varies annually, with water temperature as the primary controlling factor. Moreover, to some degree, the middle portion of the run (i.e., summer-run chinook salmon) is overlapped early in the migration by the spring-run and later by the fall-run.

Therefore, the separation of Columbia River chinook salmon into three races, based principally on adult run-timing at dams, is an arbitrary distinction (Fulton 1968, Chapman et al. 1982). Unfortunately, use of this distinction in accounting methods has often resulted in large census errors and considerable confusion regarding the ancestral relationships among chinook salmon populations in the Columbia River Basin.

Ocean-type chinook salmon in the Columbia River exist in two basic forms: "upriver brights" and "tules." Upriver brights enter the river first, mature slowly, and retain their silvery oceanic coloration well into the freshwater migration. This run of chinook salmon spawns from somewhere above the site of Grand Coulee Dam downstream to an area near the present site of The Dalles Dam. Spawning occurred both in the mainstem Columbia River and in the lower sections of tributaries (Fulton 1968, Dauble and Watson 1990) but was probably limited below the mouth of the Umatilla River (Bryant and Parkhurst 1950). The Snake River portion of the ocean-type run, historically spawning from Shoshone Falls downstream to the confluence of the Snake and Columbia Rivers, was listed as a threatened species under the ESA (Waples et al. 1991).

Tules are the last chinook salmon to enter the river; they are sexually mature upon entry and spawn in lower mainstem and tributary areas primarily below The Dalles Dam (Fulton 1968), that is, outside the petitioned area.

Currently, ocean-type chinook salmon pass Bonneville Dam between late May/early June (upriver brights) and late September/ early October (tules) (Howell et al. 1985). The early portion of the upriver bright run passes Priest Rapids Dam between mid-June and early August and spawns primarily in the lower reaches of the petitioned tributary streams above Rock Island Dam from late September through early November. In the area above Rock Island Dam, summer- and fall-run adults intermingle and spawn at the same time (Edson 1958, Mullan 1987, Craig and Suomela 1941). For example, Meekin (1967) and Meekin et al.(1966) could not distinguish mainstem spawners (presumably fall-run) from tributary spawners (presumably summer-run) based on time of passage over Wells Dam.

Naturally produced, summer-run chinook salmon introduced into the Wells summer chinook spawning channel have been observed spawning as late as mid-December (Allen et al. 1971), at least a month later than so-called summer chinook salmon are said to spawn (NEDC et al. 1993). Conversely, chinook salmon designated as fall-run according to their run timing have been observed spawning in the Priest Rapids fall chinook spawning channel as early as mid-September (Allen 1966, 1967). This spawn timing is more typical of summer- or even spring-run chinook salmon, according to some criteria (NEDC et al. 1993).

Recently, radio-tag data evaluating segregation of chinook salmon populations by run timing at dams showed that a significant portion of summer-run adults spawned in the mainstem Columbia River, while a significant portion of fall-run adults spawned in the Okanogan River system (L. Stuehrenberg, unpubl. data, NMFS). The petitioners claimed that the Okanogan River contains summer-run fish only (NEDC et al. 1993). However, it is apparent that the run times used by fishery managers to partition and allocate Columbia River chinook salmon are not necessarily recognized by the fish themselves. As Mullan (1987, p. 57) stated, "There are no clear differences between summer-run and fall-run chinook salmon in the mid-Columbia."

Fish from later in the run spawn primarily in the Hanford Reach below Priest Rapids Dam from late October to late December. A small number of fish not passing Priest Rapids Dam spawn in lower areas of the Yakima River in October and November (CBFWA 1990, WDF et al. 1993). Below McNary Dam, another small run of upriver brights enters the Deschutes River over a protracted period from late June to October, spawning in mainstem areas below Pelton Reregulating Dam from October through December (CBFWA 1990). According to Howell et al. (1985) the John Day River supports a "negligible" run of upriver brights; however, no data have been obtained for these fish.

Age at Spawning, Sex Ratio, and Fecundity

Area-specific data for age at spawning, adult sex ratios, and fecundity are generally lacking for wild populations of MCR chinook salmon. A life history characteristic that appears to differ among the three alleged forms of Columbia River chinook salmon is the abundance of early-maturing males, known as jacks (Howell et al. 1985). Generally, jacks are least abundant in stream-type chinook salmon populations and become progressively more abundant over the duration of the ocean-type run (Mullan 1987, Healey 1991, Mullan et al. 1992a).

However, because so-called summer- and fall-run fish were not observed in natural spawning areas, the difference noted between arbitrary groupings of ocean-type fish at dams is not persuasive. Based on an exhaustive summary of adult salmon counts at Rock Island Dam from 1933 through 1985, Mullan (1987) noted that jacks occurred less frequently in the early summer portion of the run (24%) than in the fall portion (48%). However, as noted earlier, attempts to partition population characteristics into run-specific clusters based on dam counts are tenuous due to inter- and intraseasonal variability in run timing of Columbia River chinook salmon.

Some of these apparently large differences in jack counts between early- and late-run ocean-type fish could simply be an artifact of the census location. For example, during the spring-run of Columbia River stream-type chinook salmon, jacks tend to migrate later and are nearly absent during the first third of the run. This is readily apparent because they are the first run of the season and, thus, are not overlapped early by another run. If this pattern holds for runs of ocean-type fish (see the section on straying below), then many jacks counted as fall-run chinook salmon may actually be destined for locations generally associated with early ocean-type, or summer-run fish. The accuracy of dam counts is also compromised because they include hatchery fish whose life history traits may have been altered (e.g., Mullan et al. 1992b).

The percentages of return by age for hatchery upriver brights have been listed by Howell et al. (1985). For the 1962-79 broods, 2-year-olds (jacks) comprised 34.1% of the total return, 3-year-olds 23.8%, 4-year-olds 34.6%, and 5-year-olds

7.5%. Six-year-old fish were rare, comprising less than 0.5% of the return (Mullan 1987). The overall age values were similar to area-specific values documented for wild upriver brights in the Deschutes (CBFWA 1990) and Snake Rivers (Chapman et al. 1991) and in the Hanford Reach of the Columbia River (Dauble and Watson 1990). Regarding age structure, mainstem Yakima River ocean-type chinook salmon were considered typical of chinook salmon in the Hanford Reach of the Columbia River (Busack 1990).

In upriver bright populations, all 2-year-old and most 3-year-old fish were males, whereas females predominated the older age classes (Howell et al. 1985, Dauble and Watson 1990). Overall, males slightly outnumbered females.

Fecundity data are not available for wild summer-run fish. At Wells Dam Hatchery (summer-run fish), fecundity averaged 4,935 eggs per female between 1967 and 1970, and at Priest Rapids Hatchery (fall-run fish), fecundity averaged 4,704 eggs from 1978 to 1992 (Howell et al. 1985). For fall-run chinook salmon utilizing artificial spawning channels in the MCR, Mathews and Meekin (1971) observed a mean fecundity of 5,015 eggs.

Ocean Distribution

Information on the ocean distribution of wild chinook salmon populations from the Columbia River Basin is limited (Waples et al. 1991, Matthews and Waples 1991). However, hatchery fish have received coded wire tags for over two decades, and catches of these fish provide some general insight into oceanic migratory patterns. Seven consecutive broods of Snake River ocean-type chinook salmon consistently displayed a more southerly oceanic catch distribution than MCR "fall-run" salmon (Waples et al. 1991). On the other hand, similar, but more limited, data showed virtually no difference in the oceanic distributions of MCR ocean-type fish released from Wells Dam ("summer-run") and Priest Rapids ("fall-run") hatcheries (Howell et al. 1985).

Juvenile Behavior

Timing of fry emergence has not been well documented for naturally produced ocean-type fish. In the MCR, fry emerge primarily in April and May (Chapman et al. 1994). At the Wells Dam spawning channel (summer-run fish), fry emerged from January through April during 1968-71 (Howell et al. 1985). For the 1963-67 broods at the Priest Rapids Hatchery spawning channel, emergence occurred primarily in late April and early May (Howell et al. 1985).

Typically, chinook salmon fry move downstream after emergence. For many populations of ocean-type fish, fry may continue migrating to the estuary or take up residence in the river for a few weeks to a year or more before entering the ocean (Healey 1991). In the Columbia River Basin and its tributaries, all ocean-type fry leave redd areas a few days to weeks after emergence (Chapman et al. 1994). Some fry rear only a short distance from nursery areas before migrating, while others may migrate downstream a considerable distance to rear. Although the exact mechanisms controlling dispersal behavior are largely unknown, they are probably related to a variety of factors such as inter- and intraspecific social interactions (Reimers 1968, Taylor 1988), habitat availability (Lister and Walker 1966), and river discharge (Healey 1991). Chapman et al. (1994) summarized results of several recent studies that suggest fish size or growth may be important variables regulating downstream movements.

Subyearling, ocean-type chinook salmon in the Columbia River tend to migrate downstream slowly, foraging and growing as they move seaward. These fish move out of rearing areas in late spring or early summer, with the majority passing downstream through McNary Dam from mid-July through mid-September. Fish originating from upstream areas migrate about 2-3 weeks later than those from downstream areas (Chapman et al. 1994). Impoundment of the river has likely shifted the migrational timings of these fish later than during predevelopment times (Park 1969). This later passage has apparently increased the proportion of fish that remain in the Columbia River over winter (Chapman et al. 1994).

Subyearling chinook salmon migrants use estuaries extensively for rearing prior to ocean entry (Healey 1991). In the Columbia River, estuarine residence times vary greatly from a few days to several months or longer. Rich (1920) recorded subyearling chinook in the estuary in all months, with some staying over winter.

"June hogs"

Many residents of the Pacific Northwest are aware of stories alleging that a specific run of particularly large chinook salmon, the so-called "June hogs," once migrated up the Columbia River (e.g., Seufert 1980). These fish, said to have averaged 18-45 kg in weight, supposedly predominated the middle portion of the run passing through the lower river and migrated to spawn somewhere in the Columbia River Basin. Most assumed that June hogs were summer-run fish.

However, Seufert (1980, p. 9), referred to them as "huge spring chinook," which would indicate stream-type chinook salmon. In addition, early settlers observed chinook salmon spawning as early as August in the upper Columbia River in British Columbia (Bryant and Parkhurst 1950), a life history pattern characteristic of stream-type chinook salmon in the Columbia River Basin. By comparison, all observed populations of upper Fraser River chinook salmon have stream-type juvenile life histories (Taylor 1989).

Regarding latitude, altitude, climate, and geography, the upper Columbia River is similar to the upper Fraser River and is more distant from the ocean. Therefore, it is logical that the life histories of chinook salmon populations in the two systems would be similar as well. In fact, after deglaciation, the Columbia River appears to have been the principal source for the repopulation of Fraser River fish fauna in general (McPhail and Lindsey 1986) and chinook salmon in particular (Utter et al. 1989).

We found no empirical evidence indicating that a unique population of massive fish ever existed in the Columbia River. Historical accounts from the early 1800s suggested chinook salmon caught by aboriginal people in the upper Columbia River at Kettle Falls averaged about 7.0 kg in weight (Mullan et al. 1992b). Wild adult ocean-type fish sampled at Rock Island Dam in 1940 weighed about 8.0 kg (Fulton and Pearson 1981). From historic catch records, Beiningen (1976) estimated a mean weight for "summer-run" chinook salmon of 8.5 kg, while Chapman (1986) used a mean weight of 10.5 kg in his estimates of population abundance for the late-1800s. On the other hand, early settlers of the upper Columbia River were said to have witnessed "summer-run" adult fish averaging 18.0 kg (Bryant and Parkhurst 1950). These anecdotes must be considered with caution, since no weights were actually reported and scale analysis was not available to determine juvenile life histories.

Considering that the size of the ancestral Columbia River chinook salmon population has been estimated at 2-4 million fish (Ebel et al. 1989), very large chinook salmon were undoubtedly common in the past. A few are occasionally observed today. As noted earlier, the ancestral chinook salmon run peaked in the lower river in early summer and was represented by many spawning populations of both stream- and ocean-type fish from upper tributaries in the Columbia and Snake Rivers. Therefore, it is possible that June hogs were simply the largest members of many different spawning populations. By the early 1900s, overfishing had largely extirpated the majority of Columbia River chinook salmon, particularly the largest individuals (Thompson 1951, Beiningen 1976). Some commercial fishing methods have been shown to dramatically reduce the mean size and age of chinook salmon populations (Ricker 1981).

Straying

Adult anadromous salmonids that spawn in areas other than their natal stream or hatchery are known as strays. However, some strays may actually be wanderers, as described by Chapman et al. (1991). Wandering fish enter nonnatal streams or areas and eventually depart to spawn elsewhere. Tagging data indicate that wandering may be a relatively common behavior in anadromous salmonids (Meekin 1967, Bjornn et al. 1992), especially in areas where hatchery releases occur close to spawning areas (Chapman et al. 1994). Unnatural obstacles (dams, weirs, traps, etc.) may partially or totally prohibit corrections or adjustments by these fish. In situations such as these, where voluntary egress is prevented, wandering fish may be falsely classified as strays.

Homing is well developed in anadromous salmonids, with olfactory cues providing the primary mechanism for river, tributary, and possibly even riffle selection (Groves et al. 1968, Hasler and Scholz 1983). Homing to specific natal environments has undoubtedly influenced the genetic interaction among neighboring populations, and in general, there is a decreasing likelihood of gene flow between salmon populations as geographic distance between them increases (see Quinn 1993, Utter et al. 1989, Shaklee et al. 1991). For example, it can be safely assumed that Alaskan stream-type chinook salmon do not stray into the Columbia River system.

While mixing between the same types of geographically-proximal chinook salmon stocks is undoubtedly greater, the extent to which it occurs naturally is not well understood. It is becoming increasingly apparent, however, that vacant habitat can be recolonized relatively quickly by salmonids from nearby populations (Milner and Bailey 1989).

Accounts of straying by Columbia River chinook salmon populations are confusing and have focused primarily on hatchery fish. Chapman et al. (1991, 1994) concluded that stream-type chinook salmon stray less than ocean-types. However, Rich and Holmes (1928) concluded the opposite.

Tule chinook salmon from the Washington Department of Fisheries Cowlitz Hatchery exhibited an average home-stream fidelity of 98.6% for four brood years (Quinn and Fresh 1984). Older fish tended to stray the most and jacks, returning later in the year, strayed the least. Straying also appeared to be related to brood-year success, with higher straying rates occurring when survival was low.

McIssac and Quinn (1988) reported 99% homing accuracy for upriver brights released from Priest Rapids Hatchery. These authors reported that homing appeared to be somewhat under genetic control. If this is true, then the large assortment of recent stock relocations, primarily for various hatchery or enhancement purposes, may have increased straying and therefore the mixing of Columbia River salmon. In fact, the petitioned populations of MCR chinook salmon were founded with many individuals originally from regions hundreds of kilometers upstream from the tributaries they now inhabit.

Portions of MCR late-run chinook salmon have been mixed considerably over the past two to three decades. This mixing was due to the variety of methods employed to collect broodstock at dams, hatcheries, or other areas and as a result of juvenile outplantings into various areas, including the petitioned streams (reviewed in Chapman et al. 1994). Since 1967, as many as 20% of summer-run chinook salmon broodstock for Wells Hatchery operations have been collected from the late component (so called fall-run) of ocean-type fish passing over Wells Dam after the nominal cutoff date (28 August) between summer- and fall-run groups (Allen 1966, 1967; Allen et al. 1971; Chapman et al. 1994). Moreover, recoveries of coded-wire-tagged adults from various juvenile releases in the late 1970s and 1980s indicated that wild and hatchery summer-run fish originating above Rock Island Dam have spawned extensively with designated fall-run fish originating in the Hanford Reach and Priest Rapids Hatchery (Chapman et al. 1994).

Conversely, about 15% of the so-called fall chinook salmon emigrating from spawning beds below Priest Rapids Dam have returned to spawn in the Columbia River system above Wells Dam (Chapman et al. 1994). The possibility of substantial genetic exchange between chinook salmon populations above and below Rock Island Dam was noted almost half a century ago (Fish and Hanavan

1948). Attempts to maintain discrete hatchery stocks have only recently been initiated.

The Yakima River has been heavily planted with Bonneville Hatchery ocean-type chinook salmon (Table 2), which are said to stray at substantial rates (Busack 1990, WDF et al. 1993).

Stock Histories

Since settlement of the Columbia River Basin in the mid-nineteenth century, a variety of activities associated with development and commerce have had negative consequences for Columbia River salmonid populations. The list of harmful activities includes prodigious overharvest of salmon; destructive or unregulated land management practices, including timber harvest, mining, livestock grazing, and irrigation; and construction of hydroelectric facilities with absent or inadequate adult and juvenile fish passage facilities.

High harvest rates continue today, primarily by fisheries in the northern ocean ranges of Columbia River salmonids (Howell et al. 1985). According to estimates, it may take scores of years for riparian habitat destroyed by logging to recover (Sedell and Swanson 1984). Livestock grazing continues to degrade stream habitats (Platts 1991). Recent examinations of screens at Columbia River irrigation diversions reveal that many screening devices need modernization (WDF et al. 1990).

Yet, in spite of historic and contemporary human activities adversely affecting Columbia River salmonids, the number of ocean-type chinook salmon returning to mid-Columbia River spawning areas has increased substantially since the construction

Table 2. Hatchery plants of ocean-type chinook salmon into the mid-Columbia River and its tributaries. From Coleman and Rasch 1981; Castoldi 1983; Castoldi and Rasch 1982; Hill 1984; Kirby 1985; Abrahamson 1986, 1987, 1988; Mullan 1987; Yakima Indian Nation 1994; and Chapman et al. 1994). Abbreviations are given below.

Stock[a]	Hatchery[b]	Agency[c]	Class[d]	Year of Plant	Stream[e]	Number Planted
Entiat River plants - Summer chinook salmon						
GCFMP	LEAV	FWS	fingerling*	41	Entiat R.	640,800
GCFMP	ENT	FWS	unknown	41	Entiat R.	150,000
GCFMP	LEAV	FWS	fingerling*	42	Entiat R.	85,500
GCFMP	ENT	FWS	unknown*	42	Entiat R.	50,400
GCFMP	ENT	FWS	fingerling	43	Entiat R.	55,900
GCFMP	ENT	FWS	unknown*	44	Entiat R.	24,900
GCFMP	ENT	FWS	unknown	45	Entiat R.	25,700
Methow	ENT	FWS	yearling	45	Entiat R.	27,700
Carson	ENT	FWS	yearling	45	Entiat R.	8,200
Entiat	ENT	FWS	yearling	46	Entiat R.	192,400
Entiat	ENT	FWS	unknown	46	Entiat R.	22,300
Entiat	ENT	FWS	fingerling	47	Entiat R.	251,400
Entiat	ENT	FWS	fingerling	49	Entiat R.	235,200
Entiat	ENT	FWS	fingerling	50	Entiat R.	432,600
Entiat	ENT	FWS	fingerling	51	Entiat R.	488,500
Entiat	ENT	FWS	unknown	51	Entiat R.	110,300
Entiat	ENT	FWS	fingerling	48	Entiat R.	396,700
Entiat	ENT	FWS	fingerling	52	Entiat R.	281,000
Entiat	ENT	FWS	fingerling	53	Entiat R.	404,500
Entiat	ENT	FWS	yearling	53	Entiat R.	254,600
Entiat	ENT	FWS	yearling	54	Entiat R.	212,000
Entiat	ENT	FWS	fingerling	55	Entiat R.	228,800
Entiat	ENT	FWS	yearling	55	Entiat R.	212,000
Entiat	ENT	FWS	yearling	56	Entiat R.	250,500
Entiat	ENT	FWS	fingerling	57	Entiat R.	32,900
Entiat	ENT	FWS	yearling	57	Entiat R.	273,900
Entiat	ENT	FWS	fingerling	58	Entiat R.	251,300
Entiat	ENT	FWS	yearling	58	Entiat R.	137,500
Entiat	ENT	FWS	fingerling	59	Entiat R.	522,500
Entiat	ENT	FWS	yearling	60	Entiat R.	143,800
Entiat	ENT	FWS	yearling	61	Entiat R.	152,300
Entiat	ENT	FWS	yearling	62	Entiat R.	316,500
Entiat	ENT	FWS	yearling	63	Entiat R.	229,800
Entiat	ENT	FWS	fingerling	64	Entiat R.	230,100
Sprng Cr.	ENT	FWS	fingerling	64	Entiat R.	990,800
Wells	ENT	FWS	yearling	76	Entiat R.	294,000
					Total =	8,617,300
Methow River plants - Summer chinook salmon						
GCFMP	LEAV	FWS	fingerling*	41	Methow R	182,000
GCFMP	WINT	FWS	fingerling	43	Methow R.	66,600
GCFMP	WINT	FWS	fingerling	44	Methow R.	10,600
Entiat	WINT	FWS	fingerling	46	Methow R.	480,600

Table 2. Continued.

Stock[a]	Hatchery[b]	Agency[c]	Class[d]	Year of Plant	Stream[e]	Number Planted
Entiat	WINT	FWS	fingerling	47	Methow R.	112,131
Entiat	WINT	FWS	fry	47	Methow R.	94,681
Methow	WINT	FWS	fry*	51	Methow R.	150,341
Methow	WINT	FWS	fingerling*	52	Methow R.	31,390
Methow	WINT	FWS	fry*	52	Methow R.	151,140
Methow	WINT	FWS	fingerling*	56	Methow R.	69,487
Methow	WINT	FWS	fry*	57	Methow R.	66,937
Wells	WINT	FWS	yearling	77	Methow R.	213,355
Wells	WINT	FWS	yearling	78	Methow R.	501,664
Wells	WINT	FWS	yearling	79	Methow R.	236,787
Wells	WINT	FWS	yearling	81	Methow R.	170,500
Wells	WINT	FWS	yearling	82	Methow R.	268,100
Methow	WINT	FWS	yearling	83	Methow R.	170,500
Wells	WELLS	WDF	fingerling	87	Methow R.	212,732
Wells	WELLS	WDF	fingerling	88	Methow R.	212,413
Wells	ROCK I	WDF	yearling	91	Methow R.	420,000
Wells	ROCK I	WDF	yearling	92	Methow R.	391,650
Wells	ROCK I	WDF	yearling	93	Methow R.	540,900
					Total =	4,754,508
Wenatchee River plants - Summer chinook salmon						
GCFMP	LEAV	FWS	fingerling*	41	Icicle R.	135,500
GCFMP	LEAV	FWS	fingerling*	42	Icicle R.	200,800
GCFMP	LEAV	FWS	fingerling*	44	Icicle R.	59,000
Leav	LEAV	FWS	unknown	46	Icicle R.	9,000
Leav	LEAV	FWS	yearling	47	Icicle R.	73,000
Leav	LEAV	FWS	fingerling	53	Icicle R.	80,700
Leav	LEAV	FWS	fingerling	55	Icicle R.	21,200
Leav	LEAV	FWS	fingerling	56	Icicle R.	1,200
Leav	LEAV	FWS	fingerling	57	Icicle R.	6,700
Leav	LEAV	FWS	fingerling	58	Icicle R.	79,800
Leav	LEAV	FWS	fingerling	59	Icicle R.	3,700
Leav	LEAV	FWS	fingerling	60	Icicle R.	19,000
Leav	LEAV	FWS	fingerling	61	Icicle R.	10,200
Leav	LEAV	FWS	fingerling	62	Icicle R.	6,500
Wenatch	ROCK I	WDF	yearling	91	Wenatchee R.	720,000
Wenatch	ROCK I	WDF	yearling	92	Wenatchee R.	124,400
Wenatch	ROCK I	WDF	yearling	93	Wenatch R.	191,179
					Total =	1,741,879
Wenatchee River plants - Fall chinook salmon						
GCFMP	LEAV	FWS	fingerling	43	Icicle Cr.	70,900
LWhite	LEAV	FWS	fingerling	46	Icicle Cr.	616,000
Sprng Cr.	LEAV	FWS	fry	65	Icicle Cr.	2,854,000
Sprng Cr.	LEAV	FWS	fingerling	65	Icicle Cr.	68,000
Eagle Cr.	LEAV	FWS	fry	67	Icicle Cr.	659,000
					Total =	4,267,900

Table 2. Continued.

Stock[a]	Hatchery[b]	Agency[c]	Class[d]	Year of Plant	Stream[e]	Number Planted
Okanogan River plants - Summer chinook salmon						
Wells	ROCK I	WDF	yearling	91	Similkameen R.	352,600
Wells	ROCK I	WDF	yearling	92	Similkameen R.	542,000
Wells	ROCK I	WDF	yearling	93	Similkameen R.	675,500
					Total =	1,570,100
Columbia River plants - Summer chinook salmon						
Wells	WELLS	WDF	fingerling	68	Columbia R.	61,000
Wells	WELLS	WDF	fry	68	Columbia R.	2,077,000
Wells	WELLS	WDF	fry	69	Columbia R.	3,443,654
Wells	WELLS	WDF	fry	70	Columbia R.	3,074,086
Wells	WELLS	WDF	fingerling	70	Columbia R.	989,700
Wells	WELLS	WDF	yearling	71	Columbia R.	359,000
Wells	WELLS	WDF	fry	71	Columbia R.	1,452,000
Wells	WELLS	WDF	unknown	72	Columbia R.	2,373,200
Wells	WELLS	WDF	unknown	73	Columbia R.	2,095,500
Wells	WELLS	WDF	fingerling	74	Columbia R.	875,800
Wells	WELLS	WDF	fry	74	Columbia R.	1,575,000
Wells	WELLS	WDF	yearling	75	Columbia R.	284,700
Wells	WELLS	WDF	fingerling	75	Columbia R.	673,250
Wells	WELLS	WDF	yearling	76	Columbia R.	155,024
Wells	WELLS	WDF	fingerling	76	Columbia R.	668,390
Wells	WELLS	WDF	fry	76	Columbia R.	3,000,904
Wells	WELLS	WDF	yearling	77	Columbia R.	94,353
Wells	WELLS	WDF	fingerling	77	Columbia R.	501,879
Wells	WELLS	WDF	fry	77	Columbia R.	248,574
Wells	WINT	FWS	yearling	77	Columbia R.	311,200
Wells	WELLS	WDF	yearling	78	Columbia R.	347,104
Wells	WELLS	WDF	fingerling	78	Columbia R.	552,682
Wells	WELLS	WDF	fry	78	Columbia R.	100,000
Wells	WINT	FWS	yearling	78	Columbia R.	94,416
Wells	WELLS	WDF	fingerling	79	Columbia R.	2,264,065
Wells	WINT	FWS	yearling	79	Columbia R.	77,602
Wells	WELLS	WDF	yearling	80	Columbia R.	313,883
Wells	WELLS	WDF	fingerling	80	Columbia R.	2,323,963
Wells	ROCK R	WDF	fingerling	81	Columbia R. (V)	29,547
Wells	WELLS	WDF	fingerling	81	Columbia R.	2,271,652
Wells	ROCK R	WDF	yearling	82	Columbia R.	101,520
Wells	WELLS	WDF	fingerling	82	Columbia R.	2,611,746
Wells	ROCK R	WDF	yearling	83	Columbia R. (V)	175,898
Wells	WELLS	WDF	fingerling	83	Columbia R.	1,432,900
Wells	WELLS	WDF	fingerling	84	Columbia R.	1,240,865
Wells	WELLS	WDF	yearling	85	Columbia R.	186,000
Wells	WELLS	WDF	fingerling	85	Columbia R.	1,549,000
Wells	WELLS	WDF	yearling	86	Columbia R.	200,440
Wells	WELLS	WDF	fingerling	86	Columbia R.	1,791,617
Wells	WELLS	WDF	yearling	87	Columbia R.	394,360
Wells	WELLS	WDF	fingerling	87	Columbia R	1,018,709
Wells	WELLS	WDF	yearling	88	Columbia R.	385,213
Wells	WELLS	WDF	fingerling	88	Columbia R.	1,759,933

Table 2. Continued.

Stock[a]	Hatchery[b]	Agency[c]	Class[d]	Year of Plant	Stream[e]	Number Planted
Wells	WELLS	WDF	yearling	88	Columbia R.	582,223
Wells	WELLS	WDF	fingerling	88	Columbia R.	1,562,710
Wells	WELLS	WDF	yearling	89	Columbia R.	429,042
Wells	WELLS	WDF	fingerling	89	Columbia R.	1,781,788
Wells	WELLS	WDF	fry	89	Columbia R.	386,269
Wells	WELLS	WDF	yearling	90	Columbia R.	602,118
Wells	WELLS	WDF	fingerling	90	Columbia R.	1,310,656
Wells	WELLS	WDF	yearling	91	Columbia R.	436,024
Wells	WEllS	WDF	fingerling	91	Columbia R.	329,669
Wells	WEllS	WDF	yearling	92	Columbia R.	371,000
Wells	WEllS	WDF	fingerling	92	Columbia R.	630,000
Wells	WEllS	WDF	yearling	92	Columbia R.	302,000
Wells	WEllS	WDF	yearling	93	Columbia R.	392,000
					Total =	54,653,496

Columbia River plants - Fall chinook salmon

Stock	Hatchery	Agency	Class	Year of Plant	Stream	Number Planted
Priest	PRIEST	WDF	fingerling	64	Columbia R.	1,073,800
Priest	PRIEST	WDF	fingerling	65	Columbia R.	349,000
Priest	PRIEST	WDF	fingerling	66	Columbia R.	1,177,000
Priest	PRIEST	WDF	fingerling	67	Columbia R.	1,470,000
Priest	PRIEST	WDF	fingerling	68	Columbia R.	7,141,000
Priest	PRIEST	WDF	fingerling	69	Columbia R.	2,990,500
Priest	PRIEST	WDF	fingerling	70	Columbia R.	1,995,300
Priest	PRIEST	WDF	fingerling	71	Columbia R.	1,804,200
Wells	WELLS	WDF	yearling	71	Columbia R.	359,000
Wells	WELLS	WDF	fry	71	Columbia R.	1,425,000
Priest	PRIEST	WDF	fingerling	72	Columbia R.	2,853,698
Priest	PRIEST	WDF	fingerling	73	Columbia R.	660,128
Priest	PRIEST	WDF	fingerling	74	Columbia R.	2,913,587
Priest	PRIEST	WDF	fingerling	75	Columbia R.	1,285,508
Simpson	WELLS	WDF	fingerling	75	Columbia R.	673,250
Simpson	ROCK R	WDF	yearling	75	Columbia R.	41,639
Priest	PRIEST	WDF	fingerling	76	Columbia R.	1,888,277
Priest	PRIEST	WDF	fingerling	77	Columbia R.	1,226,061
Priest	PRIEST	WDF	fingerling	78	Columbia R.	1,460,606
unknown	RING	WDF	fingerling	78	Columbia R.	497,806
Priest	PRIEST	WDF	fingerling	79	Columbia R.	1,199,988
Priest	RING	WDF	yearling	79	Columbia R.(RG)	275,000
Col. R.	PRIEST	WDF	fingerling	80	Columbia R.	2,383,690
Priest	RING	WDF	fingerling	80	Columbia R.(RG)	668,800
Elokomin	ROCK R	WDF	yearling	81	Columbia R.	296,127
Col. R.	PRIEST	WDF	fingerling	81	Columbia R.	946,408
Priest	PRIEST	WDF	fingerling	81	Columbia R.	2,237,970
Bonn	PRIEST	WDF	fingerling	81	Columbia R.	1,635,006
Bonn	RING	WDF	yearling	82	Sprng. Cr.	788,000
Priest	PRIEST	WDF	fingerling	82	Columbia R.	3,821,932
Bonn	PRIEST	WDF	fingerling	82	Columbia R.	1,687,309
Bonn	ROCK R	WDF	fingerling	83	Columbia R.	871,900
Bonn	SPRING	FWS	fingerling	83	Columbia R.(V)	640,857
Priest	PRIEST	WDF	fingerling	83	Columbia R.	4,245,000
Bonn	PRIEST	WDF	fingerling	83	Columbia R.	6,051,700

Table 2. Continued.

Stock[a]	Hatchery[b]	Agency[c]	Class[d]	Year of Plant	Stream[e]	Number Planted
Bonn	ROCK R	WDF	yearling	84	Columbia R.(V)	226,276
Sn x Pr	ROCK R	WDF	fingerling	84	Columbia R.(V)	533,800
Priest	PRIEST	WDF	fingerling	84	Columbia R.	245,000
Bonn	PRIEST	WDF	fingerling	84	Columbia R.	9,497,701
Sn x Pr	ROCK R	WDF	yearling	85	Columbia R.(V)	253,800
Sn x Pr	ROCK R	WDF	fingerling	85	Columbia R.(V)	95,500
Priest	PRIEST	WDF	fingerling	85	Columbia R.	6,988,800
Sn x Pr	ROCK R	WDF	yearling	86	Columbia R.(V)	252,268
Priest	PRIEST	WDF	yearling	86	Columbia R.	196,000
Priest	PRIEST	WDF	fingerling	86	Columbia R.	6,363,000
Priest	ROCK R	WDF	yearling	87	Columbia R.(V)	237,467
Wells(F)	ROCK R	WDF	fingerling	87	Columbia R.(V)	247,500
Priest	PRIEST	WDF	fingerling	87	Columbia R.	6,048,000
Wells (F)	ROCK R	WDF	yearling	88	Columbia R.	229,802
Priest	PRIEST	WDF	fingerling	88	Columbia R.	7,709,000
Priest	ROCK R	WDF	yearling	89	Columbia R.	190,000
Priest	PRIEST	WDF	fingerling	89	Columbia R.	5,404,500
Priest	ROCK R	WDF	yearling	90	Columbia R.	230,000
Priest	PRIEST	WDF	fingerling	90	Columbia R.	6,431,100
Wells(F)	ROCK R	WDF	fry	90	Columbia R.	679,800
Wells(F)	ROCK R	WDF	yearling	91	Columbia R.	220,400
Priest	PRIEST	WDF	fingerling	91	Columbia R.	5,239,700
Priest	PRIEST	WDF	fingerling	92	Columbia R.	7,000,100
Priest	ROCK R	WDF	yearling	93	Columbia R.	201,000
Priest	PRIEST	WDF	fingerling	93	Columbia R.	5,451,000
Priest	ROCK R	WDF	fingerling	93	Columbia R.	1,217,601
Wells(F)	ROCK R	WDF	fingerling	93	Columbia R.	304,399
					Total =	132,728,561
Yakima River plants - Fall chinook salmon (incomplete records)						
Klick	KLICK	WDF	yearling	76	Yakima R.	20,613
unknown	unknown		fingerling	84	Yakima R.	584,633
Bonn	SPRING	FWS	fingerling	85	Low. Yakima	1,864,155
Bonn	LEAV	FWS	fingerling	86	Low. Yakima	1,690,319
Leav	LEAV	FWS	yearling	87	Low. Yakima	215,126
unknown	unknown		fingerling	87	Low. Yakima	1,071,589
Priest	BUR	FWS	fingerling	87	Low. Yakima	17,786
Bonn	LEAV	FWS	fingerling	88	Yakima R.	1,574,671
Bonn	YAK	FWS	fingerling	88	Yakima R.	246,012
Bonn	SENN	COOP	fingerling	88	Yakima R.	9,825
unknown	unknown		fingerling	89	Low. Yakima	1,770,437
unknown	unknown		fingerling	89	Yakima R.	200,077
unknown	unknown		fingerling	90	Low. Yakima	1,360,078
unknown	unknown		fingerling	90	Yakima R.	199,980
unknown	unknown		fingerling	93	Low. Yakima	751,134
					Total =	10,804,688

Table 2. Continued.

Stock[a]	Hatchery[b]	Agency[c]	Class[d]	Year of Plant	Stream[e]	Number Planted
Release site not specified - Summer chinook salmon						
GCFMP	LEAV	FWS	--	43	--	218,000
Leav	LEAV	FWS	fingerling	49	--	50,600
Leav	LEAV	FWS	fingerling	51	--	10,300
Leav	LEAV	FWS	fingerling	52	--	139,300
					Total =	418,200

[a] Stock Abbreviations

GCFMP = Grand Coulee Fish Maintenence Project
Methow = Methow River
Carson = Carson National Fish Hatchery
Entiat = Entiat National Fish Hatchery
Sprng Cr. = Spring Creek National Fish Hatchery
Wells = Wells Hatchery and/or Wells Spawning Channel
Leav = Leavenworth National Fish Hatchery
Wenatch = Wenatchee River
L White = Little White Salmon National Fish Hatchery
Eagle Cr. = Eagle Creek National Fish Hatchery
Priest = Priest Rapids Hatchery
Simpson = Simpson Hatchery
Col. R. = mainstem mid-Columbia River
Elokomin = Elokomin Hatchery
Bonn = Bonneville Hatchery (Oregon Dep.of Fish and Wildlife)
Sn X Pr = Snake River by Priest Rapids hybrids
Wells(F) = Wells Hatchery/Spawning Channel fall chinook salmon
unknown = origin unknown or unspecified

[b] Hatchery Abbreviations

LEAV = Leavenworth National Fish Hatchery
ENT = Entiat National Fish Hatchery
WINT = Winthrop National Fish Hatchery
WELLS = Wells Hatchery and/or spawning channel
ROCK I = Rock Island Hatchery
ROCK R = Rocky Reach Hatchery and/or spawning channel
RING = Ringold Rearing Ponds
SPRING = Spring Creek National Fish Hatchery
BUR = Bureau of Reclamation
YAK = various acclimation facilities

[c] Agency Abbreviations

FWS = United States Fish and Wildlife Service
WDF = Washington Deapartment of Fish and Wildlife
COOP = Cooperative effort between WDF and another party
ODFW = Oregon Department of Fish and Wildlife

[d] Class: fry = post hatchling
unknown = size/age unknown or not specified
* = includes both spring and summer chinook salmon

[e] Stream (location planted): (V) = at Vantage
(RG)= at Ringold

of Grand Coulee Dam (discussed below). Three factors appear to be primarily responsible for the increase: 1) the number of ocean-type chinook salmon in the MCR in the early 1940s was extremely low, so any improvements to the system would result in an increase; 2) at least partial success of the Grand Coulee Fish Maintenance Project, which corrected some practices harmful to salmon and began supplementation efforts in the MCR Basin (Fish and Hanavan 1948), and 3) displacement of upriver stocks into the Hanford Reach.

Grand Coulee Fish Maintenance Project, 1939-43

The single most important event affecting the distribution of ocean-type chinook salmon in the middle and upper Columbia River was the construction of the Grand Coulee Dam (RKm 959) in 1939, which completely eliminated passage of anadromous salmon above that point. To compensate for the loss of habitat, the federal government initiated the Grand Coulee Fish Maintenance Project (GCFMP). The GCFMP sought to maintain fish runs in the Columbia River above Rock Island Dam (RKm 730) by two means: 1) improving salmonid habitat; and 2) establishing hatchery operations (Fish and Hanavan 1948).

The primary method of habitat improvement during the GCFMP was the obligatory installation of screens on irrigation diversions in tributaries of the mid-Columbia River. The screens prevented juvenile chinook salmon from being drawn into irrigation systems and presumably made a major contribution to the increase in MCR populations since the 1940s (discussed below). In contrast, chinook salmon populations in the Yakima

River did not recover during the same period, as screening of irrigation diversions was not obligatory in that system (Robison 1957).

All adult fish passing Rock Island Dam from 1939 to 1943 were taken either to USFWS hatcheries on the Wenatchee or Methow Rivers for artificial spawning or to fenced reaches of the Wenatchee or Entiat River for natural spawning. Juveniles derived from adults of mixed-stock origin crossing Rock Island Dam were reared at USFWS hatcheries and transplanted into the Wenatchee, Methow, and Entiat Rivers.

Fish trapping operations began in May 1939 and continued through late fall each year until 1943. A total of five complete brood years were affected. Early-run fish (stream type) were treated separately from late-run fish (ocean type), and few distinctions were made regarding either "summer" or "fall" components of the late run, as all late-run fish were captured.

Fish and Hanavan (1948) estimated that 20 to 34% (mean = 27%) of the fish passing Rock Island Dam each year were, by present day standards, "fall-run" chinook salmon (i.e., crossed Rock Island Dam after 20 August). Because the GCFMP continued for 5 years and used all late-run fish, including those destined for now-inaccessible spawning areas in British Columbia, all present day ocean-type chinook salmon above Rock Island Dam are the progeny of the mixture of chinook salmon collected at Rock Island Dam from 1939 to 1943.

The only MCR tributary that did not receive spawning adults or mixed-stock hatchery juveniles during the 5-year GCFMP was the

Okanogan River (Fish and Hanavan 1948, Mullan et al. 1992b). All chinook salmon adults destined for the Okanogan River from 1939 to 1943 were intercepted and either forced to spawn in other tributaries or in one of the USFWS hatcheries.

As none of the progeny of GCFMP fish were planted in the Okanogan River during this 5-year period, the native population of ocean-type chinook salmon in the Okanogan River was virtually eliminated. It is possible that 6-year old adults returned in 1944, thereby escaping the effects of GCFMP; but the low frequency of this age class (<1%) in Columbia River chinook salmon populations makes this an unlikely event. The ocean-type chinook salmon now observed in the Okanogan River are likely the progeny of mixed-stock strays from other tributaries or from the mainstem Columbia River. These strays must have repopulated the Okanogan River after termination of the GCFMP.

Artificial Propagation

Hatchery efforts with ocean-type chinook salmon in the MCR have been continuous and intensive since the implementation of the GCFMP. Three USFWS hatcheries were established during the GCFMP, and six Washington Department of Fisheries facilities have been constructed since then (Table 3). Currently, only the Leavenworth and Entiat facilities are not rearing ocean-type chinook salmon. As noted above, by 1944, all MCR chinook salmon were essentially the progeny of relocated stock (Fish and Hanavan 1948). Since 1941, over 200 million ocean-type chinook salmon have been released into the MCR Basin as either 0-age or yearling

Table 3. Rearing facilities for chinook salmon in the mid-Columbia River operated by the U.S. Fish and Wildlife Service (USFWS) and Washington Department of Fisheries (WDF). Modified from Chapman et al. (1994).

Facility	Agency	Years*	River
Leavenworth NFH	USFWS	1941-present	Wenatchee
Entiat NFH	USFWS	1941-1964	Entiat
Winthrop NFH	USFWS	1942-1983	Methow
Priest Rapids	WDF	1963-present	mid-Columbia
Rocky Reach	WDF	1974-present	mid-Columbia
Wells	WDF	1967-present	mid-Columbia
Eastbank	WDF	1990-pesent	Wenatchee
acclimation ponds	WDF	1990-present	Methow
acclimation ponds	WDF	1990-present	Okanogan

* Years when ocean-type chinook salmon were reared.
NFH = National Fish Hatchery.

fish (Table 2). Only approximately 6.2 million (~3.0%) of these fish were from stocks outside the MCR Basin.

Phenotypic Characteristics

Variation in phenotypic characteristics of chinook salmon in the Columbia River Basin was evaluated in a multivariate study by Schreck et al. (1986), who examined meristic and morphometric variation in 56 samples of ocean- and stream-type chinook salmon. Previous analysis of 20 trusslike morphometric characters had shown that fish with similar life histories tended to have similar body shapes (Winans 1984). Schreck et al. (1986) also found that ocean-type fish from the MCR grouped together (both "fall-run" and "summer-run"), and stream-type fish from the Snake River in Idaho grouped together (both "spring-run" and "summer-run").

In the same study, a multivariate analysis of nine meristic characters revealed two major groups in the Columbia River Basin. The first group contained stream-type chinook salmon from west of the Cascade Mountains and all ocean-type chinook salmon from the MCR. The other group contained stream-type chinook salmon from east of the Cascade Mountains and stream-type chinook salmon from Idaho. For all but one of the meristic characters analyzed, results indicated that between-year variability did not account for substantial levels of variation among stocks.

Genetic Characteristics

To evaluate chinook salmon populations in the Snake River, Matthews and Waples (1991) compiled a 21-locus allozymic (protein electrophoretic) data set for 44 samples within the Columbia River Basin. This analysis used relatively few loci to allow inclusion of samples dating back to 1980. Three major groups were identified: 1) fall-run and MCR summer-run fish; 2) Willamette River populations; and 3) spring-run and Snake River summer-run fish. Because summer- and spring-run fish from the Snake River were genetically similar and shared similar life histories, they were considered a single species as defined by the ESA.

Marshall (1993, 1994a and b) examined a 36-locus data set for chinook salmon which included data for several new populations in the MCR and which used only recent samples (Appendix). This data set provided a more comprehensive view of the pattern of genetic differentiation among MCR populations than the data set described by Matthews and Waples (1991). Marshall (1994a and b) provided dendrograms based on cluster analyses of two common genetic distance measures.

The dendrogram based on Nei's (1978) genetic distance produced results similar to those found by Matthews and Waples (1991). A clear separation between ocean- and stream-type fish in the Columbia River Basin was observed (Fig. 2). Notably, after correcting for sampling error, genetic distances between fall- and summer-run fish from the MCR were essentially zero.

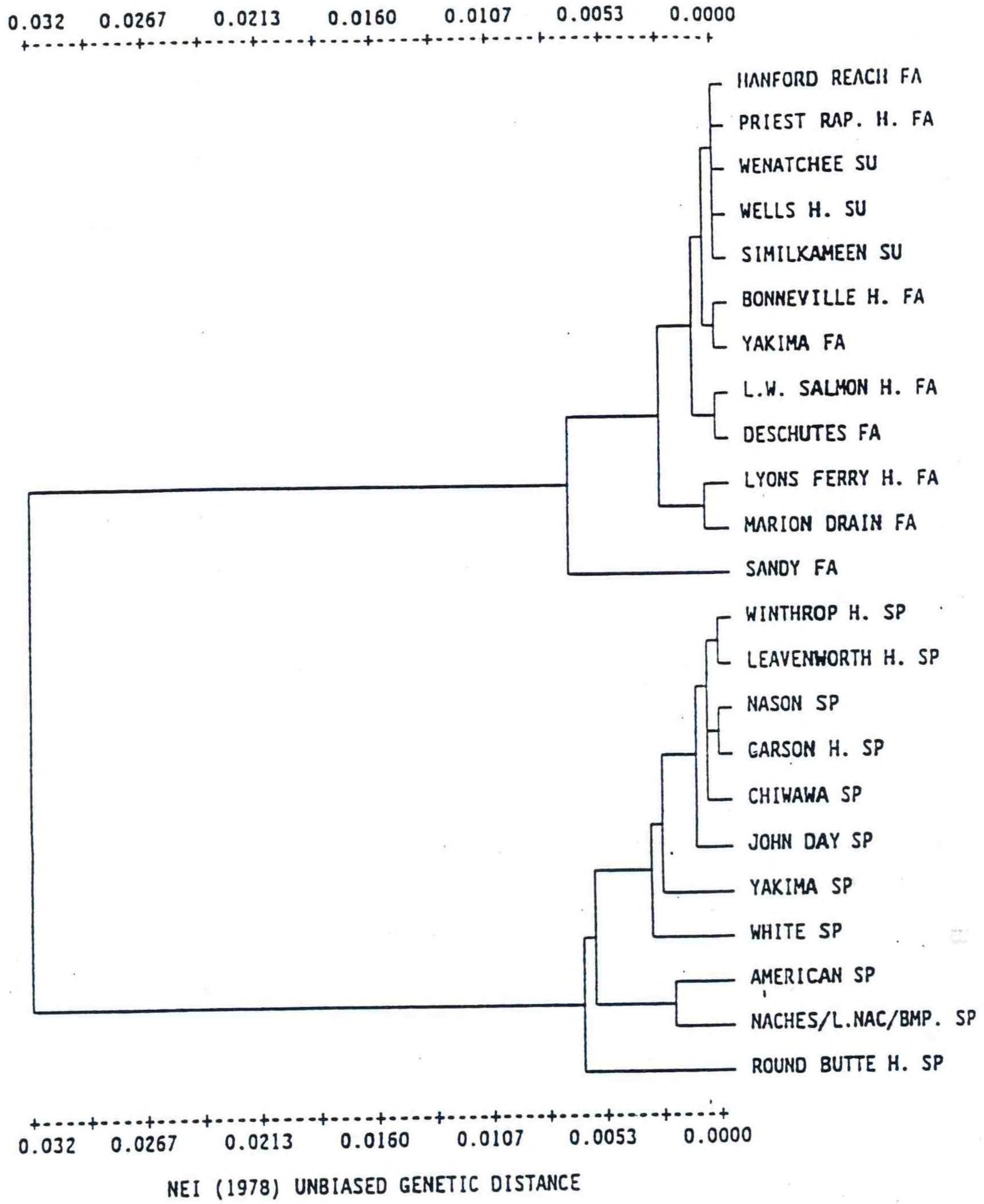

Figure 2. Genetic relationships among selected samples of chinook salmon in the Columbia River Basin based on Nei's unbiased genetic distance (1978) and unweighted, pair-group method and arithmetic averages (UPGMA; Sneath and Sokal, 1963) for 36 loci (Marshall 1994a and b). Loci used and sample information are described in the Appendix. SP = spring-run, SU = summer-run, and FA = fall-run.

The same general pattern was seen in the dendrogram based on Cavalli-Sforza and Edwards (1967) chord distance (Fig. 3): the clearest distinction was between the stream-type and ocean-type fish. This analysis differs from Nei's (1978) in that Yakima River ocean-type fish aligned more closely to Hanford Reach/Priest Rapids stocks than to Bonneville Hatchery fish, and Deschutes River fish aligned with Lyons Ferry Hatchery/Marion Drain fish rather than with fish from the Little White Salmon Hatchery. Nei's unbiased distance measure (Nei 1978) adjusts for increased genetic similarity due to small sample sizes, whereas Cavalli-Sforza and Edwards' (1967) distance metric does not. However, as in Nei's dendrogram, MCR samples formed a distinct group in which summer- and fall-run samples clustered with one another. In these dendrograms, we included a sample from the Sandy River, which feeds into the lower Columbia River below Bonneville Dam, to provide an indication of the level of divergence between fall chinook salmon from the lower and middle reaches of the Columbia River.

The close genetic relationship among the late-run MCR samples was also seen in pair-wise G-tests comparing frequencies of polymorphic loci among samples. Marshall (1993) reported that all the "summer-run" samples shared a high degree of genetic similarity (i.e., samples from the Wenatchee River, Wells Hatchery, and the Similkameen River were not significantly different ($P > 0.05$)). Further, the Priest Rapids Hatchery sample of fall-run fish was not significantly different from the Hanford Reach (fall-run), Wells Hatchery (summer-run), or

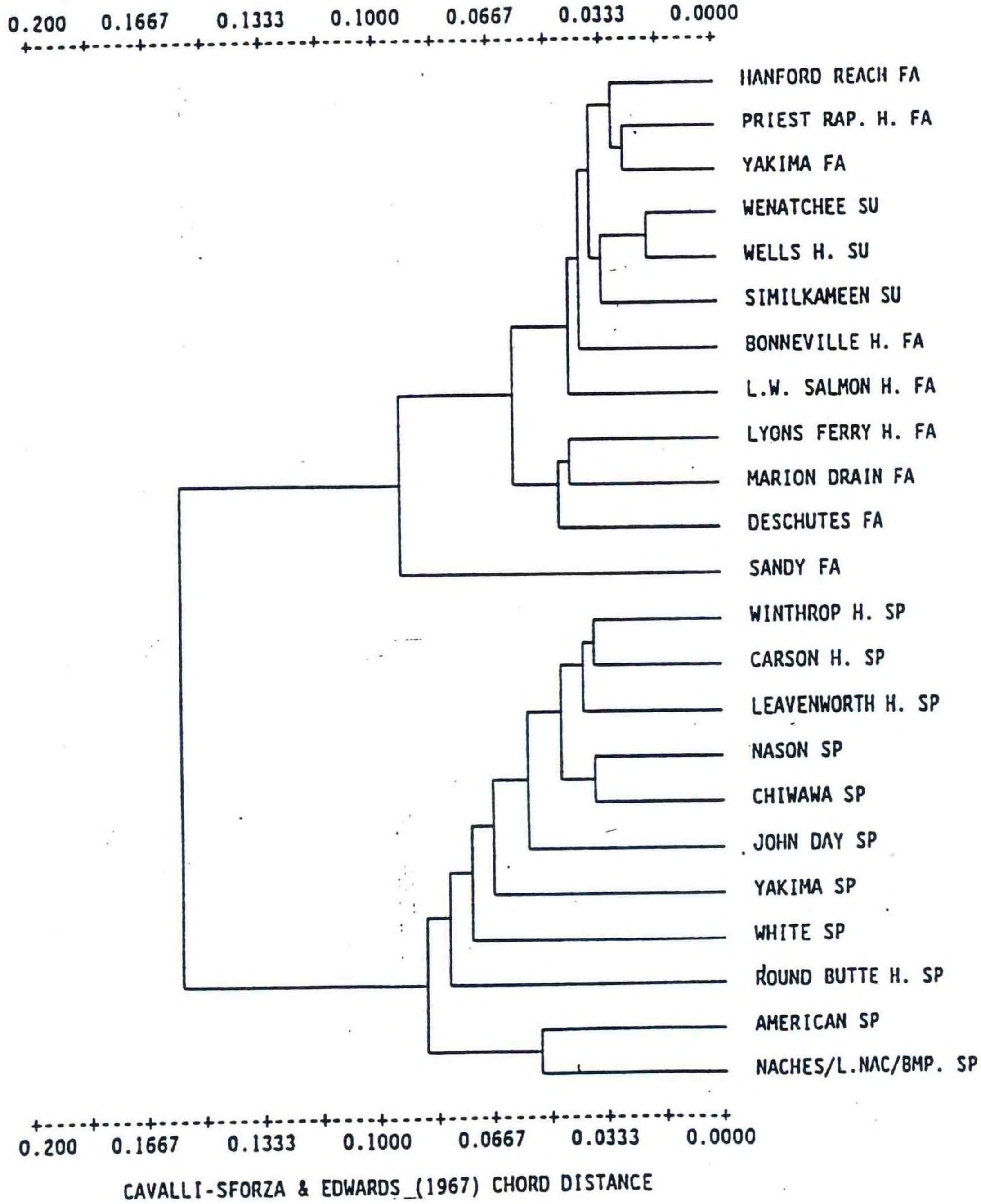

Figure 3. Genetic relationships among selected samples of chinook salmon in the Columbia River Basin based on Cavalli-Sforza and Edwards (1967) chord distance and UPGMA clustering for 36 loci (Marshall 1994a and b). Same loci and samples as Figure 2. SP = spring-run, SU = summer-run, and FA = fall-run.

Similkameen River (summer-run) samples, and it differed only slightly from the Wenatchee River (summer-run) sample ($0.01 < P < 0.05$).

These same patterns of genetic variation among populations of chinook salmon in the basin have also been reported by other investigators. Using similar clustering analyses of allozyme data sets based on fewer loci, Schreck et al. (1986), Utter et al. (1987), and Hershberger et al. (1988) all found a close relationship between summer- and fall-runs in the MCR. Utter et al. (1989) also showed a high similarity between "fall-run" and "summer-run" samples in the MCR using multidimensional analysis of allozyme data.

POPULATION ABUNDANCE AND THRESHOLD EVALUATIONS

Historic Abundance Estimates and Trends

Historic abundance estimates for chinook salmon in the upper and middle Columbia River Basin are in the hundreds of thousands (Mullan 1987). However, with the advent of commercial fisheries in the 1800s, these populations were declining by 1900. A well-documented example of this pattern of change concerns stocks in the Yakima River. Estimates of salmon returns (all species) to the Yakima River in the mid-1800s range from 160,000 to 250,000 (Robison 1957). With agricultural and fisheries development, the run size (all species) fell to 20,000 from 1875 to 1905, and then dropped to 1,000 around 1930 (Robison 1957). Summer run chinook salmon were last seen in the Yakima River in 1970 (YFP 1992).

Estimates of fall chinook salmon from 1983 to 1987 averaged 570 (range 221 to 1,332; Fast et al. 1989).

There is some historical evidence that chinook salmon upstream from the MCR underwent periodic fluctuations in abundance. Native Americans in this portion of the Columbia River Basin traditionally depended on salmon for subsistence. Yet episodes of starvation among Native American tribes were recorded in 1811, from 1826 to 1829, and in 1831 (Mullan et al. 1992b). These episodes appear to be linked to the failure of chinook salmon to return to Kettle Falls, the primary aboriginal fishing area on the upper-Columbia River (Fig. 1), in sufficient numbers to sustain the local population (Mullan et al. 1992b). In 1831, salmon had to be procured from Fraser River tribes to sustain the traders at Fort Walla Walla through the winter, since few Columbia River chinook salmon had been caught the previous summer. Assuming that spawning and rearing habitat were still pristine at the time, it is likely that variations in ocean conditions were responsible for the extreme fluctuations of chinook salmon populations of the upper Columbia River observed by the earliest settlers (Mullan et al. 1992b). Similarly, chinook salmon abundance in the Fraser River--an undammed river system--has fluctuated substantially over time, apparently due to variations in ocean conditions (Richards and Olsen 1993).

Present Abundance Estimates and Trends

In considering whether ocean-type chinook salmon of the MCR are threatened or endangered according to the ESA, we evaluated both qualitative and quantitative information. Qualitative evaluations considered recent, published assessments of the status of chinook salmon stocks within the petitioned area by agencies or conservation groups (Nehlsen et al. 1991, WDF et al. 1993). These assessments are summarized in Table 4. Nehlsen et al. (1991) considered summer chinook salmon to be of "special concern" in the Okanogan River and at "moderate risk of extinction" in the Methow River. Summer chinook salmon in the Entiat River and spring chinook salmon in the Okanogan River were considered to be extinct. No other chinook salmon populations in the MCR were reported at risk. Washington Department of Fisheries (WDF et al. 1993) considered summer chinook salmon in the Okanogan and Methow Rivers to be "depressed" but rated all other existing summer and fall chinook salmon stocks in this region as "healthy."

Quantitative assessments were based on time series of adult counts at Columbia River dams and redd counts in the tributary rivers. However, counts from lower Columbia River dams provided little direct information about MCR ocean-type fish. First, these counts included summer-run chinook salmon from the Snake River. Second, there is abundant evidence that inflexible cutoff dates between spring-, summer-, and fall-run chinook salmon can lead to erroneous conclusions based on dam counts alone, particularly in years with unusual environmental and oceanic conditions, as discussed above. This second caveat also applies to attempts to separately enumerate summer- and fall-run chinook salmon at upriver dams. Therefore, we evaluated passage of summer- and fall-run chinook salmon as a single unit.

Table 4. Recent qualitative assessments of status of ocean-type chinook salmon stocks in the mid-Columbia region (Nehlsen et al. 1991, WDF et al. 1993).

River Basin	Run	Nehlsen et al. Risk Level[a]	WDF et al. (SASSI)[b] Origin	Production	Status
Similkameen	Summer	--	--	--	--
Okanogan	Summer	Special Concern	Native	Wild	Depressed
Methow	Summer	Moderate risk	Mixed	Wild	Depressed
Lake Chelan	Fall	--	Nonnative	Wild	Healthy
Entiat	Summer	Extinct	--	--	--
Wenatchee	Summer	--	Mixed	Wild	Healthy
Hanford	Fall	--	Native	Wild	Healthy
Yakima	Fall	--	Unknown	Composite	Healthy
Marion Drain	Fall	--	Native	Wild	Healthy

[a] Nehlsen et al. (1991) identified stocks as extinct, at high risk of extinction, at moderate risk of extinction, or of special concern. Their list did not include stocks that did not qualify for one of these categories. The dash indicates that the stock(s) was not mentioned.

[b] SASSI ("Salmon and Steelhead Stock Inventory," WDF et al. 1993) classified stocks by apparent genetic origin (native, nonnative, or mixed), by current production type (wild, hatchery, or composite), and by apparent stock status (critical, depressed, or healthy). These are preliminary classes, subject to later refinement, and reflect the consensus opinion of state and tribal biologists contributing to the report. Dash indicates that the stock(s) was not mentioned.

The petitioners provided only selected information about escapement in the MCR, and we consulted other sources to provide a more complete picture. Redd counts (including both summer- and fall-run fish) for the Wenatchee, Methow, Okanogan, and Similkameen Rivers all show large fluctuations, with very low points in the early 1980s (Fig. 4). Since that time, Wenatchee River redd counts have shown a substantial increase, while those for the other three rivers have shown no discernible trend. Over the entire available data series (1956-93), only the Methow River redd counts show a substantial downward trend (Table 5), although both the Methow and Okanogan River counts are substantially below peak counts from the late 1960s and early 1970s. Both the Similkameen and Wenatchee River counts show substantial upward trends over the full data series.

Historic counts of adult salmon ascending fish ladders at dams provide additional assessment of population abundance and trends. The longest record for the mid-Columbia River is from Rock Island Dam. Because of its location, counts from Rock Island Dam provide an index primarily of the petitioned stocks, not of the entire ESU. Counts of adult late-run ocean-type chinook salmon at this dam (Fig. 5) showed a decline in the late 1930s, followed by a substantial increase during the 1940s and 1950s. Since the late 1950s, abundance has fluctuated over about a three-fold range with no substantial trend. However, over this period, the summer component has been a decreasing proportion of the total run.

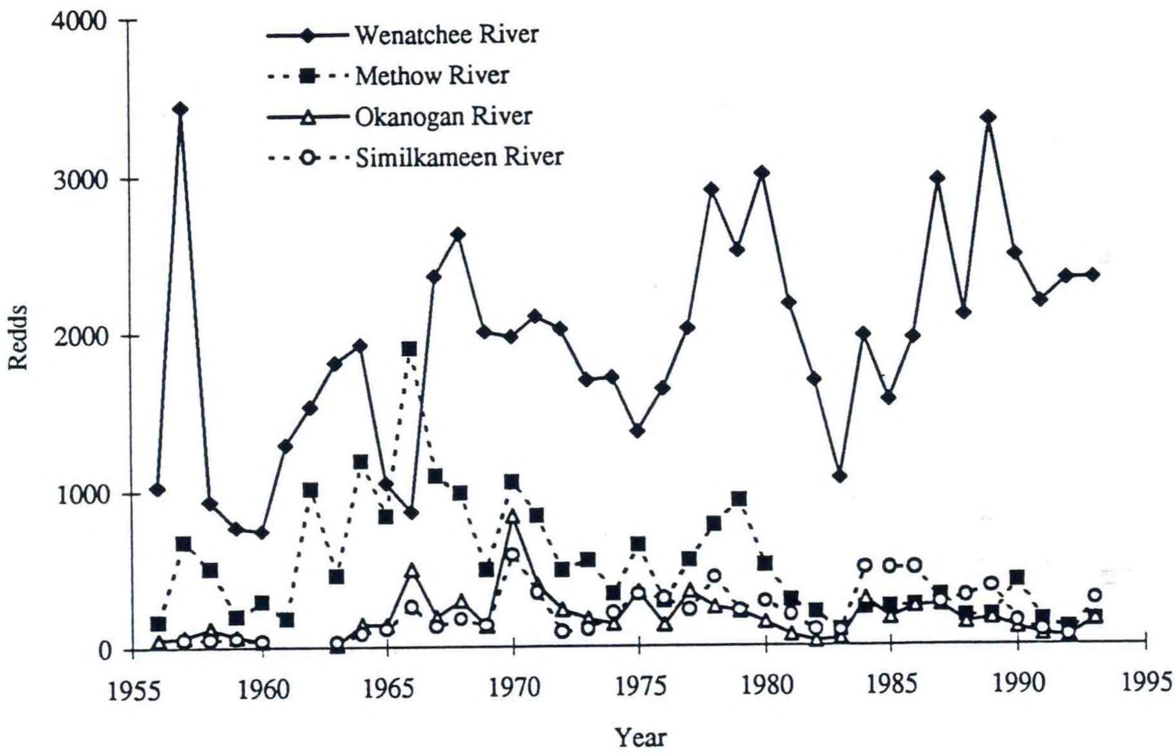

Figure 4. Ocean-type chinook salmon redd counts (expanded aerial counts) for the Wenatchee, Methow, Okanogan, and Similkameen Rivers, 1956-93. Data from Chapman et al. (1994, appendix D-2).

Table 5. Summary of recent 5-year average (1989-93) and percent annual change of ocean-type chinook salmon redd counts (expanded aerial counts) in the Columbia River Basin above Rock Island Dam (RIS). Percent annual change is based on exponential regression of passage counts against time for two time periods: the entire data series (1956-93), and the most recent 20 years (1974-93). Based on data from Chapman et al. (1994; appendix D-2).

Location	Average redd count	Percent annual change	
		Full series	Last 20 years
Similkameen	191	+2.8	-0.3
Okanogan	112	-0.1	-3.1
Methow	202	-2.9	-6.4
Wenatchee	2,530	+1.5	+1.6
Total above RIS*	3,064	+0.5	+0.3

* Includes a small number of redds counted in the Entiat River, the Chelan River, and the Columbia River between Rocky Reach Dam and Wells Dam.

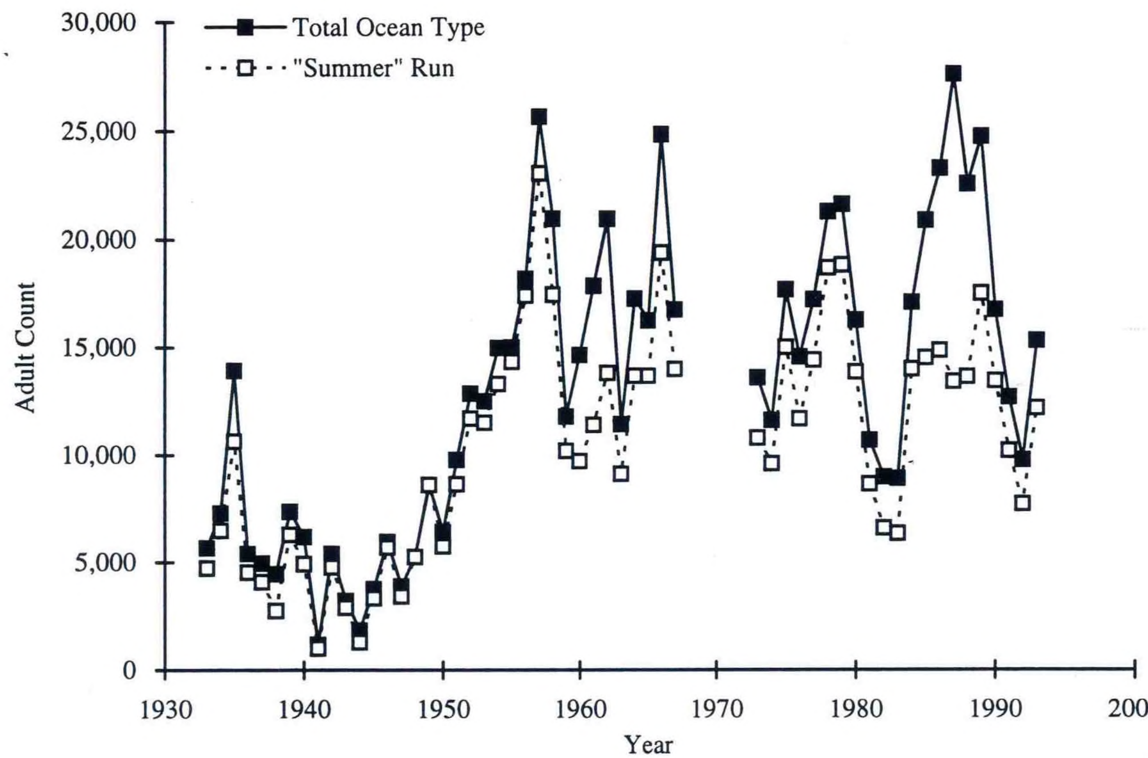

Figure 5. Counts of adult ocean-type chinook salmon passing Rock Island Dam, 1933-93. Based on data from Mullan (1987; counts for 1933-59) and the Coordinated Information System Computerized Distributed System (Anderson 1994; counts for 1960-93).

Counts of late-run ocean-type adult chinook salmon in 1991 and 1992 at mid-Columbia River dams were well below the 10-year average, and at some dams the 1992 counts were record lows. In 1993, counts at all dams were well above the 1992 low point, and most were near or above the recent (1984-93) 10-year average. While the low counts in 1991 and 1992 are of concern, they are not unprecedented. Similar low counts occurred in 1982 and 1983, after which counts increased to reach record highs at Priest Rapids and Rock Island Dams in the late 1980s. Average run-size and trend estimates for these dams are summarized in Table 6.

Total abundance of MCR ocean-type chinook salmon is relatively large, with a recent (1989-93) 5-year average annual estimate of 22,000 adults passing Priest Rapids Dam. An additional 42,000 adults spawned in the Hanford Reach and Yakima River, for a total 5-year average annual run of approximately 64,000 MCR ocean-type chinook salmon (Fig. 6). The number of fish spawning in Hanford Reach and Yakima River was estimated from McNary Dam counts, with counts from Priest Rapids Dam, Ice Harbor Dam, and various hatcheries subtracted. Note, however, that these estimates may be subject to large errors.

NMFS has not attempted to estimate extinction probabilities for these stocks and in previous status reviews has viewed such estimates with caution. However, two reports submitted to the administrative record (ADFG 1993, Chapman et al. 1994) have attempted such estimates. Both applied the model of Dennis et al. (1991) to an aggregate stock of mid-Columbia River chinook salmon. The Alaska Department of Fish and Game (ADFG 1993)

Table 6. Summary of recent 5-year average (1989-93) and percent annual change in adult ocean-type chinook salmon passing four mid-Columbia River dams. Percent annual change is based on exponential regression of passage counts against time for two time periods: the entire data series (varies by dam), and the most recent 20 years (1974-93). Based on data from the Coordinated Information System Computerized Distributed System (Anderson 1994).

Location	Run	Average run size	Percent annual change: Full series	Percent annual change: Last 20 years
Wells	Summer	2,369	-2.7	-3.3
	Fall	938	+1.9	+2.0
	Both	3,306	-1.9	-2.2
Rocky Reach	Summer	3,810	-4.5	-6.6
	Fall	2,091	-2.1	+0.6
	Both	5,901	-3.9	-4.8
Rock Island	Summer	13,015	+1.7-	0.4
	Fall	3,659	+2.8	+8.2
	Both	16,674	+1.8	+1.0
Priest Rapids	Summer	14,395	-0.2	-0.8
	Fall	10,427	+2.0	+6.3
	Both	24,822	+0.6	+1.9

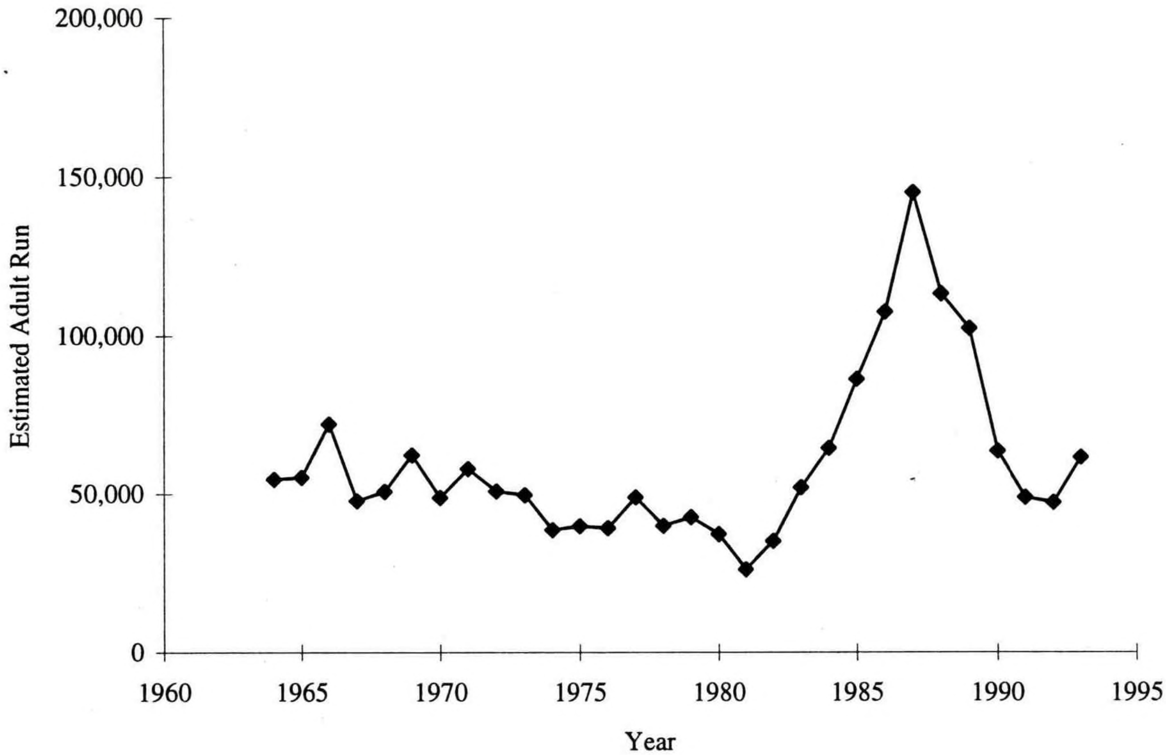

Figure 6. Estimated total adult run size for the ESU, 1964-93. Run size was estimated from total summer- and fall-run chinook salmon counts at McNary Dam with Snake River fish (Ice Harbor Dam counts) and returns to Priest Rapids and Wells Hatcheries subtracted. Data from the Coordinated Information System Computerized Distributed System (Anderson 1994), ODFW and WDF (1993), and Chapman et al. (1994).

estimated a probability of less than 0.001% that Priest Rapids Dam counts of adult summer-run chinook would decline to one fish by the year 2093.

However, the use of a threshold of one individual is inconsistent with the methods described by Dennis et al. (1991), and no confidence intervals were provided for the ADFG result. Therefore, we concluded that the reliability of this estimate is questionable. Chapman et al. (1994) applied the model to 5-year running sums of estimates of summer/fall chinook salmon spawner abundance based on redd counts above Rock Island Dam. They found that the probability of decline to 5,000 fish in 10 years was 0.02% (95% confidence interval extends from 0-0.1%) and in 50 years was 9% (confidence interval from 0-50%). Probabilities of decline to 10,000 fish were estimated to be 3% (95% confidence interval 0-15%) in 10 years, and 26% (confidence interval 10-93%) in 50 years.

These results should be viewed with caution: they are based on a very simple model with unrealistic assumptions regarding salmon population age structure, they may not include all sources of variation in stock abundance, they ignore subpopulation structure, and the estimates had wide confidence intervals. However, they suggest that the near-term risk of extinction of this stock is low.

We consider the petitioners' assessment of hatchery composition of the stocks to be accurate. Although over 200 million late-run hatchery chinook salmon have been introduced into the MCR since 1941, their influence on naturally-spawning ocean-type chinook salmon in the tributaries above Rock Island Dam has been relatively small and does not appear to pose a significant risk factor to these stocks. There has been substantial hatchery production of fall-run chinook salmon at Priest Rapids Hatchery, and upriver bright fish from this and other hatcheries have been planted in the Yakima River.

DISCUSSION AND CONCLUSIONS

A key question in the biological evaluation of MCR late-run chinook salmon is whether the summer- and fall-run fish in the MCR are reproductively isolated. Whether they are considered separately or jointly is pivotal in determing the ESU and its numeric stability. We have evaluated a variety of biological characters and have summarized them in Table 7.

Reproductive Isolation

The petitioners argue that MCR summer chinook salmon are reproductively isolated with respect to three other groups of chinook salmon within the Columbia River Basin: 1) Snake River summer chinook salmon, 2) mid-Columbia River spring chinook salmon, and 3) mid-Columbia River fall chinook salmon.

Genetic Characters

Genetic data based on protein electrophoresis are consistent with the existing view of the genetic affinities in MCR summer chinook salmon. This group of fish is clearly reproductively isolated from Snake River summer chinook salmon (previously determined by NMFS to be part of a different ESU), and from the

Table 7. Summary of biological characteristics of stream- and ocean-type chinook salmon in the mid-Columbia River.

Characteristic	Stream-type Spring-run	Ocean-type Summer-run	Fall-run
Adult run timing at Bonneville Dam	Mar.-May	June-July	Aug.-Oct.
General spawning locations	upper tributaries	mid tributaries, lower tributaries, and mainstem	lower tributaries and mainstem
Spawning time	August to mid September	late September to mid November	mid October to early December
Seaward juvenile migration	yearling	subyearling	subyearling
Ocean distribution	extended	coastal	coastal
Morphometric similarity*	a	b	b
Meristic similarity*	a	b	b
Genetic similarity*	a	b	b

* Run-types with the same letter are not significantly different. Morphometric and meristic data from Schreck et al. (1986); genetic information from Schreck (1986), Utter et al. (1989), Matthews and Waples (1991), and Marshall (1993, 1994a and b).

spring chinook salmon in the MCR as well. Although there is a lack of genetic information specifically for fall-run fish from the rivers identified in the petition (Methow, Okanogan, and Wenatchee), it has been known for some time that there is a close genetic similarity between mid-Columbia River summer chinook salmon and fall chinook salmon from the Hanford Reach area.

New data from WDF (Marshall 1993, 1994a and b) included Hanford Reach natural population and Priest Rapids Hatchery. Allele frequencies in the Priest Rapids sample did not differ significantly from those in summer-run adults that returned to Wells Hatchery, the Wells Dam trap, or the Similkameen River (a tributary of the Okanogan River).

Phenotypic Characters

Data from one multivariate study of meristic and morphometric characters of chinook salmon in the Columbia River Basin indicated that summer and fall chinook salmon from the MCR are similar to one another but different from other groups of chinook salmon in the MCR and the Snake River.

Life History Characters

Among MCR and Snake River chinook salmon populations, major juvenile and adult life history characters match the patterns of genetic variation. In both rivers, spring chinook salmon are stream-types and fall chinook salmon are ocean-types. In the Snake River, summer chinook salmon are stream-types like spring chinook salmon, while in the MCR, they are ocean-types like fall chinook salmon. Genetically, Snake River summer chinook salmon are closely related to spring chinook salmon in both rivers while MCR summer chinook salmon are closely related to fall chinook salmon in both rivers.

Spawn and Run Timing

Although groups of fish returning over dams in the MCR were once thought to spawn in different habitats at different times, this notion has not been supported by the data collected for this Biological Status Review. Both types of fish were found to spawn in tributaries as well as mainstem areas, with substantial overlap in the spawn timing and duration.

Evolutionary Significance

The petitioners argue that summer-run chinook salmon in the Methow and Wenatchee Rivers are the last remnants of the large population of summer-run fish that once spawned in areas above Grand Coulee Dam. The summer run of fish in the Columbia River was renowned for its large size (hence the term "June hogs") and abundance. Additionally, the petitioners argue that the Okanogan River, which did not receive transplants from the GCFMP, contains the "only documented native stock of summer chinook in the mid-Columbia basin" (NEDC et al. 1993. p. 6).

Phenotypic and Life History Traits

Given their extensive upriver migration and presumably distinctive habitat characteristics, it seems likely that chinook salmon spawning in the now inaccessible Lake Windermere region of the upper Columbia River historically comprised an ESU. However, for several reasons, it is unlikely that any appreciable remnants of this gene pool remain in the petitioned streams.

First, reports of spawn timing by early settlers suggested stream-type, not ocean-type fish. Comparison with upriver populations from the Fraser River, which has headwaters near those of the upper Columbia River, also suggests that the upper Columbia River chinook salmon may have been stream-type fish. Thus, it is uncertain what relationship the ocean-type fish currently residing in the mid-Columbia River have to the original upriver populations.

Second, it is likely that "June hogs" taken in the lower Columbia River were comprised of large fish from many different populations. There are conflicting accounts from the 1800s regarding the size of chinook salmon in the upper Columbia River. For example, historical accounts from the early 1800s suggest that chinook salmon taken by aboriginals at Kettle Falls in the upper Columbia River averaged only 7 kg in weight (Mullan et al. 1992b), whereas Bryant and Parkhurst (1950) reported that early settlers witnessed fish averaging 18 kg. In any case, by the time the GCFMP was initiated, wild adult ocean-type fish taken at Rock Island Dam averaged only about 8 kg (Fulton and Pearson 1981). Thus, even if a run of large fish did occur historically in the upper Columbia River, it no longer existed by 1939. "June hogs" from all populations may have been largely eliminated by the turn of the century as a result of heavy fishing pressure.

Third, adults collected for the GCFMP were a mixture of summer- and fall-run fish from all areas above Rock Island Dam.

It seems likely, therefore, that genetic admixture, in addition to translocation, has occurred in existing summer-run chinook salmon from the mid-Columbia River. Nevertheless, abundance of chinook salmon increased at least temporarily in rivers that received transplants from the GCFMP, so presumably some genes from upriver stocks were incorporated into mid-Columbia River populations. Whether any genetic traits that distinctly characterized upper Columbia River chinook salmon still exist in the MCR is not known with certainty, but we found no empirical evidence to support this hypothesis.

Finally, although the Okanogan River is the only major stream in the petitioned area that did not receive transplants from the GCFMP, it is unlikely that summer-run fish in this river represent an essentially pure native stock. All late-run (summer and fall) chinook salmon adults reaching Rock Island Dam were taken for the GCFMP for a period of 5 years. According to age data for late-run chinook salmon from the mid-Columbia River, less than 1% of returning adults are older than 5 years. Therefore, the current population in the Okanogan River, which is upstream from Rock Island Dam, must be derived largely, if not entirely, from recolonization with manipulated populations of the GCFMP.

Genetic Data

Several published genetic studies and new data from WDF presented here have shown a strong genetic similarity between summer-run fish from the Wenatchee and Okanogan Rivers and Wells

Hatchery; there is no indication that the Okanogan stock is representative of a remnant upstream chinook salmon stock.

Conclusion: Species Determination

Genetic and life-history information, as well as data from various tagging experiments, all fail to demonstrate reproductive isolation between summer- and fall-run chinook salmon in the mid-Columbia River (Table 7). In addition, coded wire tag data suggest that the two forms have a similar ocean distribution. Therefore, we concluded that all late-run, ocean-type chinook salmon from the mid-Columbia River are part of the same ESU as defined by the ESA.

We evaluated the relationship of this ESU to three other groups of Columbia River Basin chinook salmon and found substantial genetic and life-history differences: 1) stream-type, spring chinook salmon from the mid-Columbia River were clearly part of a separate ESU; 2) Snake River summer chinook salmon were much more closely related to Snake River spring chinook salmon than to summer chinook salmon from the mid-Columbia River; and 3) the closest relatives of mid-Columbia River late-run chinook salmon are other groups of Columbia River fall chinook salmon.

Two major types of fall chinook salmon were found in the basin: "tules" and "upriver brights." Substantial genetic differences have been demonstrated between these two types of chinook salmon in the Columbia River. The "upriver bright" group includes late-run chinook salmon from the mid-Columbia River as well as Snake River fall chinook salmon.

Previously, ecological, genetic, and ocean distribution data were used to demonstrate that Snake River fall chinook salmon are distinct from mid-Columbia River fall chinook salmon and represent a separate ESU. Therefore, we concluded that late-run (summer and fall), ocean-type chinook salmon from the mid-Columbia River represent an ESU separate from all other chinook salmon in the Columbia River Basin. Some of the distinctive habitat features of this ESU are discussed above.

Threshold Determination

Dam and redd count information indicated that although depression in some individual runs of late-run chinook salmon in the mid-Columbia River is cause for concern, the mid-Columbia River late-run, ocean-type chinook salmon ESU as a whole is relatively healthy, with little risk of extinction in the foreseeable future. Even if we considered populations from only those rivers identified in the petition (Okanogan including Similkameen, Methow, and Wenatchee), we would find little risk of extinction for those populations.

While redd counts in two of these rivers (Okanogan and Methow) have exhibited substantial declines since the late 1960s, they have been relatively stable since 1980, and counts in both the Wenatchee and Similkameen Rivers have exhibited long-term (1956-93) increasing trends. Based on Rock Island Dam adult counts, this group of populations is certainly more abundant than it was in the 1930s and 1940s.

Comments

While we do not believe that this ESU is at significant risk of extinction or endangerment, the low numbers of ocean-type chinook salmon above Rocky Reach Dam (including the Methow and Okanogan Rivers), despite the virtual elimination of inriver harvest on these stocks, are of concern. Declines since the mid-1970s in this region may simply be a return of the populations to normal carrying capacity following substantial hatchery supplementation, or may indicate local problems with habitat, dam passage, or hatchery practices. Special management consideration of these particular stocks may be warranted.

Some aspects of artificial propagation also pose risks for populations within the ESU. For example, there have been large releases of fall chinook salmon in the mainstem Columbia River and in the Yakima River in recent years. We do not believe that the potential genetic and ecological consequences of these releases have been adequately addressed.

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Appendix. Protein loci and sample information for genetic analyses presented in Figures 2 and 3 (Marshall 1994a and b).

Loci used in genetic analysis:

mAAT-1*, sAAT-1,2*, sAAT-3*, sAAT-4*, ADA-1*, ADA-2*, sAH*, mAH-4*, GPI-B2*, GPI-A*, GR*, HAGH*, mIDHp-2*, sIDHp-1*, sIDHp-2*, LDH-B2*, LDH-C*, sMDH-A1,2*, sMDH-B1,2*, mMDH-2*, MPI*, PEPA*, PEP-B1*, PEPD-2*, PEP-LT*, PGDH*, PGK-2*, PGM-1*, PGM-2*, sSOD-1*, mSOD-1*, mSOD*, and TPI-4* .

Sample information for genetic samples:

Sample	Run type	Years sampled	Comments
Hanford Reach	fall	1990	mainstem Columbia River
Bonneville Hatchery	fall	1990	
Little White Salmon Hatchery	fall	1990	
Priest Rapids Hatchery	fall	1987, 90, 91	
Lyons Ferry Hatchery adults	fall	1990, 91	Snake River, all tagged
Wenatchee River	summer	1989-92	
Wells Hatchery	summer	1991-92	
Similkameen River	summer	1991-92	
Winthrop Hatchery	spring	1992	
Leavenworth Hatchery	spring	1991	
White River	spring	1989, 91-92	Wenatchee River tributary
Nason Creek	spring	1989, 92	Wenatchee River tributary
Chiwawa River	spring	1989-92	Wenatchee River tributary
Carson Hatchery	spring	1989	
American River	spring	1989-92	
Naches River	spring	1989-92	includes Little Naches and Bumping River
Upper Yakima	spring	1989-92	includes Cle Elum River
Yakima River	fall	1990-92	
Marion Drain	fall	1989-92	
Sandy River	fall	1990-92	lower Columbia River

Appendix--Continued.

Sample	Run type	Years sampled	Comments
Deschutes River	fall	1990-92	Oregon
John Day River	spring	1990-92	
Round Butte Hatchery	spring	1990	Deschutes River Basin, Oregon

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