THE PACIFIC
RIVERS COUNCIL

Offices in:

Eugene
P.O. Box 10798
Eugene, Oregon 97440
Phone: 541/345-0119
Fax: 541/345-0710

Portland
921 SW Morrison, Suite 531
Portland, Oregon 97205
Phone: 503/294-0786
Fax: 503/294-1066

Seattle
P.O. Box 4735
Seattle, Washington 98104
Phone: 206/447-4186
Fax: 206/343-1526

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Phone: 208/939-8697
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Phone: 510/548-3887

Washington, D.C.
605 Prince
Alexandria, Virginia 22314
Phone: 703/836-3420
Fax: 703/836-4055

CHINOOK SALMON

Kings of the Pacific

BRIEFING BOOK

written by Cindy Deacon Williams
edited by Trygve B. Sletteland

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CHINOOK SALMON
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INTRODUCTION

There are seven native species of Pacific salmon that spawn in freshwater, migrate to sea, and return to freshwater to spawn. These seven include the pink (*Oncorhynchus gorbuscha*), chum (*O. keta*), sockeye (*O. nerka*), coho (*O. kisutch*), and chinook (*O. tshawytscha*) salmon as well as the steelhead (*O. mykiss*) and sea-run cutthroat (*O. clarki*) trout.

Pacific salmon are vulnerable to the negative effects of many human activities. In general, these negative effects have been grouped into four categories: habitat degradation, hatchery operations, hydroelectric development and water diversions, and harvest for sport, commercial and subsistence purposes. These threats have combined to substantially reduce many salmon populations from all seven species. One of the first major reviews of the status of Pacific salmon examined populations of salmon, steelhead and sea-run cutthroat trout from the lower 48 states and found 39 California stocks, 58 Oregon coastal stocks, 76 Columbia basin stocks, and 41 Washington coastal/Puget Sound stocks vulnerable to extinction and concluded at least 106 stocks already had gone extinct—apparently starting with an 1852 loss of the Mason Lake sockeye in the Puget Sound area (Nehlsen et al. 1991). A later survey of the same area identified only 99 stocks that could be called "healthy" because they were at least one-third as abundant as would be expected without human impacts (Huntington et al. 1996). Subsequent regional status studies examining in greater detail the status of Pacific salmon in the lower 48 have confirmed the scope and broadened the magnitude of the decline (e.g., Higgins et al. 1992, Nickelson et al. 1992, Washington Dept. of Fisheries et al. 1993). Using the 1991 results and the more recent regional reviews, federal agency scientists preparing the Northwest Forest Plan strategy determined that there were 259 rare stocks of Pacific salmon that occurred on federal lands within the range of the northern spotted owl in western Washington and Oregon and northwestern California (FEMAT 1993). Other stocks outside the owl's range also are rare.

Populations of six of the seven species have received formal legal protection under the federal Endangered Species Act (ESA). Additional Pacific salmon populations now are being evaluated to determine if they need ESA protection.

Pink: All populations were refused the protection of the ESA in October 1995.

Chum: All populations in Washington and Oregon are under review, with a listing determination due by December 1997.

Sockeye: Snake River sockeye were listed as endangered in November 1991 and all other populations in Washington and Oregon are under review, with a listing determination due by December 1997.

Coho: Central California (May 1996) and Southern Oregon/Northern California (May 1997) coho are listed as threatened. In addition, the Puget Sound/Strait of Georgia (July 1995), Southwest Washington/Lower Columbia River (July 1995) and Oregon Coast (May 1997) populations are candidates for listing. The Olympic Peninsula coho population (July 1995) was refused the protection of the ESA.

Chinook: Sacramento River winter-run chinook were listed as threatened in an emergency rule (August 1989), a status call later changed to endangered (January 1994). In addition the Snake River fall-runs and Snake River spring/summer-runs are listed as threatened (April 1992). All other populations in Washington, Oregon and California are under review, with a listing determination promised by January 1998.

Steelhead: Southern California (August 1997) and Upper Columbia River (August 1997) steelhead are listed as endangered. South-Central California (August 1997), Central California Coast (August 1997) and Snake River Basin (August 1997) steelhead are listed as threatened. Northern California (August 1996), Klamath Mountains Province (March 1995), Oregon Coast (August 1996) and Lower Columbia River (August 1996) steelhead are proposed for listing as threatened and California Central Valley (August 1996) steelhead are proposed endangered. In addition, the Middle Columbia River (August 1996) steelhead are candidates for listing. The Upper Willamette, Washington Coast, Olympic Peninsula and Puget Sound populations (August 1996) were refused the protection of the ESA.

Sea-run cutthroat: Umpqua River sea-run cutthroat trout (August 1996) are listed as endangered. All other populations in Washington, Oregon and California are under review, with a listing determination due by December 1998.

CHINOOK SALMON BASIC LIFE CYCLE AND THE ENDANGERED SPECIES ACT

Chinook salmon (*Oncorhynchus tshawytscha*) are anadromous and semelparous. This means that as adults, they migrate from the ocean upstream to the freshwater streams of their birth (i.e., anadromous) where they spawn and die (i.e., semelparous). The eggs laid in spawning beds, or redds, hatch and juvenile salmon migrate back downstream to the ocean where they grow to adulthood then migrate into freshwater to repeat the cycle. Chinook display great variety in following this basic life history pattern: some make their upstream spawning runs during spring, while others run upstream during summer, fall and winter; some rear in freshwater for only a few months while others spend several years in freshwater before migrating downstream to the ocean; some populations include non-migrating males that mature without ever entering the ocean while in others both sexes live in the ocean for many years while they grow to adulthood.

Life History Stages: Chinook salmon grow through six basic life history stages during the course of their lives.

Eggs—laid in spawning gravels, chinook eggs are the largest of all Pacific salmon species.

Alevins—yolk sac larvae that hatch from the eggs and remain buried in spawning gravels until the yolk sac is absorbed.

Fry—free swimming post larvae young that emerge from spawning gravels and begin feeding in the stream or migrate from it.

Parr—young salmon adapted to freshwater, they may remain in freshwater for as short as three months in some chinook populations or up to several years in others.

Smolt—young salmon that have undergone the physiological, biochemical, morphological and behavioral changes, called smoltification, that allow them to live in the ocean.

Adult—chinook salmon typically attain maturity at the age of 4-5 years and are the largest Pacific salmon, typically averaging 22 pounds and commonly reaching over 88 pounds.

The "Stock" Concept: Given the great variety of chinook life history patterns, scientists have developed a number of terms to distinguish among various populations of salmon. All Pacific salmon exhibit a strong tendency to return at a specific time of year to spawn in their natal streams, resulting in the development of distinct populations—or stocks—within each species. Each of these stocks becomes adapted to the conditions of their local streams and the length and timing of their up and downstream migrations. As a result each Pacific salmon species is composed of dozens or even hundreds of stocks that, to varying degrees, are reproductively and behaviorally isolated. The "stock" concept first gained currency in the late 1930s in a paper authored by Willis Rich (1939), an early proponent of management based on the stock concept.

Stock—a biological term to describe the many isolated, self-perpetuating local populations that are separated by the time of year and/or by the stream in which they spawn and that often exhibit distinct behavioral patterns.

Run—a biological term generally used to identify various populations on the basis of the season of year (i.e., spring, summer, fall and winter) during which upstream spawning migrations occur.

"Ecologically Significant Units:" In 1991, the National Marine Fisheries Service (NMFS) adopted a policy to guide their application of the Endangered Species Act (ESA) to Pacific salmon. The ESA allows listing of species, subspecies and "distinct population segments" of vertebrates. The NMFS policy found that a stock or group of stocks would be considered a "distinct population segment" only if they were determined by NMFS to be an Ecologically Significant Unit.

Ecologically Significant Unit or ESU—a legal term developed in 1991 by NMFS to assist in its application of the ESA to Pacific salmon and steelhead. To be considered an ESU, and hence eligible for consideration as a "distinct population segment" that could be listed pursuant to the ESA, NMFS evaluates salmon populations or groups of populations to determine: 1) their reproductive isolation and 2) the degree to which they constitute a substantial contribution to the ecological and genetic diversity of the species as a whole. Stocks are grouped into ESUs according to the two criteria, and the status of the ESU as a whole is evaluated by NMFS to determine if listing is warranted.

Important Note: Because several to many stocks often are combined by NMFS into a single ESU, the status of weaker stocks can be masked if they are grouped with a large stock in good condition. Unfortunately, in situations like this, NMFS has declined to extend the protections of the ESA to the smaller, threatened stock. This policy has the potential to result in stock extinctions that over time could have a significant effect on the long-term viability of the species as a whole.

Life History Patterns: Differences in chinook salmon life history can best be explained by looking at the timing of their spawning migration (i.e., spring-run, summer-run, fall-run, late fall-run or winter-run) and by the length of their juvenile residence in freshwater (i.e., stream-type or ocean-type). These differences result in a variety of smoltification and maturation strategies (Figure 1).

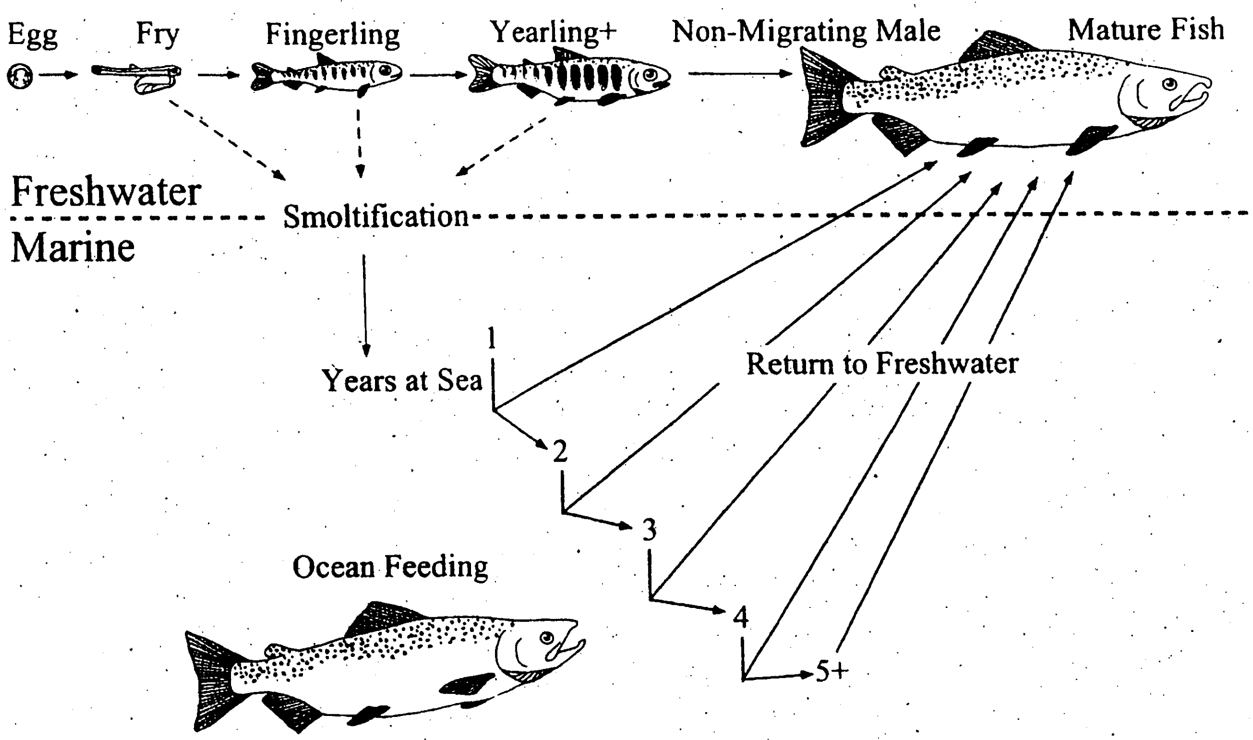


Figure 1. Diagrammatic representation of potential smolting and maturation strategies used by chinook salmon.

Stream-type chinook, typically spend one or more years as fry and parr in freshwater before migrating to sea, perform extensive offshore oceanic migrations, and typically return to their natal river in spring or summer-runs where they hold several months prior to spawning. Occasionally, stream-type males mature precociously without ever going to sea.

Ocean-type chinook migrate to sea during their first year of life, normally within three months after emergence from the spawning gravel, spend most of their ocean life in coastal waters, and typically return to their natal river in fall-runs, a few days or weeks before spawning. Chinook following this life history pattern minimize the time they spend in freshwater (both as young and as spawning adults) and rarely move far offshore while in the ocean.

Most populations in Alaska typically follow a stream-type life history pattern. South of Alaska, an ocean-type pattern is most common. However, large river basins in British Columbia and the lower 48 states typically are home to both types, with stream-type fish tending to migrate to headwater spawning areas and ocean-type chinook using downstream spawning areas. The geographic separation of the two behavioral types is not complete and both stream- and ocean-type chinook can be found on the same spawning gravels. In the Columbia River Basin, for example, middle and upper Columbia River spring-run chinook salmon as well as Snake River spring- and summer-run chinook exhibit a stream-type life history while upper Columbia River summer- and fall-run chinook as well as Snake River fall-run chinook display an ocean-type life history pattern. In smaller rivers south of Alaska, stream-type chinook are scarce, rarely comprising more than 12% of runs.

As a result of their extended stay in freshwater, stream-type chinook are more vulnerable to threats in their freshwater habitats than are other chinook populations. Furthermore, stream-type chinook disperse widely in the open ocean and therefore are subjected to limited fishing pressure as they grow to maturity, primarily facing fishing pressure only on their return to freshwater. Because of their limited stay in freshwater, ocean-type chinook are less susceptible to freshwater impacts, but more vulnerable to the effects of coastal degradation and, because they tend to stay near the coast, ocean-type chinook are vulnerable to pressure from sport and commercial fisheries throughout their ocean residence.

DISTRIBUTION AND HABITAT

Spawning stocks of chinook salmon are known from central California to at least Kotzebue Sound, Alaska, on the North American coast and from northern Hokkaido to the Anadyr River on the Asian coast (Figure 2). Historically, chinook salmon occurred as far south as the Ventura

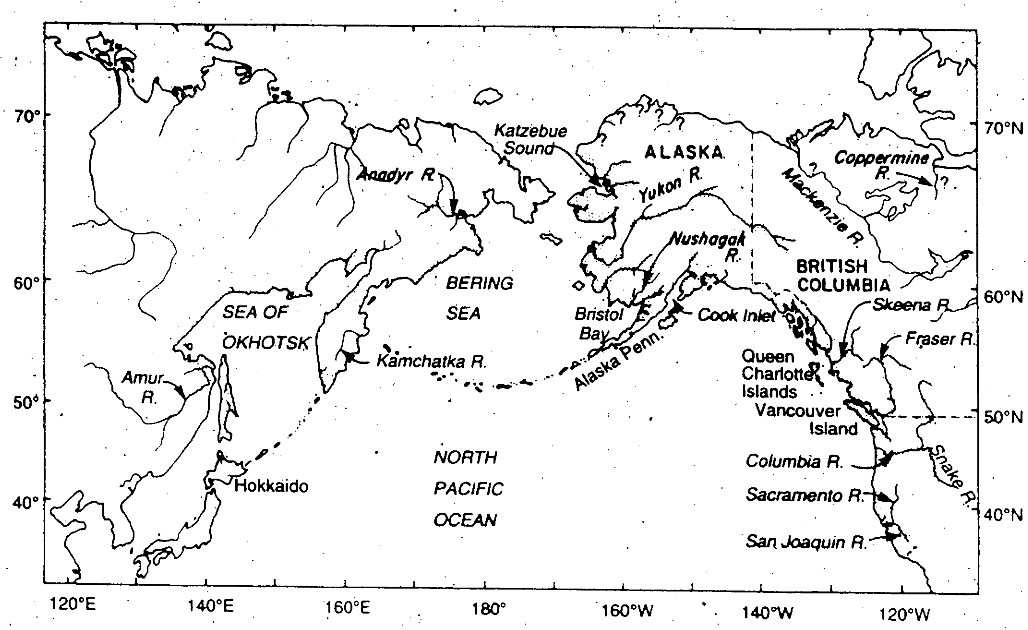


Figure 2. Distribution of chinook salmon spawning populations.

River in southern California (Moyle 1976). There probably are over a thousand spawning populations of chinook salmon in North America (Aro and Shepard 1967), each generally not exceeding a few tens of thousands of spawning adults. Large rivers tend to support the largest aggregate runs of chinook as well as the largest individual spawning populations. Many smaller rivers support runs averaging fewer than one thousand spawners.

Freshwater Habitat: Chinook salmon need several different kinds of freshwater habitat, including migratory corridors, spawning habitat and rearing habitat. Human activities can have substantial detrimental effects on the suitability of all three components of freshwater habitat.

Upstream migration: At maturity, chinook salmon leave the ocean and migrate to the stream of their birth to spawn. These migrations can require minimal effort, with spawning occurring near tidewater, or they can demand herculean effort, with spawning occurring nearly 2,000 miles upstream from the ocean. Regardless of the distance, however, dams and diversion structures as well as the slack water reservoirs they create can seriously impede upstream passage of adults (and the later downstream migration of juveniles) both by creating physical barriers to passage and by confounding migration cues and exceeding biological tolerances through changes in river flow and temperature regimes.

Redd site selection: Chinook will spawn in water that is shallow or deep, slow or fast, and where the gravel is coarse or fine. However, the site selected must have good subgravel flows in order to ensure adequate oxygenation (Healey 1991). The chinook's large eggs, with their small surface-to-volume ratio, are more sensitive to reduced oxygen levels than other Pacific salmon. As a result, areas that appear superficially comparable may have dramatically different success rates. Stream-type chinook require about 172 square feet and ocean-type chinook require about 258 square feet of well oxygenated gravel per spawning pair (Burner 1951). Female chinook defend their redd after spawning is begun. Early in the spawning period they stay on the redds for about two weeks, while their residence late in the season is only 4-5 days. Spawning adults can be chased off redds easily by minor disturbances, which if they occur frequently enough can result in death of the adult prior to successful spawning. The time of spawning tends to be earlier in the year as one moves north, with northern populations tending to spawn from July to September and southern populations from November to January (Healey 1991). However, river systems with several runs can have chinook spawning virtually every month of the year. For example, in the Sacramento River spring-run fish spawn in August to September, fall-run fish in October to December, and winter-run fish in May and June.

Hatching: The survival of eggs in undisturbed natural redds appears to be quite good, with some reports ranging up to 82-97% (Briggs 1953 and Vronskiy 1972, respectively). Adequate water flows through the spawning gravels is essential for egg and alevin survival. Stream conditions, particularly those affecting subgravel flows, can have a dramatic effect on the survival of eggs to hatching and emergence (i.e., egg to alevin and alevin to fry). Any increases in siltation in spawning beds can cause high mortality (Healey 1991).

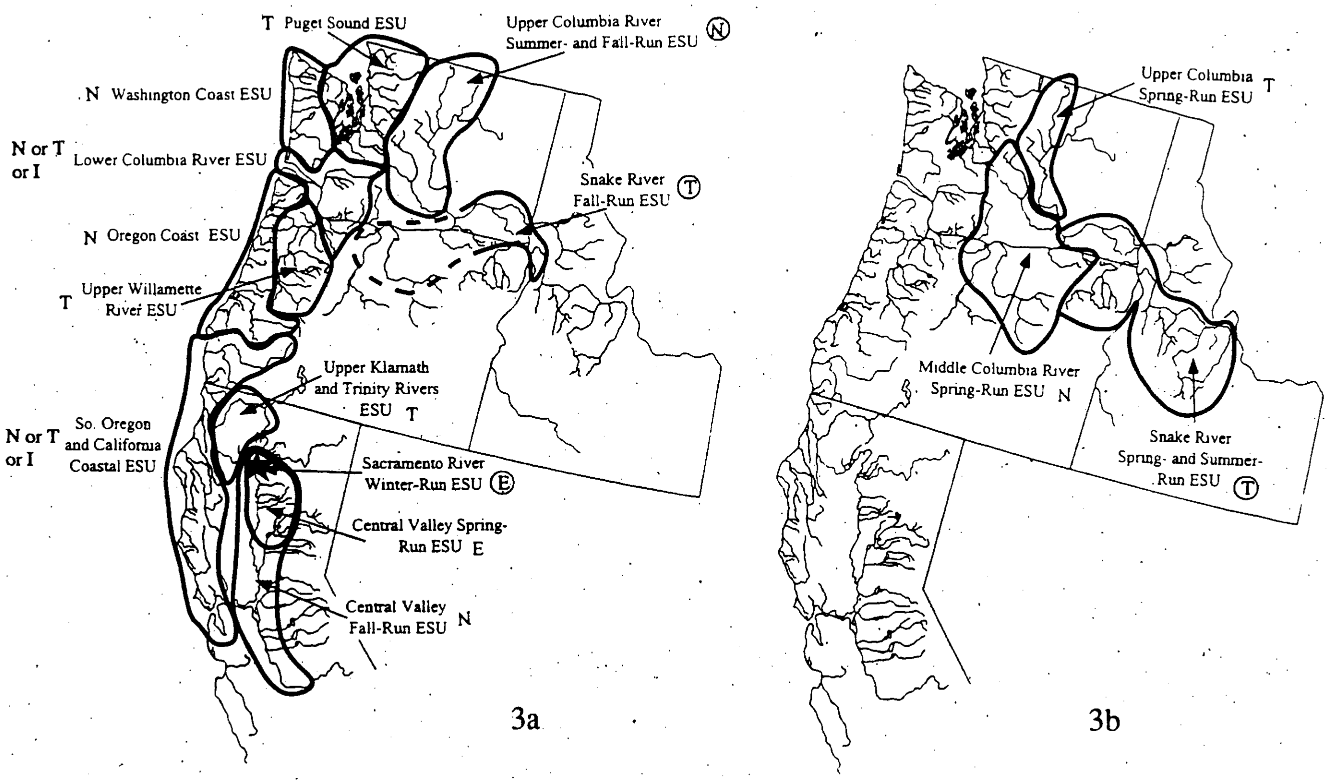
Rearing and downstream migration: At the time of emergence, fry generally swim or are displaced downstream, although some fry are able to maintain their residence at the spawning site. For populations that spawn close to tidewater, typically ocean-type, fry are carried to estuarine nursery areas. For other populations, this movement of fry upon emergence helps distribute the fry among freshwater nursery areas. Later in the spring there appears to be a second dispersal that carries remaining ocean-type populations to the sea and that further distributes stream-type populations within the river system, presumably to summer rearing areas. For the stream-type chinook, there is a third late fall redistribution to suitable overwintering habitat, usually from the tributaries to deep pools or crevices between boulders and rubble in the river main stem, followed in most cases by a migration of yearling smolts to the sea during the second spring. In some stream-type chinook populations, however, parr spend a second year in freshwater—with continued movement during the second spring flows and again the following fall—before they migrate to the ocean during their third spring. Chinook fry generally rear mainly in riverine habitat and seldom in beaver ponds or off-channel sloughs. As they grow larger, they tend to move away from shore into midstream and higher velocity areas. There are a number of reports indicating that young chinook are solitary animals that establish and defend a particular site within a riffle or glide during the day and early evening and move to the bottom of inshore quiet waters or pools at night.

Ocean Habitat: After leaving their freshwater and estuarine nursery areas, young chinook mature for one or more years in the ocean, where they tend to be distributed deeper in the water column than other species of Pacific salmon. There is a major difference in the distribution and oceanic migratory behavior of stream and ocean-type chinook. Stream-type chinook appear to move rather quickly through estuaries tending to disperse to the open ocean and becoming very widespread in their second and subsequent ocean years. Ocean-type chinook remain in the estuaries for longer periods than do the stream-type and then tend to limit their dispersal to not more than about 620 miles from the mouth of their natal stream, generally remaining in near-shore waters.

Direction of oceanic dispersal: Chinook salmon spawned in California waters migrate to the north, with some tagged California fish recaptured as far north as the Washington coast. Those spawned in Alaska generally migrate to the south, with some moving as far as the Oregon coast. Coastal Oregon stocks migrate both to the north and to the south. Stocks that spawn in central and northern Oregon streams (i.e., from the Elk River north) move to the north when they reach the ocean, contributing to fisheries from Oregon to Alaska. However, stocks from southern Oregon streams move to the south and contribute to fisheries off Oregon and northern California. The Umpqua River spring-run chinook move in both directions and are harvested in ocean fisheries from California to Alaska.

STATUS AND TRENDS

Preliminary draft reports by the National Marine Fisheries Service (NMFS) indicate that chinook salmon populations in Washington, Oregon, California and Idaho are likely to be organized into three major salmon groups with 15 ESUs whose status will be evaluated for listing (Figure 3). Chinook populations in British Columbia and Alaska are not being reviewed by NMFS to determine their relationships or their status.



Status Key

Results of Previous Reviews:

Ⓔ = Listed Endangered
Ⓣ = Listed Threatened
Ⓝ = Listing Denied

Preliminary Draft NMFS Report Suggestions:

E = Recommended Endangered
T = Recommended Threatened
N = Recommended Listing Be Denied
I = Insufficient Information to Determine

Figure 3. Approximate geographic ranges of preliminary evolutionarily significant units (ESUs) for 3a - ocean-type chinook and 3b - stream-type chinook salmon in California, Oregon, Washington and Idaho. Majority status recommendations from the preliminary draft NMFS report are indicated as are the results of previous NMFS reviews.

State and Province Status Summary

California: Sacramento River winter-run chinook are listed as Endangered, with all populations that historically spawned above Shasta Dam eliminated by its construction. Spring-runs have been extirpated from a large portion of their range and the remaining populations in both the Klamath and Sacramento basins are at low levels. Sacramento River fall-runs are declining, and have failed to meet escapement goals during recent years. Klamath River fall-run and Sacramento River late fall-run stocks also are declining.

Oregon: Chinook salmon are completely extinct in the Snake River above the Hells Canyon dam complex, in the Deschutes River above the Pelton/Round Butte dam complex, in the Oregon portion of the Klamath basin, above dams in the Sandy, Willamette, Umpqua and Rogue rivers, and in the Umatilla and Walla Walla rivers. Populations have been lost from other basins, including the Grande Ronde early fall-run, the John Day fall-run, and the upper Hood River spring-run. Winter-run populations may have been lost in the Sandy River and in Tillamook Bay. Of the remaining chinook populations, the Snake River spring-summer and fall-run chinook in Oregon (i.e., Grande Ronde and Imnaha subbasins) are listed as threatened. Elsewhere in Oregon, fall-runs are declining on the south coast but are relatively stable otherwise. Spring-runs both in the Columbia (except in the Deschutes, John Day, and North Umpqua rivers) and on the coast are declining or have stabilized at very low levels.

Idaho: Many chinook stocks were eliminated with construction of the Hells Canyon and Dworshak dams. Remaining Snake River spring-summer and fall-runs in Idaho (i.e., Salmon, Snake and Clearwater subbasins) are listed as threatened.

Washington: Stocks are extirpated in the Columbia River above Chief Joseph and Grand Coulee dams. Most remaining Columbia River and Puget Sound stocks are declining or at low levels, and five summer-run stocks are considered to be critical, that is, they are experiencing production levels that are so low that permanent damage to the stock is likely or already has occurred. Snake River spring-summer and full-runs in Washington (i.e., Grande Ronde and Tucannon subbasins) are listed as threatened. Most coastal stocks are healthy.

British Columbia: Two upper Columbia River chinook stocks historically present in the province are extinct and a stock in the Okanagon is virtually gone. Fraser River stocks generally are increasing after decreasing sharply from turn-of-the-century abundance. Chinook stocks elsewhere are suffering from long-term declines.

Yukon: Stocks generally are presumed to be stable, however little information exists on either historical or current abundance.

Alaska: Total escapement is increasing statewide under constrained harvests. There is some indication of declines in a few stocks, but general status information is not available on a stock basis.

Status Summary by Major Groupings:

A. California Central Valley Group This group includes spring, fall, late-fall and winter runs of chinook salmon, generally ocean-type, that historically spawned in much of the Sacramento and San Joaquin basins. They are likely to be grouped into three ESUs.

1. *Sacramento River Winter-run* Description: This ESU includes a single stock, winter-run chinook salmon, that enters the Sacramento River from November to June and spawns from late-April to mid-August. In general, this stock follows an ocean-type life history strategy, with smolts migrating to the ocean after 5 to 9 months of freshwater residence and remaining near the coast of California and Oregon prior to their maturity at 2-3 years of age.

Current and Historic Threats: Sacramento winter-run chinook populations spawned in the upper Sacramento River, Pit, McCloud and Calaveras rivers. Construction of dams on these rivers led to the extirpation of populations in the Pit, McCloud and Calaveras rivers and limited upper Sacramento River populations to areas below Shasta and Keswick dams. Remaining habitat is severely degraded.

Status: The Sacramento winter-run chinook salmon was listed as threatened in 1989 and reclassified as Endangered in 1994. It is protected under both the federal and California Endangered Species Acts. This stock has exhibited significant declines (Figure 4), beginning with the complete loss of populations in the upper Sacramento River system above Shasta Dam, followed by dramatic reductions in remaining populations following the construction of Red Bluff Diversion Dam from more than 100,000 returning adults in 1969, to an average of just over 2,000 from 1982 to 1988. A sharp decline in 1989 to less than 200 prompted the emergency listing of the stock.

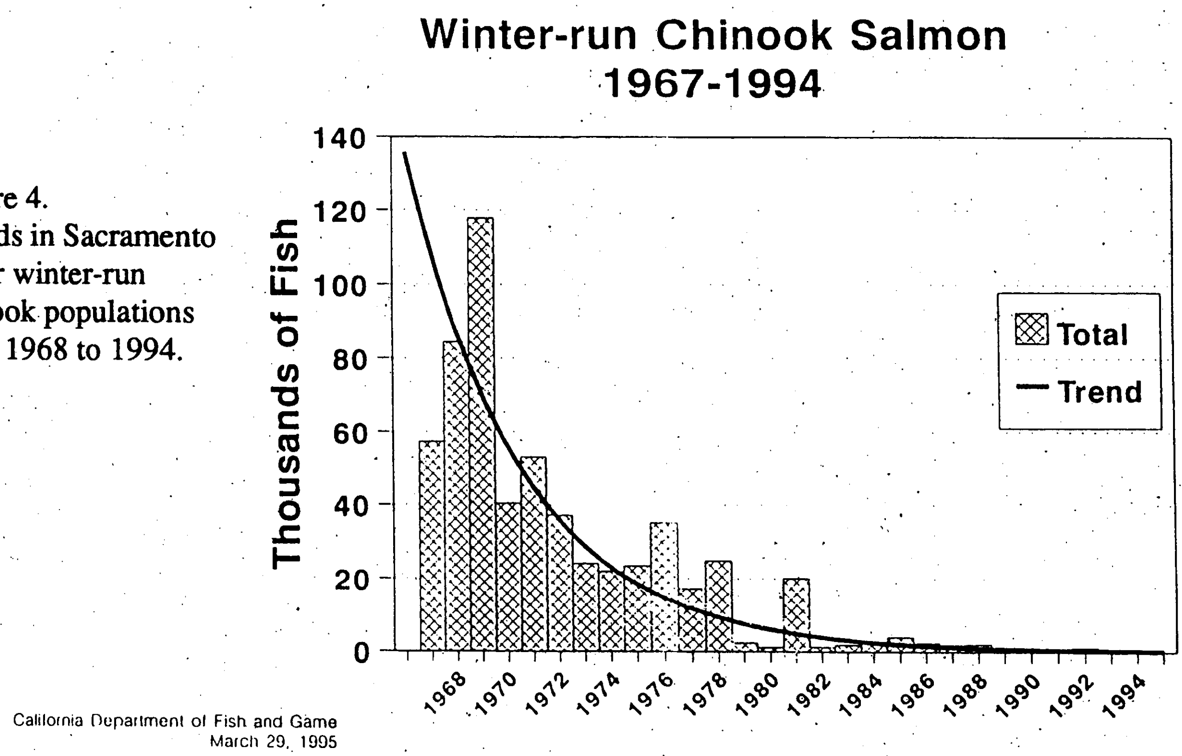


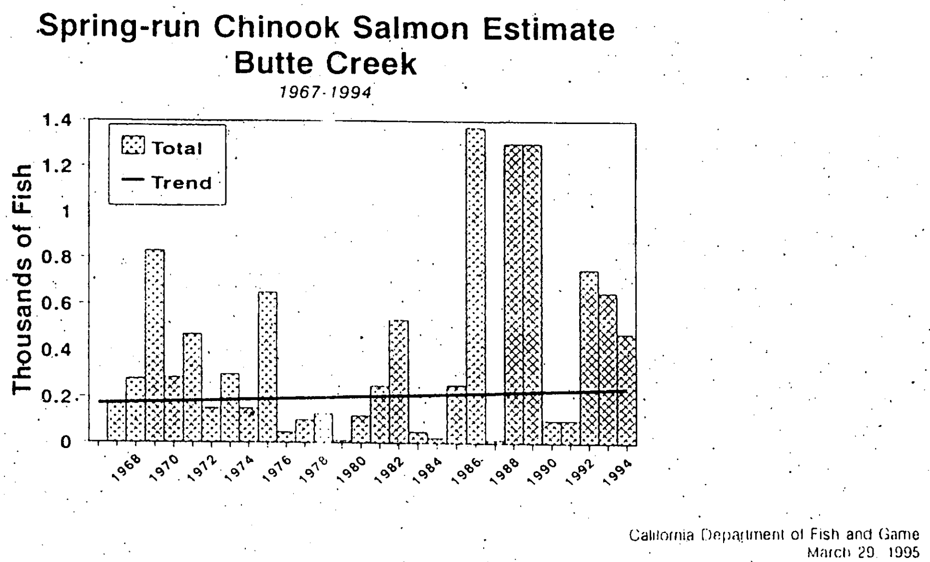
Figure 4.
Trends in Sacramento River winter-run chinook populations from 1968 to 1994.

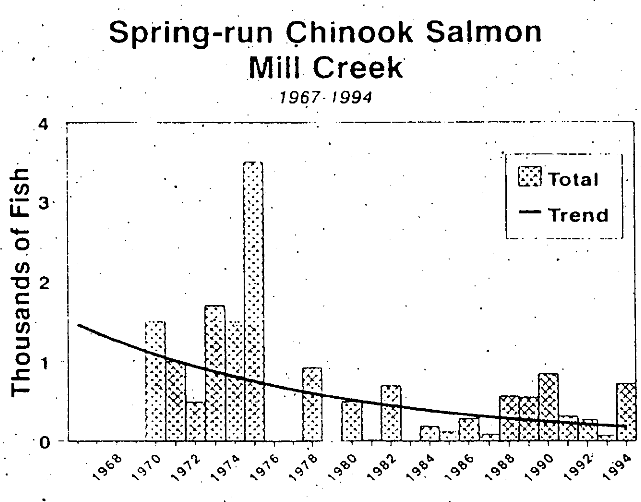
2. ***Central Valley Spring-run Stocks*** Description: This ESU includes several stocks of spring-run chinook that enter the Sacramento River from March to July and spawn from late August through early October in the mainstem Sacramento and Feather Rivers as well as in tributary streams such as Butte, Mill and Deer creeks. These stocks follow an ocean-type life history, with young migrating to the ocean as fry, subyearlings and yearlings and maturing off the California and Oregon coast. It is possible that the tributary populations are distinct from those spawning in the mainstem.

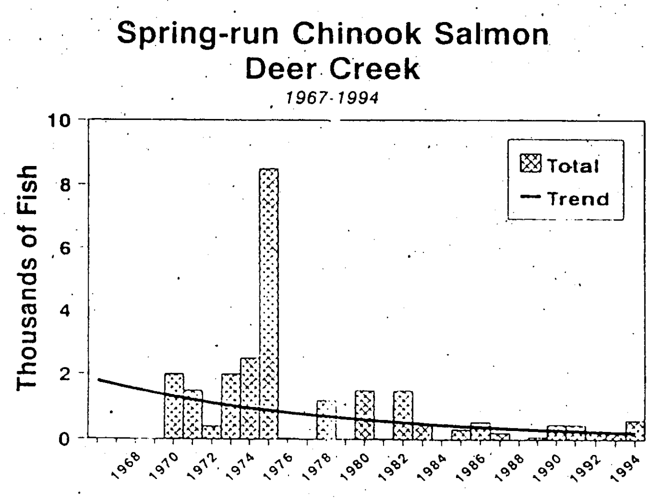
Current and Historic Threats: Most of the historical spawning and rearing habitat was blocked by construction of major dams, limiting populations of Central Valley spring-run chinook to the mainstem Sacramento River and a few lower river tributaries and forcing a previously unseen overlap with areas used by fall-run chinook. Remaining habitat is severely degraded.

Status: Central Valley spring-run chinook populations historically were the dominant run in the Sacramento and San Joaquin river basins, but native populations in the San Joaquin (which historically were the most numerous and may have constituted a separate ESU) were all extirpated following construction of Friant Dam and the complete dewatering of major portions of the river. Populations of Central Valley spring-run chinook in the Sacramento River system have seen access to spawning and rearing habitats restricted and have suffered serious declines. Escapement of spring-run chinook into key Sacramento River indicator streams have ranged from 24,000 in 1969 to 500 in 1991 and now regularly total fewer than 2,000 natural spawners (Figure 5).

Figure 5.
Trends in Central Valley spring-run chinook populations from 1968 to 1994 for 5a-Butte Creek. 5b-Mill Creek 5c-Deer Creek.







3. ***Central Valley Fall-run Stocks*** Description: This ESU includes populations of both fall and late-fall stocks of chinook that enter the Sacramento and San Joaquin rivers from July through April and spawn from October through February. These stocks follow an ocean-type life history, with young migrating to the ocean as fry and subyearlings and maturing off the California coast. San Joaquin fall-run chinook historically may have been a separate ESU, but large-scale hatchery transfers from the Sacramento and poor survival of San Joaquin populations has blurred the distinctiveness of these stocks. Furthermore, some believe that the fall and the late-fall-runs should be recognized as distinct.

Current and Historic Threats: Most of the historical spawning habitat for populations of Central Valley fall-run chinook was downstream from major dams and therefore still is accessible to natural spawners. However, dam operations pose severe temperature and flow problems to spawning success. In addition much of the spawning and rearing habitat has been degraded by agricultural practices and urbanization. Returns to hatcheries amount to approximately 20-50% of all fall-run chinook spawners in the Central Valley and hatchery strays probably also are responsible for much of the natural spawning.

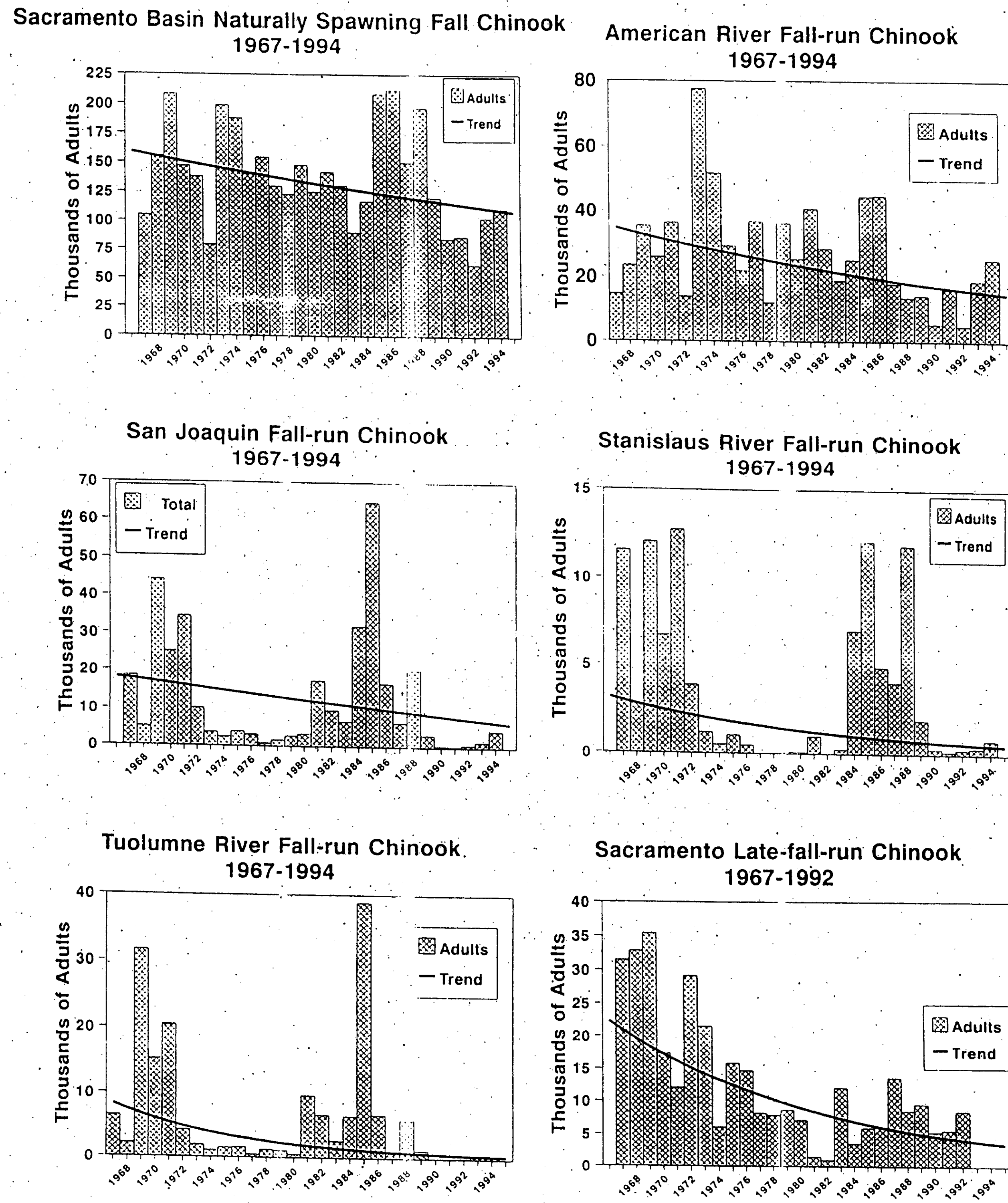
Status: Taken together, fall-run and late-fall chinook in the Central Valley still are the most abundant and widespread salmon in California, but total numbers from 1967 to 1994 exhibit a downward trend and the escapement goals established by the Pacific Fisheries Management Council have not been attained in recent years. Recent total population numbers of Sacramento River fall-run chinook range from more than 212,000 in 1986 to about 62,000 in 1992. Since 1967 fall-run stocks in Battle Creek have been on a slightly upward trend; those from the Feather, Yuba and Merced rivers have remained essentially unchanged; and fall-runs from the American, San Joaquin, Stanislaus and Tuolumne rivers as well as Sacramento River late fall-run stocks have declined (Figure 6). For example, San Joaquin fall-run chinook numbers have ranged from about 65,000 in 1985 to as few as several hundred in recent years.

B. Coastal Basins and Puget Sound Group. This group includes spring and fall-runs of chinook salmon, all ocean-type, that historically spawned in the smaller coastal drainages from central California north to Puget Sound. They are likely to be grouped into five ESUs.

4. ***Southern Oregon and California Coastal Stocks*** Description: This ESU includes all coastal chinook salmon spawning from Cape Blanco to the southern extent of the range (excluding Central Valley, Trinity River, and Klamath River populations). Major rivers within this ESU include the Rogue, Chetco, Smith, Mad, Eel and Russian rivers. These populations include both spring and fall-runs and follow an ocean-type life history, typically migrating to the ocean as subyearlings and maturing off the California and Oregon coast. Some believe that coastal chinook south of the Klamath River are distinct from those along the rest of the coast.

Current and Historic Threats: All basins have degraded habitats resulting from mining, agriculture, forestry practices, urbanization and severe flooding. Hydraulic dredge mining in the upper Rogue basin began with the 1850 gold rush. Irrigated agriculture also began early in the Rogue basin and continues today. Construction of the Lost Creek Dam on the mainstem Rogue River in 1977 made approximately 33% of the spring-run spawning area in the basin

Figure 6. Trends in Central Valley fall-run chinook populations from 1968-1994 for 6a-Sacramento Basin fall-run natural spawners, 6b-American River fall-run, 6c- San Joaquin River fall-run, 6d-Stanislaus River fall-run, 6e-Tuolumne River fall-run, and 6f-Sacramento late fall-run.



California Department of Fish and Game
March 29 1995

inaccessible. Intense logging activity and road construction in other coastal basins, beginning in the 1950s and 1960s, has seriously destabilized stream banks and hillslopes making many of these watersheds more susceptible to significant damage during flood events. In some coastal basins, urbanization also has had a significant impact. Hatchery programs in the upper Rogue, resulting in more than 50% of the fish on natural spawning grounds originating from hatchery stocks, are posing significant risks of genetic contamination. Several small fall-run hatchery programs in coastal basins also have harmed wild populations.

Status: The status of southern Oregon and California coastal stocks is highly variable. Overall abundance of coastal spawners south of Cape Blanco is relatively high (averaging 10,000) and spread among numerous stocks. Unfortunately, there is a history of downward trends in abundance in most populations, both spring and fall-runs, for which data are available. Most spring-run populations show severe declines. It is questionable whether any southern Oregon and California coastal populations outside the Rogue Basin are sustainable at current levels and the presence of hatchery fish in the Rogue Basin raises concerns about the long-term sustainability of wild chinook salmon in that location. Spring-run stocks in the upper Rogue River have remained fairly stable since monitoring began in 1942, varying from 10,000 to 40,000 spawners, although numbers dropped to below 10,000 in consecutive years during the early 1990s for the first time. Fall-run stocks in the upper Rogue River appear to have remained stable at 2,000 to 4,000 fish since the late 1970s when monitoring began. In comparison, populations in the lower Rogue and south Oregon coast basins have decline in the last two decades, with some stocks returning less than 50 spawning adults.

5. ***Upper Klamath and Trinity Rivers Stocks*** Description: This ESU includes all Klamath River Basin populations from the Trinity River and the Klamath River upstream of the confluence of the Trinity River. These populations include both spring-run chinook that enter the upper Klamath River Basin from March through July and spawn from late August through September and fall-run chinook that enter from July through October and spawn from September through January. These populations display an ocean-type life history and migrate to the ocean primarily as subyearlings and mature off the coast of California and Oregon. Because of habitat separation and differences in the timing of spawning runs, it is possible the spring and fall-runs are distinct.

Current and Historic Threats: There have been major blockages of original spawning and rearing habitat in the upper rivers and severe degradation of remaining habitat. This is especially true for the spring-run stocks in the basin which were blocked from most of their spawning and rearing habitat in the Klamath River by dam construction in the late 1800s and early 1900s and from most of their habitat in the Trinity River by construction of Trinity Dam in 1963. The relatively high hatchery production in the basin raises the potential for genetic contamination of the remaining native populations.

Status: Recent abundance of chinook salmon in the upper Klamath and Trinity rivers is low relative to historical abundance, with recent escapements averaged only about 23,000 natural spawners compared to almost 170,000 in the 1960s. Fall-run chinook natural spawner abundance has declined from an average of over 80,000 during 1986-89 to about 17,000 during the early 1990s (Table 1). Remaining native populations of spring-run chinook in the upper

Klamath and Trinity rivers are very small. The status of Klamath Basin spring-run are typified by the Salmon River stock. Since 1980, spring-run chinook stocks in the Salmon River have been as high as 1,300 and as low as 175.

Table 1. Klamath Basin fall-run chinook harvest and spawner estimates from 1986 to 1992. Modified from 1992 California Department of Fish and Game Status Report: California Salmon.

	1986	1987	1988	1989	1990	1991	1992
Angler harvest	21,448	20,572	22,647	8,951	3,624	3,096	900
Indian net harvest	27,137	57,344	55,783	49,210	8,418	11,014	3,200
Hatchery spawners	32,891	29,123	33,458	21,991	8,052	6,521	9,500
Natural spawners	113,369	101,717	78,886	43,718	13,051	11,110	27,000
TOTALS	194,836	208,756	190,774	123,870	33,145	31,741	40,600

6. *Oregon Coast Stocks* Description: This ESU includes coastal populations, including spring, summer and fall-runs, from Elk River (north of Cape Blanco) to the mouth of the Columbia River. Major rivers in this ESU include the Necanicum, Nehalem, Tillamook, Nestucca, Salmon, Siletz, Yaquina, Alsea, Siuslaw, Umpqua and Coquille rivers. These populations include both spring and fall-runs, both exhibiting an ocean-type life history, with adults reaching 3 to 5 years of age in coastal waters off British Columbia and Alaska prior to maturity. Some genetic information indicates that populations north of the Umpqua River may be distinct from southern Oregon coastal populations.

Current and Historic Threats: Freshwater habitats generally are in poor condition, with numerous problems such as low summer flows, high temperatures, loss of riparian cover and detrimental streambed changes. Hatchery programs along the Oregon coast are concentrated in the Tillamook and Coos bay areas, and in the Salmon, Alsea, Coquille and Elk rivers. The spring-run chinook hatchery program in Tillamook Bay and the fall-run hatchery programs in the Salmon and Elk rivers as well as hatchery program in the Umpqua basin pose a risk of genetic contamination.

Status: Overall abundance of chinook salmon from Elk Creek to the mouth of the Columbia River is encouraging as compared to the severely depressed numbers observed during the middle of this century, with recent average escapements about 136,000. However, these numbers still are 22% to 45% below the estimated number of fish present in 1900. Furthermore, several populations have exhibited recent short-term declines in abundance. Spring-run stocks appear to have remained depressed since declines in the 1950s. Most of the fall-run stocks reached their lowest levels between 1930 and 1960, and generally have rebounded slightly. Fall-run stocks typically number from 200-500 individuals in the smaller coastal basins and 1,000-2,000 individuals in the larger basins.

7. ***Washington Coast Stocks*** Description: This ESU includes coastal populations north of the Columbia River and west of the Elwha River. Major rivers in this ESU include the Quillayute, Hoh, Queets, Quinault and Chehalis rivers. These populations display an ocean-type life history and reach maturity at 3 to 5 years of age and exhibit a more northern ocean distribution than is seen in the Puget Sound or lower Columbia River ESUs.

Current and Historic Threats: All basins are affected by habitat degradation, largely related to forestry practices. Hatchery production is substantial within several basins, posing serious concerns about genetic contamination of wild fish from hatchery strays.

Status: Chinook run sizes increased from the mid-1960s through the 1970s and dropped in the 1990s. Recent average escapements for hatchery and natural fish combined have been about 58,000. This is considerably less than the natural run size of 190,000, the apparent historical peak abundance estimated in 1911. Current production is distributed among several stocks. Although long-term trends in many populations along the Washington Coast have been predominantly upward, several populations recently have displayed significant short-term declines. There is special concern regarding the status of spring-run populations within this ESU as well as fall-run populations in Willapa Bay and parts of the Grays Harbor drainage. Of the 32 stocks of coastal Washington chinook salmon, five were classified as depressed and seven as unknown in the 1992 Washington State Salmon and Steelhead Stock Inventory (SASSI), with 20 or 62% identified as healthy (Table 2). The five stocks identified as depressed are the Queets, Clearwater, and Quinault spring/summer-runs, Satsop summer-run and the Fall River early fall-run.

Table 2. Washington Coast chinook stocks identified as depressed and status unknown in the 1992 Washington State SASSI.

Stock	Stock Origin	Production Type	Stock Status
Queets spring/summer-run	Native	Wild	Depressed
Clearwater spring/summer-run	Native	Wild	Depressed
Quinault spring/summer-run	Native	Wild	Depressed
Satsop summer-run	Mixed	Wild	Depressed
Fall River Early (North R) fall-run	Native	Wild	Depressed
Sooes River fall-run	Native	Cultered	Unknown
Quillayute/Bogachiel sumer-run	Native	Composite	Unknown
Calawah summer-run	Native	Wild	Unknown
Raft fall-run	Native	Wild	Unknown
Moclips fall-run	Native	Wild	Unknown
Copalis fall-run	Native	Wild	Unknown
Johns/Elk & S Bay tribs fall-run	Mixed	Wild	Unknown

8. *Puget Sound Stocks* Description: This ESU includes all runs of chinook salmon in the Puget Sound region from the North Fork Nooksack River to the Elwha River on the Olympic Peninsula. Major rivers in this ESU include the Nooksack, Skagit, Stillaguamish, Snohomish, Cedar, Puyallup, Nisqually, Dungeness and Elwha rivers. They display an ocean-type life history and reach maturity at 3 to 4 years of age.

Current and Historic Threats: Freshwater habitat throughout Puget Sound has been blocked or degraded, with upper tributaries widely affected by poor forestry practices and lower tributaries and mainstem rivers affected by agriculture and/or urbanization. Substantial hatchery production occurs in Puget Sound giving rise to significant concerns regarding genetic contamination. There also is concern that harvest rates of natural stocks in mixed stock fisheries may be excessive.

Status: Run size estimates for wild chinook salmon from 1968 through 1994 show relatively stable returns until a sharp drop in abundance beginning in 1991. Recent average total escapement for all Puget Sound chinook populations is almost 71,000, with more than half that number returning to hatcheries. This is considerably less than the peak historic run-size, estimated at about 690,000 in 1911. There are few native, naturally-reproducing populations of chinook salmon left in Puget Sound. Of the 29 stocks of chinook salmon in Puget Sound, eight were classified as depressed, four as critical and seven as unknown in the 1992 Washington State Salmon and Steelhead Stock Inventory, with only 10 Puget Sound stocks or 34% identified as healthy (Table 3). The critical stocks, including the North and the South Fork Nooksack populations as well as the Puyallup spring-run and Dungeness spring/summer-runs, are experiencing production levels so low that permanent damage is likely or already has occurred. Depressed stocks, including the lower Skagit fall-run, lower Sauk summer-run, Suiattle spring-run, Stillaguamish summer and fall-run, Snohomish summer-run, Snohomish fall-run and Hoko fall-run, are suffering runs sizes below expected levels. The status of the Samish/MS Nooksack fall-run, upper Cascade spring-run, Bridal Veil Creek fall-run, north Lake Washington populations, Cedar populations, Puyallup summer and fall-run is unknown.

C. Columbia River Group. This group includes spring, summer and fall-runs, and includes four geographic assemblies of stream-type chinook as well as populations of ocean-type chinook. They are likely to be grouped into seven ESUs.

9. *Lower Columbia River Stocks* Description: This ESU includes populations from the mouth of the Columbia River to approximately the crest of the Cascade Range. Major Columbia River tributaries in this ESU include the Cowlitz, Lewis, Sandy, Little White Salmon and White Salmon rivers as well as the lower Willamette River below Willamette Falls. Populations in this ESU are ocean-type, tending to mature at age 3 and 4 after following a northerly ocean migration route that appears to stop short of Alaska.

Current and Historic Threats: Freshwater habitat is in poor condition in many basins of the lower Columbia River, with problems related to forestry practices, urbanization and agriculture. Substantial hatchery production and release of chinook in the area pose serious concerns regarding genetic contamination.

Table 3. Puget Sound chinook stocks identified as critical, depressed and status unknown in the 1992 Washington State SASSI.

Stock	Stock Origin	Production Type	Stock Status
NF Nooksack	Native	Composite	Critical
SF Nooksack	Native	Wild	Critical
White (Puyallup) spring-run	Native	Composite	Critical
Dungeness spring/summer-run	Native	Wild	Critical
Lower Skagit mainstem/tribs fall-run	Native	Wild	Depressed
Lower Sauk summer-run	Native	Wild	Depressed
Suiattle spring-run	Native	Wild	Depressed
Stillaguamish summer-run	Native	Composite	Depressed
Stillaguamish fall-run	Unknown	Wild	Depressed
Snohomish summer-run	Native	Wild	Depressed
Snohomish fall-run	Native	Wild	Depressed
Hoko fall-run	Native	Composite	Depressed
Samish/MS Nooksack fall-run	Non-native	Composite	Unknown
Upper Cascade spring-run	Native	Wild	Unknown
Bridal Veil Creek fall-run	Native	Wild	Unknown
North Lake Washington tribs summer/fall-run	Native	Wild	Unknown
Cedar summer/fall-run	Native	Wild	Unknown
White (Puyallup) summer/fall-run	Unknown	Wild	Unknown
Puyallup fall-run	Unknown	Composite	Unknown

Status: The overall average total escapement of chinook salmon in the lower Columbia River during recent years has been near 90,000. Unfortunately, long-term trends in abundance of individual populations in the lower Columbia River are about equally divided among declines and increases, and generally appears to be hatchery driven. Wild populations of fall-run chinook are much smaller than those present in the early 1900s, and even appear to be depressed relative to population sizes of the 1950s and 1960s. For example, Sandy River fall-run stocks have declined from about 10,000 fish in the early 1900s to annual returns of only 500 to 2,000 fish annually since 1984. Some fall-run stocks in the lower Columbia and Sandy river basins may be extinct. Remaining fall-run "upriver bright" chinook populations in the Wind, White Salmon and Klickitat rivers appear to be the result of hatchery introductions. Abundances of wild spring-run chinook stocks are unknown. However, spring chinook in the Clackamas and Sandy rivers appear to be significantly influenced by introductions from the Willamette River. There are few identifiable native, naturally-reproducing spring-run populations and numbers of those remaining are very low.

10. ***Upper Willamette River Stocks*** Description: This ESU includes spring-run populations above Willamette Falls. Populations in this ESU follow an ocean-type life history pattern.

Current and Historic Threat: Substantial areas of important historical habitat have been blocked by dam construction, and remaining habitat has been degraded by thermal effects of dams, forestry practices, agriculture and urbanization. Large hatchery populations, the introduction of fall-run chinook salmon into the basin and the laddering of Willamette Falls have increased the potential for genetic contamination. Sport and commercial harvest of upper Willamette River chinook is high relative to the apparent low productivity of natural populations.

Status: The recent 5-year average run size amounted to about 48,000 adults, a number comparable to the 49,000 seen in 1947. Unfortunately, production today is largely hatchery driven with extremely low levels of natural production. Furthermore, natural escapement in 1994-95 was 3,900 fish and only about 1,300 were of natural origin. The remaining 2,600 natural spawners were hatchery strays. In all recent years the proportion of hatchery fish far exceeds the proportion contributed by the very small numbers of wild fish.

11. ***Mid-Columbia River spring-run*** Description: This ESU includes stream-type chinook salmon spawning in the Klickitat, Deschutes, John Day and Yakima rivers. Spring-run populations in the Hood, Walla Walla and Umatilla rivers also may have belonged in this ESU, but they now are considered extinct. Mid-Columbia spring-run chinook follow a stream-type life history pattern. They rear in freshwater until they migrate to the ocean as yearlings and migrate far offshore (they do not appear in any appreciable number in ocean fisheries). Most adults return to spawn as 4-year olds, except those returning to the Yakima River which generally spawn at age 5. Some believe the Yakima River spring-run chinook should be recognized as distinct from other mid-Columbia River populations.

Current and Historic Threats: Spawning and rearing habitat has been affected by agriculture, and migratory corridors have been substantially affected by hydroelectric development. Substantial hatchery production has been detrimental to natural populations in the Klickitat River.

Status: Several historical populations have been extirpated and total abundance of remaining mid-Columbia River spring-run chinook is low, with recent average natural escapement about 19,000. Although hatchery production accounts for a substantial proportion of total escapement in the mid-Columbia as a whole, production in the Deschutes, John Day and Yakima rivers is predominantly natural with two of these three rivers exhibiting long-term increasing trends. The Deschutes basin includes a population of 500 to 1,000 spring-run chinook in the Warm Springs River and a second population of 100 to 300 below Pelton/Round Butte dams. The four John Day spring-run populations have been relatively stable, with about 1,500 spawning adults in the North Fork John Day stock, and about 200 to 500 fish each in the others. Only one population of fall-run chinook remains. This stock, the Deschutes River fall-run, ranged from 4,000 to 8,000 fish from 1977 to 1993 and then increased to more than 15,000 fish in 1994.

12. *Upper Columbia River summer and fall-run Stocks* Description: This ESU includes all ocean-type chinook spawning in the Columbia River upstream of its confluence with the Snake River. Major Columbia River tributaries in this ESU include the Wenatchee, Entiat, Methow and Okanogan rivers. Fish from this ESU primarily migrate to the ocean as subyearlings, but unlike the ocean-type fish in the Lower Columbia and Snake Rivers, these chinook mature at an older age during an ocean migration that takes them north to Alaskan coastal waters.

Current and Historic Threats: Access to a substantial portion of historical habitat was blocked by Chief Joseph and Grand Coulee dams. There are local habitat problems related to irrigation diversions and hydroelectric development as well as from urbanization and livestock grazing.

Status: In an earlier review, NMFS determined this ESU was neither endangered nor threatened. Its status is not under review now. Total recent abundance for all stocks within this ESU averaged 58,000 adults. Recent trends for the two largest populations are both upward, while those for the smaller populations are mixed.

13. *Upper Columbia River spring-run Stocks* Description: This ESU includes stream-type chinook spawning in the Wenatchee, Entiat and Methow rivers. These populations migrate to the ocean as yearlings and are only rarely recovered in coastal fisheries.

Current and Historic Threats: Blockage of important historical habitat above Grand Coulee Dam, high levels of hatchery production, effects of hydroelectric development on migration corridors and degradation of remaining spawning and rearing habitat have significantly impacted Upper Columbia River spring-run chinook.

Status: Recent average natural escapement was less than 10,000, and 1994 and 1995 escapements were all-time lows. Both recent and long-term trends are predominantly downward.

14. *Snake River fall-run* Description: This ESU includes fall-run chinook that spawn in the Snake River as well as Deschutes River fall-run populations. All display an ocean-type life history pattern. It is likely that historic populations of fall-run chinook salmon in the Umatilla, John Day and Walla Walla rivers also should be considered part of this ESU.

Current and Historic Threats: Almost all historical spawning habitat in the Snake River Basin was blocked by the Hells Canyon Dam complex and other habitat blockages have occurred affecting fall-run stocks within this ESU. Remaining habitat has been reduced by inundation in the mainstem Snake River and affected by agricultural water withdrawals, grazing, forestry practices and other land management activities. Migratory corridors have been affected by hydroelectric development and some areas, such as the mainstem Grande Ronde River, have been channelized.

Status: Snake River fall-run chinook currently are listed as threatened under the ESA. Hells Canyon Dam resulted in extensive population extinctions. Remaining populations in the Imnaha, Grande Ronde and mainstem Snake rivers below the dam have declined precipitously. The total annual count of Snake River fall-run at Lower Granite Dam of adults returning to Idaho averaged 441 fish from 1979 through 1992, with a record low return of only 78 fish in 1990 (Figure 7). Returns to the Snake River populations have a 5-year mean of about 700 adults, including hatchery strays, substantially down from the 72,000 adults typical during the 1930s and 1940s. The likely addition of the Deschutes River fall-run chinook to this ESU may cause a reevaluation of the status of the ESU as a whole. Returns of naturally spawning fish to the Deschutes River have averaged about 4,000 adults per year, with an apparent high proportion of returning immature males, known as "jacks."

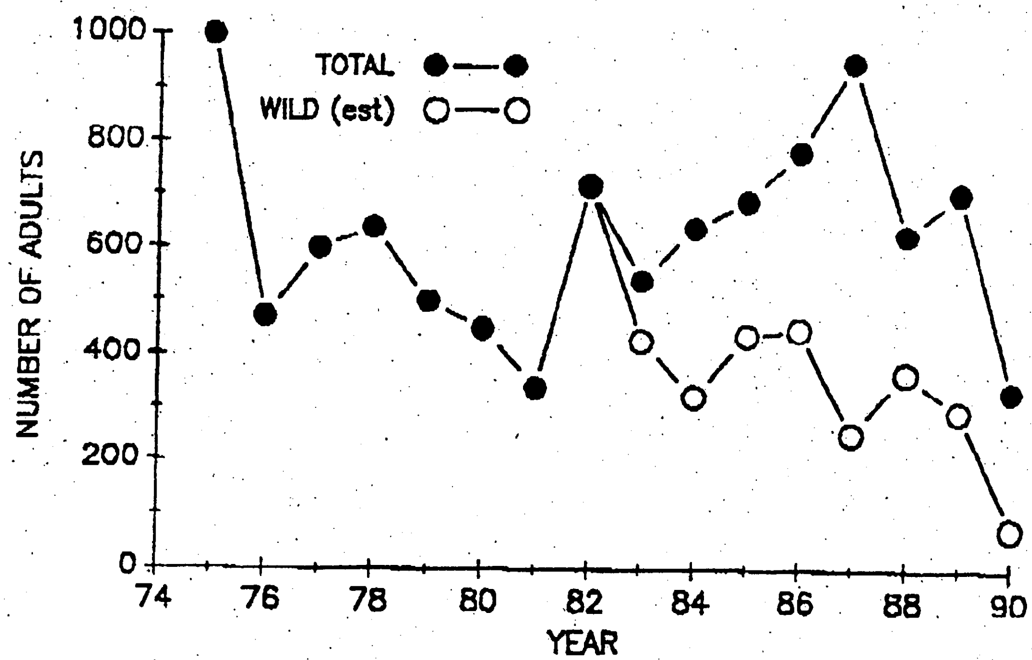


Figure 7. Trends in Snake River fall-run chinook populations counted at Lower Granite Dam 1975-1990.

15. *Snake River spring and summer-run Stocks* Description: This ESU includes populations of spring and summer-run chinook salmon from the Snake River Basin, including populations in the Grande Ronde, Imnaha, Salmon, Snake, Clearwater and Tucannon subbasins. These populations display a stream-type life history pattern, generally migrating to the ocean as yearlings and maturing at age 4 or 5.

Current and Historic Threats:. Land management practices such as those discussed as threats to fall-run chinook also have degraded habitat in areas used for spawning and rearing by spring and summer-run stocks, but to a greater effect because of this ESU's stream-type life history pattern. Spring and summer-run stocks also have been detrimentally affected by dams and diversions.

Status: This ESU presently is listed as threatened under the ESA and is not currently under further review. Most of the 200-400 summer-run in the Imnaha River are concentrated into a single population while the Grande Ronde River spring-run has become fragmented into six separate populations of fewer than 100 adults (Figure 8). In Washington, Tucannon River spring-run stocks are considered depressed. Redd counts at survey areas on the Salmon and Clearwater rivers have declined sharply over the last 33 years. On Camas Creek, a tributary to the Salmon River used as an indicator of wild production, the five-year average annual counts during 1964-68 was 118 redds. During 1987-91 the average annual counts was 18.7 redds and during 1992-96 the average dropped further to 7; a 94% drop since the late 1960s. Redd counts on five tributaries of the Clearwater River used as indicators of wild production also showed declines in the five-year annual counts dropping from 90 during 1977-1981, to 38 during 1987-91 and 26 during 1992-96, a 58% drop since the late 1970s.

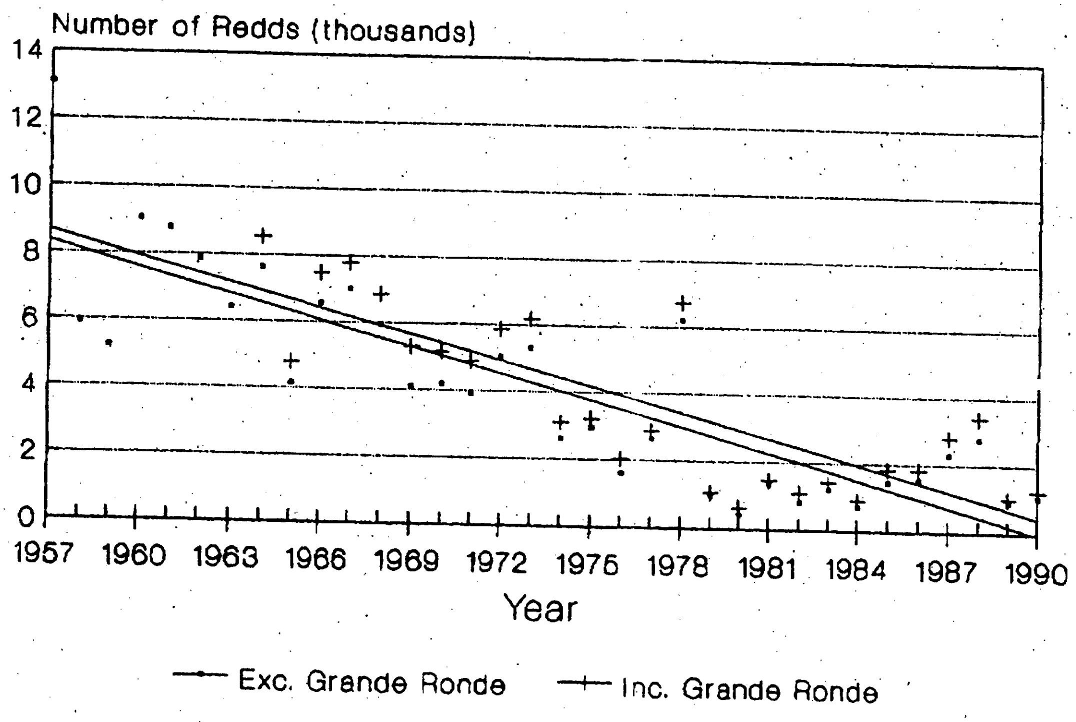


Figure 8. Trends in Snake River spring and summer-run chinook redds in index areas of the Snake River from 1957-1990.

16. *British Columbia and Yukon Stocks*. Description: Recent evaluations of Pacific salmon in Canada identified 866 stocks of chinook salmon in British Columbia and the Yukon within 18 production areas established by the Canadian Department of Fisheries and Oceans.

Current and Historic Threats: Currently, no comprehensive inventory of threats to salmon stocks in British Columbia or Yukon exists. However a number of human activities have been identified as contributing to declines in Canadian stocks. Freshwater habitat degradation from forestry practices (including removal of trees, construction of logging roads, and until 1980, log drives); urbanization; dikes, dredging and fills; mining; agriculture; road and rail construction; and effluent discharge has been substantial in some areas. These effects are particularly notable along the coast from the lower Fraser River north to southern Alaska, including Vancouver and the Queen Charlotte Islands. In addition, many of Canada's weaker salmon stocks are severely impacted by overharvest in mixed stock fisheries.

Status: Information was available to evaluate the status of only 47% of the 866 chinook salmon stocks in Canada. Of these, 17 are extinct, 47 were considered at high risk of extinction, 6 at moderate risk of extinction, 7 of special concern, and 330 unthreatened. A high proportion of stocks were at risk in some areas, while in other areas most stocks were considered unthreatened. Fourteen of 65 stocks in southwest Vancouver Island, or 36%, were determined to be at high risk of extinction. More than 20% of stocks for Queen Charlotte Islands, northwest Vancouver Island and the Vancouver Island side of the Strait of Georgia also were considered to be at high risk.

17. *Alaskan Stocks* Description: No comprehensive evaluation of chinook salmon stocks in Alaska has yet been completed. The state of Alaska maintains sport and commercial harvest records for three regions: Southeast, Central and Western. A recent examination of Pacific salmon in southeast Alaska identified 63 spawning locations in seven management units in the region. Similar information is not available for the central and western regions.

Current and Historic Threats: The most immediate long-term threat to chinook productivity is the loss of habitat for spawning and rearing. Although much of the state remains relatively undeveloped, impacts from urbanization, logging and mining have led to impaired water quality and habitat degradation. By far, the greatest potential threat to habitat identified in the recent evaluation of southeast Alaska stocks was logging. In addition, threats from urbanization, large-scale enhancement projects and overfishing of weak stocks also were noted.

Status: Statewide commercial catches of chinook remain relatively stable in all three regions (i.e., southeastern, central and western), however catch data may not provide an accurate picture of the status of all stocks. It is likely that despite the continued high catches, some weaker stocks may be in decline. The recent evaluation of southeastern Alaska stocks found that while 19 spawning aggregates were stable (30%) and 11 were increasing (17.5%), at least one was depressed and at moderate risk of extinction (1.5%) and the status of 32 was unknown (51%).

THE VALUE OF CHINOOK TO THE REGION

Chinook salmon have economic value deriving from sport, commercial and subsistence use. They also have spiritual, aesthetic and ecological value as well as providing an indicator of environmental health.

Economic Value. Chinook salmon bring economic value to the economy through a variety of pathways (Figure 9). For example, commercial fishing involves distributors and wholesalers, charter operators, processors, net and gear companies, clothing, fuel and other items. The economic value of chinook salmon also enters the economy through Indian tribal economies, sport fishing, recreation, manufacturing, tourism, retail, arts and culture, and tax revenues. A variety of means have been used to attempt to capture the direct economic value of salmon and steelhead. However, reflecting today's economic value of salmon dramatically underestimates the potential economic value that could be realized if the already severely depressed stocks were to be recovered.

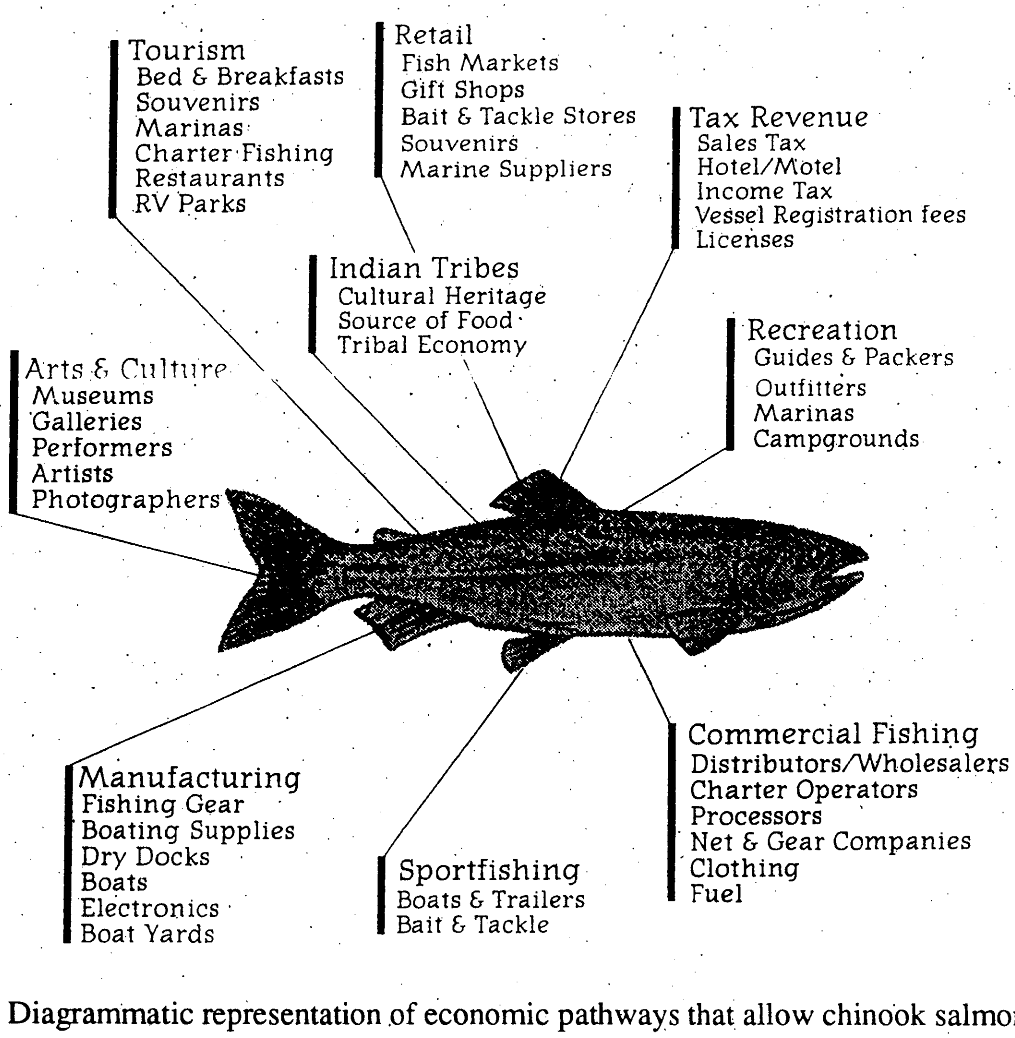


Figure 9. Diagrammatic representation of economic pathways that allow chinook salmon to bring value to the economy.

For commercial harvest values, dockside values typically are reported. However, it must be noted that these numbers fail to reflect most of the related items identified above that also result in an economic effect on the regional economy. Nonetheless, it is interesting to note that in 1990 the dockside value of chinook salmon landed in Washington was $9.3 million and amounted to about 18% of that for all salmon landed in the state, in Oregon $8 million or about 83% of that for all salmon landed and in California $11.4 million or about 95%. Efforts to determine the jobs and income for harvesters, cannery workers and employees in related industries that could have been supported by pre-development Columbia River salmon runs of 10 to 16 million spawning adults have been conducted and determined that from $250 to $505 million of personal income could be generated, supporting 13,000 to 25,000 jobs resulting in an asset value of up to $13 billion.

Other Values. Chinook salmon also have a number of values that do not appear to have a direct bearing on economics.

Spiritual and aesthetic: Throughout their range, chinook salmon have long been of spiritual and cultural value to Native Indians. Salmon also have become culturally important for non-Indians. Modern day salmon and steelhead festivals, celebrating the endurance and loyalty of anadromous fishes to their natal streams, are common in California, Oregon, Idaho, Washington, Alaska as well as in Canada. Traditional stories often highlight the cultural gift of salmon and hinge on the persistence and dedication with which they undertake their often arduous migrations.

Existence: A number of efforts have been undertaken to quantify how highly salmon and efforts to rehabilitate them are valued. Two recent efforts include a forestry-related survey completed in the fall of 1991 at Oregon State University. The second is a 1993 Western Rangelands Survey. The forestry survey found that 78% of national respondents and 55% of Oregon respondents agree that greater protection should be given to fish and wildlife habitats on federal forest lands, compared to 23% and 25% respectively who disagreed. The same survey found that 65% of national respondents and 48% of Oregon respondents do not believe that endangered species laws should be set aside to preserve timber jobs, compared to 17% and 37% respectively who believe that such laws should be set aside. The Rangelands Survey found that 75% of national respondents and 59% of Oregon respondents agree that greater protection should be given to fish in rangelands, compared to 14% and 20% respectively who disagree. It also found that 65% of national respondents and 47% of Oregon respondents do not believe that endangered species laws should be set aside to preserve ranching jobs, compared to 20% and 39% respectively who believe such laws should be set aside.

Ecological: Chinook salmon convey a variety of ecological values to the freshwater habitats they inhabit. Probably the single largest ecological direct ecological service they provide to the stream relates to nutrient cycling. As eggs, fry and parr, chinook prey upon larval and adult insects and in turn are preyed upon by large predators such as bull trout, bears and raptors. Thus, the presence of young salmon in freshwater assists in bringing the sun's energy, first captured by plants, into the freshwater food chain. However, the largest effect that chinook salmon have upon the freshwater food chain occurs as a result of the death of spawning adults. As a result of their anadromous life history, these fish transfer enormous quantities of nutrients and energy "harvested" from the ocean during their maturation to the freshwater environment, making them available for use upon their death and decomposition. Work done on Grizzly Creek, a tributary of the Snoqualmie River in Washington, established a startlingly high contribution of oceanic nitrogen in invertebrate predators (10.9%), the foliage of riparian plants (17.5%), juvenile cutthroat trout (18.5% to 25.6% depending on age) with nearly half (45%) the nitrogen in one sample of older cutthroat trout originating in the ocean and made available for use in the freshwater environment by the death of spawning salmon. While the transfer was accomplished by coho salmon in this instance, chinook salmon and other anadromous species serve equally important roles in the movement of nutrients from the ocean to the stream.

Indicators of environmental health: Chinook salmon require healthy rivers and streams to thrive. The status of chinook populations serves as a barometer of watershed and environmental health.

CAUSES OF DECLINE

A number of factors have contributed to the declines in chinook salmon. Human activities have

- reduced the capacity of rivers and streams to support salmon through detrimental changes in the chemical, biological and physical attributes;
- completely blocked access to many historic spawning and rearing areas and made access to much of the remaining habitat more difficult;
- altered temperature and flow regimes;
- altered competition and predation pressures;
- compromised genetic integrity; and
- imposed excessive fishing pressures.

Habitat degradation resulting from land management practices and dam/diversion construction has been associated with more than 90% of the documented extinctions or declines of Pacific salmon stocks. Many have concluded that all the watersheds in California, Oregon, Washington and Idaho have been affected, at least to some degree, by land management practices (Table 4). Furthermore, few river systems in the region are free from the constraints of dams and diversions.

Habitat loss associated with land use practices: Forest practices, agriculture, livestock grazing, road-building, mining and urbanization have affected much of the landscape and diminished the ability of freshwater habitats to support Pacific salmon. For example:

- Salmon survival in Idaho is 10 to 55 times higher in streams not subjected to logging, grazing and mining than in degraded streams in managed watersheds.

- Over the past 50 years, most unmanaged streams, not subjected to grazing, logging, mining and road construction, have retained or improved the number of large, deep pools (a critical instream habitat element)—even in watersheds subjected to fire, flood, drought and other natural disturbances.

- Aerial reconnaissance of storm effects related to the February 1996 storm on eastern Oregon and Washington coastal watersheds determined that 71% of the landslides were associated with recent clear cuts, 36% with roads, and 23% with older clear cuts. Only 6% of the landslides occurred in uncut areas.

- Mass movement in western Oregon was 30 to 300 times greater in roaded than in unroaded watersheds and 88% of landslides in Idaho were associated with roads. Even the best roading practices results in a sediment yield at least 51% over natural.

- Dredge and placer mining severely alter streams; the upper reaches of the Grande Ronde River, for example, now flow underground through rubble dredged from the stream bottoms decades ago.

Table 4. Areas of different land-use types in Oregon, Washington and Idaho. Modified from Jackson and Kimerling (1993).

Land use	Ownership	Oregon		Washington		Idaho	
		km^2	%	km^2	%	km^2	%
Forests	Federal	75,669	30	38,340	22	67,745	30
	Non-federal	47,984	19	51,128	29	16,475	7
Rangeland	Federal	53,160	21	6,750	4	63,463	28
	Non-federal	37,037	15	22,557	13	26,693	12
Cropland	Non-federal	24,682	10	37,968	22	40,590	18
Pasture	Non-federal	7,754	3	5,747	3	5,480	2
Urban land	Non-federal	3,808	2	6,329	4	1,930	1
Natl Parks	Federal	683	<1	7,329	4	393	<1
Total landbase	Federal	129,512	51	52,419	30	131,600	59
	Non-federal	121,265	49	123,729	70	91,168	41
	Combined	250,777	100	176,148	100	222,768	100

Timber harvest activities: The mechanical processes involved in timber harvest and associated road construction alter many components and processes of aquatic ecosystems. Soil and site disturbance often results in increased rates of erosion and sedimentation, direct modification and destruction of aquatic and terrestrial habitats, changes in water quality and quantity, and disturbance of nutrient cycles within aquatic ecosystems. Physical changes affect runoff events, bank stability, sediment supply, large woody debris retention and temperature.

Agriculture: The proportions of land in Oregon, Washington and Idaho dedicated to agriculture is relatively low whereas in California it is extremely high. Because agricultural land often is located on floodplains and valley bottoms which historically were the most productive fish sites, the effects of agricultural practices on salmon can be quite high. Agriculture practices can result in loss of native vegetation, bank instability, loss of floodplain function, removal of large woody debris sources, changes in sediment supply, changes in hydrology, increases in water temperature, changes in nutrient supply, chemical pollution, channel modification and habitat simplification. Because landscape changes resulting from agriculture are permanent and normal practices typically involves disturbing the soil several times a year, the negative effects of agriculture may be more severe than other land uses.

Livestock grazing: Livestock use can lead to reduction of soil structure; increase in soil compaction; alteration of streamside vegetation through the removal of deep-rooting plant species, reduction in stream shading, and reduction in riparian vegetation height; decreased streambank stability; reduced groundwater recharge and aquifer storage capacity; increased stream temperature; and simplification of instream habitat. Grazing is a major nonpoint source of sedimentation. Grazed watersheds typically have higher stream sediment levels than ungrazed watersheds.

Road building: Roads alter streamflow, sediment loading, sediment transport and deposition, channel stability and shape, substrate composition, stream temperatures, water quality and riparian conditions within a watershed. Roads contribute more sediment to streams than any other land management activity, and because most land management activities (e.g., mining, timber harvest, grazing, recreation, etc.) are dependent on roads, we have built many miles of them. Serious degradation of fish habitat can result from poorly planned, designed, constructed or maintained roads. Roads affect water quality through applied road chemicals and toxic spills. Roads are correlated with increased landslides, debris flows and other mass movements. Road/stream crossings can be a major source of sediment. Plugged culverts and fill slope failures are frequent and often lead to catastrophic increases in stream channel sediment. Poorly designed culverts also can create a barrier to up and downstream movement of fish. Construction of roads adjacent to stream channels often precipitates riprapping of stream banks.

Mining: Mines add large quantities of sediments, metals and acids; accelerate erosion; increase bank and streambed instability; and change channel shape and water flows. Mining contaminants enter streams through erosion of mine tailings, direct discharge of wastes to the watercourse and through movement of groundwater. Dredging and placer mining destroy riparian vegetation and rework channels and can result in severe habitat simplification and/or elimination of surface flows.

Hydroelectric development, dams and diversions: Large dams on major rivers in California, Oregon, Washington and Idaho have significantly reduced the amount of spawning and rearing habitat accessible to migrating chinook salmon. Where upstream passage is at least partially provided, significant delays in the migration of spawning adults typically occur while the fish search for the opening to passage facilities. Dams pose a risky passage problem for juvenile downstream migrants, with both turbines and elevated gases likely to cause some injuries and direct fatalities. Migration, both of adults moving upstream and young moving downstream, also is stymied by the lack of current in reservoirs impounded behind the dams resulting in further migratory delays as salmon navigate through the reservoirs. In addition, numerous smaller inventoried dams and diversions throughout the region provide water for municipal, industrial, irrigation, livestock and rural uses and untold numbers of very small projects too small to require state or federal safety inspections are even more widespread. Despite their smaller size, these minor dams and diversions can block or hinder upstream and downstream passage of migrating salmon and, if diversions are unscreened, can divert young salmon onto croplands along with the irrigation water. In addition to limiting and/or hindering access to spawning grounds, the slack water impounded behind dams and diversions of all sizes alters temperature and provides an artificial habitat likely to become home to numerous exotic gamefish. These changes in the composition of the aquatic community have fundamental effects on competition and predation pressures. Unless the dam is operated as a "run-of-the-river" facility, it also severely modifies flow regimes, altering both seasonal and daily flow patterns.

- Columbia River Basin dams completely block access to 7,733 miles of the historic range of chinook in the U.S. and Canada.

- Losses of mid and upper Columbia River chinook salmon are estimated to be about 5% per dam for adults and 18-23% per dam for juveniles

Hatcheries: Hatchery programs have hurt native wild salmon in several ways. First, the genetic integrity of many wild populations has been compromised through interbreeding between wild and stray hatchery fish. Second, hatchery programs can cause genetic changes in wild populations even when no interbreeding occurs. For example, fishing pressure targeted on a hatchery population in a mixed-stock fishery may result in selective harvest of some portions of the intermingled wild fish stock (e.g., the early or late ends of a run) resulting in a shift in the genetic characteristics of the wild population. Third, hatchery-support fisheries can result in substantial overharvest of wild stocks with small populations sizes if they intermingle with large hatchery populations while in the ocean and are part of a mixed-stock fishery. Fourth, wild populations also can be affected by hatchery populations as a result of competition, predation or other behavioral factors. Fifth, hatchery fish can introduce diseases into wild populations. Sixth, hatchery production can mask serious problems with natural freshwater habitats by artificially inflating the number of salmon produced. Finally, hatcheries have enabled a number of destructive projects that might not otherwise have been approved without the false promise of hatchery mitigation.

- NMFS denied ESA protection to the lower Columbia River coho, despite their reduced numbers, because genetic contamination from hatchery stocks was so great they concluded the "real" stock no longer existed.

- Although hatchery production of chinook salmon increased 10 fold in British Columbia during the 1970s and early 1980s, the proportion of adults returning to fisheries declined 83%.

Harvest: Chinook salmon are harvested in sport, commercial, subsistence and ceremonial fisheries. These practices can significantly reduce the abundance, alter the size and age-structure and reproductive potential of smaller stocks that are caught incidental to efforts aimed at larger stocks. In addition, freshwater anglers can trample redds and increase bank instability. Traditional approaches to harvest management focused on promoting the maximum harvest of "surplus" fish production in a mixed stock fishery. This tended to push catch levels toward those that only the most productive populations could sustain, but they often were too high for the smaller populations. As a result, local breeding populations of salmon have been fished to extinction or to severely depressed levels. During recent years, most state fish management agencies have begun to explore new policies that prioritize restoration and management of native fish stocks and their habitats. Because fishing generally occurs late in the salmon life cycle and therefore can have significant direct impact on the number of spawning adults, and because fishing often is easier to control than other causes of mortality, regulation of fishing now is often used as the "tool of last resort" to achieve desired spawning population numbers.

- Only 53% of ocean trollers registered in the 1990s reported landings, and the average landings by weight were only 43% of those in the 1980s.
- Indian fishers on the Columbia River caught only half as much during the 1990s as those in the early 1940s, even though their proportional allocation increased from 5% to 50%.

PRINCIPLES OF RECOVERY

To protect and restore chinook salmon, the primary emphasis must be placed on the protection and restoration of freshwater habitat, and on shifting management approaches from those embracing technological spot-fixes to those aimed at protecting, restoring and reconnecting through natural processes the continuum of freshwater, estuarine, and ocean habitats where chinook complete their life histories. Finally, protection and restoration efforts must recognize the importance of the life history and genetic diversity within chinook salmon. Conserving each stock contributes to the ability of chinook as a whole to cope with environmental variation that is typical of freshwater and marine environments.

The Watershed: The health of a stream ecosystem is intimately connected to and determined by the health of its drainage basin—the watershed (Figure 10). The materials that create the flowing river—the water, nutrients, energy and food for aquatic organisms—are products of the watershed. To maintain and restore the health of stream ecosystems and the species that depend on them, conditions within the whole watershed must be addressed.

Almost every watershed on the west coast, large and small, is highly fragmented and degraded. Only a few relatively healthy and productive "patches" remain scattered throughout each system. These habitats are the refugia or biological "hot spots" that act as physical refuges for vulnerable chinook salmon and other aquatic species. They also are sources of clean water, nutrients and large wood that sustain the entire stream ecosystem and maintain the tenuous health of aquatic species such as salmon.

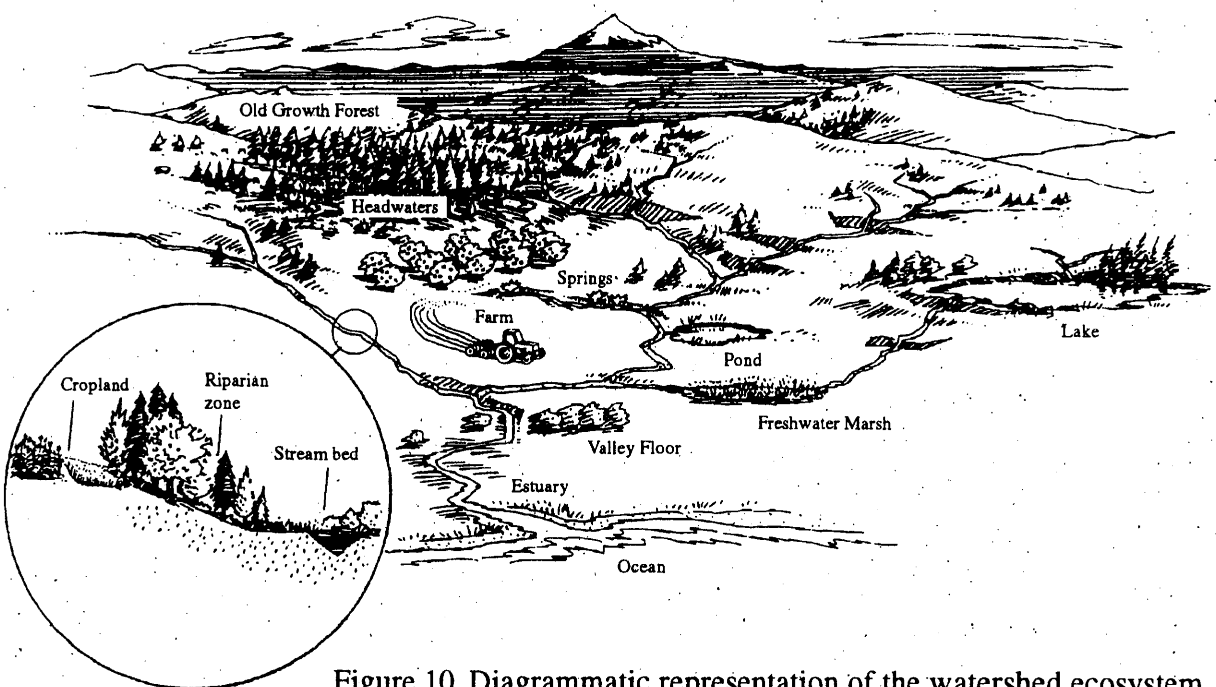


Figure 10. Diagrammatic representation of the watershed ecosystem.

First, Protect the Best : An effective watershed and chinook recovery program must be based on the principles of conservation biology. It must protect, expand and reconnect the remaining healthier aquatic habitats and it must ensure that all the genetic pieces are retained. The first step is to identify and fully protect the last best places. Most of the larger healthier refuge areas are found on federal lands, often in areas that are unroaded or only lightly roaded. Next, this initial network must be evaluated to ensure that important spawning and rearing areas crucial to the survival of declining chinook stocks are encompassed by the larger healthier refuge areas. If they are not, additional areas must be added to include these important refuges. Together these areas must be rapidly protected through a network of "Aquatic Diversity Areas" (ADAs) and "Critical Refuges."

The second step is to secure protection for riparian areas in all stream ecosystems. Ecologically defined protections must be established on all fish and non fish-bearing, permanently flowing and intermittent streams, regardless of land ownership.

The best form of restoration is protection. That is, removing the causes of degradation most often will lead to recovery without any other human intervention. To accomplish this end, human activities that are likely to lead to new harm in riparian areas, ADAs or Critical Refuges will need to be restricted and aggressive work will need to be undertaken to obliterate unnecessary roads, maintain those existing roads determined to be necessary and otherwise "un-cock the loaded gun" that much of our past land management practices have aimed at rivers and streams.

Then, Restore and Reconnect the Rest: Once the areas most important to recovery of aquatic ecosystems (i.e., the ADAs, Critical Refuges and riparian areas) are protected, a well-prioritized watershed restoration program is needed. Efforts should be focused on such things as restoring riparian areas, reconnecting streams with their floodplains, and reestablishing connectivity among the remaining healthier habitats. The goal is to reestablish stream ecosystem processes.

Hatcheries, Harvest and Hydro: The concepts from conservation biology discussed above also can be applied to management of hatchery operations and harvest management as well as dams and diversions. Clearly, to the extent hatcheries are used, they should be managed carefully to assist with the recovery of vulnerable stocks and scrupulously to ensure they do not impact the genetic and behavioral integrity of native stocks nor reduce the natural diversity represented by the numerous chinook stocks. PRC has adopted a policy on hatchery practices that discusses the details of this approach. Copies can be obtained from the Pacific Rivers Council. (PO Box 10798, Eugene, OR, 97440).

To be compatible with chinook recovery goals, harvest management will have to be done by stock and will need to emphasize the needs of the weak stocks, particularly those at risk of extinction. As with hatchery operations, the focus of harvest management must be stocks, not ESUs. As noted above, many state fisheries management agencies have begun to shift away from policies promoting maximum harvests and mixed stock fisheries towards policies that prioritize restoration and management of native fish stocks and their habitats. PRC loudly applauds the new direction.

Similar changes in our management of dams and diversions also is necessary. Expenditures of very large amounts of money and technological fixes (including everything from mitigation hatcheries to fancy collection and transport) have failed to halt the declines of Columbia River salmon. Such approaches have had no better success elsewhere in the chinook's range. Often the best answer is to give up on efforts to figure out how to moderate or mitigate the problem and decide simply to remove it. This approach was taken with some success with respect to Sacramento River winter-run chinook passage problems at the Red Bluff Diversion Dam, when it was acknowledged that efforts to improve the success of the fish ladder were unlikely to work and it was discovered that during much of the migration period, the gates of the dam could be lifted entirely out of the water allowing the river to flow essentially unobstructed! If the dams aren't removed, efforts to manage them in such a way as to allow recovery of as many as possible of the "natural river" processes should be encouraged. Certainly, efforts to reflect natural seasonal flow regimes should be undertaken and dramatic artificial daily changes in reservoir levels during spawning and rearing should be minimized.

Finally, we must recognize that chinook salmon inhabit highly variable environments. When considering whether or not a certain increment of new human impact is acceptable, we must be sure to include an adequate buffer to accommodate uncertainties in our own knowledge and natural environmental "surprises" (including everything from volcanic eruption, floods, droughts, and fires to El Niño). We can not afford to manage either our habitats or our species to the edge, but must instead conscientiously protect the natural resiliency of healthy watersheds and the natural diversity of healthy fish populations.

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