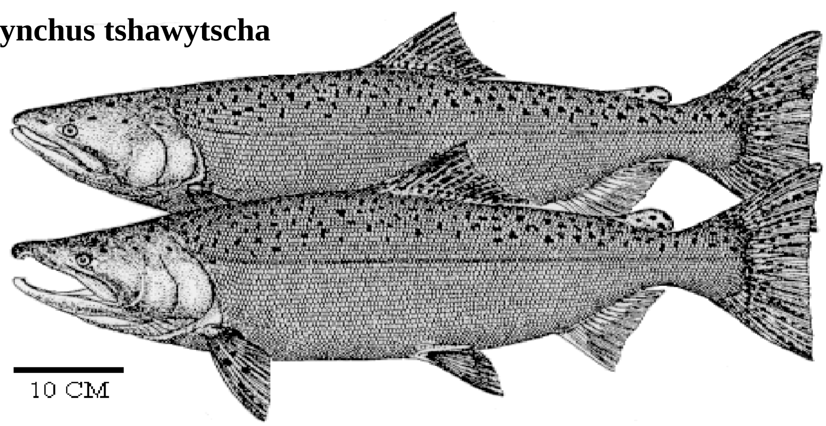
Factors Contributing to the Decline of Chinook Salmon: An Addendum to the 1996 West Coast Steelhead Factors For Decline Report

Oncorhynchus tshawytscha
Adults



Protected Resources Division
National Marine Fisheries Service
525 N.E. Oregon Street, Suite 500
Portland, Oregon 97232

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I. INTRODUCTION

The Federal Endangered Species Act (ESA)[1] states that various species of fish, wildlife, and plants in the United States have been rendered extinct as a consequence of economic growth and development untempered by adequate concern for ecosystem conservation (ESA Section 2(a))[2]. To protect species at risk of extinction, the ESA provides a mechanism for identifying and protecting at-risk species. The ESA and the listing regulations promulgated by the National Marine Fisheries Service (NMFS) set forth procedures for listing at-risk species so they may be afforded the substantive protection of the ESA itself.

The ESA divides responsibility for listing species between the Secretary of the Interior and the Secretary of Commerce[3]. Essentially, the Secretary of the Interior is responsible for all terrestrial and freshwater species while the Secretary of Commerce is responsible for all marine species. In some cases, such as that of sea turtles, the two departments share jurisdiction. The Secretary of the Interior has delegated this authority under the ESA to the United States Fish and Wildlife Service (FWS). The Secretary of Commerce has delegated this authority to the National Marine Fisheries Service (NMFS).

The NMFS' ESA implementing regulations define a "species" to include any species or subspecies of fish, wildlife, or plant, and any distinct population segment of any vertebrate species that interbreeds when mature.[4] A "threatened" species is defined as any species in danger of becoming endangered in the foreseeable future;[5] an "endangered" species is defined as a species in danger of

[1] 16 U.S.C. §§ 1531 - 1544 (1988).

[2] 16 U.S.C. § 1531(a)(1) (1988).

[3] 16 U.S.C. § 1532 (15) (1988).

[4] 50 CFR § 424.02 (k) 1995.

[5] 50 CFR § 424.02 (m) 1995.

extinction throughout all or a significant portion of its range.[6]

The ESA allows "distinct population segments" of named species to be listed. According to NMFS policy, a salmon population or group of populations is considered "distinct" and hence a "species" under the ESA if it represents an ESU of the biological species (NMFS 1991, Waples 1991a). To qualify as an ESU under NMFS policy, a salmon population or group of populations must satisfy the following two criteria: (1) it must be substantially reproductively isolated from other conspecific population units, and (2) it must contribute substantially to ecological/genetic diversity of the biological species as a whole (Waples 1991a). The reproductive isolation need not be absolute but must be strong enough to permit evolutionarily important differences to accrue in different population units.

The listing process requires that NMFS must determine if a species is at risk of extinction throughout all or a portion of their range (and are thus endangered) or if they are at risk of becoming endangered in the foreseeable future throughout all or a portion of their range (and are thus threatened) based upon any one or a combination of the following factors:

1. The present or threatened destruction, modification, or curtailment of its habitat or range.
2. Overutilization for commercial, recreational, scientific, or education purposes.
3. Disease or predation.
4. Inadequacy of existing regulatory mechanisms.
5. Other natural or human-made factors affecting its continued existence.

(see ESA Section 4(a)(1)[7], and 50 CFR §424.11(c)). Collectively, these five factors are referred to as the “Factors for Decline.” The NMFS must also take into account any efforts being made

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6 50 CFR § 424.02 (e) 1995.

7 16 U.S.C. § 1533(a)(1) (1988).

by any state, foreign nation, or any political subdivision, to protect a species before reaching a final listing decision (see ESA Section 4(b)(1)(A))[8].

II. PURPOSE OF THE REPORT

The purpose of this report is to compile and present available scientific information with respect to the factors of decline for west coast chinook salmon. The information contained in this report was presented to NMFS in response to requests for information relevant to completing the status review for chinook salmon, and has been sorted and reorganized in order to combine information on the factors for decline for west coast chinook salmon.

To ensure that the best available information was used in this report, NMFS solicited the assistance of state and tribal fisheries agencies in identifying factors of decline for west coast chinook salmon. This report is in part derived from information provided by these chinook salmon co-managers. While every attempt was made to capture the most up-to-date information on chinook salmon factors for decline, NMFS recognizes that some areas may have been overlooked or not dealt with in sufficient detail. The NMFS encourages anyone interested in providing comments on this report to submit materials to NMFS at the addresses found on page 49.

The NMFS has prepared several reports addressing the factors that have led to the decline of anadromous salmonids, including chinook salmon.[9] Most recently, NMFS completed the "Factors for Decline: A Supplement to the Notice of Determination for West Coast Steelhead Under the Endangered Species Act" (NMFS 1996a). This report is intended to compile information from the west coast steelhead factors for decline report and from the Status Review

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8 16 U.S.C. § 1533 (b)(1)(A) (1988).

9 "Factors for Decline: A Supplement to the Notice of Determination for Snake River Spring/Summer Chinook Salmon Under the Endangered Species Act" (NMFS 1991b). Coastal Coho Habitat Factors for Decline and Protective Efforts in Oregon" (April 24, 1997) (NMFS 1997a). The NMFS identified factors for decline specific to coho salmon, and generally for chinook salmon as well, in the proposed rule for coastal coho published in the Federal Register (60 FR 38011, July 25, 1995).

for chinook salmon.

III. SUMMARY OF EVENTS LEADING TO THE STATUS REVIEW

West Coast chinook salmon have been the subject of many Federal ESA actions. The NMFS listed the Sacramento River winter-run chinook as a threatened species under the ESA (54 FR 10260, August 4, 1989). As NMFS was reviewing and reclassifying the status of Sacramento River chinook, Oregon Trout and five co-petitioners petitioned NMFS on June 7, 1990, to list Snake River spring/summer and fall chinook salmon as threatened species under the ESA. The NMFS finalized its rule listing these Snake River chinook runs as threatened species on April 22, 1992 (57 FR 14653).

Meanwhile, on June 3, 1993, American Rivers and 10 other organizations petitioned NMFS to add Mid-Columbia River summer chinook salmon to the list of endangered species. Subsequently, NMFS determined that mid-Columbia River summer chinook salmon did not qualify as an ESU, and therefore was not a distinct species under the ESA (59 FR 48855, September 23, 1994). However, NMFS did determine that mid-Columbia River summer chinook salmon were part of a larger ESU that included all late-run (summer and fall) Columbia River chinook salmon between McNary and Chief Joseph Dams. The NMFS also concluded that this ESU did not warrant listing as a threatened or endangered species (Id.).

Immediately prior to that determination, NMFS announced that it would commence a coastwide status review of all west coast chinook salmon based on a petition filed on March 14, 1994, by Professional Resources Organization-Salmon (PRO-Salmon) to list various populations of chinook salmon in Washington (59 FR 46808, September 12, 1994). Shortly after initiating this coastwide status review for chinook and other salmon species, NMFS received a petition from the Oregon Natural Resource Council and Rich Nawa on February 1, 1995, to list chinook salmon throughout their range. The NMFS then reconfirmed its intention to conduct a comprehensive coastwide status review of west coast chinook salmon (60 FR 30263, June 8, 1995).

In the intervening period between the two most recent petitions to list various populations of west coast chinook salmon, NMFS published an emergency rule on August 18, 1994 (59 FR 42529) after determining that the status of Snake River spring/summer-run and Snake River fall-run chinook salmon warranted reclassifying them as endangered, based on projected declines and low abundance levels of adult chinook salmon. Because emergency rules under the ESA have a limited duration (see 16 U.S.C. §1533(b)(7) and 50 CFR §424.20(a)), NMFS published a proposed rule reclassifying listed Snake River spring/summer-run and Snake River fall-run chinook salmon ESUs as endangered on December 28, 1994 (59 FR 66784). Since publishing that proposed rule, a congressional moratorium on listing activities, a large ESA listing determination backlog, and other delays prevented NMFS from completing its assessment of the proposed rule. During this period, both stocks of Snake River chinook salmon increased in abundance. Because of these increases (and because management activities affecting these species have improved, NMFS concluded that the risks facing the listed chinook salmon ESUs are lower than they were at the time of the proposed rule, and thus NMFS withdrew the proposed reclassification (63 FR 1807, January 12, 1998). Most recently, on March 9, 1998, NMFS published a proposed rule to list 10 west coast chinook salmon ESUs as either threatened or endangered and designated critical habitat throughout their range (63 FR 11750). That proposed listing spawned this report on the factors affecting the decline of west coast chinook salmon.

IV. SUMMARY OF FACTORS CONTRIBUTING TO THE DECLINE OF CHINOOK SALMON

This section summarizes factors for decline across the range of chinook salmon. While these factors have been treated in general terms in this section, it is important to emphasize that impacts from certain factors are more acute in specific ESUs, and can vary among stocks within the same ESU. For example, impacts from hydropower development are more pervasive for ESUs in the upper Columbia River Basin than for some coastal ESUs.

Chinook salmon on the west coast of the United States have experienced declines in abundance in the past several decades as a result of both natural and human factors. Forestry, agriculture, mining, and urbanization have degraded, simplified, and fragmented habitat. Water diversions for agriculture, flood control, domestic, and hydropower purposes (especially in the Columbia River and Sacramento-San Joaquin Basins) have greatly reduced or eliminated historically accessible habitat. Studies indicate that in most western states, about 80 to 90% of the historic riparian habitat has been eliminated. Further, it has been estimated that during the last 200 years, the lower 48 states have lost approximately 53% of all wetlands and the majority of the rest are severely degraded. Wetlands in Washington and Oregon are estimated to have diminished by one-third, while California has experienced a 91% loss of its wetland habitat. Loss of habitat complexity has also contributed to the decline of chinook salmon. For example, in national forests in Washington, there has been a 58% reduction in large, deep pools due to sedimentation and loss of pool-forming structures such as boulders and large wood. Similarly, in Oregon, the abundance of large, deep pools on private coastal lands has decreased by as much as 80%. Sedimentation resulting from land use activities is recognized as a primary cause of habitat degradation in the range of west coast chinook salmon (FEMAT 1993).

Historically, chinook salmon were abundant in many Pacific coastal and interior waters of the United States. Chinook salmon support important tribal, commercial, and recreational fisheries throughout their range, contributing millions of dollars to numerous local economies, as well as providing important cultural and subsistence needs for Native Americans. The extent of that support was much greater historically. Overfishing in the early days of European settlement depleted many stocks of chinook and other salmonids even before extensive habitat degradation began. However, following the degradation of many west coast aquatic and riparian ecosystems, exploitation rates were higher than many chinook populations could sustain. Therefore, harvest may have contributed to the further decline of some populations.

Introductions of nonnative species and habitat modifications have increased predator populations in numerous river systems—thereby increasing the level of predation that salmonids experienced. Chinook salmon face predation pressures from native and nonnative fish, several species of birds, as well as from marine mammals. Predation by marine mammals is also of concern in areas where chinook salmon run sizes are dwindling. Even though chinook salmon and marine mammals have coexisted for thousands of years, most investigators consider predation a significant contributing factor to the declines being observed in chinook salmon populations, particularly in areas where habitat alterations have tipped the predator/prey balance in favor of predators.

Chinook salmon are exposed to numerous bacterial, viral, and parasitic organisms during their life cycle. Native chinook salmon have evolved with certain of these organisms, but the widespread use of artificial propagation has introduced some exotic organisms not historically present in some watersheds. Some scientific studies may indicate that chinook salmon are more susceptible to disease organisms than other salmonids. Habitat conditions such as low water flows and high temperatures can exacerbate susceptibility to disease, though hatchery chinook salmon appear to be more susceptible than native or naturally spawning chinook salmon.

Natural climatic conditions have served to exacerbate the problems associated with degraded and altered riverine and estuarine habitats. Persistent drought conditions have reduced already limited spawning, rearing and migration habitat. Further, climatic conditions appear to have resulted in decreased ocean productivity which may significantly affect chinook salmon abundance. This factor can be particularly damaging to chinook salmon populations facing degraded freshwater habitat conditions.

In an attempt to mitigate the loss of habitat, extensive hatchery programs have been implemented throughout the range of chinook salmon. While some of these programs have been successful in providing fishing opportunities, the impacts of these programs on native, naturally-reproducing stocks are not well understood. Competition, genetic introgression, and disease transmission resulting from hatchery introductions may significantly reduce the production and survival of native, naturally-reproducing chinook salmon. Furthermore, collection of native chinook salmon for hatchery broodstock purposes may result in additional negative impacts to small or dwindling natural populations. It is important to note, however, that artificial propagation could play an important role in chinook salmon recovery and that some hatchery populations of chinook salmon may be deemed essential for the recovery of threatened or endangered chinook salmon ESUs. In addition, alternative uses of supplementation, such as for the creation of terminal fisheries, must be fully explored to try to limit negative impacts to remaining natural populations. This use must be tempered with the understanding that protecting native, naturally-reproducing chinook salmon and their habitats is critical to maintaining healthy, fully-functioning ecosystems.

This report concludes that no single specific factor for decline is affecting chinook salmon; rather, habitat destruction and modification, species overutilization for recreational purposes, and natural and human-made factors all have contributed to the decline of chinook salmon.

V. FACTORS CONTRIBUTING TO THE DECLINE OF CHINOOK SALMON

As mentioned in the introduction, the ESA listing process requires that NMFS determine if a species is at risk of extinction throughout all or a portion of its range based upon any one or a combination of the five following factors:

1. The present or threatened destruction, modification, or curtailment of its habitat or range.
2. Overutilization for commercial, recreational, scientific, or education purposes.
3. Disease or predation.
4. Inadequacy of existing regulatory mechanisms.
5. Other natural or human-made factors affecting its continued existence .

(see ESA Section 4(a)(1), and 50 CFR §424.11(c)). According to the ESA, the determination of whether a species is threatened or endangered should be made on the basis of the best scientific information available, after conducting a review of the status of the species, and after taking into consideration conservation measures that are in place (ESA Section 4(b)(1)(A)). The NMFS Northwest and Southwest Regional Offices evaluate conservation measures effectiveness when making listing determinations. Each of these factors are discussed below.

VI. THE PRESENT OR THREATENED DESTRUCTION, MODIFICATION OR CURTAILMENT OF CHINOOK SALMON HABITAT OR RANGE

Natural resource use and extraction leading to habitat modification can have significant direct and indirect impacts to chinook salmon populations. Land use activities associated with logging, road construction, urban development, mining, agriculture, and recreation have significantly altered fish habitat quantity and quality. Impacts associated with these activities include: (1) alteration of streambank and channel morphology; (2) alteration of ambient stream water temperatures; (3) degradation of water quality; (4) elimination of spawning and rearing habitat; (5) fragmentation of available habitats; (6) removal of riparian vegetation resulting in increased stream bank erosion; (7) elimination of downstream spawning gravel and large woody debris recruitment; and (8) increased sedimentation input into spawning and rearing areas. Increased sedimentation results in the loss of channel complexity, pool habitat, suitable gravel substrate, and large woody debris. Studies indicate that in most western states, about 80 to 90% of the historic riparian habitat has been eliminated. Further, it has been estimated that during the last 200 years, the lower 48 United States have lost approximately 53% of all their wetlands. Wetlands in Washington and Oregon have been estimated to have diminished by one third, and it is estimated that California has lost 91% loss of its wetland habitat (FEMAT 1993).

The degree of spatial and temporal connectivity between and within watersheds is an important consideration when attempting to maintain aquatic riparian ecosystem functions. Loss of this connectivity and complexity has contributed to the decline of chinook salmon. In Washington, the number of large, deep pools in National Forest streams has decreased by as much as 58% due to sedimentation and loss of pool-forming structures such as boulders and large wood. Similarly, in Oregon, the abundance of large, deep pools on private coastal lands has decreased by as much as 80% (Gregory and Bisson 1997).

Land and water-use practices, including forestry, grazing, agriculture, urbanization, mining, flood control, dredging, water pollution, water withdrawal, and hydropower development have, and continue to substantially altered watershed functions and features necessary for productive use by anadromous salmonids. These watershed functions and features include the routing and quantity of water, sediments, nutrients and other dissolved chemicals, and woody debris delivered to salmonid streams; water quality (i.e., temperature, dissolved oxygen, presence of invertebrates, turbidity); riparian habitat complexity; stream complexity (i.e., the quality and quantity of riffles, pools, substrate, cover, bank stability, presence of side channels, eddies, and undercut banks, amount and placement of large woody debris); and predator-prey relationships (Spence et al. 1996, Bisson et al. 1997).

Anadromous salmonids require clean, cool, well-oxygenated water in adequate quantity to survive rearing and migration periods both before spawning and after juveniles emerge from the spawning redds. Salmonid eggs are highly affected during incubation and hatching by temperature and flow. Complex streams with good ratios of riffles and pools provide productive spawning habitats, as well as juvenile rearing areas in eddies and off-channel areas. The fresh and salt water mixing areas and cover found in estuarine areas are critical for both juvenile and adult salmonids. The ability of streams, estuaries and their adjacent landscapes to provide these, and other essential functions and features listed above has been reduced throughout the range of chinook salmon. A loss of connectivity between these habitat features has also contributed to the decline of chinook salmon.

Water storage, withdrawal, conveyance, and diversions for agriculture, flood control, domestic, and hydropower purposes have greatly reduced or eliminated historically accessible habitat. The modification of natural flow regimes has increased water temperatures, changed fish community structures, and depleted the flows necessary for migration, spawning, rearing, flushing of sediment from spawning gravels, gravel recruitment and large woody debris transport. Physical features of dams, such as turbines and sluiceways, have increased mortality of both adults and juvenile salmonids. Attempts to mitigate the adverse impacts of these structures have as yet met with limited success.

The following sections describe this factor's effect on chinook salmon in various regions.

A. California's Central Valley

California's Central Valley was historically one of the most productive chinook salmon areas on the Pacific coast. Large portions of spawning and rearing habitat were blocked by early water diversions, later flood control structures, and, eventually, large-scale water diversions eliminated the remaining portions of historic chinook salmon range. Large-scale mining operations in Sierra Nevada foothills further damaged the hydrologic systems that supported chinook salmon populations throughout this region.

Central Valley chinook salmon exhibit an ocean-type life history; large numbers of juvenile chinook salmon emigrate during the winter and spring (Rutter 1904, Rich 1920, Calkins et al. 1940, Kjelson et al. 1982, Gard 1995). High summer water temperatures in the lower Sacramento River (temperatures in the Sacramento-San Joaquin Delta can exceed 22°C) create a thermal barrier to up- and downstream migration and may be partially responsible for the evolution of the fry migration life history (Rich 1920, Kjelson et al. 1982, Mitchell 1987). Changes in the thermal profiles and hydrograph of the Central Valley rivers have presumably subjected chinook salmon to strong selective forces (Slater 1963). The degree to which current life history traits reflect predevelopment characteristics is largely unknown, especially since most of the habitat degradation occurred before chinook salmon studies were undertaken late in the nineteenth century. In addition, water withdrawals, for agricultural and municipal purposes have reduced river flows and increased temperatures during the critical summer months, and in some cases, have been of a sufficient magnitude to result in reverse flows in the lower San Joaquin River (Reynolds et al. 1993). Direct relationships exist between water temperature, water flow, and juvenile salmonid survival. Water temperatures in the Sacramento River have limited the survival of young salmon (Mitchell 1987, DWR 1988). Juvenile fall run chinook salmon survival in the Sacramento River is also directly related with June streamflow and June and July delta outflow (Dettman et al. 1987).

Human activities have primarily affected the spring-, winter- and late fall-run chinook salmon. Placer mining in the 1800s destroyed spawning and rearing habitats either directly or through increased sedimentation. Mine wastes still affect water quality. Water diversion and hydroelectric dams have limited or prevented access to most of the upriver areas that were historically used by spring and winter runs (Clark 1929).

Levee construction for flood protection reduced the amount of off-channel habitat. By the 1930s, only 25% of the valley floor was subject to periodic inundation. Dam and water project construction reduced habitat substantially between the 1930s and 1960s. Many hundreds of water diversion structures remain unscreened. Operation of the Red Bluff Diversion Dam, though allowing fish passage, has reduced chinook salmon rearing productivity in the mainstem Sacramento River. Within the Central Valley, major dams block access to historic chinook salmon spawning and rearing habitat. Some of the dams blocking historic spawning and rearing habitat are: (1) Nimbus Dam on the American River, (2) Camp Far West Dam on the Bear River, (3) Engelbright Dam on the Yuba River, (4) Oroville Dam on the Feather River, (5) Keswick Dam on the Sacramento River, (6) Friant Dam on the San Joaquin River, (7) Crocker Diversion Dam on Merced River, (8) Goodwin Dam on the Stanislaus, (9) New Hogan Dam on the Calaveras River, and (10) Camanche Dam on the Mokelumne River.

B. Southern Oregon and California Coastal Region

Agriculture, logging, and mining activities, in combination with periodic flood events, have affected all of the coastal river systems to some degree. Mining activities have also severely degraded habitat. The Rogue and Klamath River Basins have been sites of active mining since the mid-1800s, and suction-dredge mining still occurs. Additionally, changes in river flow and temperature have allowed fall-run chinook salmon to spawn further upstream than they did historically and thus increased the opportunities for interbreeding between fall and spring runs (ODFW 1990).

Freshwater habitat loss and alteration have strongly affected chinook salmon in this region. In 1995, PFMC stated that all of the major rivers in this area had chronic instream flow problems. Bottom et al. (1985) cited low stream flows and high summer temperatures as problems throughout the southern Oregon coastal area. Timber harvesting and associated road building occur throughout the region on Federal, state, tribal, and private lands. These activities increase sedimentation and debris flows and reduce cover and shade resulting in aggradation, embedded spawning gravel, and increased water temperatures (CACSST 1988, NMFS 1996).

Dam construction in the Rogue, Klamath, Trinity, Eel, and Russian River basins has restricted chinook salmon distribution and potentially altered their life histories, especially among spring-run fish that historically used upstream habitat. Lost Creek Dam eliminated one-third of the historic spring-run chinook salmon spawning habitat in the Rogue River (Kostow 1995). Other dams in the range of this ESU that block or restrict access to historic chinook salmon spawning and rearing include: (1) Peters Dam on Lagunitas Creek, (2) Nicasio Dam on Nicasio Creek (tributary to Lagunitas Creek), (3) Warm Springs Dam on Dry Creek (tributary to the Russian River), (4) Coyote Dam on the mainstem Russian River, (5) Scott Dam on the mainstem Eel River, and (6) Applegate Dam on the Applegate River (tributary to the Rogue River).

C. Puget Sound

Human activities have degraded extensive areas of chinook salmon spawning and rearing habitat in Puget Sound. Development activities have limited access to historical spawning grounds and altered downstream flow and thermal conditions. Urbanization effects many part of the aquatic environment. It has caused direct loss of riparian vegetation and soils, significantly altered hydrologic and erosional rates and processes by creating impermeable surfaces (roads, buildings, parking lots, sidewalks etc.), and polluting waterways. Watershed development and associated urbanization throughout the Puget Sound, Hood Canal, and Strait of Juan de Fuca regions have increased sedimentation, raised water temperatures, decreased large woody debris (LWD) recruitment, decreased gravel recruitment, reduced river pools and spawning areas, and dredged and filled estuarine rearing areas (Bishop and Morgan 1996). Large areas of lower river meanders (formerly mixing zones between fresh and salt water) have been channelized and diked for flood control and to protect agricultural, industrial and residential development. In spite of this, habitat degradation in upstream areas has exacerbated flood events in these areas—with adverse effects on chinook salmon populations. In some rivers, such as the Elwha, increased water temperatures have decreased salmonid's disease resistance.

Water diversions and hydroelectric dams have prevented access to portions of several rivers. Furthermore, the construction of Cushman Dam on the North Fork of the Skokomish River may have created a residualized population of chinook salmon in Lake Cushman. Within the Puget Sound region, approximately seven major dams block access to historic chinook salmon spawning and rearing habitat. Other dams blocking historic spawning and rearing habitat include: (1) Elwha and Glines Canyon Dam on the Elwha River, (2) Howard Hansen Dam on the Green River, (3) Cedar Falls Dam on the Cedar River, (4) Gorge Falls Dam on the Skagit River, and (5) Baker Dam on the Baker River. Passage at Chittendon Locks (Lake Washington) also poses problems for downstream juvenile chinook salmon migrants.

D. Lower Columbia River

Extensive urbanization, dredge and fill activities associated with development and navigation, and water quality degradation are significant sources of reduced habitat quantity and quality in many parts of this ESU.   Urbanization affects many part of the aquatic environment, with direct loss of riparian vegetation and soils; as well as significant changes in hydrologic and erosional rates and processes caused by the creation of impermeable surfaces (roads, buildings, parking lots, sidewalks etc.); and the introduction of pollution into waterways.

Dam construction for hydroelectric power and water diversion in this ESU has blocked many areas of historic chinook salmon spawning and rearing habitat. These habitat losses have resulted in extirpation of some seasonal runs of chinook salmon. The Cowlitz, Kalama, Lewis, Clackamas, and Sandy Rivers presently contain both spring and fall runs, while the Big White Salmon River historically contained both spring and fall runs but presently only contains fall-run fish (Fulton 1968, WDF et al. 1993). Habitat degradation and dam construction on the Clackamas and Sandy Rivers so depressed native runs on these systems that subsequent introductions of nonnative Upper Willamette River spring-run chinook salmon eliminated any detectable remnants of the native populations. The spring run on the Big White Salmon River was extirpated following construction of Condit Dam (Fulton 1968). Although some fall-run salmon spawning occurs below Condit Dam, there have been substantial introductions of nonnative stocks (WDF et al. 1993) and the persistence of a discrete native stock is unlikely. The Klickitat River probably contained only spring-run chinook salmon due to falls that blocked access to fall-run chinook salmon during autumn low flows (Fulton 1968). Whatever spawning grounds were accessible to fall-run chinook salmon on the Klickitat River below Lyle Falls would have been inundated following the construction of Bonneville Dam in 1938, however there is no record of fall chinook salmon utilizing this lower portion of the Klickitat River (Bryant 1949, Hymer et al. 1992a, Fulton 1968, WDF et al. 1993). Dams have reduced or eliminated access to upriver spawning areas on the Cowlitz, Lewis, Clackamas, Sandy, and Big White Salmon Rivers. A significant fall run once existed on the Hood River prior to the construction of Powerdale Dam (1929) and other diversion and irrigation dams (Fulton 1968); however, this run has become severely depleted and may have been extirpated (Howell et al. 1985, Nehlsen et al. 1991, Theis and Melcher 1995). Within the Lower Columbia River region, approximately seven major dams block access to historic chinook salmon spawning and rearing habitat. Some of the dams blocking historic spawning and rearing habitat include the following dams: (1) Mayfield and Mossyrock Dams on the Cowlitz River; (2) Merwin and Yale Dams on the Lewis River; (3) Condit Dam on the White Salmon River; (4) Bull Run Dam on the Bull Run River; and (5) Oak Grove Fork Dam on the Clackamas River.

E. Upper Willamette River (Above Willamette Falls)

Water diversions, dam placements, and river channelization have altered the abundance, spawning and rearing distribution, and migration timing of spring-run chinook salmon. Although the Willamette River was once highly braided, with numerous side channels offering ideal rearing habitat for juvenile salmonids (Kostow 1995), approximately 75% of that historical shoreline has been lost (Sedell and Froggatt 1984). Irrigation withdrawals began in the 1800s, and timber harvest activities and splash dam construction had severe impacts on spawning and rearing habitat access and quality (Palmisano and Kaczynski 1993). Extensive urbanization has also reduced habitat quality and quantity by eliminating access to off channel areas and by increasing the amount of impermeable surfaces.

Water diversions and hydroelectric dam construction in the 1950s and 1960s limited access to significant portions of the major spring chinook salmon tributaries of the Willamette River. In all, water storage projects eliminated access to 707 stream kilometers (Cramer et al. 1996). In addition to blocking access to habitat, the dams have altered the river's natural thermal regime; the premature emergence of spring chinook salmon fry due to releases of warmer reservoir water in the autumn may have caused high mortalities among naturally spawning fish (Kostow 1995). Conversely, cooler-than-normal waters released in the spring limit the growth of naturally rearing fish. Habitat changes may have created selective pressures that would alter the expression of historical life history traits -- primarily affecting naturally spawning and rearing salmonids. Within the Upper Willamette River region, approximately six major dams block access to historic chinook salmon spawning and rearing habitat. Some of the dams blocking historic spawning and rearing habitat include the following dams: 1) Big Cliff Dam on the North Santiam River; 2) Foster and Green Peter Dams on the South Santiam River; 3) Cougar Dam on the South Fork

McKenzie River; 4) Dexter and Hills Creek Dams on the Middle Fork Willamette River; and 5) Dorena Dam on the Row River.

F. Columbia and Snake River Region

Human influences have had a great impact on the life history and distribution of ocean-type chinook salmon in the Columbia River Basin. Water withdrawals for irrigation have lowered instream flows, and riparian conditions have been degraded by timber harvest, road construction, livestock grazing and mining. For example, the development of agricultural irrigation projects on the Yakima River during the last century has resulted in lower river flows, higher water temperatures, river eutrophication, and limited or impeded migration access (Davidson 1953, BPA et al. 1996).

Hydroelectric dams and irrigation diversions affect virtually every river containing stream-type chinook salmon (although the intensity of irrigation effects are lower in much of the Snake River Basin) and have produced changes in thermal regime, loss of spawning and rearing habitat, or direct mortality by stranding or upstream and downstream passage injury (Lindsay et al. 1989, Matthews and Waples 1991). The construction of the Hermiston Power and Light (1910) and Three Mile Dams (1914) on the Umatilla River and the Lewiston Dam (1927) on the Clearwater River largely extirpated native stocks of stream-type chinook salmon in those river basins (Olsen et al. 1992, Keifer et al. 1992). Access to spawning habitat on the mainstem Snake River was blocked to migrating salmonids beginning in 1910 with Swan Falls Dam, and most recently by the Hells Canyon Dam in 1967 (Fulton 1968, Waples et al. 1991). An additional four mainstem dams (Ice Harbor Dam, Lower Monumental Dam, Little Goose Dam and Lower Granite Dam), constructed between 1961 and 1975, on the Snake River have inundated fall-run chinook salmon spawning areas and impeded adult and smolt migrations (Fulton 1968, Chapman et al. 1991, Waples et al. 1991). Nine dams exist on that portion of the mainstem Columbia River that is still accessible to migrating salmon. Numerous historical spawning sites were inundated by reservoirs created by the dams upriver from the present The Dalles Dam (Smith 1966, Waknitz et al. 1995). Within the Columbia River region, approximately nine major dams block access to historic chinook salmon spawning and rearing habitat. Some of the dams blocking historic spawning and rearing habitat include the following dams: 1) Chief Joseph and Grand Coulee Dams on the Columbia River; 3) Pelton-Round Butte Dam Complex on the Deschutes River; 4) Dworshak Dam on the North Fork Clearwater River; 5)Hells Canyon Dam on the Snake River; 6) Oxbow Dam on the Snake River; and 7) Brownlee Dam on the Snake River.

VII. OVERUTILIZATION FOR COMMERCIAL, RECREATIONAL, SCIENTIFIC, AND EDUCATIONAL PURPOSES

Chinook salmon are harvested in tribal, commercial and recreational fisheries throughout the Pacific northwest. Chinook salmon are also taken for artificial production, supplementation, and broodstock collection activities, as well as for research purposes. Harvest restrictions have been used for many decades to reduce impacts, and to increase the number of adults escaping to spawning grounds. However, because various chinook salmon populations mix together, harvest rates targeting abundant populations have disproportionately affected weaker stocks. These so-called "mixed stock fisheries" continue to affect chinook salmon. Harvest restrictions in some regions have helped to increase spawner escapement. However, in some regions, long-term harvest reductions have not helped increased spawning escapement. Harvest has also altered species size, age structure, and migration timing for both smolts and adults. Finally, harvest can alter the structure of stream ecosystems by reducing the inputs of nutrients from spawned adult chinook salmon. The effects of overutilization are discussed by region in sections below.

A. California's Central Valley

Overall harvest rates are variable. Ocean fishery management focuses on the fall run, with no defined management objectives for spring-run fish. Because of the similarity in ocean distribution between fall-run and the smaller average sized spring-run chinook, harvest rates are probably lower for spring-run chinook salmon than for the fall run. The recent reductions in ocean harvest are intended to insure that winter-run chinook have a positive population growth rate, on average.

Recent (1990-94) overall ocean harvest rate indices (Central Valley Index = catch / [catch + escapement]) have been in the range of 71-79% (PFMC 1996b). Freshwater recreational harvest is believed to be increasing and approaching 25% (Wixom[10]). Late fall fish are larger in size and experience higher harvest rates. The Central Valley Index is not a true exploitation rate since it does not include freshwater catch or ocean catch landed north of Point Arena, California, and does not include shaker mortality (hook and release mortality of undersized fish).

Angler harvest in the Sacramento River Basin was estimated by creel census in 1991, 1992, and 1993 (Wixom see footnote 10, Wixom et al. 1995). The creel census data provide a harvest estimate of approximately 20% in freshwater.

Harvest may have reduced the age at maturation for the Central Valley chinook salmon. Fish that were gill-netted in 1919 and 1921 below the confluence of the Sacramento and San Joaquin Rivers were primarily 4-years old (about 46%), with 5- and 3-year olds constituting 32.5% and 17.0% of the spawners, respectively. Recently, Fisher (1994) estimated that the 3-year-old age class was predominant for all run types in the Central Valley, constituting 77, 57, 91 and 87% of each run for fall-, late-fall, winter- and spring runs, respectfully. Using fish collected in gill nets introduces a considerable bias into this evaluation, but the overall shift in age structure has still been considerable.

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10 L. Wixom, California Department of Fish and Game, Inland Fisheries Division, 1416 Ninth Street, Sacramento, CA 95814. Pers. Commun., June 1995.

B. Southern Oregon and Coastal California

The peak historic cannery pack of chinook salmon in the range of this ESU was 31,000 cases in 1917, indicating a run size of about 225,000 adult chinook salmon. The CDFG (1965) estimated escapement for the California portion of the ESU to be about 88,000 fish—predominantly in the Eel River (55,500) with smaller populations in the Smith River (15,000); Redwood Creek, Mad River, Mattole River (5,000 each); Russian River (500); and several smaller streams in Del Norte and Humboldt counties. Based on the 1968 angler catch records for the Oregon portion of the ESU (which estimated escapements of about 90,000 fish), the average escapement for the entire ESU in the 1960s was estimated to be 178,000 fish. Total chinook salmon spawning escapement for the California portions of this region was estimated to be about 256,000 (168,000 in the Klamath River Basin and 88,000 elsewhere) in 1965 (CDFG 1995).

In assessing abundance and trends, NMFS used extrapolations of angler catch from ODFW's punch card database (ODFW 1993) and Nicholas' and Hankin's (1988) average harvest rates to calculate geometric means of terminal run size and spawning escapement for the most recent 5-year period (1990 - 1994). Trends were calculated from either the peak index counts or from dam counts where they were available. Expanded angler catch data produce a 5-year geometric mean spawning escapement of 132,000 (run size of 148,000) for the Oregon portion of this ESU. The majority of this escapement (126,000) has been the spring and fall runs in the Rogue River. This leads to an estimated harvest of 16,000 chinook salmon in the Oregon portion of the ESU. The are no total escapement or harvest estimates are available for the California portion of this ESU, although partial counts indicate escapement in the Eel River exceeds 4,000.

Ocean harvest rates for this ESU have not been assessed, but should be comparable with ocean harvest rates on Klamath fall chinook salmon (21% in 1991 (PFMC 1996a)). Freshwater and estuarine harvest rates are estimated to range between 25-30% (calculated from data in PFMC 1996b - Table B4).

C. Puget Sound

The peak chinook salmon harvest in Puget Sound was recorded in 1908 when 95,210 cases of canned chinook salmon were packed. This corresponds to a run size of approximately 690,000 chinook salmon at a time when both ocean harvest and hatchery production were negligible. This estimate, as with most historical estimates, needs to be viewed cautiously: Puget Sound cannery pack probably included a portion of fish that were landed at Puget Sound ports but originating in adjacent areas. Consequently, the estimates of exploitation rates used in run-size expansions are not based on precise data. Recent mean spawning escapements totaling 71,000 correspond to a run entering Puget Sound of approximately 160,000 fish. Allowing for an exploitation rate of 1/3 in intercepting ocean fisheries yields a recent average potential run size of 240,000 chinook salmon (PSC 1994).

Fisheries in Puget Sound have been managed inaccurately due to the failure to identify correct “maximum sustainable yield” (msy) rates given declining productivity of natural chinook salmon stocks. High harvest rates directed at hatchery stocks have caused many stocks to fail to meet natural escapement goals in most years (USFWS 1996). The 5-year geometric mean natural spawning escapement in most Puget Sound streams has been 1,100 adult chinook salmon. This figure varies widely and has both negative short- and long-term trends (except in the Dosewallips River).

Harvest impacts on Puget Sound chinook salmon stocks have been quite high. Ocean exploitation rates on natural stocks averaged 56% to 59%, and total exploitation rates average 68% to 83% during the 1982-89 brood years (PSC 1994). Total exploitation rates on some stocks has exceeded 90% in recent years (PSC 1994).

D. Lower Columbia River Region

Harvest rates of fall-run stocks are moderately high, with an average total exploitation rate of 65% (1982-89 brood years) (PSC 1994). The average ocean exploitation rate for this period was 46%, while the freshwater harvest rate on the fall-run has averaged 20%, ranging from 30% in 1991 to 2.4% in 1994. Harvest rates are somewhat lower for spring run stocks, with estimates for the Lewis River averaging 24% for the ocean and 50% for the total exploitation rates from 1982 through 1989 (PSC 1994). For inriver fisheries, approximately 15% of the lower river hatchery stock is harvested, 29% of the lower river wild stock is harvested, and 58% of the Spring Creek hatchery stock is harvested (PFMC 1996b). The average inriver exploitation rate on the stock as a whole is 29% (1991-1995).

E. Upper Willamette River (above Willamette Falls)

The most recent 5-year geometric mean escapement above Willamette Falls was 26,000 adults (1992-1996). Willamette River spring chinook salmon are targeted by commercial and recreational fisheries in the lower Willamette and Columbia Rivers. Tribal fishers have also harvested a small number of spring chinook salmon at Willamette Falls near Oregon City (Willis et al. 1995).

Total harvest rates on stocks in this ESU are moderately high. The average total harvest mortality rate was estimated to be 72% in 1982-89, with a corresponding ocean exploitation rate of 24% (PSC 1994). This estimate does not fully account for the total escapement, and the ODFW currently estimates that the average total harvest rate of 57%, with 16% in the ocean component and 48% in the freshwater component (Kostow 1995). The inriver recreational harvest rate (Willamette River sport catch / estimated run size) for the period from 1991 through 1995 was 33% (PFMC 1996b).

F. Columbia and Snake River Region

Harvest rates are moderately high, with an average 39% ocean exploitation rate and 68% total exploitation rate (brood years 1982-89) (PSC 1994), although these may be overestimates due to incomplete accounting of escapement.

Harvest rates on these populations were moderate in 1982-89, with Snake River (Lyons Ferry Hatchery) fall chinook salmon averaging 34.9% ocean exploitation, 26% inriver exploitation, and 53% total exploitation (PSC 1994). As a result of the ESA listing, ocean harvest rates for the Snake River fall-run chinook salmon decreased to 11.5% in 1995 and 23.0% in 1996 (PFMC 1997). Hanford Reach fall chinook salmon harvest rates have averaged 39% ocean exploitation and 64% total exploitation (PSC 1994).

Harvest on these populations is low, with very low ocean harvest and moderate instream harvest (PFMC 1996b). Inriver harvest has been substantially restricted since 1991. At present, only tribal fisheries are permitted in the Snake River. The average harvest from 1986-1990 was estimated as 10.7%, and the 1995 and 1996 harvest was estimated to be 6.1 and 5.5%, respectively (PFMC 1997).

VIII. DISEASE OR PREDATION

A. Disease

Infectious disease is one of many factors that influence adult and juvenile survival. Chinook are exposed to numerous bacterial, protozoan, viral, and parasitic organisms in spawning and rearing areas, hatcheries, migratory routes, and the marine environment. Specific diseases such as bacterial kidney disease (BKD), ceratomyxosis shasta (C-shasta), columnaris, furunculosis, infectious hematopoietic necrosis (IHNV), redmouth and black spot disease, and erythrocytic inclusion body syndrome (EIBS) are known, among others, to affect chinook salmon (Rucker et al. 1953, Wood 1979, Leek 1987, Foott et al. 1994, Gould and Wedemeyer undated, Wertheimer and Winton 1982). Very little current or historical information exists to quantify changes in infection levels and mortality rates attributable to these diseases for chinook salmon. However, studies have shown that native fish tend to be less susceptible to pathogens than are hatchery-reared fish (Buchanan et al. 1983, Sanders et al. 1992).

Natural chinook salmon may contract diseases that are spread through the water column (i.e., waterborne pathogens) (Buchanan et al. 1983). Disease may also be contracted through interbreeding with infected hatchery fish (Fryer and Sanders 1981, Evelyn et al. 1984 and 1986). A fish may be infected yet not be in a clinical disease state with reduced performance. Salmonids typically are infected with several pathogens during their life cycle. However, high infection levels (number of organisms per host) and stressful conditions (crowding in hatchery raceways, release from a hatchery into a riverine environment, high and low water temperatures, etc.) usually characterize the system before a disease state occurs in the fish.

Recently, the USFWS and the CDFG monitored the health and physiology of natural and hatchery chinook salmon and steelhead trout in the Klamath and Trinity River basins (Foott et al. 1994). The bacterium, *Renibacterium salmoninarum*, the causative agent of BKD, and the trematode parasite, *Nanophyetus salmincola*, were identified as the most significant pathogens affecting both natural and hatchery smolt health in the basin.

It is possible that steelhead can tolerate *R. salmoninarum* infection better than chinook or coho salmon (Foott et al. 1994). The impacts of BKD disease are subtle. Juvenile salmonids may survive well in their journey downstream, but may be unable to make necessary changes in kidney function for a successful transition to sea water (Foott 1992).

Increased physiological stress and physical injury in migrating juvenile salmonids (Matthews et al. 1986, Maule et al. 1988) may increase the susceptibility of migrating salmonids to pathogens (Maule et al. 1988). Stress during migration may also cause BKD to come out of remission (Schreck 1987). The presence of adequate water quantity and quality during late summer are critical factors in controlling disease epidemics. As water quantity and quality diminish, and freshwater habitat becomes more degraded, many previously infected salmonid populations may experience large mortalities because added stress can trigger the onset of disease. These factors (common in various rivers and streams) may increase anadromous salmonid susceptibility and exposure to diseases (Holt et al. 1975, Wood 1979).

Until the late 1970s, *Ceratomyxa shasta* was thought to be confined to waters below the Deschutes River (Wood 1979). Recent investigations of adult summer chinook salmon indicate that upper Snake River waters are also infected (Chapman 1986). Operational problems associated with *C. shasta* began to occur shortly after the opening of Iron Gate Hatchery, located on the Klamath River in California (CH2M Hill 1985). Periodic outbreaks of this parasite continued into the early 1980s (CH2M Hill 1985). *C. shasta* is often found in reservoir environments (Wood 1979); therefore, impounding the upper Columbia, Snake, and Klamath Rivers may have contributed to the spread of the parasite.

In many cases, disease outbreaks have occurred as a result of introduced, nonnative salmonid populations susceptible to disease. High straying rates of nonnative fish exacerbate the situation by spreading pathogens throughout the native community (KRBFTF 1991). For example, in the early 1970s, many Trinity River Hatchery steelhead strayed to the Iron Gate Hatchery. Excess steelhead adults in the Iron Gate Hatchery were then transferred to the Shasta and the Scott Rivers and other small Klamath River tributaries (KRBFTF 1991). Carlton (1989) found that chinook salmon at Iron Gate Hatchery had a four percent susceptibility to *C. shasta* while the Trinity River Hatchery chinook salmon had roughly a 12 percent susceptibility. Additionally, many viral diseases that are vertically transmitted (i.e. from parent to offspring) were introduced into previously uncontaminated river basins through the transfer of eggs from hatchery to hatchery. The establishment of hatchery health guidelines and restrictions on the transfer of eggs or fish have reduced the risk of disease transfer between basins; however, historical transfers have already established a number of pathogens outside of their native range.

B. Freshwater Predation

Water development activities have increased predation on juvenile salmon by creating ideal habitats for predators and nonnative species. Turbulent conditions near dam bypasses, turbine outfalls, water conveyances, and spillways disorient juvenile chinook salmon migrants and increase their avoidance response time, thus improving predator success (Sigismondi and Weaver 1988). Reduced water flow through reservoirs has increased juvenile travel time and thereby increased their exposure to predators (Columbia Basin Fish and Wildlife Authority 1991). For example, the northern pikeminnow (*Ptychocheilus oregonensis*) (formerly the northern squawfish) and avian predator populations have increased as dam impoundments have created ideal predator foraging areas. Results from numerous studies indicate that in many reservoirs, northern pikeminnow are the primary predator of juvenile salmon.

Other predators such as walleye (*Stizostedion vitreum*), smallmouth bass (*Micropterus dolomieui*), and channel catfish (*Ictalurus punctatus*) consume significant numbers of juvenile salmon. In the Columbia and Snake Rivers, these predators, together with the northern pikeminnow consume between nine and 19% of the juvenile salmonids entering reservoirs, with northern pikeminnow accounting for approximately 78% of this loss (Rieman et al. 1991). The northern pikeminnow consumption rates tend to be highest during the summer months -- coinciding with the juvenile chinook salmon migration (Poe and Rieman 1988). Several studies have documented northern pikeminnow population increases in the Columbia and Snake River chinook salmon migration corridor. The estimated pikeminnow population in the upper half of Lower Monumental reservoir increased from 120,000 in 1975 to 133,000 in 1976 (Sims et. al. 1978), and, in the John Day pool, from 68,947 in 1984 to 102,888 in 1986 (Beamsderfer and Rieman 1988). Lynch (1993) estimated pikeminnow abundance near The Dalles Dam tailrace and cul-de-sac area to range from 160,000 to 1.7 million in 1991 and from 150,000 to 500,000 in 1992. In 1980, the Bonneville Dam forebay pikeminnow population was estimated to range between 6,701 and 23,700 individuals (Uremovich et al. 1980); in 1989 it was estimated to range between 43,302 and 108,960 (NMFS unpublished).

Sacramento pikeminnow (*Ptychocheilus grandis*) (formerly squawfish) is a species native to the Sacramento River Basin and has evolved along with the anadromous salmonids in this system. However, rearing conditions in the Sacramento River today (e.g., warm water, low and irregular flow, standing water, diversions) compared to its natural state 70 years ago, are more conducive to warmwater species such as Sacramento pikeminnow and striped bass (Marone saxatilis) than to native salmonids. In the early 1980s, Sacramento pikeminnow were illegally introduced to the Eel River Basin via Pillsbury Lake. Today, in little over a decade, Sacramento pikeminnow have spread to most areas of the Eel River Basin— illustrating the fact that the Eel River habitat has been altered significantly enough to make it conducive to a species that is better adapted than native salmonids to the artificially warm water conditions that currently exists (Brown et al. 1994). As a result, Sacramento pikeminnow constitute a serious problem for native salmonid populations (Higgins et al. 1992, CDFG 1994). If increased water temperatures and altered ecosystem trends continue, a shift towards the dominance of warmwater species can logically be expected (Reeves 1985).

In addition to the predators mentioned above, striped bass (*Marone saxatilis*) are often thought to be a significant predator of juvenile salmonid. Around the turn of the century, striped bass were introduced into the Sacramento River as a forage and recreational fishery. Attempts to plant striped bass in several California coastal tributaries have been unsuccessful (Bryant 1994). Presently, striped bass abundance is quite low relative to the earlier part of this century; however, striped bass are distributed throughout the California Aquaduct system and associated reservoirs and have been noted in Lake Mendocino and the Russian River system. Nevertheless, there is little reliable data available regarding predation rates of striped bass on any chinook salmon population in California.

In addition to predation by freshwater fish species, avian predators have also been shown to affect juvenile salmonids. Such predation may occur in freshwater areas as well in nearshore marine environments. Ruggerone (1986) estimated that ring-billed gulls (*Larus delawarensis*) consumed two percent of the salmon and steelhead trout passing Wanapum Dam during the spring smolt outmigration in 1982. Wood (1987) estimated that common mergansers (*Mergus merganser*), known freshwater predators of juvenile salmonids, were able to consume 24% to 65% of the coho salmon production in coastal British Columbia streams. Known avian predators in the nearshore marine environment include herons and diving birds such as cormorants and alcids (auklets, murres, murrelets, guillemots, and puffins)(Allen 1974). Manuwal (1977) estimated that in Washington, juvenile salmon constituted about five percent of auklet prey biomass. Mathews (1983) found that the common murre can consume several smolts per day. As the quality of riverine and estuarine habitat decreases, avian predation will increase. Salmonids and avian predators have co-existed for thousands of years, but with the loss of avoidance habitat (e.g., deep pools and estuaries, large woody debris, and undercut banks), avian predation may play a larger role in reducing some chinook stocks. Botkin et al. (1995) stressed that overall predation rates on chinook should be considered a minor factor in their decline; however altered habitats for both birds and chinook may produce certain localized circumstances where predation is more significant.

C. Marine Predation

Marine predation on Northwest salmonid fishes has likely increased as marine mammal numbers, especially harbor seals (*Phoca vitulina*) and California sea lions (*Zalophus californianus*), increased on the Pacific Coast (NMFS 1988). Anadromous salmonids have historically coexisted with both marine and freshwater predators. Based on catch data, some of the best catches of coho, chinook, and steelhead along the West Coast of the United States occurred after marine mammals, kingfishers, and cormorants were fully protected by law (Cooper and Johnson 1992). However, the relative impact of marine predation on anadromous salmonids is not well understood.

Earlier investigators believed it has been a minor factor in chinook salmon declines. Botkin et al. (1995) reported that marine mammal predation on anadromous salmonid stocks in southern Oregon and northern California was only a minor factor for their decline. In California at the mouth of the Russian River, Hanson (1993) reported that the foraging behavior of California sea lions and harbor seals with respect to anadromous salmonids was minimal. Hanson (1993) also stated that predation on salmonids appeared to be coincidental with the salmonid migrations rather than dependent upon it. Cooper and Johnson (1992) reported that marine mammals do prey on some local steelhead populations. However, they believed that it was not an important factor in the decline of coastwide steelhead populations. Although Roeffe and Mate (1984) found that pinnipeds fed opportunistically on fast swimming salmonids, less than 1 percent of the adult Rogue River (Oregon) summer steelhead were preyed on during their upriver spawning migration. In most cases, salmonids appear to be a minor component of the diet of marine mammals (Scheffer and Sperry 1931, Jameson and Kenyon 1977, Graybill 1981, Brown and Mate 1983, Roffe and Mate 1984, Hanson 1993). Principal food sources of marine mammals include lampreys (Jameson and Kenyon 1977, Roffe and Mate 1984), benthic and epibenthic species (Brown and Mate 1983), and flatfish (Scheffer and Sperry 1931, Graybill 1981).

Several studies have indicated that piscivorous predators may control salmonid abundance and survival. Holtby et al. (1990) hypothesized that temperature-mediated arrival and predation by Pacific hake may be an important source of mortality for coho salmon off the west coast of Vancouver Island. Finally, Beamish et al. (1992) documented predation of hatchery-reared chinook and coho salmon by spiny dogfish (*Squalus acanthias*).

Predators play an important role in the ecosystem by culling out unfit individuals and thereby strengthening the species as a whole. However, the combination of increased predator populations and large-scale modifications of habitat that favor predators has shifted the entire predator-prey balance. For example, Harvey (1988) noted that harbor seal numbers on the Oregon coast had increased at a rate of six to 8.8% per year between 1975 and 1983. In 1990, 19.2% of the adult spring and summer chinook salmon observed in the Snake River at Lower Granite Dam exhibited wounds attributable to marine mammals—primarily harbor seals (Harmon et al. 1989). Prior to 1990, adult salmonid injuries resulting from marine mammal attacks were thought to be on the order of a few percent annually (NMFS 1988).

Predation may significantly influence salmonid abundance in some populations when other prey are absent and physical habitat conditions lead to the concentration of adult and juvenile salmonids in small areas (Cooper and Johnson 1992). Pearcy (1992) reviewed several studies of salmonids off the Pacific Northwest coastline and concluded that salmonid survival was influenced by the factional responses of the predators to salmonids and alternative prey. Low streamflows can also enhance predation opportunities -- particularly where adult chinook salmon may congregate at the mouths of streams waiting for flows high enough to allow for access. Also, warmer water temperatures due to water diversions, water development, and habitat modification may affect chinook salmon mortality—directly through predation, or indirectly through stress and disease associated with wounds inflicted by pinnipeds or other piscivorous predators.

The NMFS convened a Working Group to implement 1994 amendments to the Marine Mammal Protection Act (MMPA). That working group reviewed existing scientific information on the effects of pinniped predation on chinook salmon and other anadromous salmonids and made the following findings:

1. Existing information is inconclusive about the effects of pinniped predation on any specific anadromous salmonid population except steelhead at Ballard Locks in Washington. The working group assumed that given the low abundance of salmonids in certain areas, pinniped predation could be a significant factor for decline where local conditions allowed pinnipeds to prey on salmon.

2. Marine mammals interacted and created conflict with many commercial and recreational fisheries, marinas and landings on the west coast, raised some human safety concerns, and these conflicts are not easily deterred by non-lethal methods.

3. Marine mammal biomass consumption figures may be higher than previously estimated, and this number is increasing. However, no estimate as to the ecosystem effects of this consumption was made.

(NMFS 1997b). The working group also assessed mitigation measures for pinniped/fisheries interactions, although there was no analysis of the effectiveness or the effect on salmonid populations of these measures. Mitigation measures assessed included:

1. Harassment, including firecrackers, cracker shells, acoustic harassment devices, acoustic deterrent devices, predator sounds, vessel chase, and tactile harassment.

2. Aversive conditioning, which uses the application of unpleasant stimulus such as taste aversion.

3. Exclusion from selected areas, including physical barriers, predator models, and scarecrows or alarms on haul-out areas.

4. Nonlethal removal of offending individual pinnipeds, including capture and relocation, capture and placement in captivity.

5. Lethal removal of offending individual pinnipeds.

6. Pinniped population control.

As indicated above, the increased abundance of certain predators is due primarily to ecosystem modification and to some degree to the success of marine species protection laws. Even though increased predation is but a symptom of a much larger problem, namely, habitat modification and decreases in water quantity and quality, the effects of marine predation on chinook salmon populations cannot be ignored.

IX. INADEQUACY OF EXISTING REGULATORY MECHANISMS

Evaluation of existing regulatory mechanisms will not be extensively reviewed in this document. The NMFS reviewed many state and Federal efforts in several sections of the March 9, 1998 Federal Register notice announcing the proposed listings for chinook salmon (63 FR 11481). Additionally, NMFS published a separate report detailing the conservation measures in place to protect steelhead (Steelhead Conservation Measures: A Supplement to the Notice of Determination for West Coast Steelhead Under the Endangered Species Act (NMFS 1996b). Many of those measures will affect chinook salmon.

Although it is extremely difficult to quantify or analyze the extent to which existing regulatory mechanisms have failed to prevent the serious depletion of chinook and other anadromous salmonids, the current poor health and low abundance of many distinct populations of chinook salmon can only point to one conclusion: existing regulatory mechanisms have largely failed to prevent this depletion. This is due in part to the lack of coordination and accountability among multiple Federal, state, local, and tribal jurisdictions with responsibilities for land management, resource allocation, and enforcement of related regulations.

X. OTHER NATURAL AND MANMADE FACTORS

The NMFS may consider other natural and human-induced factors in assessing the decline of chinook salmon. Natural factors affecting chinook salmon abundance may include climatic conditions such as drought, fire, floods, and cyclic ocean conditions. Other human-induced factors affecting chinook salmon abundance include the initiation and operation of hatcheries and other artificial production facilities, and adverse predation and competition effects from the introduction of exotic, nonnative species.

A. Natural Factors

Natural factors causing variability in chinook salmon populations, and possibly preventing their recovery include cyclic ocean conditions, drought, fire, landslides, and floods. These natural events have occurred with regularity over the millennia. Chinook salmon have evolved, survived, and even flourished in the face of these events. However, as other deteriorating conditions have adversely affected chinook salmon populations, these cyclic natural events have posed serious threats to the persistence of some chinook salmon populations.

1. Ocean Conditions

The ocean migration and rearing of chinook salmon populations vary widely. Chinook salmon are dispersed from California to Alaska and they commonly intermingle during their ocean rearing and migration. Chinook salmon primarily migrate in nearshore areas, particularly populations of ocean-type chinook salmon which rarely migrate farther than 600 miles from their natal river (Healey 1987). Chinook salmon from California are rarely found north of the Washington coast (though there is little evidence of their southernmost migrations). Columbia River basin chinook salmon rarely migrate farther north than southeastern Alaska, though they have been found as far west as the Aleutian chain. Stream-type chinook salmon may make more open ocean migrations — extending farther west than do ocean-type chinook from the same regions (Healey 1987).

Marine conditions are the dominant "natural" factor influencing chinook salmon population abundance, distribution, and survival in the marine environment. Climatic conditions can change prevailing currents; ocean productivity associated with nutrient-rich cold waters shifts depending upon these ocean currents. These shifting ocean currents, named either "El Nino" or "La Nina," can produce widely varied cycles of productivity (Spence 1996). Ocean conditions resulting from large-scale weather patterns such as El Nino affect food supplies, predator distribution and abundance, and migratory patterns for chinook salmon. Correlations between climate and chinook salmon abundance over the past 20 years indicate that the marine environment has contributed to the variability and decline of chinook salmon returning to the Columbia River in recent years (Francis and Sibley 1991, Pearcy 1992).

Pacific salmon catches have fluctuated widely during the past century. Annual world harvest of Pacific salmon has varied from 347 million pounds (lbs) in the 1930s to about 184 million lbs in 1977 and back to 368 million lbs by 1989 (Hare and Francis 1993). Mechanisms linking atmospheric and oceanic conditions to fish population survival and production have been suggested for stocks in general (Shepherd et al. 1984) and for Pacific salmon specifically (Rogers 1984, Nickelson 1986, Johnson 1988, Brodeur and Ware 1992, Francis et al. 1992, Francis 1993, Hare and Francis 1993, Ward 1993). Vernon (1958), Holtby and Scrivener (1989), and Holtby et al. (1990) have reported associations between salmon survival during the first few months at sea and ocean conditions such as sea surface temperature and salinity. Some studies have tried to link salmon production to oceanic and atmospheric climate change. For example, Beamish and Bouillon (1993) and Ward (1993) found that trends in Pacific salmon catches were similar to trends in winter atmospheric circulation in the North Pacific.

The Subarctic Front, the most prominent feature of the North Pacific Transitional Region, plays a role in defining the major physical and biological domains in the Northeast Pacific Ocean. It is possible that changes in the location or structure of the Subarctic Front may affect any of the physical and biological gradients in this area (Pearcy 1991). McGowan (1986) reported that Subarctic Frontal dynamics influence forage aggregations and biological productivity which, in turn, affects salmonid species at higher trophic levels.

The influence of Subarctic Frontal dynamics on salmonids is probably characterized by indirect trophic interactions rather than a direct cause-effect relationship (Pearcy 1992). The interaction (population control) might be "bottom-up" by lower trophic levels, or "top-down" by predators. This is especially true for prey organisms including phytoplankton, zooplankton, cephalopods, and fish (Pearcy and Fisher 1988), as well as predatory organisms including marine mammals and sea birds (Rogers 1984). Pearcy (1992) suggests that predatorial response to coho smolt and alternative prey availability could influence prey survival rates. This is especially important during years of high upwelling—which cause greater smolt dispersal and alternative prey availability. Several studies have examined the possibility that salmonid production or survival is indirectly related to primary production. For example, Pearcy and Fisher (1988) linked salmon abundance with coastal chlorophyll concentrations, primary production, and upwelling.

Many studies of biological production identify high and low periods of abundance for the study organism. Abundance shifts for many organisms appear to have coincided with the shift in salmon abundance in the late 1970s (Rogers 1984). Francis and Sibley (1991) and Francis et al. (1992) have developed a model linking decadal-scale atmospheric variability to the salmon production hypotheses developed by Hollowed and Wooster (1991) and Wickett (1967), as well as to evidence presented in many other studies. This model describes a time series of biological and physical variables from the Northeast Pacific which appear to share decadal-scale patterns; most notably synchronous shifts in mean conditions during the late 1970s and out-of-phase relationship between variables in the Coastal Upwelling and Coastal Downwelling domains. Biological and physical variables that appear to have undergone shifts during the late 1970s include the following: salmon (Rogers 1984, 1987, Hare and Francis 1993); other pelagic fish, cephalopods, and zooplankton (Brodeur and Ware 1992); oceanographic properties such as current transport (Royer 1989), sea surface temperature and upwelling (Hollowed and Wooster 1991); and atmospheric phenomena such as atmospheric circulation patterns, sea-surface pressure patterns, and sea-surface wind-stress (Trenberth 1990, Trenberth et al. 1993). Variables from the Coastal domains which appear to fluctuate out-of-phase include salmon (Francis and Sibley 1991), current transport (Wickett 1967, Chelton 1983), sea surface temperature and upwelling (Tabata 1984, Hollowed and Wooster 1991), and zooplankton (Wickett 1967).

Finally, Scarnecchia (1981) reported that near-shore conditions during the spring and summer months along the California coast may dramatically affect the strength of individual salmonid year-classes. Bottom et al. (1986) believed that coho salmon along the Oregon and California coasts may be especially sensitive to upwelling patterns because these regions lack extensive bays, straits, and estuaries—such as those found along the Washington, British Columbia, and Alaskan coasts—that could buffer adverse oceanographic effects. Ocean-type chinook salmon tend to remain in the estuarine habitats longer than other chinook (Reimers 1971, Myers and Horton 1992). At the same time, young chinook salmon were also observed in offshore areas. The paucity of high quality, near-shore habitat coupled with variable ocean conditions may be the cause of the rapid northward migration of young stream-type chinook salmon. However, Miller et al. (1983), in conducting set-net sampling tests saw no clear trend in either a north or south migration from the mouth of the Columbia River. This may indicate that migrating chinook salmon movements are based on encounters with favorable marine conditions.

a. El Niño

"El Niño" is an environmental condition often cited as a cause for the decline of west coast salmonids. El Niño is an unusual warming of the Pacific Ocean off South America. It is caused by atmospheric changes in the tropical Pacific Ocean (Southern Oscillation-ENSO). El Niño events occur when there is a decrease in the surface atmospheric pressure gradient from the normally steady trade winds that blow across the ocean from east to west on both sides of the equator. Sometimes, there is a drop in pressure in the east off South America and a rise in the pressure in the western Pacific. The alteration of the pressure gradient across the Pacific Ocean causes the easterly trade winds to relax, and even reverse in some years. When the trade winds weaken, sea level in the western Pacific Ocean drops, and a plume of warm sea water flows from west to east toward South America, eventually reaching the coast where it is reflected south and north along the continents.

El Niño ocean conditions are characterized by anomalous warm sea surface temperatures and changes in coastal currents and upwelling. Principal ecosystem alterations include decreased primary and secondary productivity and changes in prey and predator species distributions. Several El Niño events have been recorded during the last several decades, including those of 1940-41, 1957-58, 1982-83, 1986-87, 1991-92, 1993-94, and 1997-98.

Anadromous salmonids have managed to persist in the face of numerous climatic events and changes. The long-term persistence of chinook salmon populations depends on their ability to withstand fluctuations in environmental conditions. It is apparent that the combination of tremendous freshwater habitat loss, and extremely small anadromous salmonid populations has caused these fish to be more vulnerable to extirpation arising from natural events. Until salmonid populations reached their recent critical levels, these environmental conditions largely went unnoticed (Lawson 1993). Therefore, it would seem that environmental events and their impacts on remaining salmonid populations may become a more significant factor for decline as unstable chinook salmon populations reach particularly low levels.

Ocean conditions and the incidence of El Niños are factors that may not be capable of human intervention and control; however they must be taken into account when trying to assess the effects of human intervention on chinook salmon survival during freshwater spawning, rearing and migration.

2. Terrestrial Conditions

Variable climatic events such as drought, fire, and floods have long had adverse effects on chinook salmon abundance. Droughts and floods may reduce spawning and rearing success. However, the effects on water conditions caused by these types of events may also be the impetus for wild chinook to stray into other spawning or rearing habitats — one of the principle strategies for long-term survival and a major aspect of life history diversity. Floods may also have positive effects when they change stream channels, scour gravels, and move large woody debris—though simplified stream channels in many areas only serve to exacerbate the adverse effects of flooding. Changes in upland habitats alter the flow and delivery of surface waters to the streams—often causing earlier and higher peak flows. Higher, earlier peak flows can decrease the spawning success for chinook salmon adults, and increase the mortality of emerging chinook salmon juveniles.

The extensive modification of freshwater chinook salmon habitat contributes to the adverse effects of drought, fire, and floods. Drought conditions can create both physical and thermal blocks to migrations. Low water conditions can also reduce chinook salmon spawning success, and lead to high mortality as they emerge from their spawning gravel. Low stream flows and higher water temperatures caused by drought can exacerbate predation, stress, and disease. Upland and riparian habitat alteration can increase the adverse effects of fire in both forest and range habitats. Healthy riparian areas can withstand the effects of fire, but altered habitats can increase the incidence of fire as well as intensify its adverse effects on woody debris recruitment, shade, and soil stability. The loss of riparian vegetation and overall stream complexity has reduced many stream's buffering capacity—their ability to withstand high water events, maintain cool water temperatures, retain deep pools, and retain large woody debris (Spence 1996).

B. Manmade Factors

1. Artificial Propagation

In an attempt to mitigate the effects of lost habitat and reduced fisheries, extensive hatchery programs were implemented throughout the range of chinook salmon on the West Coast. While some of these programs successfully provided fishing opportunities, the impacts of these programs on wild stocks are not well understood. Competition, genetic introgression, and disease transmission resulting from hatchery introductions may significantly affect wild chinook salmon production and survival. Furthermore, the displacement of wild fish for broodstock purposes may have additional negative impacts on small or dwindling natural populations. However, it is important to note that the use of hatcheries will likely play an important role in reestablishing depressed Pacific salmonid stocks. Alternative uses of supplementation, such as for the creation of terminal fisheries, must be fully explored to limit negative impacts on remaining wild populations. This use must be tempered with the understanding that protecting wild fish and their habitats is critical to maintaining healthy, fully-functioning ecosystems (Hard et al. 1992, Waples 1991b).

West Coast production of hatchery chinook salmon has been summarized by NMFS (Myers et al. 1998)(See Table 2 of this report). The data are taken from a database developed under contract to NMFS (NRC 1996). Some release information presented here dates back to the turn of the century, but any data prior to 1950—when hatchery records became more reliable—should be considered incomplete.

The ratio of hatchery- to naturally-produced chinook salmon on the West Coast varies from region to region (as well as from watershed to watershed) within a particular ESU. Chinook salmon populations are dominated by hatchery production in some areas and maintained by natural production in others (Howell et al. 1985, WDF et al. 1993, Kostow 1995). Large hatchery programs have produced substantial numbers of fish relative to natural production in many West Coast regions, especially in areas where hatcheries have been used to create or enhance harvest opportunities. These areas include many locations in the Sacramento River Basin, the Klamath River Basin, several Oregon coastal streams, Puget Sound, and the majority of the watersheds in the Columbia River Basin (Howell et al. 1985; WDF et al. 1993; PFMC 1994,1997; Kostow 1995).

2. Regional Summaries for Artificial Propagation

a. California's Central Valley

In 1872, the U.S. Fisheries Commission constructed the first hatchery in the Central Valley — the Baird National Fish Hatchery. Early efforts focused on preserving the already much depleted spring run of chinook salmon. The life history strategy of spring-run chinook salmon requires that adults over-summer in cold headwater areas prior to spawning. As the natural holding and spawning areas for the spring run were degraded or rendered inaccessible, hatcheries became unable to provide suitable conditions for maintaining spring-run chinook salmon prior to spawning and they could not mitigate the declines in the habitat. Emphasis was increasingly placed on producing fall-run chinook salmon to compensate for the decline in the spring runs. Recent artificial propagation efforts have been undertaken at the Coleman NFH (1943-1953) and the Feather River Salmon Hatchery (1967-present). In both cases, efforts to rear both spring- and fall-run chinook salmon at the same facility have resulted in the inadvertent hybridization of the two temporal runs (Cope and Slater 1957, Morishima et al. 1996, Cramer 1996).

Fall-run chinook salmon have been reared at a number of hatcheries in the Central Valley. The state-run Feather River, Nimbus, and Merced Hatcheries, and the Coleman NFH account for the majority of releases into the Central Valley. Exchanges between hatcheries have been commonplace and probably reduced much of the regional variation among stocks. Furthermore, the practice of releasing fish off-station has resulted in a high proportion of returning adults straying into other basins within the Central Valley. The loss of homing fidelity has probably further eroded the distinctiveness of many stocks and inflated the numbers of naturally spawning adults observed. Based on CWT recoveries, the contribution of hatchery strays to naturally spawning populations may exceed 50% in many basins. There are no accurate estimates for the contribution of hatchery strays to natural spawning populations in most Central Valley basins, and, in the absence of such data, the relative health of these stocks may be overestimated.

The propagation of winter-run chinook salmon has been undertaken as part of recovery efforts following their listing under the ESA. Due to the limited number of returning adults, these efforts have been relatively small in size. The success of these programs is still being evaluated.

b. Southern Oregon and California Coastal Region

Artificial propagation began in southern Oregon on the Rogue River in the late 1870s with fall-run chinook salmon hatcheries operated by canneries (Cobb 1930, Kostow 1995). Artificial propagation on the Rogue River became increasingly dominated by state programs after the construction of the Oregon Game Commission Hatchery at Butte Falls in 1916. By 1928, 85 million chinook salmon had been released into the Rogue River from state, federal, and private hatcheries (Cobb 1930).

Spring-run chinook salmon hatchery efforts in the Rogue River Basin did not begin in earnest until the mid-1970s, however nearly 23 million hatchery-produced spring-run chinook salmon have been released into the Rogue River since the completion of the Cole Rivers Hatchery in 1974. This is perhaps the largest spring-run chinook salmon hatchery program on the west coast of North America (Kostow 1995). In 1993, nearly 1.5 million spring-run chinook salmon were released from the Cole Rivers Hatchery alone (Kostow 1995). Cole Rivers hatchery produced spring-run chinook salmon represent approximately half of the total escapement to the Rogue River Basin.

The influence of fall-run chinook salmon artificial propagation in southern Oregon, though small in scale, has resulted in some problems. Fall-run chinook salmon hatchery supplementation programs in some southern Oregon tributaries (Chetco River, Hunter Creek, and Pistol River) were intended to increase natural production; however, the results have been disappointing with a decrease in the effective population size for each river over the course of these programs (Kostow 1995). Furthermore, there was an increase in the incidence of hatchery-derived strays between rivers in the region (Kostow 1995). As a result supplementation programs, in all but Indian Creek (in lower Rogue River), and the Chetco River, have been terminated. In December of 1992, the ODFW Coastal Chinook Salmon Management Plan was implemented to provide guidelines for stock transfers and to identify streams where stocking of hatchery fish should be excluded (Kostow 1995). As mentioned, the size of fall-run chinook salmon artificial production is small.

The Chetco River is the one exception, having been stocked with almost 9 million fish since 1974 (although these have been primarily of Chetco River stock). All other southern Oregon streams have received a total of about 5 million fall-run chinook salmon during the same period. Hatchery fall-run chinook salmon comprised only about 7% of the total Rogue River adult fall-run in 1987 (Cramer 1987).

A total of 95 million chinook salmon fry were released into California coastal rivers from 1875 to 1919, the majority (84 million) into the Eel River (Cobb 1930). Facilities on the Eel and Mad Rivers were constructed to rehabilitate depressed north coast populations (Kelly et al. 1990). Hatchery releases of fall-run chinook salmon since the 1970s have been relatively small, especially when compared to the large programs in the adjacent Sacramento River Basin. The majority of the current coastal California fall-run chinook hatchery programs tend to use stock developed within basin, although these stocks may not be wholly native due to the long history of interbasin transfers that were common in earlier decades (CDNR 1931). The Russian River is a notable exception to this rule, having received artificially propagated fall-run chinook salmon from a variety of sources, most commonly Sacramento River stocks and the Great Lakes (which were stocked with a myriad of populations from Washington, Oregon, and California). In the absence of existing permanent native runs of chinook salmon, local enhancement efforts south of San Francisco Bay in this area have generally used Sacramento River fall-run chinook salmon, although stocks from Washington, Oregon and the Great Lakes have been released there as well (Bryant 1994, NRC 1996). Spring-run chinook salmon artificial propagation has been very limited in the coastal river basins of California, with the exception of the Klamath River Basin.

c. Puget Sound

Fall-, summer-, and spring-run chinook salmon stocks are artificially propagated in Puget Sound. Currently, the majority of production is devoted to fall-run (also called summer/fall) stocks for the purpose of fisheries enhancement. Conversely, because of the depressed nature of spring- and summer-run stocks, approximately half of the stocks recognized by WDF et al. (1993) are under captive culture or supplementation recovery programs. Captive broodstock/recovery programs for spring-run chinook salmon have been undertaken on the White River (Appleby and Keown 1994), and the Dungeness River (Smith and Sele 1995). Supplementation programs currently exist for spring-run chinook salmon on North Fork Nooksack River and summer-run chinook salmon on the Stillaguamish and Skagit Rivers (Marshall et al. 1995, Fuss and Ashbrook 1995). Due to the small size of these spawning populations the potential for inadvertent selection, inbreeding, or accidental loss is heightened while they are under artificial propagation. Fall run transfers between Puget Sound, Washington Coast, and Lower Columbia ESUs were commonplace earlier in this century. Since the 1950s, transfers between ESUs were greatly reduced, but within ESU transfers have been commonplace. One of the greatest impacts has been the widespread use of Green River fall-run chinook salmon in a number of hatchery programs throughout Puget Sound. Marshall et al. (1995) lists 30 artificial propagation programs throughout this ESU that use stocks which have received large transfers of Green River fish. The use of delayed release programs from net-pen to enhance Puget Sound sport fisheries increases the potential for artificially produced fish to stray into nonnative watersheds. Given the magnitude of artificial propagation programs in this ESU, it is probable that hatchery-produced fish constitute a substantial proportion of naturally spawning fish in many Puget Sound Basins. Where specific information on the influence of strays is not known it is possible that the productivity of many natural populations is inflated.

d. Lower Columbia River (Ocean Type)

Hatchery programs are widespread throughout this region, and most populations, with the possible exceptions of fall-run chinook salmon in the Lewis and Sandy Rivers, are maintained to a significant extent by artificial propagation (Howell et al. 1985, WDF et al. 1993, Kostow 1995). The life history characteristic of spring- and fall-run populations in many rivers have probably been influenced by transfers of non-indigenous stocks. Introductions of upriver bright fall-run chinook salmon at the Bonneville Hatchery, Little White Salmon NFH, and Klickitat Hatchery have resulted in naturalized populations of these nonnative fish and the hybridization of upriver bright and tule fall-run chinook in number of watersheds. In the lower Columbia River ESU, releases of Rogue River Basin (Oregon Coast) fall-run from Big Creek Hatchery and Youngs Bay have resulted in these nonnative fish spawning in a number of tributary watersheds of the lower Columbia River (Marshall et al. 1995), with the potential for hybridization with native stocks. For spring-run populations there has been a similarly complex history of stock transfers and large scale artificial propagation. This is especially true of the stream-type chinook salmon spring runs (founded by upper Columbia and Snake River stocks) established in the Wind River at the Carson NFH, and at the Little White Salmon NFH. Transfers of Cowlitz Hatchery spring-run chinook salmon to supplement dwindling populations in the Kalama and Lewis Rivers probably altered the genetic composition of populations in those watersheds. Similarly, when native populations in the Clackamas and Sandy Rivers were at critically low levels they were subjected to large-scale transfers of Upper Willamette River spring-run fish (Nicholas 1995).

e. Upper Willamette River

Native spring-run populations in the Upper Willamette River Basin are maintained primarily through artificial propagation efforts. Less than 10% of the escapement to this ESU are the progeny of naturally-spawning fish. Also, during the first half of this century there were extensive transfers of fish between hatcheries <u>within</u> this ESU. Although the genetic integrity of the ESU, as a whole, has not been greatly impacted, there has been a considerable homogenization of the populations within the ESU. Currently, ODFW maintains three hatchery stocks of spring-run fish in the Upper Willamette Basin: the McKenzie, Santiam, and Middle-Fork Willamette Rivers. Transfers between facilities in these basins have been greatly restricted. Fall-run chinook salmon are present in the upper Willamette River, but these fish are the result of transplants that occurred after the construction of improved fish passage facilities at Willamette Falls in 1971 and 1975 (Bennett 1988). Although there has been no documented hybridization between spring- and fall-run fish the potential for nonnative introgression exists.

f. Columbia River (east of the Cascade Crest)

Artificial propagation in the Columbia River basin initially developed along with the expansion of the commercial fishery. The first Columbia River Basin hatchery was built in 1876 on the

Clackamas River and operated by a cannery interest (CBFWA 1990). State and Federal hatchery operations intended to enhance commercial fisheries began soon afterward and, by the 1890s, many hatcheries and egg-taking stations were in operation between the Chinook River at the mouth of the Columbia River and the Little Spokane River in the upper basin (CBFWA 1990). By 1905, about 62 million fry were released annually; however, due to poor hatchery returns, support for Columbia River hatcheries waned shortly thereafter (CBFWA 1996). After the initial development of the Columbia River dam complex, the negative effects of agricultural development, timber activities and other land use practices increased the need to mitigate reduced natural production (CBFWA 1990). Between 1957 and 1975, eleven new mainstream dams were constructed on the Columbia and Snake Rivers, resulting in further habitat loss and increasing migrational mortality. Artificial production appeared to be the only means available to mitigate for fish losses and the resulting declines in fish available for harvest. Several of these mitigation programs are briefly discussed here.

(1) Grand Coulee Fish Maintenance Project: After the construction of the Grand Coulee Dam in 1939, without anadromous salmon passage, the Federal government initiated the Grand Coulee Fish Maintenance Project (GCFMP), which lasted from 1939 to 1943. The GCFMP sought to maintain fish runs in the Columbia River above Rock Island Dam by two means: (1) improving salmonid habitat, and (2) establishing hatcheries (Fish and Hanavan 1948).

Adult chinook salmon 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 Rivers for natural spawning. Juveniles derived from adults passing over 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 of each year until 1943. A total of five brood years were affected. Early-run fish (stream type) were treated separately from late-run fish (ocean type), but few distinctions were made regarding either the so-called "summer" or "fall" components of the late run, as all late-run fish were captured. The GCFMP continued for five years and intercepted all chinook salmon passing Rock Island Dam, including those destined for now inaccessible spawning areas in British Columbia. As a result, all present day chinook salmon above Rock Island Dam are the descendants of the mixture of chinook salmon collected at Rock Island Dam from 1939 to 1943 (Waknitz et al. 1995).

(2) Chinook Salmon Spawning Channels: Artificial spawning channels for ocean-type chinook salmon were operated during the 1960s and 1970s near Priest Rapids (1963-1971), Turtle Rock (1961-1969), and Wells Dams (1967-1977). They were later discontinued in favor of more traditional hatchery methods due to high pre-spawning mortality in adult fish and poor egg survival in the artificial spawning beds (CBFWA 1990, Chapman et al. 1994).

(3) Mitchell Act: Congress passed the Mitchell Act in 1938 in response to the construction of Bonneville and Grand Coulee Dams, . It required the construction of hatcheries to compensate for fish losses caused by these dams and by logging and pollution (Mighetto and Ebel 1994). Amendments to the Mitchell Act in 1946 led to the development of the Lower Columbia River Fishery Development Plan (CRFDP) in 1948. This plan initiated the major phase of hatchery construction in the Columbia River Basin (CBFWA 1990). In 1956, the CRFDP was expanded to include the upper Columbia River and Snake River Basins. Although the Mitchell Act was supposed to mitigate for lost natural salmonid production in the upper Columbia and Snake River basins, only four of the 39 facilities eventually authorized by this Act were constructed above Dalles Dam on the lower Columbia River. This was partly due to concerns regarding the ability of fish to bypass dams in the upper basin, and partly because the primary goal was to provide fish for harvest in the ocean and lower river (CBFWA 1990; 1996).

(4) Lower Snake River Compensation Plan: Congress authorized the Lower Snake River Fish and Wildlife Compensation Plan (LSRCP) in 1976 to replace lost salmonid production caused by fish passage problems at four Federal dams in the lower Snake River (CBFWA 1990). To date, 22 facilities have been constructed under the LSRCP - including hatcheries and acclimation ponds. In general, LSRCP facilities have had more success in increasing the abundance of steelhead than chinook salmon (Mighetto and Ebel 1994).

(5) U. S. Army Corps of Engineers: The Corps of Engineers (COE) has funded the construction or expansion of 19 hatcheries as mitigation for fish losses caused by COE hydroelectric programs throughout the entire Columbia River basin, including 12 dams in the Willamette River basin between 1941 and 1968 (CBFWA 1990). The COE funded construction of many so-called "Mitchell Act hatcheries."

(6) Public and Private Power Generators: These non-governmental entities have funded the construction and operation of 16 artificial propagation facilities in the Columbia River basin as compensation for fish production lost to their water-use projects. Utilities and companies participating in Columbia River fish culture operations include Chelan, Douglas, and Grant County PUDs in Washington (ESUs 12 and 13); the Idaho Power Company (ESUs 14 and 15); Portland General Electric (ESUs 9 and 11); Tacoma City Light (ESU 9); and Pacific Power and Light (ESU 9) (CBFWA 1990).

Several million upriver brights and smaller numbers of lower Columbia River fall-run hatchery chinook salmon have been released into the Yakima River (Howell et al. 1985, Hymer et al 1992b). The upriver brights stocks represent a composite of Columbia and Snake River populations and were generally founded by random samples of fall-run chinook salmon intercepted at a number of mainstem dams (Howell et al. 1985). The majority of these introductions on the Yakima River have occurred below Prosser Dam and may be responsible for genetic and life history differences between Marion Drain and lower Yakima River fall-run fish (Marshall et al. 1995). Water temperatures in the Yakima River have increased to the point where returning fall-run adults must delay river entry and juveniles must emigrate from the river sooner than they did historically. Conditions above Prosser Dam are such that only in the Marion Drain—a 27-km long irrigation return water canal which is supplied with more thermally stable ground water—is it possible for fall-run chinook salmon to naturally produce smolts in any number (BPA et al. 1996, Watson 1996). It has been speculated that the Marion Drain fish are representative of “native” Yakima River fish (Marshall et al. 1995). If this is the case, then the phenotypic expression of their life history traits (spawn timing, age at smoltification, age at maturation, size at maturation) may have been altered by the artificial environment in which they currently spawn and rear.

3. Introduction of Nonnative Chinook Salmon into Hatcheries

Chinook salmon have often been transferred between watersheds, regions, states, and countries, either to initiate or maintain hatchery- or naturally-spawning populations in other watersheds. The transfer of nonnative fish into some areas has shifted the genetic profiles of some hatchery and natural populations so that the affected populations are genetically more similar to distant hatchery populations than to local populations (Kostow 1995, Howell et al. 1985, Marshall et al. 1995).

It is often difficult to determine the proportions of native and nonnative hatchery fish released into a given watershed. Estimates of the proportion of nonnative fish introduced into each ESU are underestimates for two reasons. First, hatchery or outplanted fish that were designated as "origin unknown" in the database (NRC 1996) were counted as native fish, even though in some cases they were probably not native. Second, transplanted hatchery fish routinely acquire the name of the river system into which they have been transferred. For example, spring chinook salmon released from the Leavenworth NFH are primarily the descendants of the Carson NFH stock (Marshall et al. 1995), but they are designated as Leavenworth stock when released or transferred (NRC 1996). These fish were counted as native fish in this review. Sol Duc River spring chinook salmon (Washington Coast ESU) were derived from a hybrid of two out-of-ESU stocks (WDF et al. 1993), but they were identified as Sol Duc stock when released from the Sol Duc Hatchery or when transferred to other ESUs, such as Hood Canal in the Puget Sound ESU (WDF et al. 1993, NRC 1996). Similarly, the Russian River (So. Oregon and Coastal California ESU) receives fall chinook salmon from a number of hatcheries in other ESUs; these are correctly identified by hatchery of origin at release, but they become "Russian River” stock when they return and are propagated for release in subsequent generations at the Warm Springs Hatchery (NRC 1996).

Until recently, transferring hatchery chinook salmon stocks between distant watersheds and facilities was a common management strategy (Matthews and Waples 1991, WDF et al. 1993, Kostow 1995). Fish from a number of sources have since been used to reestablish stream-type chinook salmon stocks on the Umatilla and Clearwater Rivers. Certain spring-run chinook salmon stocks, such as the Carson NFH stock, have been widely transferred to rivers throughout the Columbia and Snake River Basins, and it is likely that they have been integrated into many local populations. Agencies have instituted policies to reduce the exchange of non-indigenous genetic material among watersheds. In 1991, chinook salmon co-managers in Washington adopted a statewide plan to reduce the number of out-of-basin hatchery-to-hatchery salmon transfers. This policy included genetic guidelines specifying which transfers were acceptable. However, these guidelines applied only to transfers between hatcheries and did not explicitly prohibit introductions of nonnative salmonids into natural populations (WDF 1991). At present, co-managers in Washington State are developing guidelines for transfers of hatchery chinook salmon into natural populations (WDFW 1994). In 1992, the Oregon Coastal Chinook Salmon Management Plan was implemented; it also provides guidelines for stock transfers (Kostow 1995).

4. Introduction of Nonnative Species

The extensive introduction of nonnative species have dramatically altered the biological relationships between and among chinook salmon and the natural communities that share these rivers. Many of the effects of nonnative species introductions have been discussed in the previous section **Disease and Predation**, above. However, in addition to the effects discussed in those sections, additional adverse interactions may include competition for food and rearing space, inhibition of reproduction, environmental modification, and hybridization.

XI. CONCLUSIONS

Chinook salmon on the west coast of the United States have experienced dramatic declines in abundance during the past several decades as a result of human-induced and natural factors. The scientific literature is replete with information documenting the decline of chinook salmon populations and their habitats. No single factor is solely responsible for this decline, though every factor identified in this report has contributed to the decline in varying degrees. Given the complexity of this species' life history and the ecosystem in which it resides, the authors believe it is impossible to accurately quantify the relative contribution of any one factor to the decline of a given chinook salmon ESU. Rather, the authors have found it possible only to highlight those factors which have significantly affected the status of a particular ESU (Table 1). This list will change as more information becomes available. It is important to note in reviewing this list that recovery efforts must focus on those areas which are within human ability to control.

XII. AUTHORS

The NMFS Chinook Salmon Biological Review Team (BRT), led by Jim Myers, Fishery Biologist, NMFS Northwest Fisheries Science Center, and Greg Bryant, Fishery Biologist, NMFS Southwest Region, were the primary authors of this report. The Factors For Decline Report for West Coast Steelhead by Greg Bryant, Fishery Biologist, NMFS, Southwest Region, and Jim Lynch, Fishery Biologist, NMFS, Northwest Region, was instrumental to this report. David Moskowitz, Natural Resource Specialist, NMFS, Northwest Region, was the principal compiler and editor of the materials that formed the basis of this report.

Copies of this report may be obtained by writing to NMFS' Northwest Regional Office of Protected Resources Division at 525 N.E. Oregon Street, Suite 500, Portland, Oregon 97232; calling that office at 503/230-5400; or by writing to NMFS' Southwest Regional Office of Protected Resources Division at 501 West Ocean Boulevard, Suite 4200, Long Beach, California 90802-4213, or by calling 562/980-4027.

XIII. CITATIONS: FACTORS FOR THE DECLINE OF WEST COAST CHINOOK SALMON

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Table 1. Summary of Factors Affecting Each Chinook Salmon ESU

Name of ESU	Geographic Range of ESU	Factors Affecting ESU
1) Sacramento River Winter-run	Sacramento River, CA	●Water diversion\extraction ●Mining ●Agriculture ●Urbanization ●Habitat blockages ●Hydropower development ●Hatchery introgression
2) Central Valley Spring-run	Sacramento River, CA and San Joaquin River, CA.	●Water diversion\extraction ●Mining ●Agriculture ●Urbanization ●Habitat blockages ●Harvest ●Hydropower development ●Hatchery introgression
3) Central Valley Fall-run	Sacramento River, CA and San Joaquin River, CA.	●Water diversion\extraction ●Mining ●Agriculture ●Urbanization ●Habitat blockages ●Harvest ●Hydropower development ●Hatchery introgression
4) Southern Oregon and Coastal California	Cape Blanco, OR south of the Elk River, including the Rogue, Pistol, Chetco, and Winchuck Rivers, OR, and including the Smith River, Redwood Creek, Humboldt County streams, Eel River, to Russian River, CA to drainages north of San Francisco and San Pablo Bays, CA; excluded is the Sacramento/San Joaquin River Basin.	●Historic Flooding ●Predation ●Water diversion\extraction ●Habitat blockages ●Poaching ●Logging ●Agriculture ●Mining ●Hatchery introgression ●Harvest
5) Upper Klamath and Trinity Rivers	Upstream of the confluence of the Klamath and Trinity Rivers, to the uppermost accessible reaches of the Klamath and Trinity Rivers in CA.	●Hatchery introgression ●Logging ●Water diversion\extraction ●Habitat blockages ●Poaching ●Agriculture ●Hydropower development ●Historic flooding ●Mining

Table 1. Summary of Factors Affecting Each Chinook Salmon ESU (continued)

Name of ESU	Geographic Range of ESU	Factors Affecting ESU
6) Oregon Coast	Oregon coast north of Cape Blanco, OR excluding Columbia River tributaries.	●Logging ●Hatchery introgression ●Agriculture ●Minor habitat blockages ●Historic flooding ●Harvest
7) Washington Coast	Mouth of Columbia River, north to Olympic Peninsula, and Strait of Juan De Fuca east to Elwha River, WA.	●Hatchery introgression ●Logging ●Agriculture ●Minor habitat blockages ●Harvest ●Hydropower ●Predation
8) Puget Sound	Strait of Juan De Fuca east of Elwha River, Puget Sound, and Hood Canal, WA.	●Habitat blockages ●Hatchery introgression ●Urbanization ●Logging ●Hydropower development ●Harvest ●Flood control and flow effects
9) Lower Columbia River	Mouth of the Columbia River eastward including tributaries downstream of Willamette Falls, OR and west of the Klickitat River, WA	●Hatchery introgression ●Habitat blockages ●Logging ●Eruption of Mt. Saint Helens ●Hydropower development ●Predation ●Harvest
10) Upper Willamette River	Willamette River, OR, from Willamette Falls upstream	●Habitat blockages ●Hatchery introgression ●Urbanization ●Logging ●Hydropower development ●Harvest

Table 1. Summary of Factors Affecting Each Chinook Salmon ESU (continued)

Name of ESU	Geographic Range of ESU	Factors Affecting ESU
11) Mid-Columbia River Spring-run	Site of former Celilo Falls, upstream to the Yakima River, WA exclusive of the Snake River	●Water diversion\extraction ●Hydropower development ●Agriculture ●Hatchery introgression ●Predation ●Harvest
12) Upper Columbia River Summer/Fall-run	The Columbia River upstream of its confluence with the Snake River, WA including the Yakima River, Hanford Reach, and	●Water diversion\extraction ●Hydropower development ●Agriculture ●Hatchery introgression ●Predation ●Harvest
13) Upper Columbia River Spring-run	The Columbia River upstream of Rock Island Dam.	●Water diversion\extraction ●Hydropower development ●Agriculture ●Hatchery introgression ● ●
14) Snake River Fall-run	The Columbia River upstream of the Dalles Dam, including the Deschutes, John Day, Umatilla and Walla Rivers; the Snake River from its confluence with the Columbia River, upstream to hells Canyon Dam, the Clearwater River to its confluence with Lobo Creek, ID; to the Lower Salmon River, ID.	●Logging ●Agriculture ●Hydropower development ●Water diversion\extraction ●Hatchery introgression ●Habitat blockages ●Mining ●Harvest
15) Snake River Spring/Summer-run	Snake River, WA, upstream from confluence with Columbia River, Snake and Salmon Rivers, ID	●Logging ●Agriculture ●Hydropower development ●Water diversion\extraction ●Hatchery introgression ●Habitat blockages ●Mining ●Harvest

Table 2. Summary of chinook salmon releases by ESU during selected years. Releases are broken down into those originating from 'within' or 'outside' the geographic boundaries of the ESU. For reasons explained in the text, these figures may underestimate the percentage of fish introduced from outside the ESU. Data for years prior to 1960 may not be complete.

ESU	Years	Within ESU (1,000s)	Outside of ESU (1,000s)	% of Total (Outside ESU)
1) Sacramento River Winter Run	1962-95	347	0	0
2) Central Valley Spring Run	1943-93	39,180	0	0
3) Central Valley Fall Run	1944-93	1,683,325	876	>1
4) Southern Oregon and California	1953-93	55,623	16,371	23
5) Upper Klamath and Trinity Rivers	1964-94	286,246	43	>1
6) Oregon Coast	1907-93	303,076	94,172	24
7) Washington Coast	1952-93	256,651	61,794	19
8) Puget Sound	1953-93	1,757,915	13,047	1
9) Lower Columbia River	1910-94	3,364,477	233,432	6
10) Upper Willamette River	1902-94	498,670	208,202	29
11) Mid-Columbia River Spring-Run	1919-93	57,954	62,746	52
12) Upper Columbia River Summer and Fall-Run	1941-93	177,548	14,497	8
13) Upper Columbia River Spring-Run	1941-94	63,827	18,808	23
14) Snake River Fall-Run	1945-93	27,245	1,595	6
15) Snake River Spring- and Summer-Run	1914-94	211,197	15,939	7