

# Seafood Watch

## Seafood Report



MONTEREY BAY AQUARIUM\*

### Pacific Salmon

**Chinook salmon** (*Oncorhynchus tshawytscha*)

**Chum salmon** (*Oncorhynchus keta*)

**Coho salmon** (*Oncorhynchus kisutch*)

**Pink salmon** (*Oncorhynchus gorbuscha*)

**Sockeye salmon** (*Oncorhynchus nerka*)



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### US West Coast Region

Final Report

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## **About Seafood Watch® and the Seafood Reports**

Monterey Bay Aquarium's Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch® defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. Seafood Watch® makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from the Internet ([seafoodwatch.org](http://seafoodwatch.org)) or obtained from the Seafood Watch® program by emailing [seafoodwatch@mbayaq.org](mailto:seafoodwatch@mbayaq.org). The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Each sustainability recommendation on the regional pocket guides is supported by a Seafood Report. Each report synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program's conservation ethic to arrive at a recommendation of "Best Choices," "Good Alternatives," or "Avoid." The detailed evaluation methodology is available upon request. In producing the Seafood Reports, Seafood Watch® seeks out research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch® Fisheries Research Analysts also communicate regularly with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch's sustainability recommendations and the underlying Seafood Reports will be updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Reports in any way they find useful. For more information about Seafood Watch® and Seafood Reports, please contact the Seafood Watch® program at Monterey Bay Aquarium by calling (831) 647-6873 or emailing [seafoodwatch@mbayaq.org](mailto:seafoodwatch@mbayaq.org).

### **Disclaimer**

Seafood Watch® strives to have all Seafood Reports reviewed for accuracy and completeness by external scientists with expertise in ecology, fisheries science and aquaculture. Scientific review, however, does not constitute an endorsement of the Seafood Watch® program or its recommendations on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

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## **I. Executive Summary**

This seafood report evaluates the ecological sustainability of wild-caught U.S. West Coast salmon. To make an overall recommendation, salmon fisheries have been analyzed using Seafood Watch's five basic criteria: inherent vulnerability to fishing pressure, status of wild stocks, nature and extent of bycatch, effects of fishing methods on habitats and ecosystems, and effectiveness of the management regime. Due to the substantial variation observed between salmon fisheries, this report breaks U.S. West Coast salmon down along geographic lines (i.e., by state – Alaska, Washington, Oregon, and California) in order to better inform consumers.

### **Inherent Vulnerability**

Salmon have natural reproductive traits that imply a biological resilience to overfishing. They are relatively short-lived animals (two to five years on average) that release large numbers of eggs when spawning, indicating a high potential reproductive rate. However, the dependence of salmon on specific freshwater areas leaves them susceptible to habitat loss and concomitant population crashes. Notably, in the contiguous U.S. (i.e., the lower 48 states) numerous stocks of salmon have been severely depleted or entirely extirpated due to human activities. Where these downturns have occurred, remaining stocks are left considerably more vulnerable to fishing pressure. The comparatively pristine freshwater systems in Alaska have left salmon runs there comparatively resilient to fishing pressure.

### **Stock Status**

As a result of habitat loss, climatic shifts, historic overfishing, and other factors, the abundance of many populations of salmon has declined substantially over the past century. Overall, Chinook, coho, sockeye, and pink salmon stocks in California, Oregon, and Washington have been significantly depleted from peak abundances, although fishing is not considered one of the primary causes of the declines in many cases. In Washington, several large runs continue to be viable. In several cases, long-term declines in abundance have been halted or reversed in the recent past. The health of Washington stocks are considered a moderate conservation concern because abundances and trends vary in space and time, with targeted stocks depleted from historical levels of abundance, but generally meeting conservation goals. However, a major run supporting both California and Oregon fisheries (Sacramento River Fall Chinook, or SRFC) was recently at record low abundance and failed to meet minimum escapement goals for three consecutive years, triggering a formal Overfishing Concern. Escapement improved in 2010 to a level just over the minimum annual escapement goal. As the stock met conservation objectives in 2010, the stock status of salmon landed in California and Oregon is considered a moderate conservation concern. In contrast, Alaskan salmon, augmented by large hatchery operations, appear to be in robust health, with record abundance and harvests over the past two decades. The status of Alaska salmon stocks is therefore a low conservation concern.

### **Bycatch**

The gear employed in commercial salmon fisheries includes drift and set gillnets, purse seines, and trolling gear (also referred to as hook-and-line gear). When combined with management constraints such as area closures and gear restrictions, the methods used to catch salmon are highly selective for salmon, and overall bycatch rates appear low in all salmon fisheries. However, one of the inherent difficulties of managing salmon is that they are captured in mixed-stock fisheries, in which salmon from a variety of different areas may be caught in the same nets

or on the same hooks. This poses a particularly difficult problem in California and the Pacific Northwest where nearly thirty salmon and steelhead Evolutionarily Significant Units (ESUs) have been listed as Threatened or Endangered under the Endangered Species Act. Regular landings of these fish remains a serious concern despite management efforts to reduce exploitation rates. In Alaska, the relative health of salmon stocks and low bycatch rates of endangered and threatened stocks from the Pacific Northwest has reduced the seriousness of the bycatch issue for most Alaska fisheries, although bycatch of ESA listed stocks remains a concern in southeast Alaska troll fisheries.

### **Habitat Effects**

The gear types used in salmon fisheries (drift gillnets, purse seines, and trolling gear) rarely touch the sea floor. As such, salmon fisheries have little lasting physical impact on aquatic habitats. However, the salmon fishery system can indirectly affect aquatic habitats. Most notably, the widespread use of salmon hatcheries for conservation and fisheries augmentation purposes has, in many cases, significantly degraded the natural habitat of wild salmonids. Hatcheries have often been poorly integrated with wild runs, and can jeopardize their health especially in areas where wild salmon populations are depleted. The effects of salmon hatcheries on the health of wild salmon stocks has been empirically demonstrated in California and the Pacific Northwest, and important questions about Alaskan hatcheries remain unanswered.

### **Management**

Managers of U.S. West Coast salmon fisheries assess stocks on a timely basis, typically issuing preseason abundance forecasts and updating regulations as the season progresses. Managers regularly assess fisheries-dependent data, such as landings, and fisheries-independent data, such as run size, ocean conditions, and fish age, to determine stock status and fishing levels. Management does not have a track record of setting catch quotas over what its scientific advisors have recommended. Managers require specific gear types and employ closed areas to reduce wasteful discards, and actively craft fishing seasons and regulations to reduce harmful impacts on endangered or struggling stocks. However, the effectiveness of the bycatch reduction measures is not clear, as bycatch of some species has decreased, while bycatch of other species remains high, including bycatch of some ESA-listed salmonids. Alaska salmon regulations also limit gear sizes (including mesh size as well as boat and gear length) and limit the time during which gear can be in the water. Management has not prevented the long-term declines of many salmonids in Washington, Oregon, and California, largely because of non-fishing related factors. However, management has responded to the poor condition of stocks with more precautionary management measures, and many stocks that have been a concern in the last few years are now meeting conservation objectives. As a result of this rapid response to fluctuations in stock condition, regular assessments and data collection, and strong enforcement, management of all the U.S. salmon fisheries is considered highly effective.

### **Summary**

The fundamental finding is that Alaskan salmon fisheries, which comprise the vast majority of U.S. Pacific salmon, are very robust, and represent a **Best Choice**. In contrast, many of the remaining Pacific salmon stocks on the West Coast (including inland river systems) are in trouble, primarily because of damage to freshwater ecosystems that are important as spawning and rearing habitats. Historically, overfishing also has caused damage to salmon runs. Hatchery enhancement has, in some circumstances, also contributed harm. Fish from vulnerable ESUs occur in groups with or in proximity to fish from “healthy” stocks. As a result, some of the fish

from depleted/threatened/endangered populations are caught in commercial fisheries that are directed at “healthy” stocks. This problem may occur regardless of how well-managed the commercial fisheries are. While recognizing that recreational and commercial uses are well-established, a strongly precautionary approach requires that vulnerable “by-catch” from mixed stocks be minimized. In general, stocks targeted by the Washington fishery are moderately healthy, while one of the major stocks targeted by both California and Oregon fisheries has only recently (2010) recovered from an overfished condition (and only by a very small margin).

The Seafood Watch **Good Alternative** recommendation for wild-caught California and Oregon (south of Cape Falcon) salmon is based on recent improvements in the Sacramento River fall Chinook stock, which represents a large percentage of commercial landings south of Cape Falcon, Oregon. In 2009, the Sacramento River fall Chinook escapement (the number of adult salmon returning to spawn) was the lowest on record: only 39,000 fish – less than one-third of the fisheries management goal of between 122,000 and 180,000 salmon. In 2010, escapement increased to just above the minimum escapement goal, thus meeting conservation objectives..

Salmon from Columbia River stocks make up most of the catch north of Cape Falcon, Oregon. Based on the difference in stock composition and the Pacific Fisheries Management Council’s delineation of a single management area, (extending from Cape Falcon, Oregon to the Canadian border) salmon north of Cape Falcon, Oregon are considered under the Seafood Watch recommendation for Washington state. The Columbia River stocks targeted by these fisheries have generally met escapement goals in recent years and the stock is considered moderately healthy; therefore salmon caught in the ocean fisheries north of Cape Falcon, Oregon and in the Columbia River in-river fisheries are considered a **Good Alternative**. Please see Figure 2.14 on page 54 of this report for a map of the management area.

In summary, all California, Oregon and Washington salmon are a **Good Alternative**, and all Alaska salmon are considered a **Best Choice**.

**Pocket guide note:** It is sometimes necessary to consolidate Seafood Watch recommendations for consumer pocket guides, to best reflect the product available in the U.S. seafood market.

**This report has updated multiple times, most recently on May 10, 2011. Please see Appendix I for a summary of changes made at this time.**

**Table of Sustainability Ranks**

Sustainability Criteria	Conservation Concern			
	Low	Moderate	High	Critical
Inherently Vulnerability	√ (AK)	√ (CA, OR, WA)		
Status of Wild Stocks	√ (AK)	√ (WA, OR, CA)		
Nature of Bycatch	√ (AK except Chinook)	√ (AK Chinook)	√ (CA, OR, WA)	
Habitat Effects	√ (AK)	√ (CA, OR, WA)		
Management Effectiveness	√			

**About the Overall Seafood Recommendation:**

- A seafood product is ranked “**Avoid**” if two or more criteria are of High Conservation Concern (red) OR if one or more criteria are of Critical Conservation Concern (black) in the table above.
- A seafood product is ranked “**Good Alternative**” if the five criteria “average” to yellow (Moderate Conservation Concern) OR if the “Status of Stocks” and “Management Effectiveness” criteria are both of Moderate Conservation Concern.
- A seafood product is ranked “**Best Choice**” if three or more criteria are of Low Conservation Concern (green) and the remaining criteria are not of High or Critical Conservation Concern.

**Overall Seafood Recommendation:**

**Alaska:**

Best Choice  Good Alternative  Avoid 

**Washington, Oregon and California:**

Best Choice  Good Alternative  Avoid 

## **II. Introduction**

Pacific salmon include several species of fish belonging to the family Salmonidae and to the genus *Oncorhynchus*. Of the seven members of *Oncorhynchus* found on the West Coast, five are reviewed in this report: Chinook salmon (*Oncorhynchus tshawytscha*), chum salmon (*Oncorhynchus keta*), coho salmon (*Oncorhynchus kisutch*), pink salmon (*Oncorhynchus gorbuscha*), and sockeye salmon (*Oncorhynchus nerka*). The anadromous trouts (steelhead and cutthroat trout) are not reviewed here due to the absence of a commercial fishery.

Pacific salmon share some special life history characteristics. Notably, salmon are anadromous; they are born in freshwater but live their adult lives at sea. Once at sea, anadromous salmon only return to freshwater to spawn (see *Important Terms*, below). Generally, salmon spawn in the rivers and lakes of their birth, and do so in different seasonal “runs” (e.g., summer, fall, late-fall, winter) identified by when the fish enter freshwater. Salmon are also unusual in that they are “semelparous,” spawning only once in their lives and subsequently dying, with their very carcasses carrying marine nutrients to freshwater spawning grounds.

### **Important Terms**

**Anadromous** – Anadromous fish are those that spend their adult life in the ocean, but migrate upriver to freshwater spawning grounds in order to reproduce.

**Escapement** – The portion of a salmon run that is not killed or harvested and survives to reach the spawning grounds.

**ESU** (Evolutionarily Significant Unit) – To be considered for protection under the U.S. Endangered Species Act, a group of organisms must first qualify as an “Evolutionarily Significant Unit,” or ESU. ESUs, by definition, are reproductively isolated from conspecific populations, and contribute substantially to the ecological/genetic diversity of the species. An example of an ESU is California Coastal Chinook (See “run” and “stock” below).

**Run** – A salmon “run” is comprised of all of the salmon that migrate upstream to spawn at a specific time. It is frequently discussed in terms of a specific river, species, and season (e.g., Sacramento River winter-run Chinook). An ESU may be comprised of a single run or multiple runs.

**Semelparity** – A life history characteristic in which the organism dies after spawning or reproducing.

**Stock** – The part of a fish population under consideration from the point of view of potential utilization. “Stock” can also refer to an ESU.



In part because of the concentrated nature of salmon runs and the tremendous productivity they embody, salmon fisheries on the Pacific Coast have a notable history. Seasonal runs of salmon have long formed a staple for Native American tribes and First Nations along the West Coast, with pre-industrial harvests in some regions (e.g., California) considerably greater than they are today. The arrival of Europeans brought even greater fishing efforts. The intensive commercial salmon fishery as we know it truly began in 1864 with the introduction of canning technology to the Sacramento River (McEvoy 1986, Lichatowich et al. 1999).

Despite the apparent plentitude of salmon runs, even 130 years ago the U.S. was well aware of the factors that can endanger salmon populations. In 1875, America's first national Fish Commissioner, Spencer Baird, issued a report identifying habitat alteration, dam construction, and over-exploitation as factors with the potential to threaten salmon populations (Lichatowich et al. 1999). Unfortunately, this foresight was not sufficient to prevent declines in salmonid populations throughout California and the Pacific Northwest. Harvests in rivers throughout the contiguous U.S. generally peaked between 1880 and 1920, and have gradually declined despite management efforts. By the early 1990s, native salmon species had been extirpated from an estimated 40% of their native spawning territory in California, Idaho, and the Pacific Northwest. Moreover, numerous remaining ESUs are listed as Threatened or Endangered under the U.S. Endangered Species Act (ESA). In contrast to their southern cousins, Alaskan salmon populations have remained numerically healthy, and landings have soared over the past quarter century.

Today, Pacific salmon are one of the most intensively monitored and managed groups of fish on the planet. Given their commercial importance as well as their ESA status, considerable attention is devoted to stock abundance. The species are managed by a variety of agencies including state and tribal authorities, the Pacific Fishery Management Council (PFMC), the National Marine Fisheries Service (NMFS), the North Pacific Anadromous Fish Commission, and the U.S.-Canadian Pacific Salmon Commission.<sup>1</sup>

**Scope of the analysis and the ensuing recommendation:**

This report focuses on the five main Pacific salmon species: Chinook, chum, coho, pink, and sockeye. Steelhead trout, a related salmonid, is not assessed due to the absence of a large commercial fishery, though bycatch of steelhead is addressed. The geographic range examined in this report extends from Southern California through Alaska.

The status of Canadian stocks is only briefly mentioned in this report, as recommendations are specific to U.S. salmon stocks. British Columbia salmon fisheries are important, however, as the Fraser River system historically supported one of the largest salmon runs in North America.

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<sup>1</sup> Unlike its southern counterpart, the North Pacific Fishery Management Council does *not* play an active role in salmon management.

## **Availability of Science**

Pacific salmon are intensively managed for several reasons, including their commercial value, their anadromous nature, and the listing of depleted salmon ESUs under the Endangered Species Act. As a result, a large body of both scientific and management literature exists regarding salmon. Despite the availability of this literature, a number of difficulties in conducting a review of West Coast salmon fisheries still exist. Assessments of fisheries are complicated by the role of habitat degradation, climatic oscillations, and other non-fishery related factors in impacting stocks, as well as by the mixed-stock nature of many salmon fisheries and the shifting role of hatcheries in salmon conservation and stock augmentation. An abundance of hatchery fish can mask long-term trends in natural spawners. More importantly, because salmon return to their natal streams to spawn, there can be and often is a high level of variation between the health of salmon stocks in relatively close proximity. Given this geographic difference, along with the remaining uncertainties and complicating factors, this assessment does not claim to review each individual salmon run. Instead, it provides basic guidelines for assessment, and attempts to make recommendations on a broad regional basis.

## **Market Availability**

### **Common and market names:**

- Pacific salmon:
  - Chinook salmon is also known as king salmon or spring salmon.
  - Coho salmon is also known as silver salmon.
  - Sockeye salmon is also known as red salmon or blueback salmon.
  - Chum salmon is also known as dog salmon or silverbright.
  - Pink salmon is also known as humpback salmon.
- Salmon may also be marketed by the name of their river of origin.

### **Seasonal availability:**

Pacific salmon may be found year-round in both retail and service markets, with peak abundance varying by season and region. The wild supply of salmon is augmented by a comparatively small international production of farmed Pacific salmon. Additionally, large quantities of farmed Atlantic salmon are available year-round. Farmed salmon are reviewed separately in the Seafood Watch® Farmed Salmon report.

### **Product forms:**

Pacific salmon are marketed as canned, fresh, or frozen fillets, frozen whole fish, smoked, or value-added products (e.g., prepared meal portions).

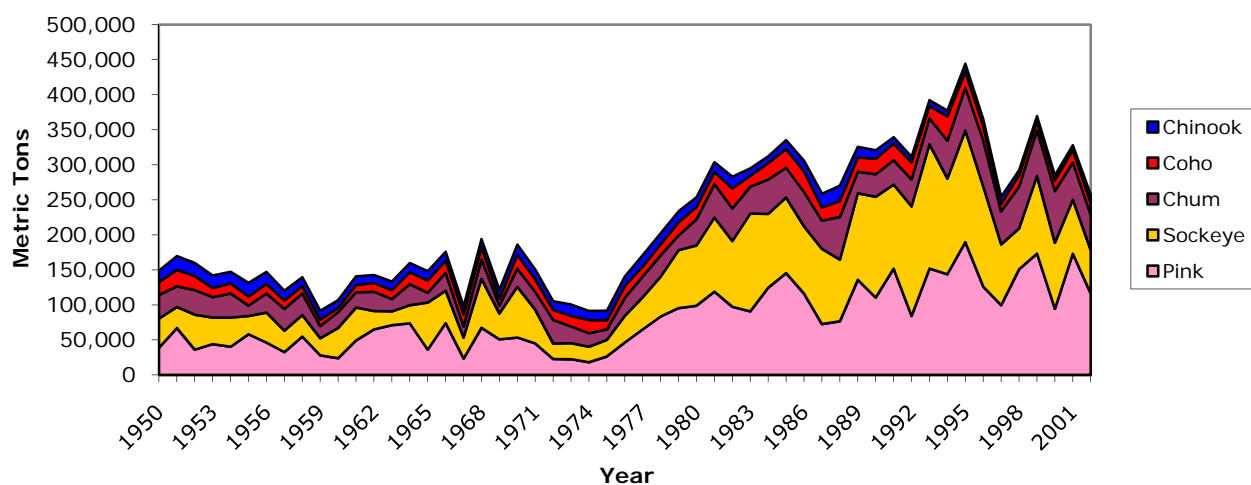
### **Import and export sources and statistics:**

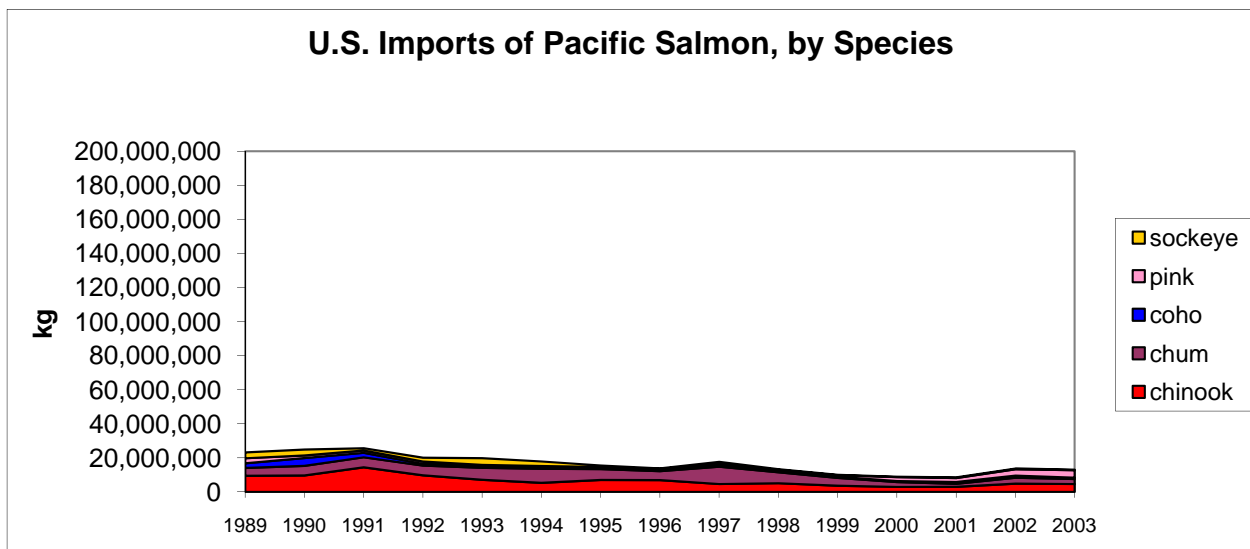
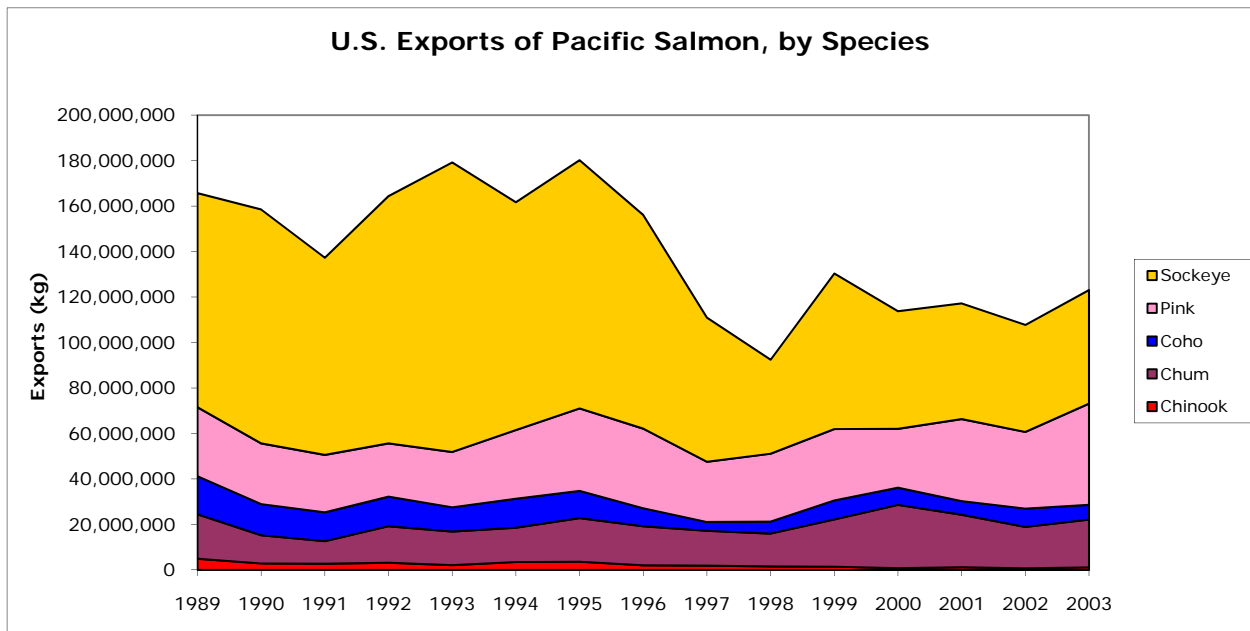
The vast majority of Pacific salmon on the U.S. market is landed domestically, with a large quantity of landings exported abroad. Since 1980, between 250,000 and 450,000 metric tons (mt) of Pacific salmon have been landed annually at U.S. ports. By quantity, the main species landed have been pink and sockeye salmon from Alaska, followed by chum salmon and to a lesser extent coho and Chinook salmon (NMFS 2004b). In addition to commercial landings, a thriving recreational fishery for salmon exists, and salmon remains an important subsistence fishery (particularly in Alaska).

In 2002, the U.S. exported 108,000 mt of salmon worth over \$330 million, consisting mainly of sockeye (44%) and pink salmon (31%). The same year, the U.S. also imported a smaller quantity of wild salmon, around 6,000 mt, primarily from Canada (NMFS 2004b). The value of imported wild Pacific salmon was approximately \$18 million. Canadian exports of wild Pacific salmon to the U.S. consisted mainly of pink, chum, coho, and Chinook salmon. Small quantities of *farmed* Pacific salmon are also imported from Canada, and significantly larger quantities of farmed Atlantic salmon are imported from Canada, Chile, and other nations. Farmed salmon is not addressed in this report.

This report evaluates the ecological sustainability of wild-caught West Coast salmon using Seafood Watch's five basic criteria: inherent vulnerability to fishing pressure, status of wild stocks, nature and extent of bycatch, effects of fishing methods on habitats and ecosystems, and effectiveness of the management regime. Where relevant, West Coast salmon are broken by species, region, state, river of origin, or specific run.

### U.S. Commercial Salmon Landings by Species





### **III. Analysis of Seafood Watch® Sustainability Criteria for Wild-caught Species**

#### **Criterion 1: Inherent Vulnerability to Fishing Pressure**

*Guiding Principle: Sustainable wild-caught species have a low vulnerability to fishing pressure, and hence a low probability of being overfished, because of their inherent life history characteristics.*

**Summary:** Pacific salmon possess life history characteristics that vary by species and by stock or Evolutionarily Significant Unit (ESU). Generally speaking, Pacific salmon have relatively resilient life histories based on their high reproductive capacity. The specifics are detailed in tabular form (Table 1.1), but include:

- A young age at maturity; on average age 2 to 5 depending on the species.
- A low maximum age (less than ten years) due in part to the fact that adults die after reproducing.
- Relatively high fecundity, with hundreds to thousands of large eggs produced per female during reproduction.

Due to their short maturation period and high fecundity, Pacific salmon are far more resilient to fishing pressure than long-lived species slow to reach maturation, or animals that bear only a few young. These reproductive traits and the high intrinsic rate of growth they imply can help salmon to recover from periods of low populations. As a result, the resilience of salmon populations is considered to be moderate to high, with a minimum doubling time between one and a half and four and a half years (Musick 1999, Froese and Pauly 2004). Other considerations aside, these factors would merit a low conservation concern for all Pacific salmonids under the Inherent Vulnerability criterion.

Yet despite these relatively robust reproductive characteristics, recent history indicates that salmon are far more vulnerable than most species to anthropogenic pressures. Over 120 years ago, habitat alteration, hatcheries, dams, and over-harvesting were identified as major factors with the potential to impact the Pacific salmon industry (Lichatowich et al. 1999). Today, this list remains essentially unchanged. By the early 1990s, native salmon had been extirpated from roughly 40% of their original range in California, Oregon, Washington, and Idaho (Anderson 1993). Given the empirical success of America in decimating numerous salmon populations, it is clear that the fish have a higher inherent vulnerability than their age at maturation might otherwise suggest. There are reasons to suggest that many populations of Pacific salmon have characteristics apart from their life-cycle that increase their vulnerability to fishing pressure.

First, salmon are anadromous, spawning in freshwater but living the bulk of their adult lives at sea. Far more so than the marine environment, many freshwater habitats have been highly degraded by humans, thereby increasing the vulnerability of populations dependent upon them. In many cases, habitat destruction from a variety of human activities (e.g., dams, logging, water diversions, etc.) has *already* combined with other factors such as pollution, introduced species,

and fishing to exterminate or endanger salmon runs. These habitat losses have been particularly evident in the southern half of salmon's North American range.

Second, salmon have a highly developed "homing" instinct, generally returning to the specific lakes and rivers of their birth. This homing instinct is a fundamental component of salmon biology, and is largely responsible for the formation of discrete populations. While the degree of homing (and its opposite, "straying") varies across species and locations, homing creates reproductive isolation and helps to facilitate localized adaptation (Stewart et al. 2003). The combination of isolation and adaptation has led to the evolution of numerous Evolutionarily Significant Units (ESUs), which are treated under Endangered Species Act legislation as separate species. As a consequence of the diversity of Pacific salmon ESUs, the loss of local populations increases the chance of losing overall genetic diversity.

Third, Pacific salmon populations are subject to natural fluctuations that can increase their vulnerability. Salmon populations are strongly influenced by changing atmospheric-oceanic conditions on a number of different temporal scales. Changes in climate affect oceanic structure and can generate significant and often sudden differences in salmon marine survival and returns (Francis and Hare 1994). These include both the subdecadal variability of the El Niño Southern Oscillation (ENSO) and the longer-scale (50-70 years) climate oscillations that have operated over the North Pacific for at least the past three centuries.

Over the long-term, sediment cores indicate that sockeye salmon populations have undergone significant swings during the past two millennia (Finney et al. 2002). For example, populations were depressed from ~ 100 BC to AD 800, but consistently higher from AD 1200 to 1900. Similarly, Bristol Bay sockeye salmon have undergone several major shifts over the past three centuries (Finney et al. 2000). In the medium-term, regime shifts in the subarctic and California Current ecosystems associated with the Pacific Decadal Oscillation (PDO) have strongly influenced salmon productivity. A regime shift during the late 1970s (and again in the late 1980s) appears to have reduced oceanic survival of salmon in the Pacific Northwest, while increasing oceanic survival in Alaska (Hare et al. 1999, Tolimieri and Levin 2004). Hilborn, Quinn et al. (2003) note that "the productivity of Alaskan sockeye salmon populations appears to be among the *more sensitive* biological systems that respond to interdecadal climate shifts and is strongly coherent with changes in the Pacific Decadal Oscillation."

In the near-term, smaller scale environmental conditions have significant effects on salmon population variability. One recent study documents that early marine survival of three species of salmon from Washington to Alaska is strongly influenced by sea surface temperature (SST) within a few hundred kilometers of the stock's natal stream (Mueter et al. 2002). SST is likely a proxy for changes in ecological interactions in the marine realm. The authors found that survival of pink, sockeye, and chum salmon was strongly affected by the oceanic processes related to SST, and that these effects were consistent across species. Interestingly, it appears that water conditions during the salmon's first few months at sea have a greater influence on salmonid survival than larger-scale variability associated with the PDO. Complicating the management picture, stocks of even the same species may react in a non-uniform manner to changing climatic conditions (Tolimieri and Levin 2004).

While these fluctuations demonstrate that shifts between productivity regimes occur outside of the influence of anthropogenic factors, human pressures can add to the natural instability facing

salmon. Finney, Gregory-Eaves et al. (2002) conclude that “a more thorough understanding of the linkages between climatic change and ocean ecosystems is critical for future sustainable management of northern Pacific fisheries, as fish stocks are now faced with many additional stresses including commercial fishing, habitat degradation and global warming.”

These fluctuations are compounded by the fact that Pacific salmon are semelparous (PFMC 2004a). Ecological studies indicate that semelparity increases the amplitude of population fluctuations and reduces the “effective” population size of some salmonid populations by roughly one half (Waples 2002). In contrast to semelparity, larger population sizes tend to dampen natural fluctuations due in part to a more complex spatial and genetic structure and wider spatial distribution (Einum et al. 2003). As a corollary, it would seem that the reduced populations now seen in West Coast salmon runs are likely to be effectively both smaller *and* less stable than their numbers imply.

As a result of these factors—most notably habitat loss—Pacific salmon in the southern half of the North American range (California, Oregon, Washington, and Idaho) have proven to be more vulnerable than reproductive capacity would otherwise suggest. The reduced resilience depresses the ability of salmon runs to sustain fishery pressure. Consequently, the inherent vulnerability ranking for salmon in California and the Pacific Northwest is downgraded from resilient (low conservation concern) to moderately resilient (moderate conservation concern). The geographic division of southern North American versus Alaska corresponds roughly to a species division as well: Chinook and coho runs have lost the largest share of habitat, while pink, chum, and sockeye salmon in Alaska have been less impacted to date. Alaskan freshwater habitat overall has remained relatively pristine, and salmon originating in Alaska do not share the same vulnerabilities as those in California and the Pacific Northwest.

Table 1.1 provides a summary of relevant life-history factors, and Table 1.2 summarizes Pacific salmon habitat degradation in North America. The tables are followed by in-depth species-by-species assessments of inherent vulnerability.

**Table 1.1. Life history information for commercially important Pacific salmon.**

COMMON NAME	SPECIES RANGE <sup>2</sup>	GROWTH RATE/MAX SIZE	AGE at MATURITY	LONGEVITY	FECUNDITY	LITERATURE
<b>Chinook</b>	Arctic and Americas: Ventura River, CA to Point Hope, AK. Asia: Japan, Sea of Japan, Bering Sea, and Sea of Okhotsk	Max Size: 50 kg, 150 cm TL (total length)	Mean age at maturity: 4 years. Range: 2-7 years.	Maximum reported age: 9 years	Fecundity: 1,200-14,000 eggs	(Delaney 1994, Myers et al. 1998, DFO 2001, Froese and Pauly 2004)
<b>Coho</b>	N. America: Baja California to Kotzebue Sound, AK; Aleutian Islands. Asia: Kamchatka, Hokkaido, and Korea. CoA in N. America: OR to SE AK.	Max Size: 15 kg, 110 cm TL male, 66 cm TL female	Mean age at maturity: 3 years. Range: 2-4 years.	Maximum reported age: 5 years	Fecundity: 1,400-4,500 eggs	(Elliott 1994, DFO 2001, 2003, Froese and Pauly 2004, PFMC 2004a)
<b>Chum</b>	Arctic and Americas: Sacramento River, CA to Mackenzie River, Canada. Asia: Kyushu, Japan to Lena River, Siberia, Bering Sea, Sea of Okhotsk.	Max Size: 16 kg, 100 cm FL (fork length) K: 0.27-0.45	Mean age at maturity: 3-4 years. Range: 2-5 years	Maximum reported age: 6 years	Fecundity: 700-7,000 eggs (2,400-3,100 typical)	(Buklis 1994, Froese and Pauly 2004)
<b>Pink</b>	Arctic and Americas: CA to AK, Aleutian Islands. Asia: Bering Sea, Okhotsk Sea, Korea, Hokkaido, Russia.	Max Size: 7 kg, 76 cm TL	Mean age at maturity: 2 years. Range: Almost exclusively 2 year olds (odd + even year populations)	Maximum reported age: 3 years	Fecundity: 800-2,000 eggs	(Kingsbury 1994, Froese and Pauly 2004, PFMC 2004a).
<b>Sockeye</b>	Americas: Klamath River, CA to Bathurst Inlet, Canada. Asia: Hokkaido to Anadyr River, Siberia. CoA: Bristol Bay, AK.	Max Size: 8 kg, 84 cm TL male, 71 cm TL female K: 0.37-0.58	Mean age at maturity: 3 years. Range: 2-7 years in different stocks.	Maximum reported age: 7 years	Fecundity: 2,000-4,500 eggs	(ADFG 1994, NMFS 2001a, Froese and Pauly 2004)

<sup>2</sup> CoA = Center of Abundance



**Table 1.2. Vulnerability of Pacific salmon.<sup>3</sup>**

STATE	PERCENTAGE of ALL U.S. PACIFIC SALMON LANDED SINCE 1950 <sup>4</sup>	COMPOSITION of SALMON LANDED WITHIN GIVEN STATE SINCE 1950 <sup>5</sup>	HYDROELECTRIC FACILITIES	LOGGING	WETLAND LOSSES	INTRODUCED SPECIES
<b>California</b>	Chinook 21% Coho 2%	Chinook 88.1% Coho 11.9%	Significant in-state hydro-generation, equivalent to Oregon. 40 billion mWh <sup>6</sup> generation	85% loss coastal redwood forests; 90% loss Central Valley forests; 90-98% loss Sac. River riparian forests	91% all wetlands lost; 94% inland wetlands lost; 62% salt marsh lost; 69% tule marsh lost	~200 introduced fish species. Brook trout in 20 drainages; mainly Sierra Nevada.
<b>Oregon</b>	Chinook 17% Coho 10% Sockeye < 0.01% Pink < 0.01%	Chinook 54.7% Coho 43% Chum 0.7% Sockeye 0.7% Pink 0.7%	200+ large dams on Columbia, 90% without fish ladders, 1,000+ smaller dams; Majority of Snake River obstructed. 40 billion mWh generation	96% coastal temperate rainforest logged; 80% Douglas-fir old growth forests logged	1/3 of wetlands lost since 1780	~70 introduced fish species. Significant negative effects documented from brook trout in Columbia, Snake, Rogue, etc.
<b>Washington</b>	Chinook 23% Coho 23% Chum 10% Sockeye 6% Pink 4%	Sockeye 23.9% Coho 22% Chum 18.7% Pink 18.5% Chinook 16.9%	200+ large dams on Columbia, 90% without fish ladders, 1,000+ smaller dams; Majority of Snake River obstructed. 80 billion mWh generation	75% coastal temperate rainforest logged; 90% Douglas-fir old growth forests logged	1/3 of wetlands lost since 1780	~70 introduced fish species. Significant negative effects documented from brook trout in Columbia, Snake, Rogue, etc.
<b>Alaska</b>	Pink 96% Sockeye 94% Chum 90% Coho 65% Chinook 39%	Pink 40.3% Sockeye 34.7% Chum 16.5% Coho 5.9% Chinook 2.6%	160 dams; ~1% of WA hydroelectric generation	11% coastal forests logged	0.1% wetland losses	< 10 introduced fish species – brook trout insignificant factor.

<sup>3</sup> Sources: Noss 2004; EIA 2002; Noss et al. 1995; USGS 2004; Schmidt 1994; Fuller 2003; DFG 2003; Levin et al. 2002.

<sup>4</sup> The column reflects the state-by-state distribution of Pacific salmon landings totaled over the past fifty years. It is intended to serve as a rough proxy for the distribution of salmon habitat, though it has several shortcomings. Most notably, the shortcomings include: 1) it shows variable fishing effort across species and states (landings do not correspond to habitat); 2) it does not account for the considerable habitat loss that occurred before 1950; and 3) it ignores the presence of rare populations.

<sup>5</sup> In-state commercial landings since 1950 is intended to better reflect relative abundance of each species within states. It is subject to the same qualifications and caveats as the preceding column. In addition, significant changes in harvests and management have occurred over the past twenty years.

<sup>6</sup> mWh = megawatt hour (one million watt-hours), a unit of electrical generation.

## **Chinook Salmon (*Oncorhynchus tshawytscha*)**

Chinook salmon, also called king or spring salmon, is the largest of the Pacific salmon species, with adult fish commonly exceeding 30 pounds. Chinook salmon is Alaska's state fish and represents an important commercial and recreational species throughout the northern Pacific (Delaney 1994).

### ***Distribution***

In North America, the natural range of freshwater habitats for Chinook salmon stretches from the Ventura River in California northward to Kotzebue Sound in Alaska (Figure 1.1) (DFO 2001). Once at sea, Chinook may swim anywhere from the U.S.-Mexico border to the Chukchi Sea off of Alaska.

On the Asian side of the Pacific, Chinook occur in freshwater from the Anadyr River area of Siberia (64 degrees north) southward to Hokkaido, Japan. In marine waters, they are found in the Sea of Japan, Bering Sea, and Sea of Okhotsk (Delaney 1994, Froese and Pauly 2004).

### ***ESUs***

In the contiguous U.S., 17 ESUs of Chinook salmon have been identified:

- **Sacramento River Winter-run**
- **Upper Columbia River Spring-run**
- **Snake River Spring/Summer-run**
- **Snake River Fall-run**
- **Puget Sound**
- **Lower Columbia River**
- **Upper Willamette River**
- **Central Valley Spring-run**
- **California Coastal**
- **Central Valley Fall and Late Fall-run**
- Upper Klamath-Trinity Rivers
- Oregon Coast
- Washington Coast
- Middle Columbia River Spring-run
- Upper Columbia River Summer/Fall-run
- Southern Oregon and Northern California Coastal
- Deschutes River Summer/Fall-run

As of June 2004, two of these 17 ESUs (Sacramento River Winter-run and Upper Columbia River Spring-run) were listed as **Endangered Species**. In addition, seven of the 17 ESUs were listed as **Threatened Species**, and one ESU (Central Valley Fall and Late Fall-run) was designated a **Species of Concern** (NMFS 2004a).

In Alaska, Chinook salmon are managed on a regional basis, rather than dividing the species into ESUs. The four overarching regions in Alaska are: Southeast Alaska, Central Region, Westward Region, and Arctic-Yukon-Kuskokwim Region. Chinook salmon are predominantly harvested in

Southeast Alaska, but significant commercial landings are taken in all four regions. Once in Alaska's interior, it is unclear where many fish go to spawn.

### ***Life History Traits***

As with most Pacific salmon, Chinook salmon are anadromous. Many Chinook salmon make far-reaching freshwater spawning migrations to reach home streams that form the tributaries to larger river systems (Delaney 1994). These spawning habitats can lie relatively close to the coast or over 3,000 kilometers upriver (PFMC 2004a). For example, Yukon River Chinook spawners bound for Yukon Territory, Canada, can travel more than 3,000 river kilometers during a 60-day period. Chinook do not feed during their return freshwater migrations, and their bodies gradually deteriorate as their energy stores are used up over the course of the run and in the production of gametes (Delaney 1994).

Adult Chinook typically spend between one and four years in the ocean before returning to spawn. Chinook salmon usually become sexually mature between their second and sixth year, with a maximum reported age of nine years. As a result, they also vary greatly in size, ranging from less than four pounds to well over fifty pounds (Delaney 1994). Most returning Chinook salmon are between three and five years old (PFMC 2004a), though a significant fraction of Chinook salmon mature at age two to three after spending only one winter in the ocean. These precocious fish are commonly referred to as "jacks" and are usually males (Delaney 1994, PFMC 2004a).

During spawning, female salmon each typically deposit several thousand eggs in several gravel nests, called redds (Delaney 1994, Myers et al. 1998). Generally, redds are located in stream bottoms with specific characteristics including clear water and gravel of a size that can be manipulated by the fish (PFMC 2004a). In Alaska, eggs usually hatch in late winter or early spring, depending on time of spawning and water temperature (Delaney 1994). The newly hatched fish, called fry, live in the gravel for several weeks, absorbing the food in their attached yolk sacs. These fry then emerge, and, after maturing into smolts capable of living in salt water, migrate downstream towards the ocean, though they may pause in lakes or estuaries before entering the marine environment (PFMC 2004a). In Alaska, most juvenile Chinook salmon remain in fresh water for a year, and migrate to the ocean in their second year of life (Delaney 1994). Once at sea, Chinook salmon can travel widely. The adult fish prey on a wide diversity of organisms, including "fish, squid, euphausiids, amphipods, copepods, pteropods, crustacean larvae, gelatinous zooplankton, polychaetes, chaetognaths, and appendicularia" (Kaeriyama et al. 2004).

Despite these commonalities, Chinook salmon also show significant life history variation between fish. Scientists have identified two kinds of Chinook salmon, one called stream-type and the other called ocean-type (Myers et al. 1998). There are significant differences in the age at which they move to the sea, their migration patterns, and spawning times, between the two types of Chinook. Stream-type Chinook spend more time in streams (one to two years) before they head out to the ocean. Once they are in salt water they make long voyages away from their natal streams and come back early before spawning. Adult stream-type Chinook typically enter rivers in the spring and summer, and spawn in late summer or early fall (PFMC 2004a). Conversely, ocean-type Chinook spend less time in fresh water (just a few days to months), though they may remain longer in estuarine areas. Once ocean-type Chinook reach the ocean they stay close to their natal streams, but only return to freshwater just before spawning (Delaney 1994, DFO

2001). Generally, the timing of returns of ocean-type Chinook varies between late summer and the winter months, though in some river systems the fish may return for much of the year (PFMC 2004a).

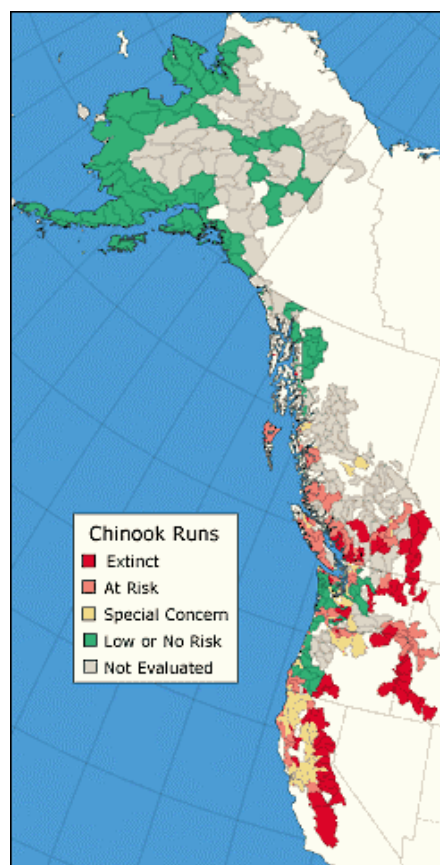
The seasonal variation in salmon spawning is important as the same river system can support several runs of salmon. The 2004 PFMC Environmental Assessment notes that “not all runs types are equally abundant. In Oregon and Washington, spring (March through May) and fall (August through November) Chinook runs are most common; a few stocks run in summer (May through July). In California there are also late fall and winter runs (December through July) in the Sacramento River. A late fall run has also been reported from the Eel River” (PFMC 2004a).

The fact that Pacific salmon are semelparous reduces the stability of population sizes. Because there is no overlap in the breeding population between years, one study (Waples 2002) demonstrated both theoretically and empirically that variable semelparous populations with overlapping year classes can reduce the effective population size in Pacific salmon. With respect to Chinook in particular, the author estimated a reduction of 40-60% in the effective population size of one particular Snake River Chinook salmon population due to variability in run sizes between years (Waples 2002).

### ***Habitat***

*Human settlement along stream and river corridors during the past 150 years has altered the fundamental processes that created the habitat conditions under which salmonid populations have evolved and adapted over centuries.* (Larsen et al. 2004b)

Over the past two centuries, habitat loss has become a major issue for Chinook and other salmonid species. Damming, logging, pollution, and hatchery fish have all put undue pressure on many wild Chinook stocks. As a consequence, the Pacific Fishery Management Council notes that “wild Chinook populations have disappeared from large areas where they used to flourish, and several evolutionarily significant units (ESUs) have been listed or proposed for listing as at risk for extinction under the Endangered Species Act” (PFMC 2004b). This is particularly true in the southern half of the Chinook salmon range, as graphically depicted in Figure 1.1.



**Figure 1.1. North American Chinook salmon range (Brownell 1999).<sup>7</sup>**

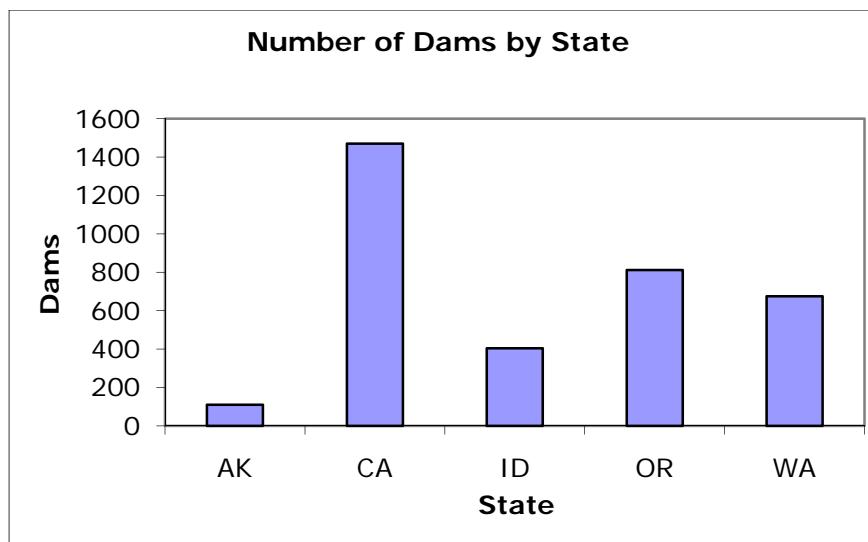
### *Dams*

One of the key factors in Chinook freshwater habitat loss has been the construction of dams. The presence of a dam can profoundly alter salmon habitat by changing several factors including stream flow, sedimentation rates, nutrient levels, and obstacles to passage. In some cases, fish are unable to pass dams, effectively excluding them from the freshwater habitat above. As of the year 2000, the Columbia River Basin alone possessed over 200 large (> 15 meters high) dams and thousands of other dams as little as a meter or two in height. Of the large dams, less than 10% were equipped with fish ladders or similar devices (Levin and Tolimieri 2001), often excluding salmon from the spawning grounds above. Of those dams passable to fish, many still cause significant mortality. For example, a single mid-Columbia River hydroproject consisting of two powerhouses is estimated to kill 5% of migrating salmon smolts (Skalski et al. 2002). Levin and Tolimieri similarly examined the fate of 16 Chinook salmon populations before and after dam construction in several areas of the Pacific Northwest (Levin and Tolimieri 2001). The authors concluded that in all cases dam construction had obvious detrimental effects on Chinook salmon habitat. Moreover, dams in the Upper Columbia River *continue* to have significant

<sup>7</sup> One reviewer raised concerns about the accuracy of this map in the Columbia/Puget Sound region. The scientist noted that mid-Columbia spring Chinook are regarded as relatively healthy, and that Grande Ronde and Upper Columbia Chinook are listed, but not extinct. In contrast, the map variably marks Puget Sound Chinook, but the ESU is listed as threatened. These maps are intended to provide a general sense of the relative health of salmon throughout their historical distribution. However, they are not substitutes for the more detailed information available in the Stock Status and Bycatch criteria of this report.

negative effects on salmon populations despite mitigation measures, and may be currently preventing recovery of endangered salmon populations.

Prior to 2002, the Army Corp of Engineers compiled information on the location and distribution of dams by state. The National Inventory of Dams indicated that in 2001 California had 1,470 existing dams, Oregon 812, Washington 675, Idaho 404, and Alaska just 110 (Figure 1.2) (USACOE 2002).

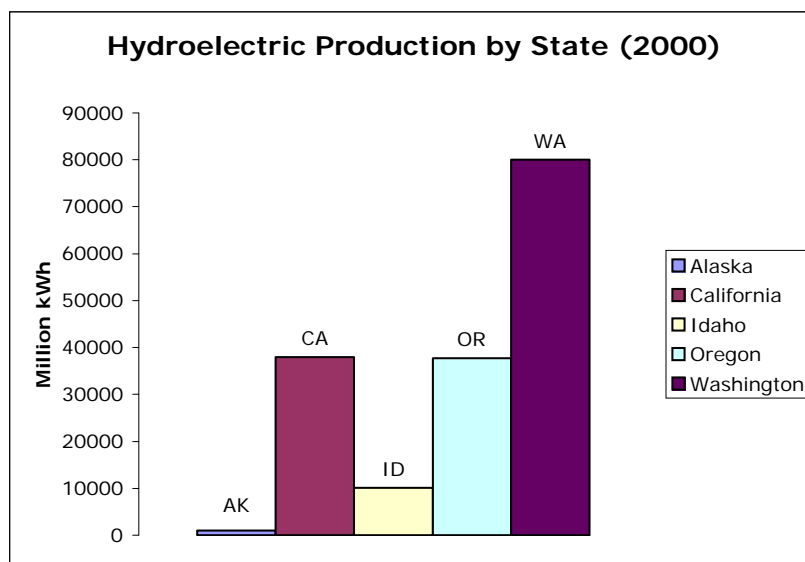


**Figure 1.2. Number of dams in the U.S. Pacific Northwest and Alaska.**

While it is clear that these hydroprojects have been devastating to many fish populations in North America, and more generally worldwide (Pringle et al. 2000), Chinook and coho salmon in the contiguous states have been among the most negatively affected. According to one recent analysis (Dauble et al. 2003), only 13% and 58% of Chinook salmon's original riverine habitat in the Columbia and Snake Rivers, respectively, remains, with much of the Snake River habitat located behind the Hells Canyon dam and therefore inaccessible to salmon. Of the nearly 1,500 km of these rivers once used for spawning by fall Chinook salmon, under 250 km (<20%) are still used, due in large part to the loss of alluvial floodplains. Similarly, in California's Central Valley over 70% of traditional salmon spawning and rearing habitat has been lost due mainly to the presence of impassable dams (BRT 2003). Summarizing these effects on Pacific salmon, the National Marine Fisheries Service (NMFS) Office of Protected Resources notes:

Water storage, withdrawal, conveyance, and diversions for agriculture, flood control, domestic, and hydropower purposes have greatly reduced or eliminated historically accessible habitat and/or resulted in direct entrainment mortality of juvenile salmonids. Modification of natural flow regimes have [since] resulted in increased water temperatures, changes in fish community structures, depleted flows necessary for migration, spawning, rearing, flushing of sediments from spawning gravels, gravel recruitment, and transport of large woody debris. Physical features of dams, such as turbines and sluiceways, have resulted in increased mortality of both adults and juvenile salmonids. (OPR 2004)

In contrast to the widespread use of dams in California, Oregon, and Washington, water storage and hydroelectric projects are far less abundant in Alaska, due largely to the scarcity of major metropolitan or agricultural areas and greater abundance of water. According to one count, of the roughly 75,000 dams in the U.S., just 160 are located in Alaska (Alaska 2000). However, where dams do exist, they continue to have effects on anadromous fish. Few of the existing hydro facilities in Alaska appear to have anadromous fish ladders, and there is evidence that where dams do exist formerly strong salmon runs have dwindled (Boltwood 2002). As a proxy for the presence and extent of dams, data from the Energy Information Agency indicates that in the year 2000 hydroelectric facilities in Alaska generated 1 billion kilowatt hours (kWh) (Figure 1.3). In contrast, California and Oregon each generated 38 times that amount, and Washington State generated more than the other three states combined (EIA 2002).



**Figure 1.3. Hydroelectric production in the year 2000. Data source: (EIA 2002)**

#### *Other Habitat Alterations*

In addition to dam development, Pacific salmon habitat has been compromised by other forms of human activity, including logging, water diversions, road construction, the proliferation of impervious surfaces, channelization of rivers, the removal of woody debris and riparian vegetation, disruption in sediment and nutrient supply, and a general fragmentation of habitats (Larsen et al. 2004b, OPR 2004). Again according to the NMFS Office of Protected Resources: “Studies indicate that in most western states, about 80 to 90 percent of the historic riparian habitat has been eliminated.... In Washington, the number of large, deep pools in National Forest streams has decreased by as much as 58 percent 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 percent” (OPR 2004). The disappearance of these natural features can reduce the suitable habitat for Pacific salmon.

An earlier but more comprehensive review by the U.S. Geological Survey notes that Oregon and Washington have witnessed the logging of 96% and 75% of their original coastal temperate rainforests, respectively (Noss et al. 1995). In addition, both states have incurred losses of old-growth forests in Douglas-fir regions on the order of 80-90%. California’s habitat losses have

been even more severe, and read like an encyclopedia of habitat destruction: an 85% loss of coastal redwood (*Sequoia sempervirens*) forests, an 89% loss of Central Valley riparian forests, a 90-98% decline of Sacramento River riparian and bottomland forests, a 99.9% loss of Central Valley riparian oak forest, a 94% loss of inland wetlands (including the Central Valley), a 69% loss of tule marsh, a 66-88% loss of Central Valley vernal pools, and a 62% loss of salt marshes (compiled by: (Noss et al. 1995)). Notably, Washington and Oregon both lost over a third of their wetlands between 1780 and 1980, and 91% of California's wetlands have been drained or otherwise destroyed (Noss et al. 1995). In contrast, just 0.1% of Alaska's wetlands were lost over that period. Indeed, Alaska is the only region of the United States without endangered ecosystems. While 11 percent of Alaska's original coastal temperate rainforests have been logged, the percentage still compares favorably against the 75-90% losses in California, Oregon, and Washington.

Pollution can also be detrimental to salmon habitat. In many coastal regions, agricultural and urban run-off as well as atmospheric deposition have significantly reduced freshwater, estuarine, and coastal water quality (Boesch et al. 2001). Pollution can reduce the viability of salmon embryos, though the extent of these effects has not been quantified on West Coast salmon. Typically, agricultural chemicals such as pesticides are found in freshwater habitats at levels well below thresholds for acute mortality; however, pesticides can still cause sublethal effects that could ultimately cause ecological mortality. Potential harms include impaired swimming ability, reduced sense of smell, and disrupted immune and hormonal systems. The lack of data on the sublethal toxicity of pesticides for salmonids has been described as a "key uncertainty" for the recovery prospects of many ESUs (Sandahl et al. 2004). In 2002, a court order prohibited the application of 30 types of pesticides within close proximity to salmon waters in California, Oregon, and Washington.

As with dams, this wide array of damages to salmon habitat appears to have significantly reduced both the quantity and quality of available Pacific salmon spawning habitat in the southern half of their traditional range. Alaskan habitat appears to have remained relatively robust during this period. Pollution is likewise less prominent of an issue in Alaska. While the Exxon Valdez oil spill received considerable attention for the detrimental effects it caused to salmon and other animals, current research indicates that spawning habitat has largely recovered from the spill 15 years ago (Carls et al. 2004).

### *Introduced Species*

In addition to physical alterations, biological alterations to habitat can have substantial effects on salmon. In particular, introduced species can represent a subtler degradation of habitat. For example, over the past 150 years, over 20 species of fish have been introduced into the Columbia River Basin, several of which have become established. Currently, one fifth of the number of fish found in designated "wilderness area" streams in the basin are introduced species (Levin et al. 2002). In many areas, introduced species are even more pervasive. For example, in a 1993 survey of nearly one thousand samples (boat electrofishing, gillnets, and hoopnets) in the southern Sacramento-San Joaquin Delta, introduced species represented 99% of the total number of fish collected (Feyrer and Healey 2002).

In many areas, these introductions have had significant detrimental effects on salmon. One of the most detrimental introductions is brook trout (*Salvelinus fontinalis*), the most abundant introduced species in threatened spring and summer-run Chinook spawning habitat in the



Columbia River. Brook trout have been stocked widely for sport fishing throughout the American West, including California, Oregon, Idaho, Washington, and Alaska (Fuller 2003). Levin, Achord et al. (2002) note that brook trout “appear to easily outcompete anadromous salmon and may be important predators of salmon eggs and juveniles.” Levin, Achord et al. (2002) found a 12% decrease in the survival rates of juvenile salmon in sites where brook trout were present. It seems likely that where brook trout and Pacific salmon co-occur, brook trout may reduce salmon survival rates.

In addition to the Columbia, brook trout have also been introduced into the Snake, Bear, Kootenai, and Rogue Rivers and into other drainages in Idaho, Oregon, and Washington. In California, brook trout have been stocked in over twenty rivers and drainages, and are currently spread throughout the Sierra Nevada (CDFG 2003, Fuller 2003). In Alaska, brook trout have only been stocked in Southeast Alaska. None of the fish introduced into Alaskan drainages have survived in the rivers and streams, and few brook trout have survived in lakes with access to the sea, leaving only a few brook trout populations in enclosed lakes (Schmidt 1994). As such, and in contrast to the Columbia River, it appears unlikely that brook trout are degrading salmon habitat in Alaska.

Another introduced species, striped bass, can also have a negative effect on salmon, as they can prey upon juvenile Chinook salmon. Striped bass were introduced into the Sacramento River in 1879 to encourage a commercial fishery. Striped bass have performed well in the Sacramento, but over the past three decades bass populations declined from 2 million to 1 million adults for a number of reasons (e.g., entrainment in water diversion projects and habitat loss). As of 2003, a proposed augmentation of Sacramento River striped bass populations was under debate. Such an augmentation program could negatively affect Chinook salmon populations. An analysis by Lindley and Mohr (2003) indicates that the Sacramento River winter-run Chinook population has a 28% chance of going extinct in the next 50 years, though the probability of extinction nearly doubles if striped bass populations are enhanced and stabilized at 3 million fish.

As a more general point about the effects of introduced species and habitat, it appears that Alaskan habitat has been significantly less affected by introduced species to date than the rest of the West Coast. The Nonindigenous Aquatic Species Database maintained by the U.S. Geological Survey (USGS) indicates that only a handful of fish have been introduced and successfully established in Alaska. In contrast, the USGS database lists over 190 species introduced in California and 60 to 70 species introduced in each of the states of Oregon, Washington, and Idaho (USGS 2004).

### ***Summary: Chinook Salmon***

Overall, there is little debate that Chinook salmon habitat and other Pacific salmon freshwater habitat has been severely compromised over the past two centuries. Most of the habitat loss and fragmentation has been concentrated on the lower 48 states. Fortunately, freshwater habitats appear to have remained relatively intact in the sparsely populated state of Alaska. Figure 1.1 depicts the consensus that Alaskan freshwater systems, by and large, have not been impacted to nearly the same extent as those in California, Oregon, Idaho, and Washington.

## **Coho Salmon (*Oncorhynchus kisutch*)**

Coho salmon is also known as “silver” salmon. Of the five main Pacific salmon species, coho have proven to be the species perhaps most vulnerable to human pressure. While coho occupy the widest range of freshwater habitat types, they are not the most abundant species and have seen their numbers decline substantially throughout the southern portion of their range (Olsen et al. 2003).

### ***Distribution***

In North America, coho salmon spawn in many locations between the San Lorenzo River in Monterey Bay, California and Point Hope, Alaska in the Chukchi Sea (PFMC 2003). At sea, coho salmon range throughout the Pacific, from as far south as Baja California to Kotzebue Sound in the north. They are most frequently found in coastal waters between Central Oregon and Southeast Alaska (DFO 2001, PFMC 2004c).

On the Asian side of the Pacific, coho salmon range throughout the Aleutian Islands, Kamchatka Peninsula, Hokkaido, Japan, and Korea (DFO 2001).

### ***ESUs***

Seven evolutionarily significant units (ESUs) of coho salmon have been identified on the West Coast of the United States:

- **Central California (Endangered under California Endangered Species Act)**
- **Southern Oregon/Northern California Coasts**
- **Oregon Coast**
- **Lower Columbia River**
- **Puget Sound/Strait of Georgia**
- Southwest Washington
- Olympic Peninsula

As of 2008, the Central California ESU is listed as endangered, the next three ESUs above were listed as threatened species, while the Puget Sound/Strait of Georgia ESU has a “species of concern” designation, all under the U.S. Endangered Species Act (NMFS 2010a). Additionally, coho south of Punta Gorda in California are listed as Endangered under the California Endangered Species Act.

In Alaska, fishery managers have not divided coho salmon into ESUs. Instead fishery management is divided along geographic lines, splitting the state harvest into four overarching regions: Southeast Alaska, Central Region, Westward Region, and Arctic-Yukon-Kuskokwim Region. Coho salmon are harvested in all four of these regions, with a slight majority of landings coming from Southeast Alaska (Plotnick and Eggers 2004).

### ***Life History Traits***

Like the other species of Pacific salmon, coho salmon are anadromous, and generally have a life history similar to Chinook salmon. However, there are some differences between Chinook and coho salmon. Unlike Chinook salmon, the amount of time coho salmon spend in fresh and salt water is relatively fixed. Juvenile coho typically spend at least a year in freshwater, followed by

18 months at sea, predominantly maturing at age-three (PFMC 2004a). However, in Southeast Alaska and Alaska's Central Region, the majority of coho salmon adults are four year-olds, having spent an additional year in fresh water before going to sea (NWFSC 1995). As with Chinook salmon, precocious jacks will return to spawn at a younger age, typically just spending 5-7 months at sea. The maximum reported age for coho is five years (Froese and Pauly 2004).

Unlike Chinook salmon, where most production comes from mainstem spawning areas,<sup>8</sup> coho salmon tend to use smaller streams and tributaries. While coho salmon are capable of utilizing the full range of freshwater environments, most coho spawning is found in "smaller, low-gradient streams and tributaries" (PFMC 2004a). Typical coho populations are small in size, and they tend to spawn late in the year (early fall to mid winter) and utilize distant headwater streams (Olsen et al. 2003).

With respect to reproductive capacity, female coho salmon typically deposit several thousand eggs, which develop during the winter and hatch in early spring. The emergent fry occupy shallow stream margins, and, as they grow, establish territories, which they defend from other salmonids. Coho fry live in ponds, lakes, and pools in streams and rivers, usually along stream banks, in quiet areas free of currents. During the fall, juvenile coho may travel miles before locating to an off-channel habitat where they pass the winter free of floods. Some fish leave fresh water in the spring and rear in brackish estuarine ponds and then migrate back into fresh water in the fall (Elliott 1994).

Little is known about the ocean migrations of coho salmon. Coho appear to not migrate as far as other species of salmon, staying fairly close to shore (DFO 2003). High seas tagging indicates that maturing Southeast Alaska coho move northward throughout the spring and appear to concentrate in the central Gulf of Alaska in June. In the Gulf, the fish prey on gonatid squids and a wide range of other organisms such as fish, euphausiids, amphipods, and copepods (Kaeriyama et al. 2004). The salmon later disperse towards shore and migrate along the shoreline until they reach their stream of origin (Elliott 1994).

### ***Habitat***

As with Chinook salmon, coho salmon have lost a considerable portion of their habitat, particularly in the southern half of their range. The same sources of habitat degradation (i.e., dams, water diversion, siltation, introduced species, and other human activities) have equally affected coho salmon. The current ESU listings indicate that coho salmon runs have been highly compromised in the contiguous states (Figure 1.4).

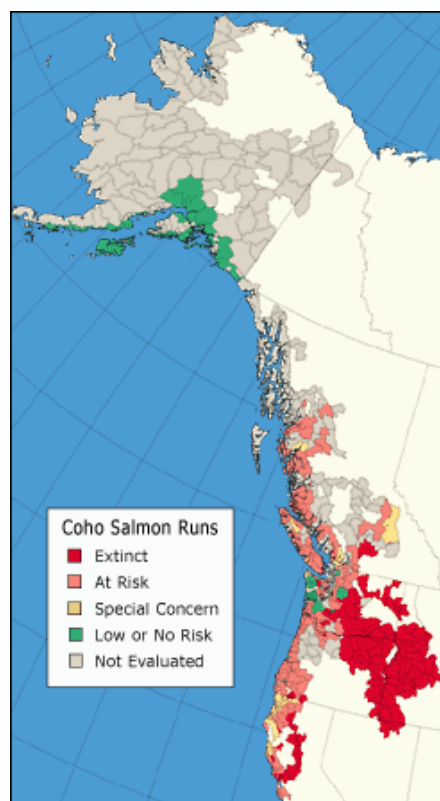
In fact, coho salmon appear to be more vulnerable to habitat loss than other species. This additional vulnerability stems from at least three factors. First, while coho salmon populations are highly adaptable and can be found in a range of freshwater environments, many coho salmon rely on distant headwaters for spawning grounds (Elliott 1994). The longer lengths of freshwater migration leave the species more vulnerable to habitat disruption and loss from hydropower projects or water diversion en route. Second, the number of fish in coho runs tends to be smaller owing in part to the lesser tributaries coho prefer. Third, coho exhibit significant genetic diversity, with only weak "geographic concordance." Because populations of coho are small

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<sup>8</sup> Stream-type Chinook do not spawn in mainstem areas. They are also likely to make long migrations into the interior.

relative to many other salmon runs, genetic diversity in coho is largely influenced by genetic drift (Olsen et al. 2003). This combination of small population sizes and the low degree of genetic overlap between coho stocks makes coho runs particularly vulnerable to anthropogenic damages. Olsen, Miller et al. (2003) comment: “Activities or conditions that cause declines in population abundance are more likely to have strong negative impacts for coho salmon than for species in which genetic variation is distributed over a broader geographic scale (e.g., chum salmon). Coho salmon are probably more susceptible to extirpation, less likely to be augmented or ‘rescued’ by other populations through straying (gene flow), and the loss of populations means loss of significant amounts of overall genetic variability.” Indeed, the National Marine Fisheries Service confirms that coho populations have been declining in streams throughout Oregon, Washington, and California, with the southernmost and easternmost stocks in the worst condition. Over the last hundred years, nearly all of the naturally reproducing populations of coho salmon are believed to have been extirpated from Columbia River tributaries (NMFS 1999).

As with Chinook salmon, roughly half of the natural range of coho in North America is found in Alaska. The freshwater habitat of Alaskan coho stocks has been substantially less impacted than spawning habitat in the contiguous U.S., and appears capable of supporting healthy populations (Figure 1.4).



**Figure 1.4. North American coho salmon range (Brownell 1999).<sup>9</sup>**

<sup>9</sup> While coho are extinct in the interior Columbia, they historically did not extend very far up the Snake River; as such the map misrepresents the species' original range.

## **Sockeye Salmon (*Oncorhynchus nerka*)**

Sockeye salmon, often referred to as “red” or “blueback” salmon, is the third most abundant of the Pacific salmonids, after pink and chum salmon. Unique in their appearance, adult spawning sockeye salmon typically turn bright red (with a green head), hence the name red salmon. During the ocean and adult migratory phases of their life cycle, sockeye often have a bluish back and silver sides (NMFS 2001a).

### ***Distribution***

Sockeye salmon occur in the North Pacific and Arctic oceans and associated freshwater systems. Sockeye are found from the Columbia River and its tributaries north and west to Kotzebue Sound in western Alaska, straying as far as Bathurst Inlet in the Canadian Arctic (Figure 1.5). On the Asian side of the Pacific, sockeye range from as far south as northern Hokkaido, Japan, to as far north as the Anadyr River in Siberia (ADFG 1994).

### ***ESUs***

Seven ESUs of sockeye salmon have been identified in the contiguous U.S.:

- **Snake River**
- **Ozette Lake**
- Baker River
- Okanogan River
- Lake Wenatchee
- Quinault Lake
- Lake Pleasant

As of June 2004, the Snake River ESU was considered an **Endangered Species** and the Ozette Lake ESU was listed as a **Threatened Species** under the Endangered Species Act (NMFS 2004a).

The ESU system has not been applied by the Alaska Department of Fish and Game, which manages roughly 98% of the U.S. commercial sockeye fishery. Instead, Alaska breaks commercial salmon fishing into four major areas: Southeast Alaska, Central Region, Westward Region, and Arctic-Yukon-Kuskokwim Region. Sockeye salmon are predominantly harvested in Alaska’s Central Region and Westward Region (with over half of the 2003 harvest coming from Bristol Bay, one of four management sub-units in the Central Region) (Plotnick and Eggers 2004).

### ***Life History Traits***

As with other Pacific salmon, sockeye generally mature relatively quickly, typically spawning within the first four years after birth. Sockeye occasionally, however, spawn as late as seven years of age. During spawning, a female usually deposits 2,000 to 4,500 eggs in a redd, depending upon her size (ADFG 1994). Consistent with these factors, the growth rate for sockeye salmon has been reported as 0.37-0.58 (Froese and Pauly 2004).

In general, sockeye salmon exhibit a wide variety of life history patterns that reflect a varying dependency on the fresh water environment (NMFS 2001a). Sockeye salmon may possess the

highest degree of natal homing of any Pacific salmon species, which helps to maintain these differences (Stewart et al. 2003).

With the exception of certain river-type and sea-type populations, the vast majority of sockeye salmon spawn near lakes. Most sockeye salmon spawn in the tributaries or outlets of lakes (and occasionally in the lakes themselves) because juvenile sockeye are adapted to remain in lakes for one or two years before beginning their marine migration (Stewart et al. 2003). Appropriate spawning grounds include streams and rivers ranging in depth from 10 cm to several meters, as well as groundwater-fed beaches in lakes. In these outwash areas, sockeye may spawn anywhere from the shoreline to a depth of several meters, and on substrates including small gravel, cobble, and rocky beaches (Hilborn et al. 2003, Moore et al. 2004). For this reason, the major distribution and abundance of large sockeye salmon stocks are closely related to the location of rivers that have accessible lakes in their watersheds for juvenile rearing (NMFS 2001a).

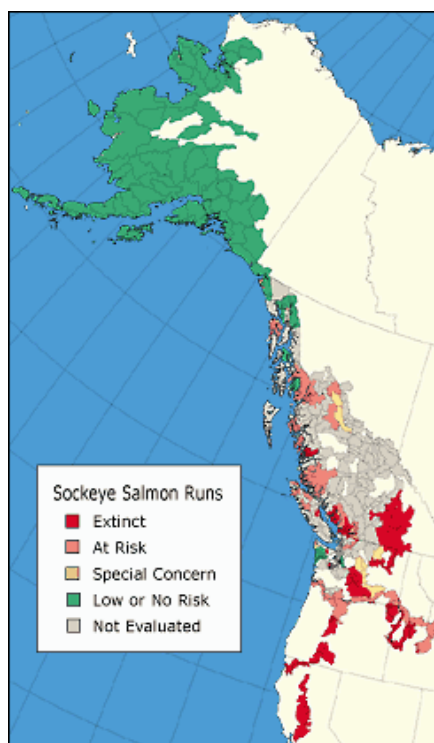
Once at sea, sockeye salmon spend two to three years feeding before returning to spawn (Finney et al. 2000). In the Gulf of Alaska, sockeye prey upon a wide range of marine life including fish, squid, and other taxa. Their dominant prey appears to be gonatid squid, but sockeye salmon (along with pink and chum salmon) have demonstrated a high plasticity in diet, readily shifting prey in response to changing availability or ocean conditions (Kaeriyama et al. 2004).

Some sockeye are not anadromous, spending their entire lives in freshwater (NMFS 2001a). Non-anadromous sockeye in the Pacific Northwest are known as kokanee. Occasionally, a proportion of the juveniles in an anadromous sockeye salmon population will remain in their rearing lake environment throughout their lives and will be observed on the spawning grounds together with their anadromous siblings (NMFS 2001a). Taxonomically, kokanee and sockeye salmon do not differ.

### ***Habitat***

On the Pacific Coast, sockeye salmon inhabit riverine, marine, and lake environments. Sockeye are no longer present in the southern reaches of their historic range, such as the Central Valley of California. As with Chinook and coho salmon, sockeye freshwater habitat in the contiguous United States has fared poorly over the past two centuries. Where sockeye salmon populations persist south of Alaska, they appear to be in sub-standard health (Figure 1.5).

However, unlike Chinook and coho salmon the vast majority of sockeye salmon have traditionally been found north of the regions most impacted by habitat degradation. The center of abundance of sockeye stocks is in Bristol Bay, Alaska. Currently, roughly 98% of the U.S. commercial sockeye salmon harvest comes from Alaska, “The Last Frontier State.” As such, the bulk of sockeye freshwater habitat has been significantly less degraded than the habitat of coho or Chinook salmon, and remains capable of supporting robust populations.



**Figure 1.5. North American sockeye salmon range (Brownell 1999).<sup>10</sup>**

### **Chum Salmon (*Oncorhynchus keta*)**

Chum salmon, known in parts of Alaska as “dog salmon,” may have historically been the most abundant of all salmonids (NMFS 2001b). Chum salmon traditionally provided a major source of dried fish to Native Americans and First Nations in the winter (Buklis 1994).

#### ***Distribution***

Chum salmon have the widest natural geographic and spawning distribution of any Pacific salmonid, primarily because its range extends farther along the shores of the Arctic Ocean than any other salmonid (NMFS 2001b, Froese and Pauly 2004). In the Arctic, chum range east to the Mackenzie River in Canada and west to Siberia’s Lena River (Buklis 1994).

Historically, chum salmon were distributed down the West Coast of the United States as far south as Monterey, California (NMFS 2001b). Presently, however, major spawning populations are found only as far south as Tillamook Bay on the northern Oregon coast (Figure 1.6) (NMFS 2001b). In Asia, the southern limit to chum salmon is the island of Kyushu in the Sea of Japan (Buklis 1994).

<sup>10</sup> The map appears to list Ozette Lake Sockeye as low or no risk; in reality, they are listed as threatened. Similarly, the interior Columbia coloring makes the sockeye range appear larger than it actually is. The map also indicates that sockeye extend north to Kotzebue Sound. Commercially important densities, however, are only found as far north as the Kuskokwim. (Burgner RL. 1991. Life History of Sockeye Salmon (*Oncorhynchus nerka*). Pp. 1-117 in: Groot C, Margolis L, editors. *Pacific Salmon Life Histories*. Vancouver, British Columbia, Canada: UBC Press.)

### ***ESUs***

As of June 2004, four ESUs of chum salmon had been identified by NMFS in the contiguous United States:

- **Hood Canal Summer-run**
- **Columbia River**
- Puget Sound/Strait of Georgia
- Pacific Coast

Of these four, the first two ESUs are listed as **Threatened Species** under the Endangered Species Act. Both threatened ESUs are supported by NMFS Critical Habitat Designation (NMFS 2004a). The designation provides notice to federal agencies and the public that the chum areas are vital to conservation.

In Alaska, chum salmon are not divided by ESUs. Instead, state salmon fishery management is divided into four overarching regions: Southeast Alaska, Central Region, Westward Region, and Arctic-Yukon-Kuskokwim Region. In Alaska, chum salmon are predominantly harvested in Southeast Alaska and Alaska's Central Region (Plotnick and Eggers 2004).

### ***Life History Traits***

Chum salmon are anadromous, semelparous, and spawn primarily in fresh water. Chum salmon grow to be among the largest of Pacific salmon, second only to Chinook salmon in adult size, with individuals reported over a meter in length and greater than 20 kg in weight. Average size for an adult chum is 3 to 9 kg (Buklis 1994, NMFS 2001b).

The species is best known for the enormous canine-like fangs and striking body color (a calico pattern, with the anterior two-thirds of the flank marked by a jagged, reddish line and the posterior third by a jagged black line) of spawning males. Females are less boldly colored and lack the extreme dentition of the males (NMFS 2001b).

Most chum salmon mature between ages two and five, with 60-90% of fish maturing at four years of age (particularly in southeastern Alaska, though there is variation in maturation rates between streams) (Buklis 1994). Age at maturity appears to follow a latitudinal trend in which a greater number of older fish occur in the northern portion of the species' range. The maximum age reported for chum salmon is six years (Froese and Pauly 2004).

Chum salmon tend to spawn in the lowermost reaches of rivers and streams, typically within 100 km of the ocean. That said, some chum in the Yukon River travel over 2,000 miles to spawn in the Yukon Territory. Buklis (1994) notes: "Chum salmon often spawn in small side channels and other areas of large rivers where upwelling springs provide excellent conditions for egg survival. They also spawn in many of the same places as do pink salmon, i.e., small streams and intertidal zones." Fecundity for female chum normally ranges between 2,400 and 3,100 eggs. The semelparous fish cease feeding on their return freshwater migration.

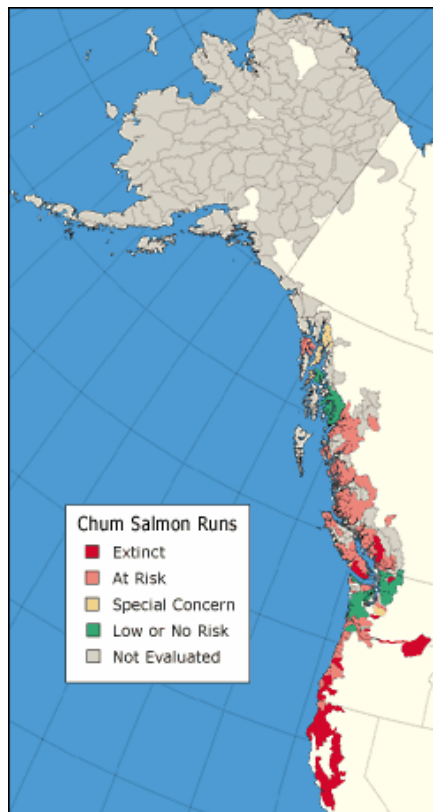
After hatching, chum salmon migrate almost immediately to estuarine and ocean waters, in contrast to coho, Chinook, and sockeye salmon, which migrate to sea after months or years in freshwater. Migrating chum form schools in estuaries, presumably to reduce losses to predation,



and, while in freshwater and estuarine areas, feed on small insects. After entering marine environments, chum remain close to shore for a few months before dispersing to sea (Froese and Pauly 2004). Once in marine waters, Alaskan chum move into the Bering Sea and Gulf of Alaska by the fall, where they spend the next several winters (Buklis 1994). At sea, chum feed on a relatively diverse array of prey, able to shift the main components of their diets between jellyfish, micronekton, and zooplankton in response to prey availability (Buklis 1994, Kaeriyama et al. 2004). As a result of their rapid transition from freshwater to estuarine and marine environments, chum salmon appear to be less dependent on freshwater conditions than on favorable estuarine and marine conditions.

### ***Habitat***

As with the other Pacific salmonids, freshwater chum salmon habitat in the contiguous U.S. has been negatively affected by development. Chum salmon have been extirpated from historical spawning areas in California and parts of Oregon (Figure 1.6), and two of the four chum ESUs in the Pacific Northwest are currently listed as Threatened Species. In Alaska, chum habitat appears to be relatively robust.



**Figure 1.6. North American chum salmon range (Brownell 1999).<sup>11</sup>**

<sup>11</sup> The historic distribution of chum salmon up the Columbia may be over-represented by this depiction. Additionally, Hood Canal chum, shown here as low/no risk, are a listed ESU. Presumably, were Alaskan chum salmon to have been analyzed, the runs would rank as low or no risk.

## **Pink Salmon (*Oncorhynchus gorbuscha*)**

Pink salmon are the smallest of North American salmon, with adults weighing on average less than four pounds and measuring under two feet long (PFMC 2004a). Pink salmon (pinks), also known as “humpback” salmon because of the pronounced hump that develops on the backs of mature adult males, maintain a two-year lifecycle, thus large runs follow a biennial pattern.

### ***Distribution***

Pink salmon are found on both sides of the North Pacific. On North American shores they extend from Puget Sound north to Alaska and the Aleutian Islands. In Asia, pink salmon spawn between Russia, North Korea, and Hokkaido, Japan, and range into the Bering and Okhotsk Seas (Hard et al. 1996, Froese and Pauly 2004). In latitudinal terms, pink salmon currently spawn around the Pacific Rim from 44°N to 65°N in Asia and from 48°N to 64°N in North America (Hard et al. 1996).

Currently, Washington appears to be the southern limit of the spawning distribution of pink salmon in North America (Hard et al. 1996); however, historic pink drainages may have stretched further south into California (Brownell 1999, Froese and Pauly 2004).

### ***ESUs***

The National Marine Fisheries Service has not identified geographically-specific ESUs for pink salmon in the Pacific Northwest. It has identified, however, odd- and even-year runs, but neither odd- nor even-year pink salmon runs have been listed as threatened or endangered (NMFS 2004a). In Alaska, pink salmon are not divided by ESUs. Fishery management is instead divided into four overarching regions: Southeast Alaska, Central Region, Westward Region, and Arctic-Yukon-Kuskokwim Region. Of these four regions, pink salmon are predominantly harvested in the first three (Plotnick and Eggers 2004).

### ***Life History Traits***

Adult pink salmon enter spawning streams between late June and mid-October (Kingsbury 1994, Hard et al. 1996). Most pink salmon spawn within a few miles of the coast and spawning within the intertidal zone or the mouths of streams is common (Steelquist 1992, Kingsbury 1994). Shallow riffles, where flowing water breaks over coarse gravel or cobble-size rock, and the downstream ends of pools are favored spawning areas (ADFG 2000). Female pink salmon each carry 1,500 to 2,000 eggs depending on her size (Steelquist 1992, Kingsbury 1994, Hard et al. 1996). As with the other species of Pacific salmon, females dig nests, or redds, with their tails and release the eggs, which are then fertilized by males and covered over. The process is commonly repeated several times until all of the female's eggs have been released, after which the spawning adults soon die, usually within two weeks (Kingsbury 1994).

Sometime during early to mid-winter, eggs hatch. The alevins, or young fry, feed on attached yolk sac material, and continue to grow and develop (Kingsbury 1994). In late winter or spring, the fry swim up out of the gravel and migrate downstream into salt water. The emergence and outward migration of fry is heaviest during hours of darkness and usually lasts for several weeks before all the fry have emerged (Kingsbury 1994).

Following entry into salt water, juvenile pink salmon move along the beaches in dense schools near the surface, feeding on plankton, larval fishes, and occasional insects (Steelquist 1992,

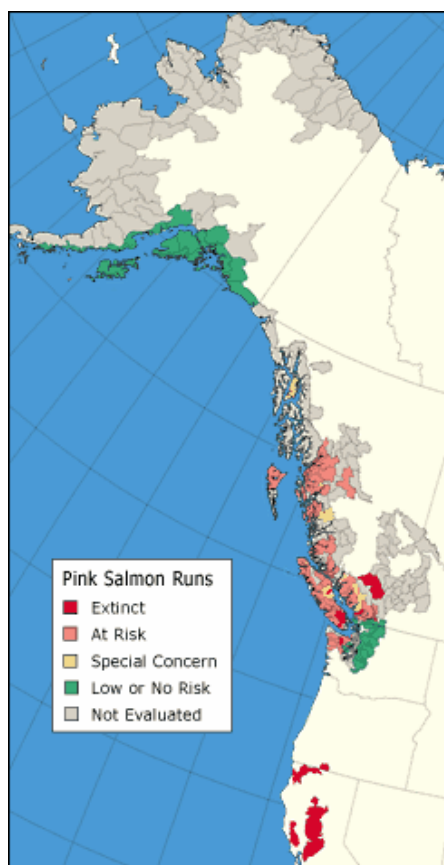
Larsen et al. 2004a). Predation is heavy on the very small, newly emerged pink salmon fry, but growth is rapid. By fall, at an age of about 1 year, juvenile pink salmon are 4 to 6 inches long and are moving into ocean feeding grounds in the Gulf of Alaska, the Aleutian Islands, and the Puget Sound areas (Kingsbury 1994, Hard et al. 1996). High seas tag-and-recapture experiments have revealed that pink salmon originating from specific coastal areas have characteristic distributions at sea which are overlapping, non-random, and nearly identical from year to year (Kingsbury 1994). The ranges of Alaska pink salmon at sea and pink salmon from Asia, British Columbia, and Washington overlap each other (Kingsbury 1994). Once at sea, pink salmon in the Gulf of Alaska prey on a wide diversity of organisms (e.g., squids and zooplankton), and show a high degree of plasticity in their diets, readily changing between types of prey in response to their availability (Kaeriyama et al. 2004).

Pink salmon almost exclusively mature in two years, which means that odd-year and even-year populations are essentially unrelated. Frequently in a particular stream or region the odd-year or even-year cycle will predominate, although in some streams both odd- and even-year pink salmon are about equally abundant. Occasionally cycle dominance will shift, and the previously weak cycle will become most abundant (Kingsbury 1994). At present, pink salmon in the Pacific Northwest are most abundant during odd-numbered years.

In terms of homing, it is interesting to note that pink salmon may have a higher degree of straying than other species, and occasionally use streams as far as 640 km from their natal waters (Froese and Pauly 2004). The high incidence of straying helps to explain why pink salmon have fewer distinct ESUs than other Pacific salmon.

### ***Habitat***

As with sockeye and chum salmon, most pink salmon habitat is found in Alaska and has been relatively unperturbed. Historic spawning populations in California have already been eliminated, and remaining spawning habitat in the Pacific Northwest has been compromised to the extent that it no longer fully supports robust populations (Figure 1.7); of the 15 populations of pink salmon in Washington only 6 are classified as healthy. Because pink salmon typically spawn within a few miles of the coast, they have been less affected by the development of hydropower projects and upstream water diversion than have other salmonids.



**Figure 1.7. North American pink salmon range (Brownell 1999).<sup>12</sup>**

### Synthesis

Salmon have relatively resilient life-history traits, including short life spans and high fecundity. These traits would typically result in a very low estimate of inherent vulnerability. However, salmon's resilience belies a significant vulnerability based on their dependence on freshwater environments. Freshwater spawning habitats throughout the contiguous U.S. have been severely degraded by a large number of factors including the presence of dams, habitat alteration, introduced species, and pollution. In many cases, these losses have crippled the capacity of salmon runs to sustain even moderate fishing pressure. When these losses are combined with a limited range (river-specific ESUs) and a mixed-stock fishery, the vulnerability of salmon stocks to fishing in California, Oregon, and Washington must be considered moderate. In contrast, the relatively pristine rivers and streams of Alaska have allowed stocks there to remain resilient to heavy fishing pressure.

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<sup>12</sup> Northern and western Alaskan drainages were not mapped by Brownell (1999), but presumably would be ranked as low or no risk.

### Primary Inherent Vulnerability Factors to Evaluate

#### Intrinsic rate of increase ('r')

- High (> 0.16)
- Medium (0.05 - 0.16)
- Low (< 0.05)
- **Unavailable/Unknown**



#### Age at 1<sup>st</sup> maturity

- **Low (< 5 years)**
- Medium (5 - 10 years)
- High (> 10 years)
- Unavailable/Unknown



#### Von Bertalanffy growth coefficient ('k')

- High (> 0.16)
- Medium (0.05 - 0.15)
- Low (< 0.05)
- **Unavailable/Unknown**



#### Maximum age

- **Low (< 11 years)**
- Medium (11 - 30 years)
- High (> 30 years)
- Unavailable/Unknown



#### Reproductive potential (fecundity)

- **High (> 100 inds./year)**
- Moderate (10 – 100 inds./year)
- Low (< 10 inds./year)
- Unavailable/Unknown



### Secondary Factors to evaluate

#### Species range

- Broad (e.g., species exists in multiple ocean basins, has multiple intermixing stocks or is highly migratory)
- Limited (e.g., species exists in one ocean basin)
- **Narrow (e.g., endemism or numerous evolutionarily significant units or restricted to one coastline)**



Special Behaviors or Requirements: Existence of special behaviors that increase ease or population consequences of capture (e.g., migratory bottlenecks, spawning aggregations, site

fidelity, unusual attraction to gear, sequential hermaphrodites, segregation by sex, etc., OR specific and limited habitat requirements within the species' range)

- No known behaviors or requirements OR behaviors that decrease vulnerability (e.g., widely dispersed during spawning)
- **Some (i.e., 1 - 2) behaviors or requirements**
- Many (i.e., > 2) behaviors or requirements



Quality of Habitat: Degradation from non-fishery impacts  
*Chinook, Coho, Sockeye, Chum, and Pink Salmon in AK*

- **Habitat is robust**
- Habitat has been moderately altered by non-fishery impacts



*Chinook, Coho, Sockeye, Chum, and Pink Salmon in CA, OR, ID, WA*

- **Habitat has been substantially compromised from non-fishery impacts (e.g., dams, pollution, or coastal development) and thus has reduced capacity to support this species**



### Evaluation Guidelines

#### 1) Primary Factors

- a) If 'r' is known, use it as the basis for the rank of the Primary Factors.
- b) If 'r' is unknown, then the most conservative rank from the remaining Primary Factors is the basis for the rank (in order of importance, as listed).

#### 2) Secondary Factors

- a) If the majority (2 out of 3) of the Secondary Factors rank as Red, reclassify the species into the next lower rank (e.g., Green becomes Yellow, Yellow becomes Red). No other combination of Secondary Factors can modify the rank from the Primary Factors.
- b) If the rank of the Primary Factors is Red AND the majority of Secondary Factors are also Red, inherent vulnerability represents a **Critical Conservation Concern** and the species receives a rank of "**Critical**" for this criterion and an overall seafood recommendation of "**Avoid**" regardless of the other criteria.

#### *Conservation Concern: Inherent Vulnerability*

##### **Pacific Salmon in AK**

- Low (Inherently Resilient)



##### **Pacific Salmon in CA, OR, WA**

- Moderate (Inherently Neutral)



## **Criterion 2: Status of Wild Stocks**

*Guiding Principle: Sustainable wild-caught seafood species have stock structure and abundance sufficient to maintain long-term fishery productivity.*

This criterion examines the stock structure and abundance of targeted salmon fisheries on the U.S. West Coast. Healthy stocks are those believed capable of supporting long-term fishery production. The primary factors evaluated in this criterion are long- and short-term trends in escapement.<sup>13</sup> Where escapement data are not present, long-term trends in fishery landings can provide a proxy for abundance, though landings are influenced by variable fishing effort and regulations.

This criterion (and the following criterion on Bycatch) relies heavily on management “escapement goals.” It needs to be recognized that these escapement goals, and associated maximum sustainable yields (MSYs), are not necessarily accurate. Standard fisheries curve-fitting techniques are notoriously poor for salmonids and management efforts that rely on curve-fitting contain substantial uncertainty. On the other hand, abundance data is often much better for salmon than for other species as they are generally easier to count (Chuck Tracy, PFMC, pers. comm.). Nonetheless, managers do not always know what an appropriate MSY or escapement goal is with a great degree of certainty.

It is also important to note that declines in salmon abundance in many areas predate the fifty years of landings data in the NMFS database; the absence of historical data creates the danger of a shifting baseline. Conversely, there is a difficulty in separating current fishing impacts from historical overfishing. Because the data uncertainties are so large, the report may appear to be conflating past and present fishing pressure.

Because of dramatic differences between the health of many salmon stocks, assessments of salmon fisheries are necessarily divided by species and along geographic lines. The process of aggregating stock data into larger geographic units may result in recommendations that are over-inclusive; however, the usefulness of the analysis for Seafood Watch® and ultimately for consumers requires aggregation and generalization. The regional distribution of salmon landings is presented here, followed by state-specific assessments of salmon stocks (Table 2.1). Because of the relatively unique role of artificial production in supporting salmon fisheries, this analysis is necessarily prefaced with a clarification of the role of hatchery salmon in assessing stock structure and abundance.

### **Hatchery Salmon**

Unlike every other major marine fishery in the United States, West Coast salmon are heavily augmented by hatchery production. Salmon hatcheries exist for a variety of purposes, most notably the conservation, restoration, mitigation, and/or augmentation of salmon runs. In the United States, several hundred public and private hatcheries collectively release nearly two billion salmon annually (NPAFC 2004). The presence of these fish can significantly complicate

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<sup>13</sup> Ocean escapement is defined as the number of fish surviving ocean fisheries and returning to the freshwater environment to spawn.

commercial fishery assessments, as neither the positive nor the negative effects of hatcheries are generally considered in the fishing mortality calculus used in most fisheries analyses.

**Table 2.1. Summary abundance of targeted wild West Coast salmon species, by state.**

State	Species	Abundance <sup>14</sup>	Trends (Escapement or Landings)
California	<i>Chinook</i>	Depleted from historic levels.	Recent decreases in Sacramento River fall, followed by increase in 2010. Variable in Klamath River – meeting escapement goals in 2009.
Oregon	<i>Chinook</i>	Highly depleted from historic levels.	Variable. Most Oregon stocks appear to be meeting escapement goals
Washington	<i>Chinook</i>	Highly depleted from historic levels.	Variable.
	<i>Chum</i>	Variable: Puget Sound stocks at record abundance; Coastal stocks unknown.	Short-term increases in escapement and run-size in Puget Sound.
	<i>Pink</i>	Variable: 6 stocks healthy, 6 stocks depleted. Targeted stocks healthy.	Short-term increases in escapement.
	<i>Sockeye</i>	Variable: 2 stocks healthy, 4 stocks depleted. Targeted stocks healthy.	Variable: Targeted runs have increasing short-term trends.
Alaska	<i>Chinook</i>	Excellent: Escapement within management targets.	Landings steady. Average escapement.
	<i>Chum</i>	Escapement at or above management targets.	Long-term increases in landings. Average escapement.
	<i>Coho</i>	Escapement strong for all monitored rivers.	Long-term increases in escapement and landings.
	<i>Pink</i>	Historic highs due to augmentation; wild escapement meeting management targets.	Long-term increases in escapement and landings due largely to hatchery supplementation.
	<i>Sockeye</i>	Excellent.	Long-term increases in escapement, landings since mid-70s.

There is an ongoing debate in the management and legal community as to whether artificially propagated salmon ought to be included when considering the health of an ESU. While there are valid economic and sometimes environmental reasons to encourage hatcheries, this review attempts to focus on the health and abundance of only *wild* fish for the following reasons.

First, when hatchery fish are included in stock assessments, many ESUs that are otherwise failing, such as several in the Columbia River Basin, appear to be in reasonable health. As such, high levels of hatchery releases can mask declines in wild populations. Because salmon fisheries

<sup>14</sup> See subsequent discussion for citations.



are generally mixed-stock fisheries, targeting hatchery fish can increase the harvest rates of wild fish. Myers, Levin et al. (2004) comment: “Including hatchery fish in an ESU confounds risk of extinction in the wild with ease of captive propagation and ignores important biological differences between wild and hatchery fish.”

Second, by competing with wild salmon for food and other resources, empirical evidence indicates that hatchery releases reduce marine survival rates of wild salmon, particularly in years of poor ocean conditions. As a consequence, a high abundance of hatchery fish that might otherwise indicate a healthy ESU has the potential to negatively affect survival rates and the long-term viability of wild fish. These competitive interactions are explored in greater detail in the criterion on Habitat Effects.

Third, in addition to habitat effects, hatchery fish have the potential to erode the long-term health of wild salmon ESUs by homogenizing their gene pool. Because they are exposed to a different set of environmental factors, hatchery broodstocks are inevitably domesticated,<sup>15</sup> with adaptations to the hatchery environment generally reducing performance in the wild (Myers et al. 2004). One scientist (Waples 1991) posited that the primary concern with hatchery salmonids is that “a variety of locally adapted stocks will be replaced with a smaller number of relatively homogeneous ones. This process of consolidation tends to limit the evolutionary potential of the species as a whole.... Hybridization of different gene pools can theoretically have two important genetic consequences: loss of interpopulational genetic diversity and outbreeding depression.” The disruption of adaptive gene complexes in endangered populations of wild salmon is of particular concern. Empirical evidence bears this concern out. As of the late-1990s, at least eight studies had documented genetic differences between wild and hatchery-raised Pacific salmon affecting traits that could reduce the wild fitness of hatchery fish (Reisenbichler and Rubin 1999). It has been repeatedly demonstrated that fish from hatcheries typically have lower success and survival rates in the wild, as do wild-hatchery hybrids. In addition to genetic differences, hatchery fish may exhibit unusual reproductive behaviors. For example, one study observed that a disproportionately large share of hatchery-reared Chinook salmon males in the Yakima River (37-49%) are precocious, some of which may “residualize” in the upper Yakima River Basin (Larsen et al. 2004a). The authors surmise that “an unnaturally high incidence of precocious male maturation may result in the loss of returning anadromous adults, the skewing of female:male sex ratios, and ecological and genetic impacts on wild populations and other native species” (Larsen et al. 2004a).

In terms of process, genetic introgression occurs when hatchery salmon breed with wild fish. This can occur either when hatchery fish stray or are introduced into wild breeding areas. While some degree of straying is natural, hatchery fish appear to have higher straying rates in many cases than wild salmon (Myers et al. 2004). In Alaska, a particularly high incidence of straying has been noted with pink salmon in Prince William Sound and chum salmon in Southeast Alaska

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<sup>15</sup> While hatchery salmon may originate from broodstock captured in the wild and representative of the ESU gene pool, some degree of selection inevitably occurs within the hatchery environment. In addition, behavioral deficiencies may emerge from neurological problems. Recent research on artificially propagated Chinook salmon has identified lower ratios of brain size to body mass in both the olfactory bulb and the telencephalon (Kihlsgner et al. 2003). These neurological problems (while presumably not hereditary) introduce other selective pressures on the hatchery fish.

(Kelly 2001). In light of this straying and the potential genetic effects, one reviewer comments: “Alaska has been successful in augmenting salmon harvest with hatchery-produced fish, but whether or not salmon biodiversity has been adequately protected in the process is unanswered. Data necessary to evaluate interactions between hatchery and wild salmon populations have not, in most cases, been collected” (Kelly 2001). While Alaskan wild escapement generally remains high, the state has been favored by beneficial environmental conditions. If conditions worsen, the detrimental effects of hatcheries may become more pronounced.

This is not to say that there is no role at all for hatchery fish. Clearly, hatcheries can have important conservation uses, such as preventing genetic drift where wild numbers have dwindled below sustainable thresholds (Brannon et al. 2004). However, given the substantial differences between wild and hatchery fish, the range of interactions possible between them, and the uncertainties that remain, this review concentrates on trends in the health and abundance of wild fish. In many cases, such as long-term landings data, it is difficult to disaggregate hatchery and wild fish.

### **Distribution of Landings**

Alaska dominates West Coast salmon fisheries. Over the past twenty years, Alaska has landed roughly ten times as much salmon as California, Oregon, and Washington combined (Figures 2.1 and 2.2). Pink, sockeye, and chum salmon are the main species landed in the U.S., and are all harvested almost exclusively in Alaska. The large majority of coho are also primarily landed in Alaska. Only the relatively small quantity of Chinook salmon landings are distributed somewhat evenly across the four West Coast states (Figure 2.3).

Alaska’s dominance in U.S. salmon fisheries was solidified in the late 1970s. The dramatic increase in landings that occurred then is believed to have been a result of a regime shift in ocean conditions that favored Alaska combined with the state’s conservation-oriented management and aggressive investment in hatcheries following a period of low returns in the mid-1970s. Hatcheries generated 23% of Alaska’s commercial harvest in 2002, with hatchery releases focusing on pink salmon (938 million) and chum salmon (451 million) (Farrington 2003).

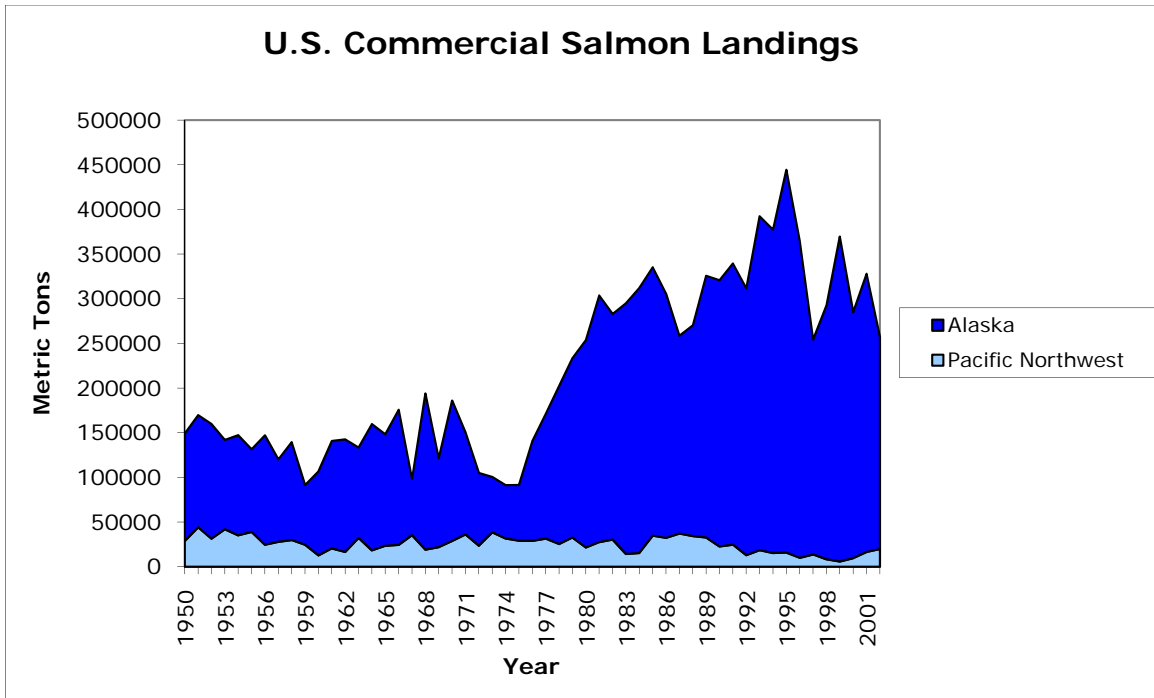


Figure 2.1. U.S. commercial salmon landings by region (1950-2002) (NMFS 2004b).

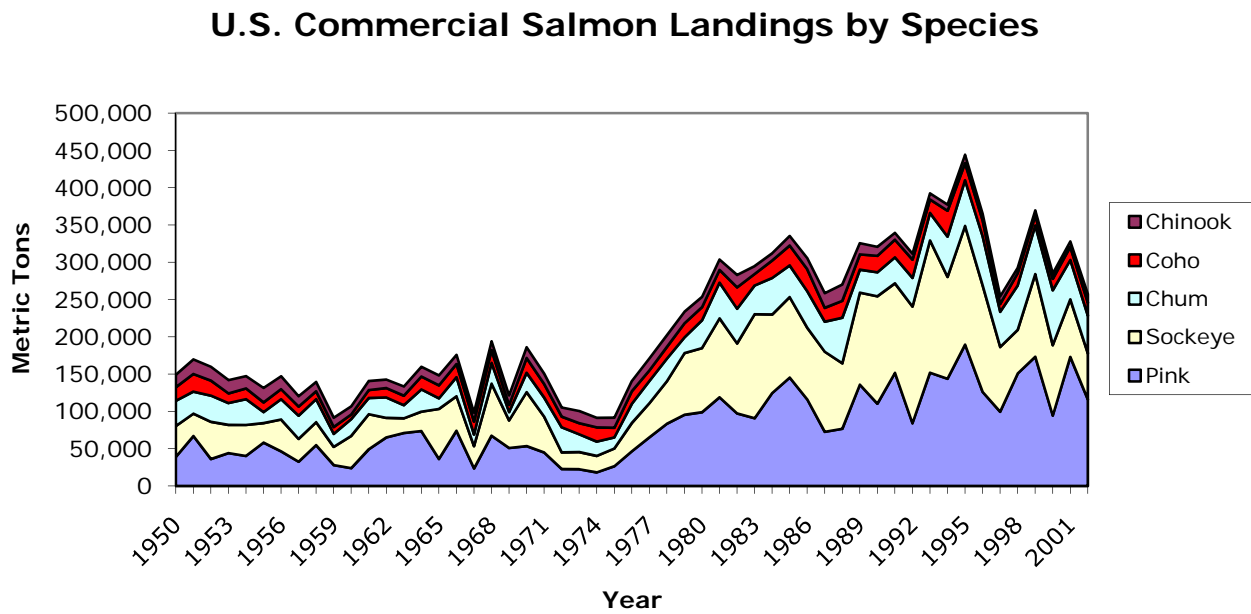
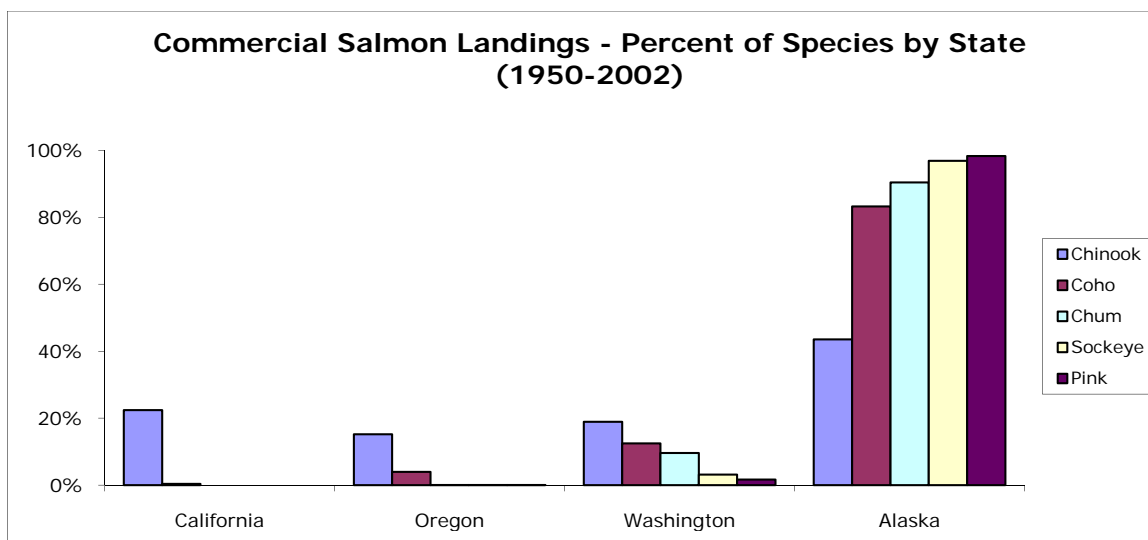


Figure 2.2. U.S. commercial salmon landings by species (1950-2002) (NMFS 2004b).



**Figure 2.3. State share of commercial salmon landings, by species (NMFS 2004b).**

### **Stocks by Region: Alaska**

In numerical terms, Alaskan stocks appear very healthy, particularly relative to the pattern of declining yields observed in many fisheries. Even excluding landings of hatchery fish (which in recent years have been around one-third of landed salmon), Alaskan salmon landings over the past quarter century have been significantly larger than landings in any other time period, with data stretching back to 1880 (Figure 2.4). A brief survey of landings in Alaska by region or by species shows positive trends over the past fifty years. The main exceptions to this rule are western Alaska, where runs have been significantly lower over the past decade than in previous periods, and landings of Chinook salmon, which have shown a slight downward trend. In general, the fluctuations in Alaskan landings are believed to be mainly climate-driven (Adkinson and Finney 2003).

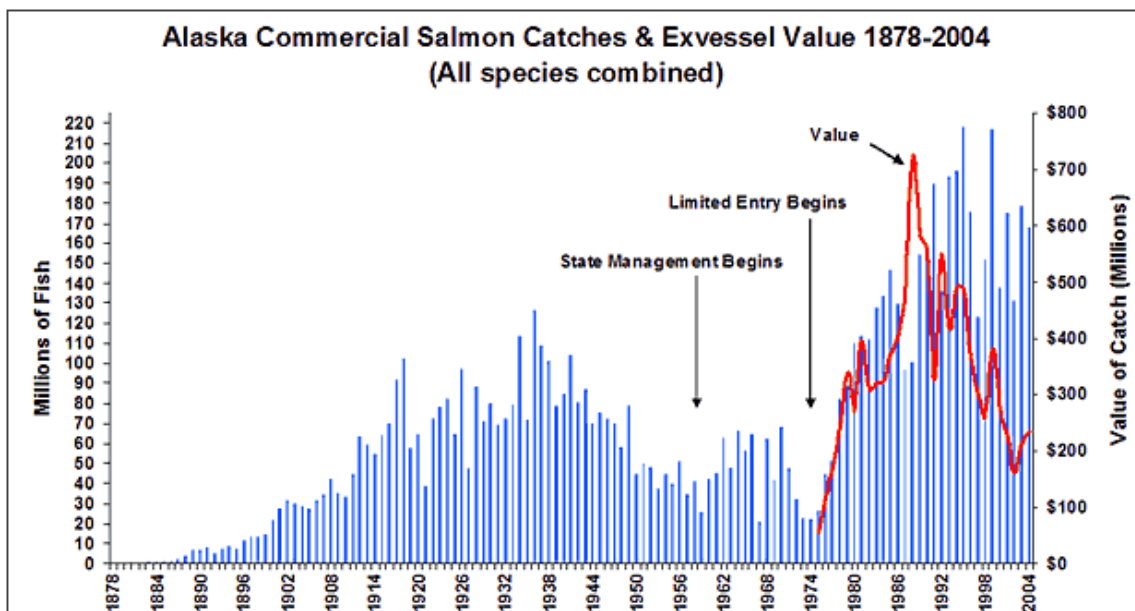
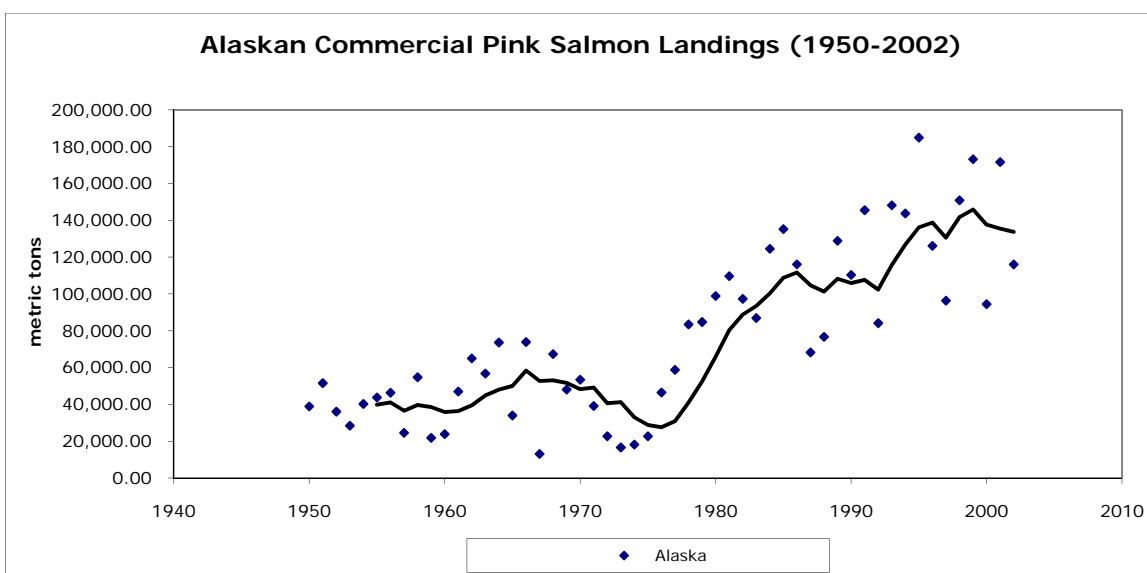


Figure 2.4. Alaskan commercial salmon landings and value (Plotnick and Eggers 2004).

***Alaskan Pink Salmon***

The largest landings of any single salmonid species in Alaska are of pink salmon. Spurred by a combination of favorable climatic conditions and hatchery production, growth in pink salmon harvests accounts for much of Alaska’s overall increase in landings over the past quarter century. During the past fifty years, pink salmon landings have demonstrated a strong upward trend (Figure 2.5); this increase holds true for both northern and southern Southeast Alaska pink salmon stocks (Kelly 2001). The 2003 commercial harvest of pink salmon was over 500 million pounds, one of the highest landings ever (Plotnick and Eggers 2004). Given that the fish live a two-year life cycle, the long-term increasing harvests are a fair indicator of stock health.



**Figure 2.5. Commercial landings of Alaskan pink salmon (NMFS 2004b).**

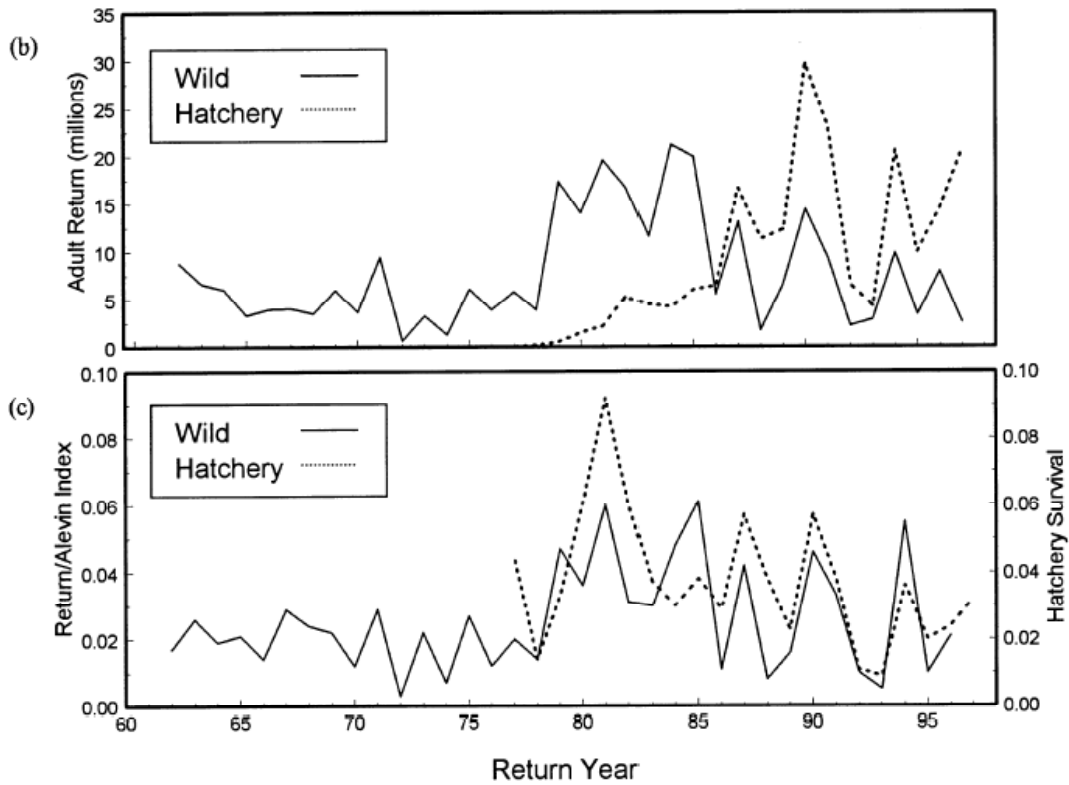
Landings of pink salmon in Alaska primarily occur in Prince William Sound in Alaska's Central Region (189 million pounds in 2003), Southeast Alaska (184 million pounds), and Alaska's Westward Region (127 million pounds) (Plotnick and Eggers 2004). In all three regions, stocks appear to be numerically in remarkable health. The main concerns regarding stock health surround the unusually high percentage of hatchery fish in the pink salmon harvest.

In Prince William Sound, the pink salmon harvest is largely a hatchery phenomenon. Nearly three million pink salmon spawned in the Sound in 2003, the second highest escapement since the mid-1960s, indicating that pink salmon are at least numerically healthy. Moreover, the combined wild-hatchery harvest of pink salmon was a record high in the Sound in 2003 (Plotnick and Eggers 2004). However, since 1986, returns of hatchery salmon have significantly outnumbered wild pink salmon in Prince William Sound (Figure 2.6); the ratio of hatchery to wild salmon in 2003 was 8:1. Kelly (2001) has highlighted this abundance of hatchery pink salmon as a potential threat to the integrity of the wild gene pool. The comprehensive salmon plan for Prince William Sound recommends that hatchery fish comprise less than 2% of long-term wild stock escapement—a recommendation that has been ignored. Straying of hatchery fish remains a major concern, and one for which insufficient data exist to measure the effects (Kelly 2001).

In Southeast Alaska, pink salmon also had a solid year in 2003. Escapement for all 45 monitored pink salmon stock groups in Southeast Alaska was at or above management targets (biological escapement goals), and the region collectively recorded the third highest escapement index since 1960 (Plotnick and Eggers 2004). Escapement of pink salmon in Southeast Alaska has increased over 150% in the past two decades (Zadina et al. 2003). Similarly, in the Westward Region, Kodiak Island reported that wild pink salmon escapement in 2003 was over 5 million fish, well above the management target of 1-3 million fish, while North Peninsula pink salmon harvests exceeded the usual bounds (Plotnick and Eggers 2004).

Overall, pink salmon landings in Alaska indicate the stock is in good health. Despite record landings, the main concern revolves around the long-term effects of hatchery supplementation, particularly in Prince William Sound. As Figure 2.6 indicates, returns of wild pink salmon in Prince William Sound have fallen over the past twenty years, while returns of hatchery pink salmon have increased. This disparity has led at least one set of analysts to conclude that Prince William Sound pink salmon hatcheries are replacing rather than augmenting wild pink salmon production in the region, with the likely causes of replacement being “a decline in wild escapement associated with harvesting hatchery stocks and biological impacts of the hatchery fish on wild fish” (Hilborn and Eggers 2000). A more recent summary of research has suggested that wild pink salmon decreases in the Sound have been primarily caused by biophysical variables (Heard 2003). The authors note that pink salmon hatcheries in the Prince William Sound create a *net* gain of pink salmon up to 25 million fish, though “under certain worst-case scenarios there might be up to a 4.5 million annual wild stock yield loss due to hatchery releases” (Heard 2003). In summary, hatchery operations in Prince William Sound appear to be depressing escapement of wild pink salmon, though the significance of this decrease (e.g., relative to direct fishery impacts on other stocks) remains unclear. Despite the decline, projected wild pink salmon

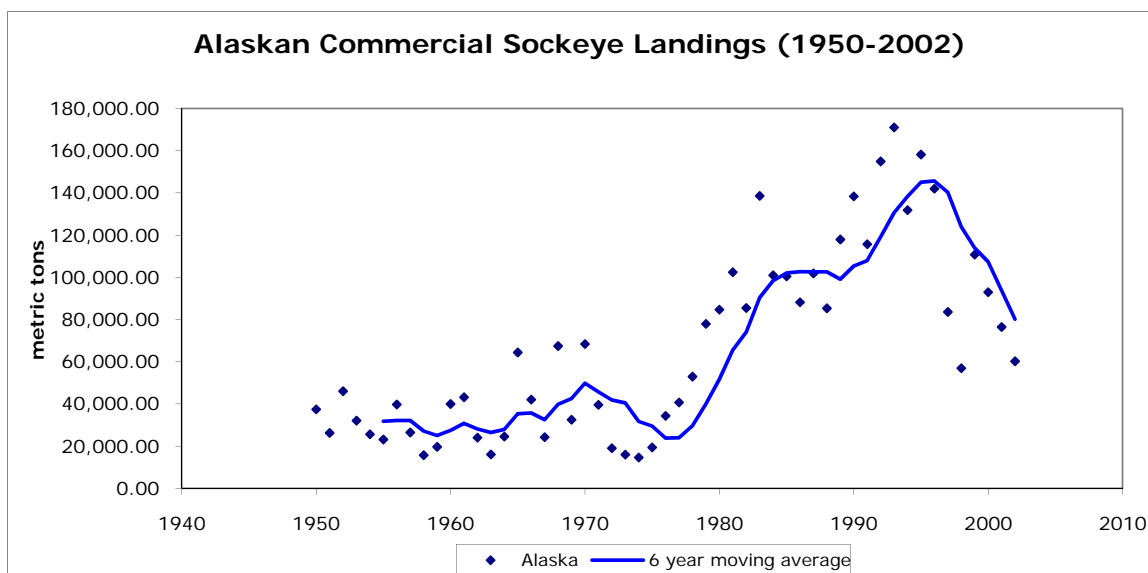
escapement in Prince William Sound in 2004 is 4.6 million fish, above the sustainable escapement goal range of 1.3-2.8 million fish (Plotnick and Eggers 2004).



**Figure 2.6. Returns and survival of hatchery and wild pink salmon in Prince William Sound (Willette et al. 2001).**

### *Alaskan Sockeye Salmon*

After pink salmon, sockeye salmon is the largest contributor to Alaska's salmon harvest. As with pink salmon, Alaskan commercial sockeye landings have followed a generally upward trend since 1950 (Figure 2.7). Productivity of Alaskan sockeye salmon stocks has generally increased over the past thirty years, particularly following 1973. Increases in productivity have not been uniform across the state. Rather, there has been variation between different runs, reflecting the diversity of mechanisms through which environmental conditions influence the productivity of individual stocks (Peterman et al. 2003). In particular, Hilborn, Quinn et al. (2003) document how the genetic diversity embedded in the hundreds of distinct populations of sockeye in the Bristol Bay area allowed the stock complex to successfully adapt to changing environmental conditions.



**Figure 2.7. Commercial landings of Alaskan sockeye salmon (NMFS 2004b).**

The largest harvest of sockeye salmon in the U.S. occurs in the Bristol Bay area of southwestern Alaska where 10 million to more than 30 million sockeye are caught each year during a short, intensive fishery lasting only a few weeks. The Bristol Bay sockeye fishery has been described in the fisheries literature as a “classic example” of a sustainable fishery (Hilborn et al. 2003). In 2003, fishermen in Bristol Bay landed 15 million fish, roughly half of the state's total. These landings reflected the seventh smallest run of sockeye in Bristol Bay in the past twenty years. Harvests of 3-4 million fish each were also reported for Kodiak Island, Cook Inlet, and Prince William Sound.<sup>16</sup> Year 2003 runs in Prince William Sound were average, while Cook Inlet and Kodiak Island reported runs that generally exceeded escapement goals. The projection for 2004 landings of sockeye salmon is up over 50% from 2003 (Plotnick and Eggers 2004).

Overall, sockeye salmon appear to be managed around their maximum sustainable yield. In anecdotal support of this, reduced fishing pressure following the 1989 Exxon Valdez oil spill in

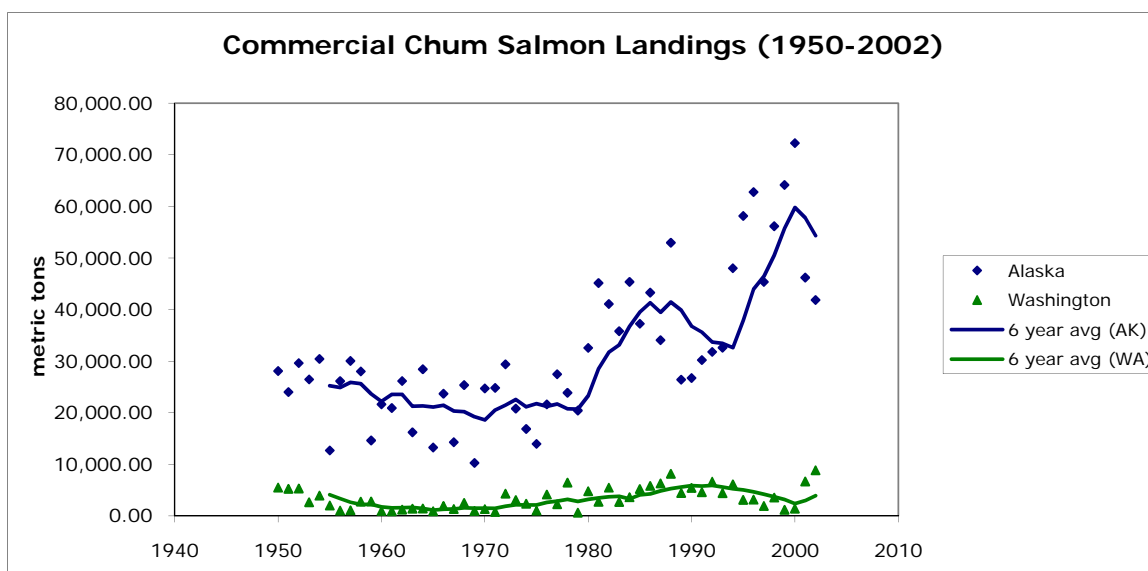
<sup>16</sup> In contrast, sockeye stocks just south of Alaska have fared poorly. The Canadian government has been petitioned to list sockeye salmon in British Columbia as an endangered species (McRae and Pearse 2004).



Prince William Sound led to returns of sockeye salmon significantly larger than management goals as far as 800 km from the spill. These increased returns indicate that the main factor affecting sockeye salmon returns is the abundance of spawners in the parent year. However, due to habitat limitations, large spawner abundances can create overcrowding. In three of the four major populations, subsequent juvenile sockeye salmon growth was reduced as a result of the larger number of spawners during the fishery closures while oil was present in the spill area (Ruggerone and Rogers 2003).

### *Alaskan Chum Salmon*

In 2003, chum was the third most harvested salmon in Alaska, with over 124 million pounds landed. Nearly two-thirds of the state harvest was landed in Southeast Alaska (79 million fish), followed in quantity by Prince William Sound (24 million fish) and the Kodiak area (8 million fish) (Plotnick and Eggers 2004). As with pink and sockeye salmon, commercial chum landings in Alaska have followed an upward trend over the past fifty years (Figure 2.8) and show no signs of having plateaued.



**Figure 2.8. Commercial landings of Alaskan chum salmon (NMFS 2004b).**

Chum landings in Southeast Alaska were up 50% in 2003 from the previous year, though escapement in the region was apparently “slightly below average” (Plotnick and Eggers 2004). Over the past 21 years, peak escapement in Southeast Alaska has been stable or increasing in 71 of 82 monitored streams, and decreasing in 11 streams. The escapement goals in Southeast Alaska appear to be largely without scientific justification—as of two years ago, improvements in the measurement system were underway (Heinl et al. 2003). In Prince William Sound, 2003 escapement was near or above biological escapement goals for monitored systems, while Kodiak reported escapement within management goals.

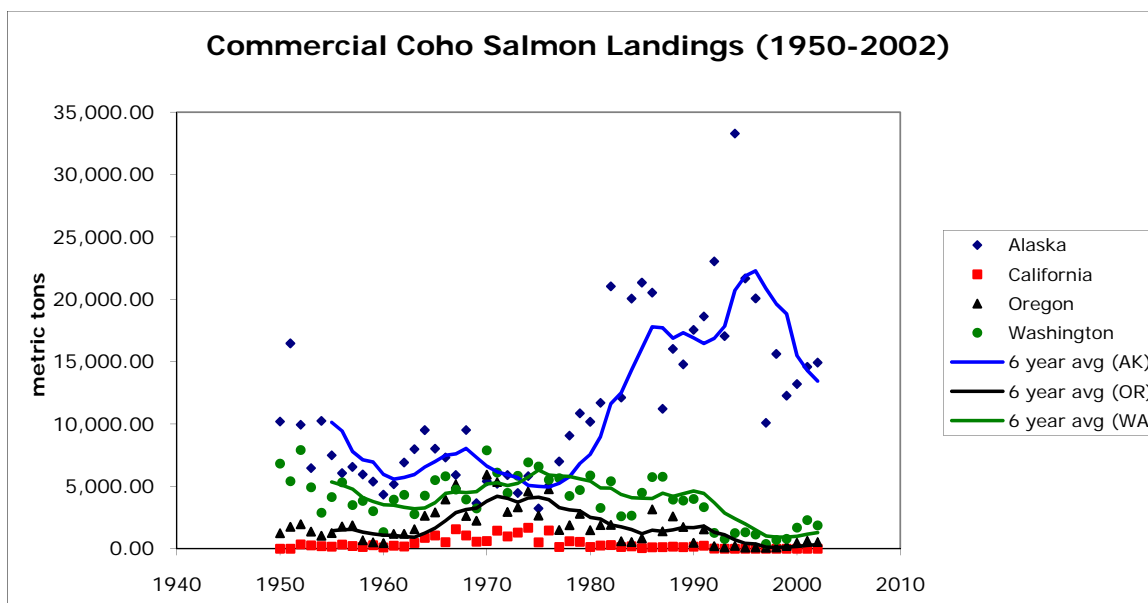
As with pink and sockeye salmon, chum landings in Alaska are strongly influenced by hatchery production. Chum in both Southeast Alaska and Prince William Sound have been singled out as areas where straying hatchery fish may be interbreeding with wild fish—a cause for significant

concern over the long-term (Kelly 2001). In Southeast Alaska alone, nearly 10 million hatchery chum were caught in common fisheries (Farrington 2004).

### ***Alaskan Coho Salmon***

Alaskan coho populations appear to be healthy when compared to a historic baseline. In contrast to the rest of the West Coast, landings of coho have increased steadily in Alaska over the past fifty years (Figure 2.9). In terms of escapement, Olsen, Miller et al. (2003) note: “Most Alaskan coho salmon populations are believed to be healthy. A 100 year review of fishery harvest data, as well as abundance estimates for some individual populations in Southeast and Southcentral Alaska, suggest the number of coho salmon in most regions of Alaska is stable or increasing.” Escapement trends for coho salmon in Alaska are primarily monitored for 34 streams in six stock groups. None of the 34 streams demonstrated declining trends in escapement between 1981 and 1996 (Plotnick and Eggers 2004).

The main region from which coho is harvested in Alaska is Southeast Alaska. Coho escapement in Southeast Alaska has been relatively stable since the mid-1980s, with marine survival the main determinant of escapement variability (Shaul et al. 2003). In 2003, coho escapement in Southeast Alaska was good to excellent in monitored streams. The total Alaska coho harvest was over 4 million fish, collectively weighing 31 million pounds. Regionally, nearly 60% of the harvest was landed in Southeast Alaska (2.5 million fish), followed by Alaska’s Central Region (0.7 million fish, mainly in Prince William Sound and Cook Inlet), and Alaska’s Westward Region (0.6 million fish, mainly in the Kodiak area and the South Peninsula). Exploitation rates have been reduced over the last several years due to poor market conditions (Shaul et al. 2003). From 1998 to 2002, an average of 22% of the coho harvested was of hatchery origin. Of the hatchery fish, 97% originated at Alaskan facilities (Shaul et al. 2003). The 2004 projected coho salmon harvest from Alaska is over five million fish, mainly from Southeast Alaska (Plotnick and Eggers 2004). Overall, coho runs appear healthy, with age distributions normal, and there is no reason to believe that stocks are depleted or being overexploited.



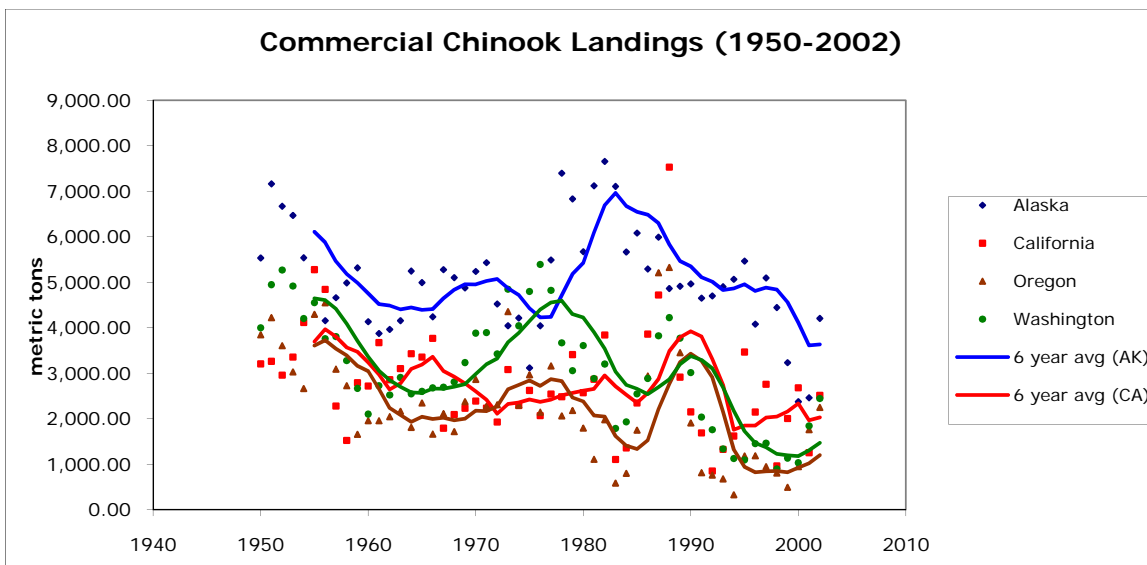
**Figure 2.9. Commercial landings of Alaskan coho salmon (NMFS 2004b).**

### *Alaskan Chinook Salmon*

Chinook salmon make up the smallest portion of Alaska's salmon harvest. In 2003, roughly 10 million pounds of Chinook salmon were landed, comprising just over 1% of the state salmon harvest (Plotnick and Eggers 2004). In contrast to the other four salmon species, landings of Chinook salmon in Alaska have shown a downward trend over the past fifty years (Figure 2.10).

Two-thirds of Alaska's 2003 landings came from Southeast Alaska (418,000 fish), with the remainder split between a number of other regions including Prince William Sound (48,000 fish), Bristol Bay (44,000 fish), and the Arctic-Yukon-Kuskokwim Region (57,000 fish) (Plotnick and Eggers 2004). The Southeast Alaska harvest of 418,000 fish was the largest on record since 1953. Chinook salmon are also remarkable in that they are the only salmon species in Alaska for which a significant quantity (roughly half) are landed with troll gear. Notably, the Southeast Alaska troll fishery recorded the 4<sup>th</sup> highest landings of Chinook salmon since Alaskan statehood, and also notable is that most of those fish are of Canadian and southern U.S. origin. Hatchery fish are estimated to have contributed just 7% to troll landings. Chinook escapement within Southeast Alaska fell between 2002 and 2003, but remained within management goals for all but two rivers. Prince William Sound Chinook landings were the 7<sup>th</sup> largest on record in 2003, while escapement remained within management targets. Bristol Bay landings of Chinook salmon were lower than average in 2003, while escapement was just slightly above the target level (Plotnick and Eggers 2004).

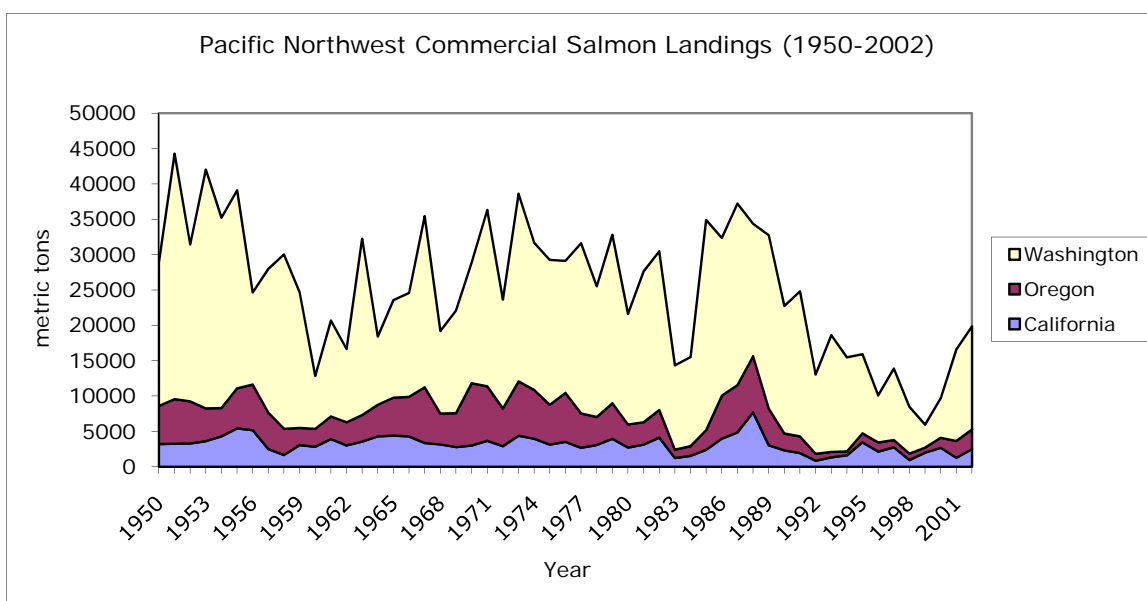
Overall, the trend in landings of Chinook salmon in Alaska appears to be relatively flat or slightly downward. It is possible that reduced fishing pressure following falling salmon prices over the past decade has contributed to this reduced harvest. In any case, recent record harvests and escapement levels within management targets generally indicate a healthy stock status.



**Figure 2.10. Commercial landings of Alaskan Chinook salmon (NMFS 2004b).**

**Stocks by Region: Contiguous U.S.**

In comparison to Alaska, the contiguous states are a small contributor to overall West Coast salmon landings, although a significant contributor to Alaska troll fisheries. Alaskan salmon production generally dwarfs the combined landings of Washington, Oregon, and California. Within the Pacific Northwest, Washington is the largest salmon producer, generally followed by Oregon then California. Figure 2.11 shows the fluctuations in total salmon landings for each state over the past half-century.



**Figure 2.11. Contiguous U.S. commercial salmon landings by state (NMFS 2004b).**

With respect to species, the Pacific Fishery Management Council-controlled ocean salmon fisheries mainly catch Chinook and coho salmon; pink salmon are caught in odd-numbered years, mainly off the coast of Washington (PFMC 2004a). In addition, Chinook, coho, chum, sockeye, and pink salmon are landed in Washington State in coastal fisheries, and in mainstem Columbia River fisheries managed by the state and by tribes, not under the PFMC management plan.

As with Alaska, salmon fishing is a time-honored profession on the West Coast. The intensive commercial fishery for Pacific salmon began in 1864 with the introduction of canning technology (McEvoy 1986). Salmon yields in California, Oregon, and Washington peaked in the twenty years around 1900, and have since been in relatively continuous decline despite significant public investment in preventative measures (Lichatowich et al. 1999). Today, two wild Chinook stocks are listed as endangered species under the Federal Endangered Species Act, and 17 wild Chinook and two wild coho stocks are listed as threatened (Figure 2.12).

Generally, the stock health for all salmon populations in the contiguous U.S. declines as one progresses either south or east, due to warming climates and longer freshwater migrations, respectively. Similarly, populations with longer residence times in freshwater have also seen greater declines. The greatest losses have been observed in Chinook, coho, and sockeye salmon, with pink and chum salmon faring better (Kope and Wainwright 1998). To better assess the health of salmon caught in the contiguous U.S., fisheries are examined on a state-by-state basis.

Chinook	Coho
California Central Valley Sacramento River Fall Sacramento River Spring ( <b>threatened</b> ) Sacramento River Winter ( <b>endangered</b> )	Oregon Production Index Area Central California Coast ( <b>threatened</b> ) Northern California ( <b>threatened</b> ) Oregon Coastal Natural <sup>a/</sup> Columbia River Late Hatchery Columbia River Early Hatchery Columbia River Natural ( <b>federal candidate, Oregon State-endangered</b> )
Northern California Coast Eel, Mattole, Mad ( <b>all threatened</b> ), and Smith Rivers, Fall and Spring Klamath River Fall Klamath River Spring	
Oregon Coast Southern Oregon (aggregate of several stocks) Central and Northern Coast (aggregate of several stocks)	
Columbia River Basin North Lewis River Fall ( <b>threatened</b> ) Lower River Hatchery Fall Lower River Hatchery Spring Upper Willamette Spring ( <b>threatened</b> ) <sup>b/</sup> Mid-Columbia Bright Hatchery Fall Spring Creek Hatchery Fall Klickitat, Warm Springs, John Day, and Yakima Rivers Spring <sup>a/</sup> Snake River Fall ( <b>threatened</b> ) Snake River Spring/Summer ( <b>threatened</b> ) <sup>a/</sup> Upper River Bright Fall <sup>a/</sup> Upper River Summer <sup>a/</sup> Upper Columbia River Spring ( <b>endangered</b> ) <sup>a/</sup>	
Washington Coast Willapa Bay Fall Natural <sup>a/</sup> Willapa Bay Fall Hatchery Grays Harbor Fall <sup>a/</sup> Grays Harbor Spring <sup>a/</sup> Quinalt Fall <sup>a/</sup> Queets Fall <sup>a/</sup> Queets Summer/Spring <sup>a/</sup> Hoh Fall <sup>a/</sup> Hoh Spring/Summer <sup>a/</sup> Quillayute Fall <sup>a/</sup> Quillayute Spring/Summer <sup>a/</sup> Hoko Summer/Fall <sup>a/</sup>	Washington Coastal Willapa Bay Hatchery Grays Harbor Quinalt Hatchery Queets Hoh Quillayute Fall Quillayute Summer Hatchery Western Strait of Juan de Fuca
Puget Sound Eastern Strait of Juan de Fuca Summer/Fall ( <b>threatened</b> ) <sup>a/</sup> Skokomish Summer/Fall ( <b>threatened</b> ) <sup>a/</sup> Nooksack Spring ( <b>threatened</b> ) <sup>a/</sup> Skagit Summer/Fall ( <b>threatened</b> ) <sup>a/</sup> Skagit Spring ( <b>threatened</b> ) <sup>a/</sup> Stillaguamish Summer/Fall ( <b>threatened</b> ) <sup>a/</sup> Snohomish Summer/Fall ( <b>threatened</b> ) <sup>a/</sup> Cedar River Summer/Fall-Lake Washington ( <b>threatened</b> ) <sup>a/</sup> White River Spring ( <b>threatened</b> ) <sup>a/</sup> Green River Summer/Fall ( <b>threatened</b> ) <sup>a/</sup> Nisqually River Summer/Fall-South Puget Sound ( <b>threatened</b> ) <sup>a/</sup>	Puget Sound Eastern Strait of Juan de Fuca Hood Canal Skagit Stillaguamish Snohomish South Puget Sound Hatchery
Southern British Columbia Coastal Stocks <sup>a/</sup> Fraser River <sup>a/</sup>	Southern British Columbia Coast Coastal Stocks Fraser River

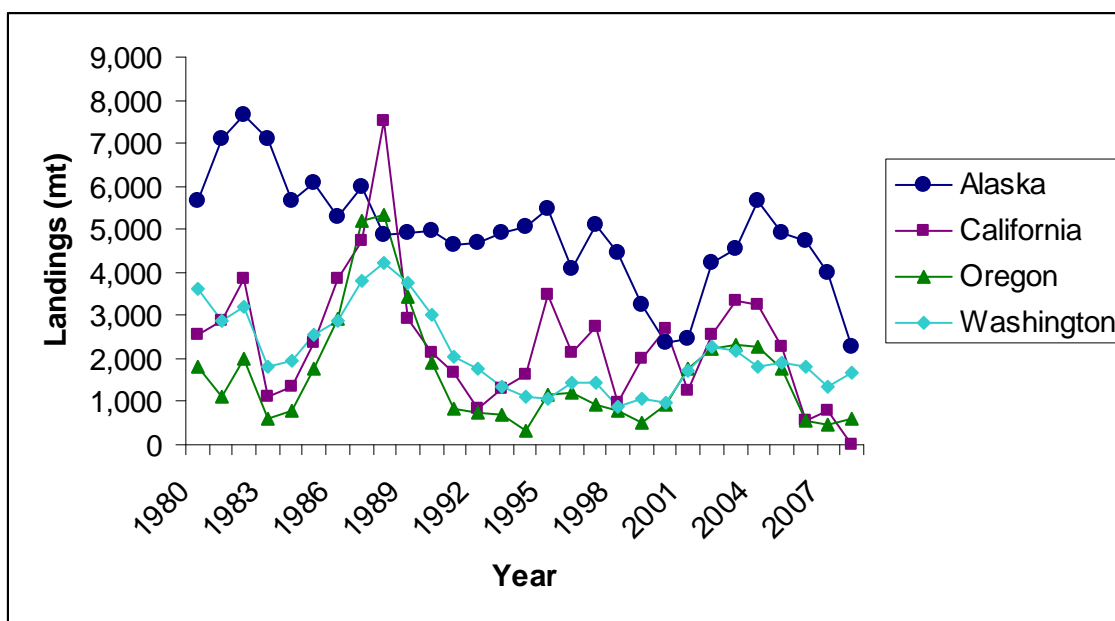
a/ On February 24, 2004, the Ninth Circuit Court of Appeals dismissed the appeals in the Alsea Valley Alliance case and sent the case back to Judge Hogan. The practical effect of the decision is there is no Federal protection under the ESA for Oregon Coastal coho at this time.

b/ This stock impacted at a rate of less than 5% in Council-area fisheries.

**Figure 2.12. Status of Chinook and coho stocks managed by the PFMC (PFMC 2004a).**

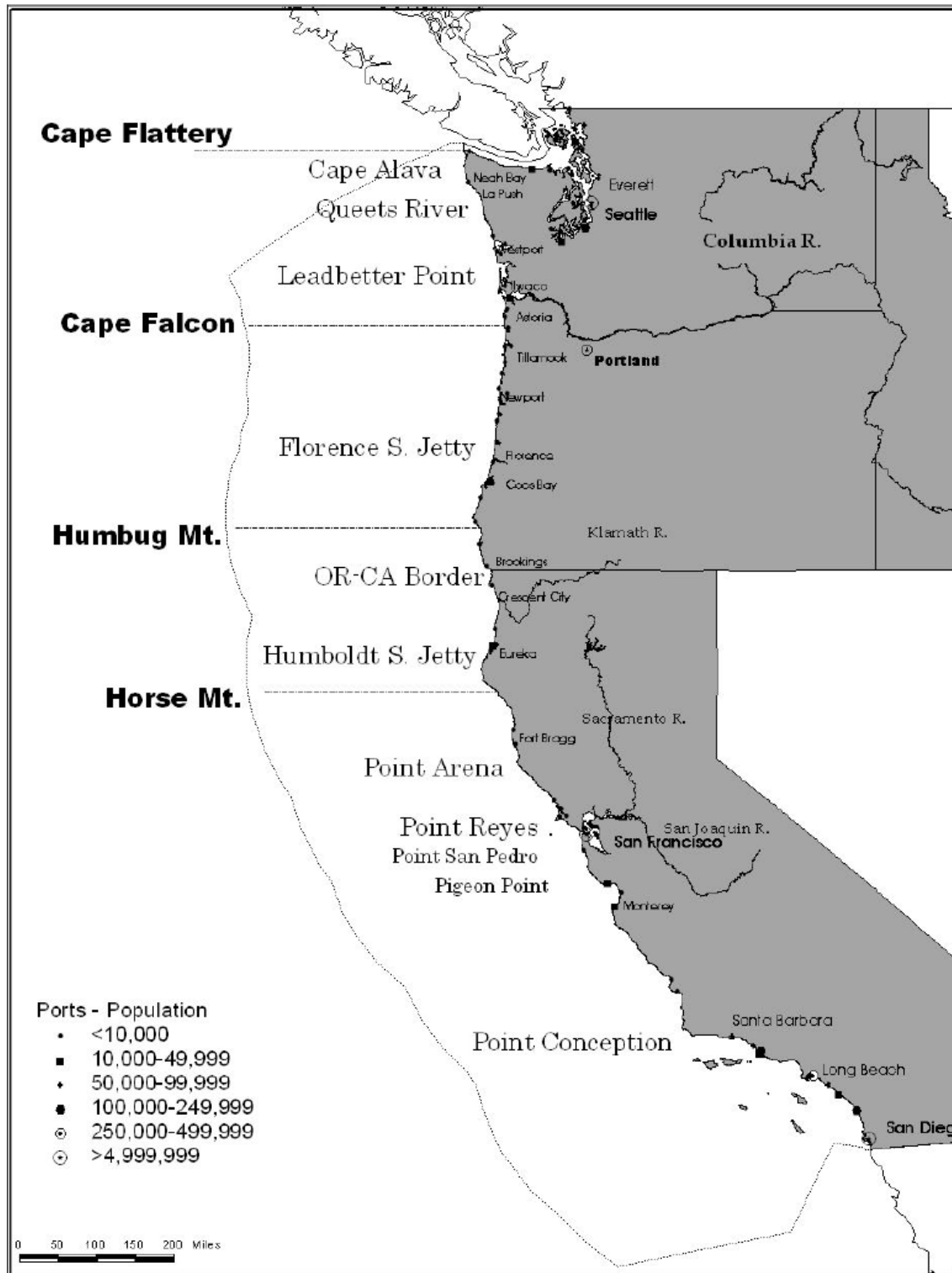
### California

California's commercial salmon fishery is a mixed-stock Chinook salmon fishery, with Chinook from several different evolutionarily significant units (ESUs) contributing to overall landings. As background, Chinook salmon are commercially the most important salmon species landed in the contiguous United States. Moreover, unlike sockeye, pink, chum, or coho salmon, Alaska does not land the majority of U.S. Chinook salmon. Instead, landings are spread widely over several ESUs and stocks in all four West Coast states. Generally, trends in landings of Chinook salmon have been down in all four states over the past decade (Figure 2.13).



**Figure 2.13. Commercial Chinook salmon landings by state, 1980-2008 (NMFS 2010b).**

In terms of management, the Pacific Fishery Management Council (PFMC) divides ocean salmon fisheries in California into two main areas: the region south of Horse Mountain (see Figure 2.14), which includes most of California; and the region from Horse Mountain north to Humbug Mountain in Oregon. Over the past decade, the large majority of California landings (>95%) came from the southern area. Though exact numbers are not available, based on historical coded-wire-tags the vast majority of salmon caught in the southern fishery (particularly south of Fort Bragg) have been determined to be Sacramento River fall Chinook. In addition, some Chinook from the Klamath River and southern Oregon are landed south of Horse Mountain.



**Figure 2.14. Map of Pacific Fishery Management Council management areas (PFMC 2004a).**

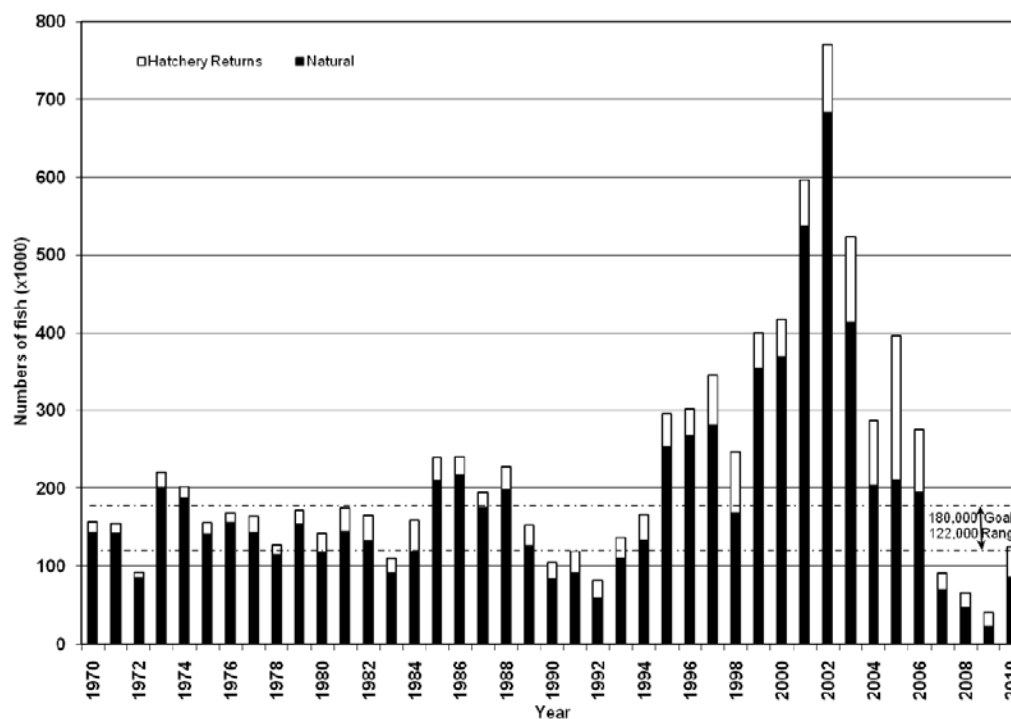


The more northern area, from Horse Mountain to Humbug Mountain, is the Klamath River management zone (KMZ). Chinook harvested in this area are a mix of Klamath River, Central Valley, and southern Oregon stocks (PFMC 2004a). Overall, California salmon fisheries in the KMZ primarily target Central Valley and Klamath River fall-run Chinook salmon.

Retention of coho salmon is prohibited in California. Incidental mortality of coho salmon is addressed in “Criterion 3: Nature and Extent of Discarded Bycatch”. Similarly, landings and abundance of stocks that are listed as Threatened or Endangered under the Endangered Species Act (ESA) are addressed under “Criterion 3: Nature and Extent of Discarded Bycatch” for reasons explained therein.

### *Central Valley Fall Chinook*

The California Central Valley drainage (the Sacramento and San Joaquin Rivers) once formed “one of the richest regions in the world for Chinook salmon production” (Yoshiyama et al. 1998). Maximal production levels of Central Valley Chinook salmon stocks are estimated to have been at least one to two million natural spawners annually, spread across the four runs (fall, late-fall, winter, and spring). The commercial Chinook fishery started around 1850 in the San Francisco Bay and river delta area; however, it was predated by Native American harvests in the region, which are estimated to have been around 8.5 million pounds—roughly on par with peak commercial harvests in the last century (Yoshiyama et al. 1998). Today, Chinook salmon in the Central Valley are a fraction of their former abundance, with the winter and spring runs imperiled and only the fall run commercially viable. Even the fall run is at a substantially smaller volume than historically, particularly in the San Joaquin River (Yoshiyama et al. 1998).



**Figure 2.15. Escapement estimates for Sacramento River fall run Chinook by origin, 1970-2010 (PFMC 2011c)**

As Figure 2.13 indicates, despite supplementation by hatchery programs, total salmon landings in California have been declining. Recent statewide landings of around 2,000 tons are roughly half the Native American harvest from the Central Valley alone. In 2006 and 2007, landings declined even more to under 1,000 tons, and in 2008 and 2009, most of the California ocean Chinook fishery was closed due to low abundance (PFMC 2010b). Of the remaining runs, the Sacramento River fall Chinook run is historically by far the most important contributor to California's wild salmon fishery and the most abundant, although abundance has declined severely in recent years (PFMC 2010b). Management's goal for Sacramento River fall Chinook is to return 122,000-180,000 natural and hatchery adult spawners. This meets a minimum sustainable yield proxy adopted in 1984 (PFMC 2004c). Until the late 2000s, this escapement goal was met nearly every year. However, fall Chinook runs to the Sacramento River failed to meet escapement goals for three consecutive years, 2007-2009, triggering a formal Overfishing Concern. Declines in the run continued each year despite fishery closures in 2008 and 2009. In 2009, a total of 39,530 adults returned to spawn, just 32% of the lower end of the escapement goal range, and the lowest escapement on record (PFMC 2010b). In addition, hatchery returns have been making up an increasing proportion of returning adults, from only 5% (hatchery/hatchery+natural) in 1970 to 40% in 2005 (Lindley et al. 2009, PFMC 2010b). Of the adults returning to spawn in 2009, 17,435 returned to hatcheries and 22,095 (56%) spawned in natural areas. (PFMC 2010b).

Escapement was projected to improve in 2010, and the California and Oregon ocean salmon fisheries (both of which catch Sacramento River fall run Chinook) were reopened under regulations expected to result in an escapement of 180,000 adults. Estimated escapement for 2010 (125,353 adults) fell short of this number, but was still slightly above the minimum escapement goal. Natural spawners also made up a larger percentage of total returns in 2010 (85,651 natural spawners and 39,702 hatchery spawners) (PFMC 2011c). Escapement is expected to continue to improve in 2011 (preseason forecast of 729,893 adults in 2011 compared to 245,483 in 2010) (PFMC 2011b). Although overfishing is not considered a primary reason for the stock's decline and low escapement from 2007-2009, it is a contributing factor (Lindley et al. 2009). One reason for this is that models have overestimated returns in recent years. For example, the PFMC predicted a 2007 escapement of 265,000 Sacramento River fall Chinook adults, but actual escapement in 2007 was only 87,900. Because of this overly optimistic prediction, fishing in the 2007 season was not constrained as much as would be appropriate for such a depleted stock, further exacerbating the problem of low escapement (Lindley et al. 2009). While the model bias leading to overestimates is considered corrected (Lindley et al. 2009), there is still cause for concern. The model predicted escapement of 122,050 fish in 2009, yet only 39,530 adults returned to the river, despite the fishery closures of 2008-2009 (PFMC 2010b). In 2010, the preseason forecast of 245,483 adults was 1.6 times the postseason estimate (PFMC 2011b).

Despite its recent record low abundance, the Sacramento River fall run Chinook remains the largest stock of Central Valley salmon. The Sacramento River Chinook winter and spring runs are listed under the ESA, with escapement totaling only about 4,000-5,000 fish annually for each run. Fall Chinook natural spawning escapement in the San Joaquin River Valley was just over

2,000 fish in 2009, and has comprised less than 10 percent of the total Central Valley escapement for fall run Chinook since 1986 (PFMC 2010b).

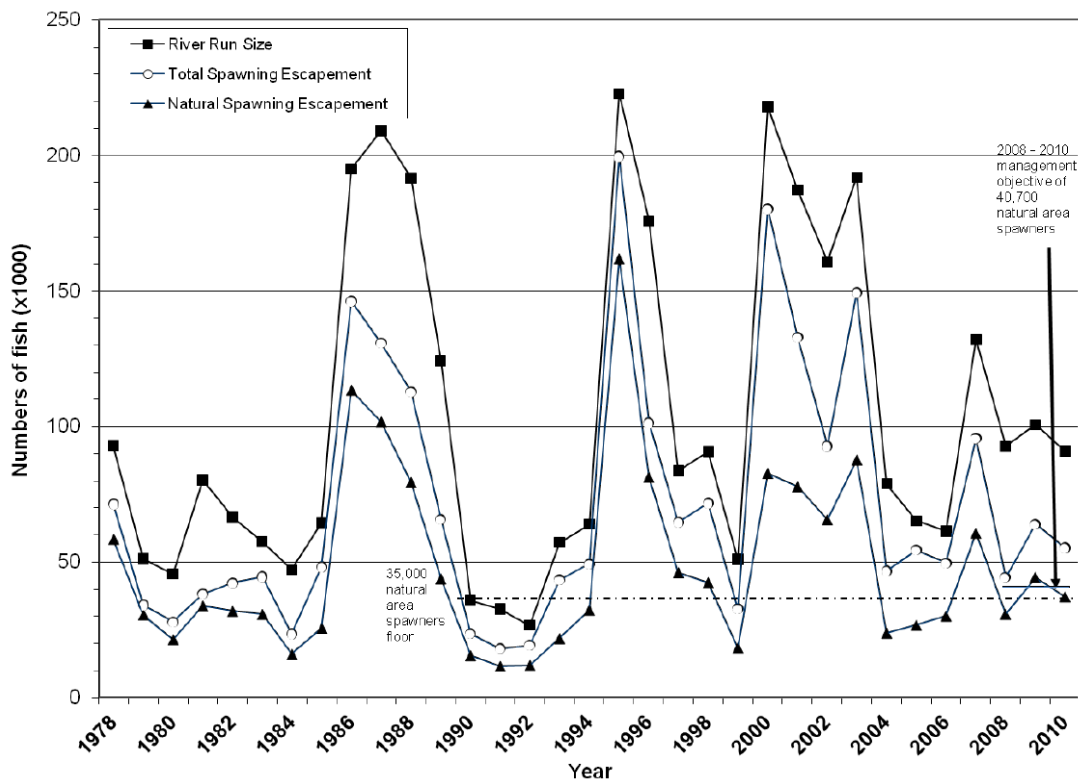
### *Klamath River Fall Chinook*

The other major contributor to California Chinook salmon harvests is the Klamath River fall Chinook run. In general, prior to 2007, California salmon fishery management has been constrained by the health of the Klamath River fall run rather than the Sacramento River. The PFMC manages salmon fisheries to meet a Klamath River natural fall spawner floor of 35,000 fish (e.g., the estimated escapement of Klamath River natural fall spawners in 2004 is 35,000 fish). Yearly escapement of Klamath River fall Chinook has averaged over 75,000 fish since the late 1970s, with a decadal escapement high of 190,000 fish in 1995 and another spike of 180,000 fish in 2000 (Figure 2.16). The lowest escapement years during the last twenty years occurred between 1991 and 1992, when average escapement was under 20,000 fish, and in 1999 less than 34,000 fish were counted (PFMC 2004c). However, these numbers include both wild and hatchery-origin fish. In 2004-2006, Klamath River fall Chinook natural escapement goals were not met, triggering a formal Overfishing Concern. In 2008, managers increased the management objective for escapement from 35,000 to 40,700 fish for the years 2008-2010, and adopted criteria to end the Overfishing Concern (at least 35,000 spawners in three of four consecutive years or 40,700 spawners in two consecutive years<sup>17</sup>). Estimated escapement was above 35,000 in 2007, 2009 and 2010 (though only just in 2010) (Figure 2.16) (PFMC 2010b, 2011c), thus ending the Overfishing Concern. Furthermore, a larger proportion of returns were to natural areas in 2010 (PFMC 2010b, 2011b).

Overall, targeted runs in California appear to be severely reduced from their historic size. As discussed previously, the causes of these declines are manifold, and often not attributable directly to fisheries. From 2007 to 2009, the Sacramento River fall Chinook run, historically the largest and most commercially important run in California, declined to record lows, failed to meet escapement goals for three consecutive years, and was increasingly composed of hatchery returns. Escapement improved in 2010, just meeting the minimum escapement goal and increasing the proportion of natural area spawners. Klamath River fall Chinook salmon, the second most targeted run, show a similar pattern. A failure to meet the a minimum escapement floor of 35,000 fish in 2004-2006 triggered an Overfishing Concern, which was removed in 2010 after escapement in three out of four consecutive years was above the escapement floor (though only just in 2010). Due to being severely reduced from historic size, the recent Overfishing Concern status in the SRFC and KRFC salmon runs, and a record low escapement of less than a third of target escapement in 2009 in the SRFC run improving to just over the minimum escapement goal in 2010, California salmon are considered to have moderate stock status according to Seafood Watch®.

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<sup>17</sup> <http://www.pcouncil.org/resources/archives/council-meeting-decisions/march-2008-decisions/>



**Figure 2.16. Klamath River adult fall Chinook returns and spawning escapement, 1978-2010 (PFMC 2011c).**

### ***Oregon and Washington***

The PFMC divides the Oregon and Washington coastline into three main fishing areas (Figure 2.14). The most southerly is the Oregon portion of the Klamath River management zone (KMZ), discussed previously, which only contributes a small percentage of the overall ocean landings in these two states. The two larger areas are: 1) Humbug Mountain to Cape Falcon (just south of the Washington border), which includes most of Oregon; and 2) Cape Falcon north to the Canadian border, which includes all of Washington and a small region of northern Oregon. In 2003, roughly 90% of ocean troll Chinook landed in Oregon and Washington waters were landed in Oregon, between Humbug Mountain and Cape Falcon (PFMC 2004c).

### ***Oregon (south of Cape Falcon)***

Oregon fisheries south of Cape Falcon under the management of the PFMC catch a mix of stocks, which change annually with the productivity of the yearly runs. These include Oregon Coast, Central Valley, and Klamath River Chinook stocks. The Oregon Coast Chinook stocks in particular exemplify the difficulties in regulating mixed-stock fisheries. Oregon Coast Chinook are typically divided into two groups: north-migrating Chinook stocks (e.g., the Elk River stocks and northwards); and south/local migrating Chinook stocks (e.g., Rogue River, Umpqua River, and south of the Elk River). The north-migrating stocks are primarily caught in British Columbia and Southeast Alaskan fisheries, and “to a much lesser degree” in Oregon and Washington (PFMC 2004c). As such, north-migrating stocks contribute little to Oregon and Washington

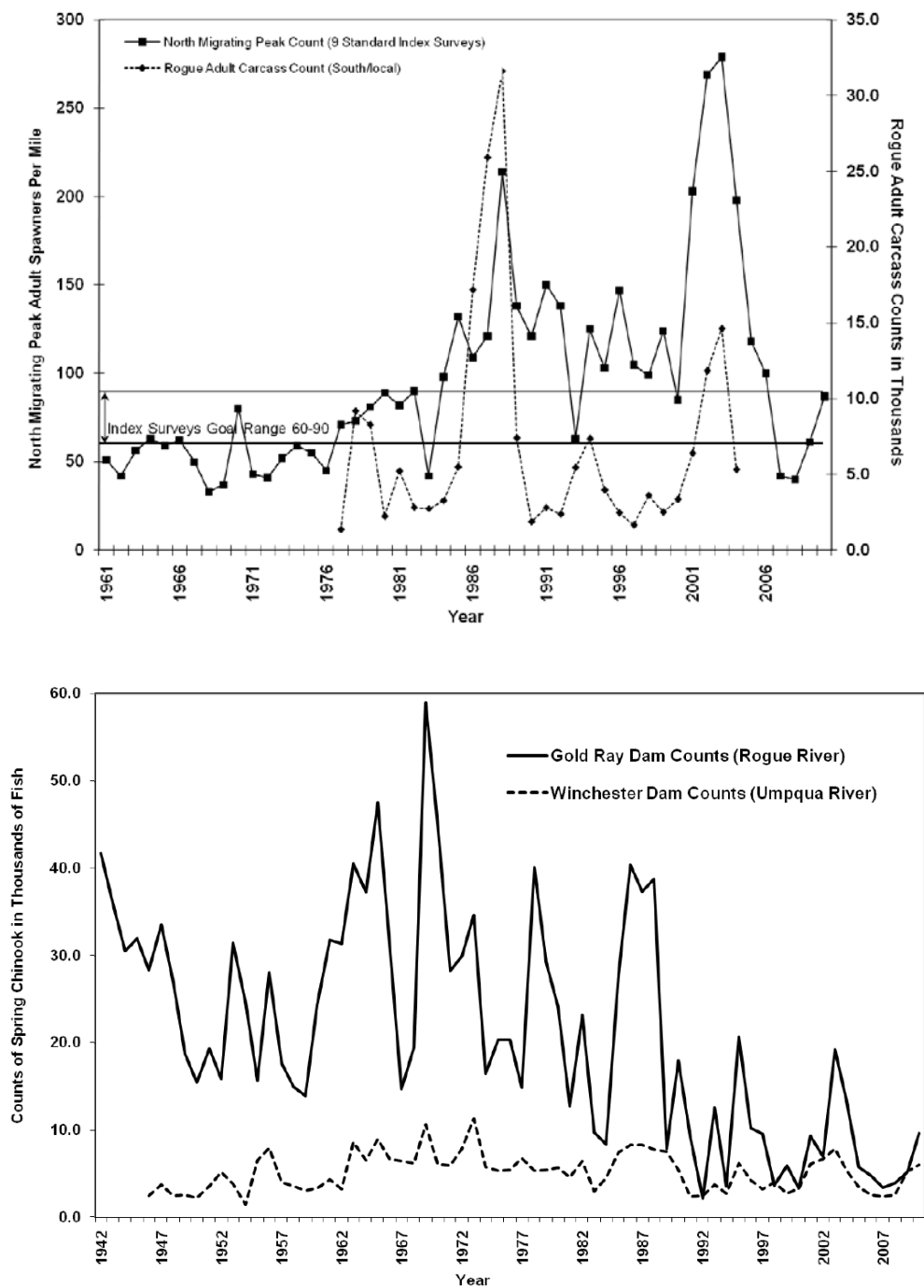
ocean fisheries. To further complicate the situation, mid-Oregon Chinook salmon (from the Coos River through the Elk River) are harvested in ocean fisheries ranging from British Columbia to Oregon (and to a lesser extent in California), south/local migrating stocks are mainly landed in Oregon and Northern California, and Umpqua River spring Chinook stocks are caught everywhere from California to Southeast Alaska. The dispersed nature of these runs makes attributing impacts of state-specific fishing fleets on the health and abundance of the runs a difficult task (PFMC 2004c).

In any case, the main contributing stocks to Oregon ocean troll fisheries south of Cape Falcon are Chinook salmon from the Central Valley and Klamath River, and Chinook salmon from south/local migrating Oregon Coast stocks. As discussed in the previous section, Central Valley and Klamath River runs are reduced from historic size, and Central Valley salmon have declined and failed to meet escapement goals in recent years, while Klamath River runs have met escapement objectives in the last few years.

#### *Oregon Coast Chinook*

The precise health and abundance of south/local migrating Oregon Coast Chinook stocks is difficult to estimate because of the scarcity of available data. The conservation objective for Oregon Coast Chinook is 150,000 to 200,000 naturally spawning adult salmon, indicated by peak spawner counts of 60-90 fish per mile in standard index surveys.

The PFMC reports that abundance estimates have “not been of critical management concern” because stocks have historically been abundant, and constraints on other fisheries (e.g., Klamath River and Northern California coast Chinook) are likely to maintain the health of Oregon stocks. Rather than directly counting coast-wide escapement, fishery managers employ a number of proxies including carcass counts in the Rogue River (not conducted since 2004), observations of northward migrating fish, and escapement counts in the Rogue River and Umpqua River (Figure 2.17). Estimates indicate that peak adult spawner counts were about 87 adults per mile in 2010, well within the goal range of 60-90 fish per mile (Figure 2.17a) (PFMC 2011c). The escapement in the Rogue and Umpqua Rivers is declining in general, although it increased in 2009 and again in 2010 relative to 2007 (Figure 2.17b) (PFMC 2011c). Overall, the PFMC contends that “the aggregate Oregon coast goal of 150,000 to 200,000 naturally spawning Chinook adults was probably met in 2010.” (PFMC 2011c)



**Figure 2.17. a) (top) Spawner indices for naturally produced Oregon coastal fall Chinook, 1961-2009 (PFMC). b) (bottom) Escapement indices for naturally produced Oregon coastal south/local migrating spring Chinook, 1942-2010 (PFMC 2011c)**

Overall, the status of Oregon salmon fisheries is somewhat unclear. The ocean fishery primarily targets Chinook salmon from the Central Valley and Klamath River, and south/local migrating Oregon Coast Chinook, in proportions that vary on an annual basis. As previously discussed, the

Central Valley fall run appears to have been depleted from 2007-2009 and only just meeting the minimum management goal in 2010, while the Overfishing Concern in place for the Klamath River run was only removed in 2010 (and returns that year were also only just over the escapement floor). The status of south/local migrating Oregon Coast stocks is both variable and poorly documented. Because Oregon fisheries largely target Sacramento River fall Chinook runs, and these stocks are considered a moderate conservation concern, the stock status of Oregon salmon fisheries is considered moderate.

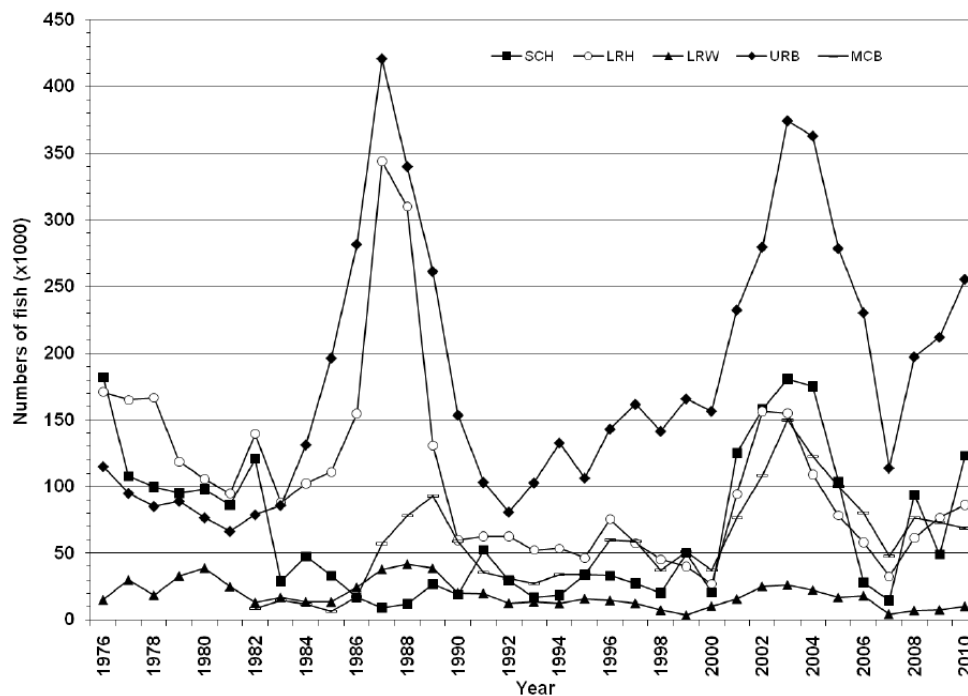
### ***Washington and Oregon (north of Cape Falcon)***

Ocean salmon fisheries in Washington State and Oregon (north of Cape Falcon) fall within a single PFMC management area, extending from Cape Falcon north to the Canadian border (Figure 2.14). The PFMC reports that Columbia River stocks represent the majority of Chinook salmon caught in ocean fisheries in this area. In addition to Columbia River salmon, stocks from British Columbia, Puget Sound, Central and Northern Oregon, and California also contribute to ocean fishing off of Washington.

### ***Columbia River Basin Chinook***

Historic salmon runs in the Columbia River once numbered anywhere between 7 and 16 million anadromous fish annually (McClure et al. 2003, Robinson 2004). Today, the number of wild spawners has been sharply reduced. Eleven ESUs in the Columbia River Basin have been listed as threatened, and upper Columbia River spring-run Chinook are federally endangered. The majority of these stocks are unlikely to be viable. Even under the most optimistic assumptions (e.g., hatchery fish have zero reproduction), nine of eleven ESUs have declining population trends, and global warming is only anticipated to worsen conditions. Already, wild coho are extinct in the interior Columbia River basin, and Columbia River sockeye are maintained in a captive broodstock program. These problems are relatively widespread across the basin, with every accessible sub-basin in the Columbia River containing at least one threatened or endangered ESU (McClure et al. 2003).

Clearly, numerous anadromous salmon runs in the Columbia River system are in distress. The effects of fisheries on these threatened and endangered stocks are addressed in the Bycatch criterion. However, Columbia River fall Chinook escapement has increased in recent years. There are five major stock groups of Columbia River Basin fall Chinook: lower river hatchery (LRH) tule stock and lower river wild (LRW) bright stock, both of which are part of the ESA-listed lower Columbia River Chinook ESU; Spring Creek Hatchery (SCH) tule stock; upriver bright (URB) stock, which includes the ESA-listed Snake River fall Chinook ESU; and mid-Columbia bright (MCB) hatchery stock. All stocks other than MCB increased in 2010, and combined returns increased from 430,500 in 2009 to 556,191 in 2010 (Figure 3.18). All stocks met their escapement objectives (PFMC 2011c).



**Figure 2.18. Columbia River mouth adult returns of the five major fall Chinook stock groups, 1976-2010 (PFMC 2011c)**

In reality, fisheries are supported by a combination of stocks that remain in relative health and hatchery supplementation. Hatcheries, in particular, play a major role in supporting fisheries. It is important to note that the majority of returning spawners in the Columbia are hatchery-raised fish, with only 1 of every 5 fish of natural origin (see the Habitat Effects criterion) (Robinson 2004, Stetkiewicz 2004). In terms of ocean fisheries off of Washington, the PFMC reports that the most important contributor are Columbia River fall tulle<sup>18</sup> stocks, which generally mature at an earlier age than natural fall stocks and do not migrate as far north. Lower Columbia River tulle stocks are primarily of hatchery origin, with wild tulle stocks officially listed as endangered (see the Bycatch criterion).

#### *Puget Sound Chinook*

As mentioned, Puget Sound Chinook runs also contribute to marine fisheries off of Washington, along with Chinook from the Columbia River system, California, British Columbia, and the Oregon Coast. Naturally spawning spring and summer/fall Chinook originating in Puget Sound remain depressed. Runs in the Nooksack, Skagit, White, and Dungeness Rivers are of continuing concern. Preliminary data indicate that in 2010, hatchery escapement goals were met, but no Puget Sound spring Chinook natural stocks met their escapement goal, while natural escapement goals were met in some areas but not others for Puget Sound summer/fall Chinook (PFMC 2011c).

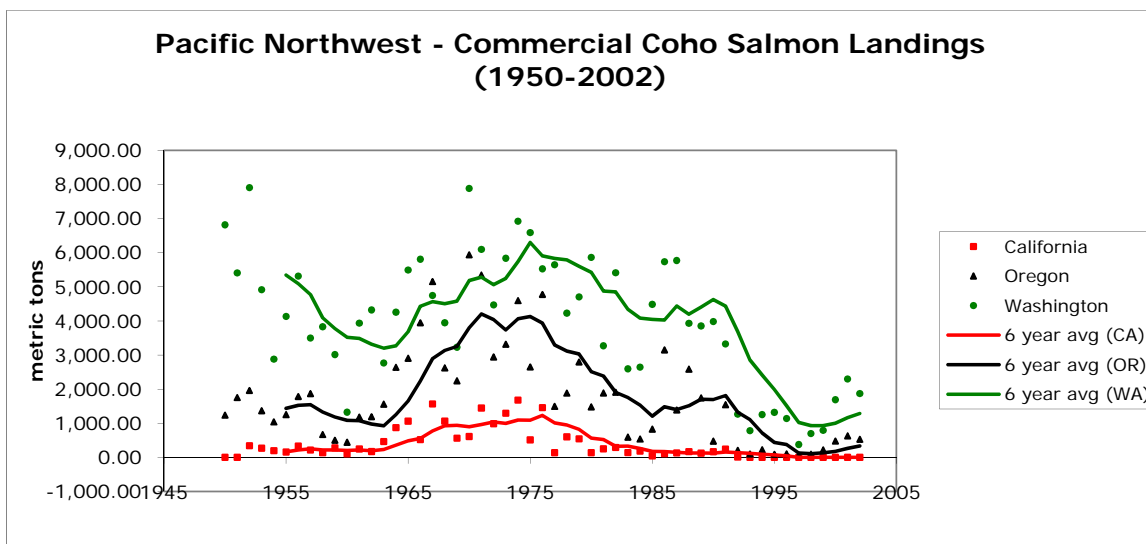
<sup>18</sup> 'Tulle' refers to wetland areas in the lower river area.



## Other Washington Salmon Fisheries

### *Coho Salmon*

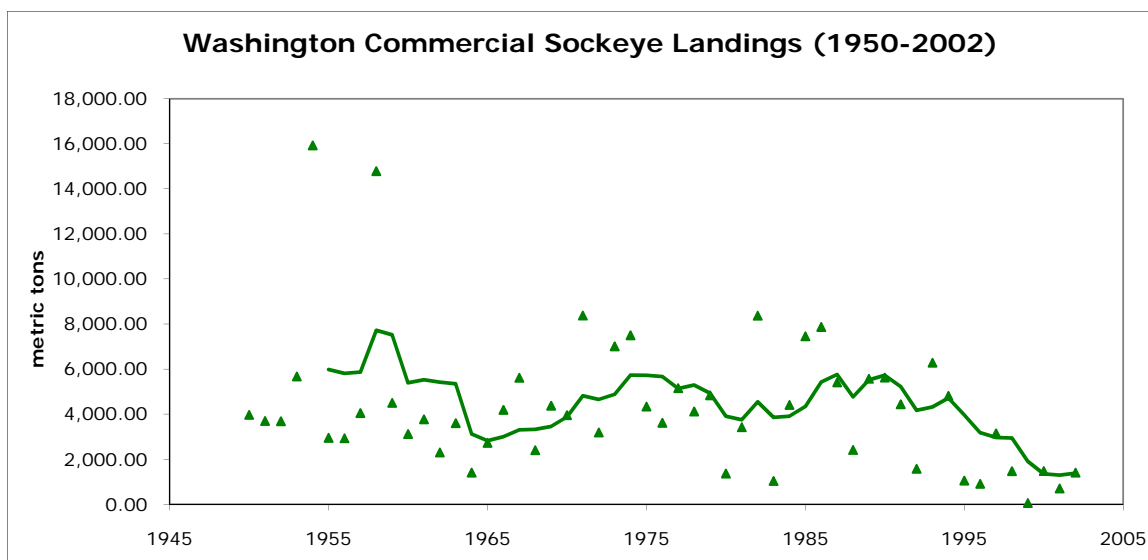
The region north of Cape Falcon (which includes all of Washington and a small section of Oregon) is the only area in the contiguous U.S. where coho salmon can be retained in commercial fisheries (hatchery-origin coho only). All fisheries that allow retention of coho are selective for hatchery fish marked with a healed adipose fin clip. In addition, there are provisions for “inseason action to allow retention of all legal sized coho in commercial and recreational fisheries north of Cape Falcon, with specific dates set for decision points” (Lohn 2004). Columbia River, Washington Coast, and Puget Sound are the primary areas of origin for coho caught in this region, with historic landings shown in Figure 2.19. Over the past half-century, landings of coho have fallen significantly, such that California and Oregon no longer permit coho to be commercially landed in their waters. Incidental mortality of wild coho in this fishery is reviewed in greater detail under the Bycatch criterion. In contrast, landings and the abundance of hatchery-origin coho is not an area of concern for this review. In Washington, three stocks of coho – Grays Harbor coho, Queets coho, and Western Strait of Juan de Fuca (SJF) coho – failed to meet conservation goals for three consecutive years. More recently, Gray’s Harbor and Queets coho are thought to have met their escapement goals in 2009, and the PFMC has recommended to NMFS that they be considered not overfished (PFMC 2011c). In 2009 the PFMC modified the Salmon FMP, combining the eastern and western SJF stocks into a single stock. The combined stock met the escapement objectives in 2009, and so the PFMC has recommended the Western SJF stock be considered not overfished (C. Tracy, pers. comm.). At the time of the current update to this report, however, the western SJF stock is still listed as overfished by NMFS, and in 2009 fell a little short of the management objective under the old FMP criteria (i.e. the escapement objective for the Western SJF stock alone - 11,044 with an objective of 11,900) (C. Tracy, pers. comm.) (see “Criterion 5: Effectiveness of the Management Regime”).



**Figure 2.19. Commercial coho landings in the contiguous U.S. (NMFS 2004b).**

### *Sockeye Salmon*

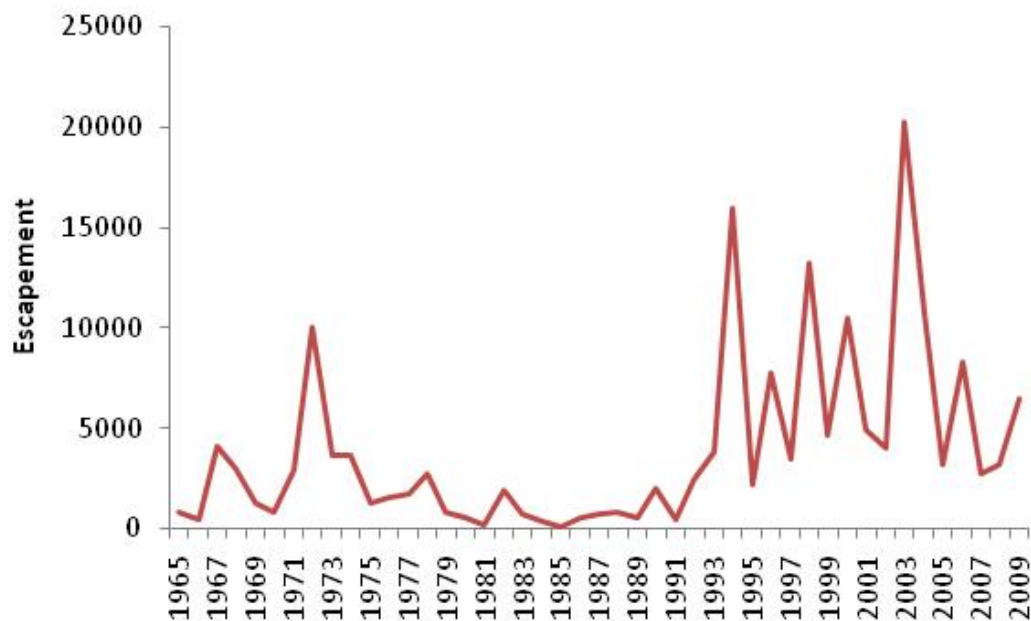
Outside of Alaska, sockeye salmon are only landed in small quantities in Washington State. Historic landings are shown in Figure 2.20 and have declined over the past fifty years.



**Figure 2.20. Commercial landings of sockeye salmon in Washington (NMFS 2004b).**

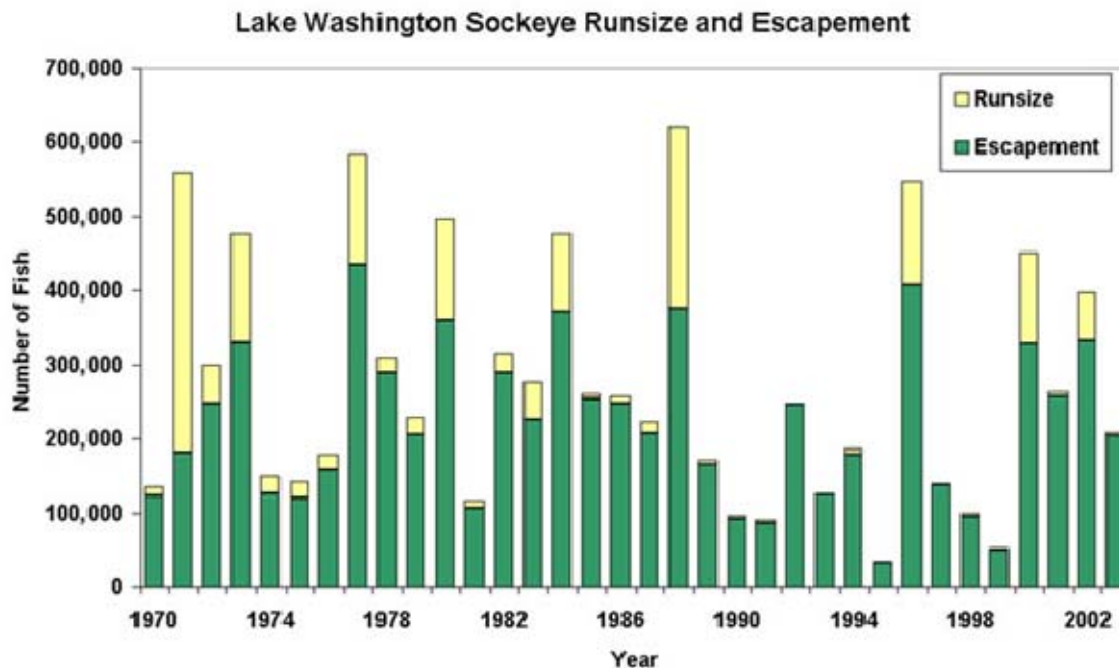
Somewhat less information is available for sockeye salmon than for Chinook or coho salmon. Because sockeye are not fished in the open ocean (they are caught in coastal waters with gillnets and seines), the species is not managed under the PFMC's Salmon Fishery Management Plan. Instead, state managers shoulder the majority of management responsibility. According to the Washington State Department of Fish and Game, there are currently six populations of sockeye in Washington not listed under the Endangered Species Act. Two of the six populations are classified as healthy: Baker River and Lake Washington.

Baker River is an artificially supported stock, in the sense that an artificial spawning beach was created in 1957 to offset the detrimental effects of a hydropower project. Historical abundances of around 20,000 spawners per year declined to very low levels in the 1970s and 1980s, and the stock was classified as critical in 1992, meaning the stock was in danger of significant loss of genetic diversity or at risk of extinction. The stock recovered to healthy levels in 2002 and has generally remained at or above the escapement goal of around 5000 fish through 2009 (Figure 2.21) (WDFW 2011c, 2011b). The 2010 forecasted run is 4,485 fish (WDFW 2011d).



**Figure 2.21. Escapement (trap counts) of sockeye salmon from Baker River ((WDFW 2011c)).**

Lake Washington is actually an introduced stock, initially stocked with Baker River fish between the two World Wars. It is unclear when anadromous sockeye last existed in Lake Washington, though the lake has long been full of kokanee. In any case, Lake Washington sockeye populations have fluctuated widely over the past decades, often falling in response to a series of floods associated with the Pacific Decadal Oscillation (Figure 2.22). Stocked trout may also have been a factor in their decline (see the Inherent Vulnerability criterion) (Ames 2004). Runs in the early 2000s were relatively strong and generally approached or met the escapement goal of 350,000 fish. In contrast, runs were weak from 2007 to 2009 (2009 counts indicated an escapement of only 21,718 fish). The 2010 run is estimated at 156,752 fish (WDFW 2011d). Only in years when run size is predicted to be larger than the escapement goal is a commercial fishery allowed (WDFW 2004b).

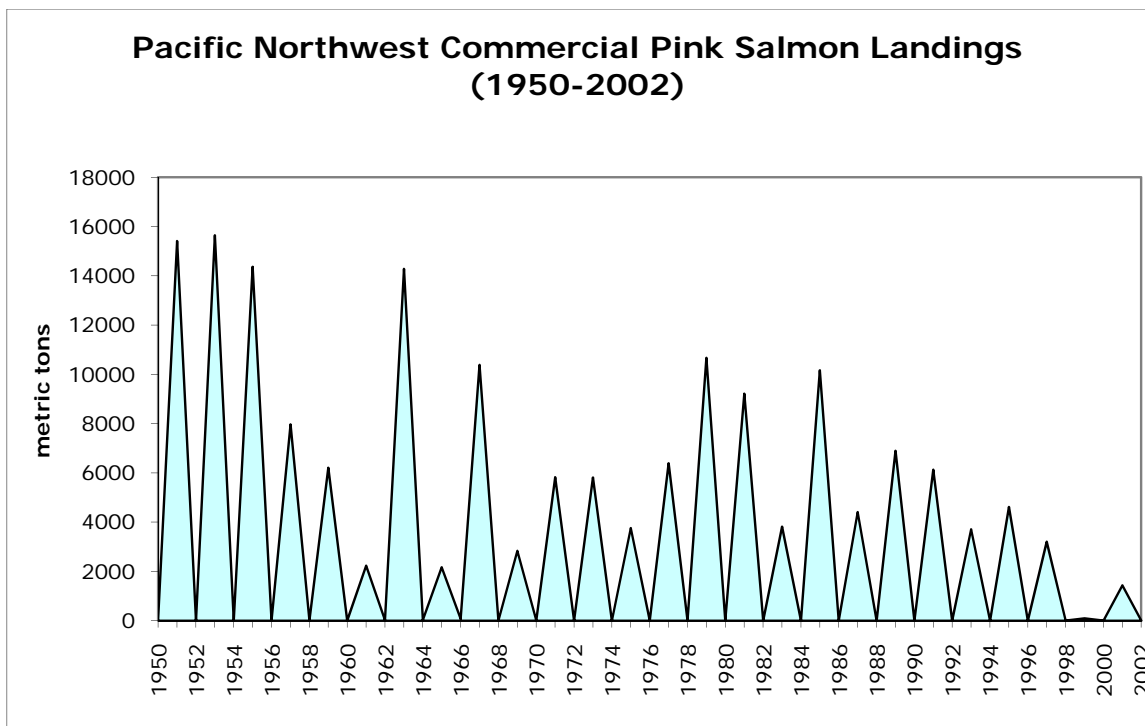


**Figure 2.22. Lake Washington sockeye spawner escapement and total runsize (spawners plus catch) (WDFW 2004c).**

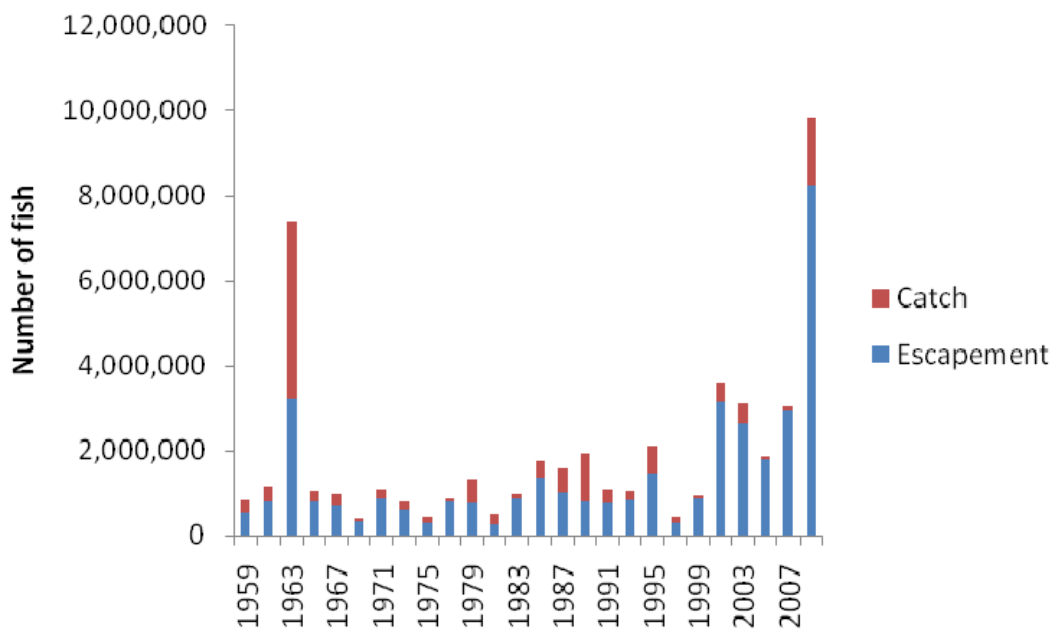
The four remaining sockeye populations in Washington are classified by managers as “depleted” due to low escapement. These populations include Columbia River sockeye, which formerly supported runs as large as three million fish. Today, Columbia River sockeye populations remain severely depressed due to habitat loss and other factors. Total escapement varies considerably from year to year, and has ranged from less than 5000 to 50,000 or more fish since the 1960s. Escapement has been below the escapement goal (23,000 fish) more often than not since the mid-1990s (WDFW 2011c). The Columbia does not support a directed commercial sockeye fishery (WDFW 2004b). In addition, Lake Ozette sockeye are listed as threatened and Snake River sockeye (in Idaho) are endangered under the ESA (see the Bycatch criterion).

### ***Pink Salmon***

As with sockeye salmon, small quantities of pink salmon are also landed in Washington, and occasionally in Oregon and California. Because pink salmon follow a two-year life cycle, landings of pink salmon follow a biannual cycle, with harvests mainly in odd-numbered years. Since 1950, landings of pink salmon have fluctuated, with an overall declining trend (Figure 2.23). However, it is important to note that landings are not a strong indicator of escapement. The falling price of pink salmon (now around 10 cents per pound) has severely depressed effort levels in the commercial fishery (mainly purse seines). Additionally, pinks sometimes return with listed Chinook runs. When they co-occur, harvest restrictions on Chinook further reduce fishing pressure on pink salmon (Ames 2004).



**Figure 2.23. Commercial landings of pink salmon in the Pacific Northwest (NMFS 2004b).**



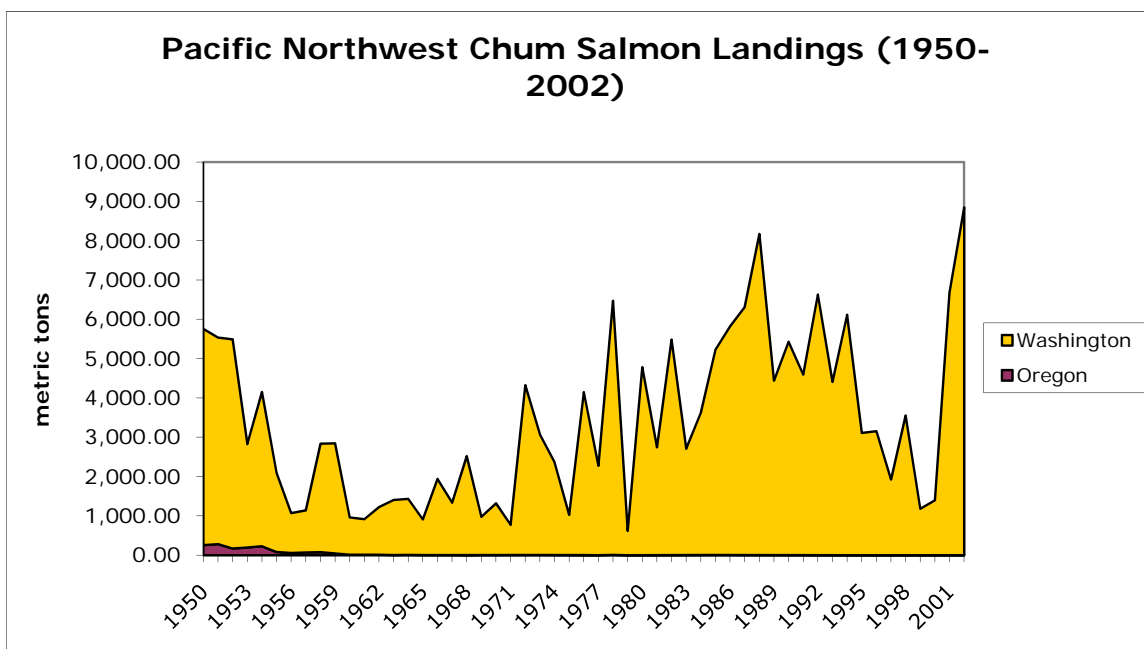
**Figure 2.24. Total pink salmon runsize (escapement+catch) in Puget Sound, 1959-2009 odd years only (Data acquired from Val Tribble, WDFW, May 4 2011).**

There are fifteen stocks of pink salmon in Washington, all in Puget Sound. With respect to the population status of pink salmon populations in Washington State, the Washington Department

of Fish and Game has ranked six pink salmon population as healthy, four as depleted, and two as critical, with the status of three other populations unknown (WDFW 2011b). Many of the stocks have shown significant improvement, and escapement has been at a relatively high level in the last decade. In fact, at over 8 million fish, escapement in 2009 was the highest on record (Figure 2.24). Typically, less than 2% of pink salmon in Puget Sound are of hatchery origin.

### ***Chum Salmon***

In the Pacific Northwest, chum salmon, like pink and sockeye salmon, are harvested mainly in Washington State. Today, chum salmon are the most abundant wild salmon species in Washington, and are predominantly landed with gillnets and purse seines. They are fished in coastal waters, under state management. Landings of chum salmon have fluctuated widely over the past fifty years, as run sizes are particularly dependent upon environmental conditions and are generally volatile (Ames 2004). The 2002 harvest was the largest on record in the past fifty years (Figure 2.25). However, it is important to recognize that this data set is limited. Historically, chum populations declined substantially prior to 1950. A more complete picture is provided in Figure 3.1 in the criterion on Bycatch.



**Figure 2.25. Commercial landings of chum salmon in the Pacific Northwest (NMFS 2004b).**

According to the Washington Department of Fish and Wildlife, the health of chum stocks is also variable, largely by region. Washington State divides its chum runs into three main geographic areas: Puget Sound, Coastal, and Columbia River (Figure 2.26). Puget Sound stocks, which account for the majority of targeted fish, have recently been at record abundance (with the exception of Hood Canal summer run stocks) but have declined in 2008 and 2009. Coastal stocks are less important to the commercial fishing industry, but also appear to be doing well. Chum populations in the Columbia River, however, are very depressed, and do not support a directed commercial fishery (see the Inherent Vulnerability and Bycatch criteria) (Ames 2004). Overall, at present 41 chum stocks are classified as healthy, nine are depressed, two are in critical

condition (the Liliwaup Creek and Jimmycomelately Creek summer runs), eight are already extinct, and 23 are in unknown condition (WDFW 2011b).



**Figure 2.26. Chum areas in Washington State (WDFW 2002a).<sup>19</sup>**

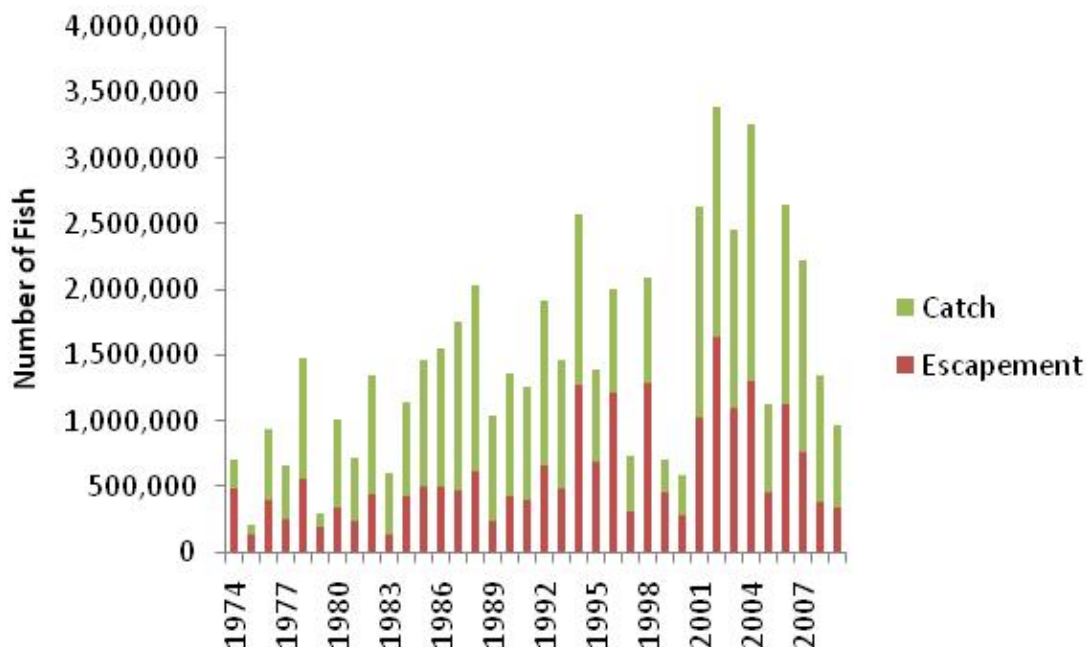
#### *Puget Sound Chum*

Both overall run size and escapement of wild chum in Puget Sound have been increasing since the mid-1970s (Figure 2.27). Chum in the Pacific Northwest are dominated by the fall run, which accounts for roughly 90% of the fish. The remainder is comprised of summer and winter runs. Fall- and winter-run stocks appear to be in excellent health. Of the fifty-five stocks of chum salmon identified in the Puget Sound area, thirty-eight are considered healthy, and thirteen of the smaller runs are of unknown condition. As part of an ESA review, the National Marine Fisheries Service (NMFS) published a coast-wide chum salmon status review in December 1997. This review found that the Puget Sound/Strait of Georgia ESU was “neither presently at risk of extinction nor likely to become endangered in the foreseeable future. Current abundance is at or near historic levels, with a total run size averaging more than 1 million fish annually in the past five years. The majority of populations within this ESU have stable or increasing population trends, and all populations with significant trends are increasing” (Johnson et al. 1997). With respect to hatchery fish, in the mid-1990s roughly 70% of the chum in Puget Sound was of wild origin, with 30% from hatchery operations. More recently, Puget sound chum salmon declined to low levels in 1999 and 2000, increased to record levels in the early 2000s, and declined again in 2008 and 2009 (Figure 2.27).

The exception to the general rule of healthy Puget Sound chum stocks is summer-run chum in Hood Canal and the Strait of Juan de Fuca. Of these stocks, one is classified by the State of Washington as depressed, two are considered critical, and a fourth is now extinct. These stocks are not targeted in commercial fisheries. As such, incidental landings are addressed in the criterion on Bycatch.

<sup>19</sup> This map, supplied by the management agency, is not intended to imply that chum are distributed far into the interior of Washington State. In reality, chum in the Columbia River do not extend much past the Bonneville Dam.





**Figure 2.27. Total runsize (escapement+catch) of Puget Sound chum salmon (WDFW 2011a).**

#### *Coastal Chum Salmon*

Available data suggest that chum in the Coastal region of Washington State are doing well. The majority of classified stocks (9 of 14) have been classified as healthy, with the status of the remainder unknown due to poor data on abundance {WDFW, 2011 #145}. The southern coast supports a higher abundance of chum; all stocks in Grays Harbor and Willapa Bay are classified as healthy. The unknown stocks are all small runs found in streams in the northern coast that contain a much lower abundance of salmon. The low abundance appears to be the natural distribution given that the rivers along the north coast lack wide bays and estuaries suitable for spawning (Ames 2004). The status of stocks along the north coast is generally classified as unknown (6 stocks), with one stock classified as healthy (WDFW 2004a). The hatchery program in coastal areas has been stopped, so the fish are predominantly of wild origin.




#### *Columbia River Chum*

Historic chum runs on the Columbia River are believed to have approached 1.4 million fish. By 1951, the chum salmon run on the Washington side of the Columbia had been reduced to 25,000 adults. The current run size is even further depleted, with numbers less than 3% of historic runs, and less than 12% of the 1951 run (WDFW 2004a). Just two population centers for chum salmon in the Columbia remain. Because neither supports a directed commercial fishery, Columbia River chum are further addressed in the criterion on Bycatch.



## Primary Stock Status Factors to Evaluate

### Management Status



- Underutilized OR close to virgin biomass 
- **Fully fished** OR recovering from overfished OR unknown 
- Recruitment/growth overfished, overexploited, depleted, threatened or “endangered” 

### Current population abundance relative to $B_{MSY}$ <sup>20</sup>




#### *AK salmon*

- **At or above  $B_{MSY}$  (> 100%)** 




*WA, OR, CA salmon (South of Cape Falcon depressed relative to historical size and failing to meet escapement objectives for multiple recent years; North of Cape Falcon unknown/variable)*

- **Below  $B_{MSY}$  (50 – 100%) OR unknown (variable)** 
- Substantially below  $B_{MSY}$  (e.g., < 50%) 

### Occurrence of overfishing (current level of fishing mortality relative to overfishing threshold)

- **Overfishing is not occurring ( $F_{CURR}/F_{MSY} < 1.0$ )** 
- Overfishing is likely/probable OR fishing effort is increasing with poor understanding of stock status OR unknown 
- Overfishing occurring ( $F_{CURR}/F_{MSY} > 1.0$ ) 

### Overall degree of uncertainty in status of stock

- **Low (i.e., current stock assessment and other fishery-independent data are robust OR reliable long-term fishery-dependent data available)** 
- Medium (i.e., only limited, fishery-dependent data on stock status are available) 
- High (i.e., little or no current fishery-dependent or independent information on stock status OR models/estimates broadly disputed or out-of-date) 

### Long-term trend (relative to species’ generation time) in population abundance as measured by either fishery-independent (stock assessment) or fishery-dependent (standardized CPUE) measures

#### *AK coho, chum, pink, and sockeye salmon*

- **Trend is up** 

#### *AK Chinook; CA, OR, WA salmon*

- **Trend is flat or variable (among areas, over time or among methods) OR unknown** 

<sup>20</sup>  $B_{MSY}$  is the biomass associated with maximum sustainable yield. This standard fishery measure does not apply very well to anadromous and semelparous salmon. Escapement relative to escapement goals is assessed instead. This factor’s scoring was updated in 2011 based on the most recent available data on realized escapement (2010), rather than future projections. In addition, considering only current abundance is inappropriate for salmon, which experience large natural fluctuations in abundance. A strong track record of meeting or exceeding escapement goals is required for a “green” ranking for this factor, uncertainty or fluctuation around the escapement goals results in a “yellow” ranking, and a current Overfishing Concern merits a “red” ranking for this factor.

- Trend is down



Short-term trend in population abundance as measured by either fishery-independent (stock assessment) or fishery-dependent (standardized CPUE) measures

*WA, OR and CA; AK pink*

- **Trend is up**



*AK chum, coho, and Chinook*

- **Trend is flat or variable (among areas, over time or among methods)  
OR unknown**



*AK sockeye*

- **Trend is down**



Current age, size, or sex distribution of the stock relative to natural condition

- **Distribution(s) is(are) functionally normal**
- Distribution(s) unknown
- Distribution(s) is(are) skewed



### Evaluation Guidelines

A “**Healthy**” Stock:

- 1) Is underutilized (near virgin biomass); OR
- 2) Has a biomass at or above  $B_{MSY}$  AND overfishing is not occurring AND distribution parameters are functionally normal AND stock uncertainty is not high.

A “**Moderate**” Stock:

- 1) Has a biomass at 50-100% of  $B_{MSY}$  AND overfishing is not occurring; OR
- 2) Is recovering from overfishing AND short-term trend in abundance is up AND overfishing not occurring AND stock uncertainty is low; OR
- 3) Has an Unknown status because the majority of primary factors are unknown.

A “**Poor**” Stock:

- 1) Is fully fished AND trend in abundance is down AND distribution parameters are skewed; OR
- 2) Is overfished, overexploited, threatened, or depleted AND trends in abundance and CPUE are up; OR
- 3) Overfishing is occurring AND stock is not currently overfished.

A stock is considered a **Critical Conservation Concern** and the species is ranked “Avoid,” regardless of other criteria if it is:

- 1) Overfished, overexploited, threatened, or depleted AND trend in abundance is flat or down; OR
- 2) Overfished AND overfishing is occurring; OR
- 3) Listed as a “threatened species” or similar proxy by national or international bodies.

*Conservation Concern: Status of Wild Stocks*

**Pacific Salmon in AK**

- **Low (Stock Healthy)**



**Pacific Salmon in WA, OR, and CA**

- **Moderate (Stock Moderate or Unknown)**
- **High (Stock Poor)**



**Criterion 3: Nature and Extent of Bycatch**

*Guiding Principle: A sustainable wild-caught species is captured using techniques that minimize the catch of unwanted and/or unmarketable species.*

The term “bycatch” refers to the landing and discarding of animals not specifically targeted by fishing vessels. Animals may be discarded for a variety of reasons, both economic and regulatory. Commonly discarded animals include those that are of an undesirable size, sex, or species. In addition to intentional discards, fishing typically involves some degree of unobserved animal mortality associated with fishing gear (e.g., animals passing through nets, breaking free of hooks or lines, and ghost fishing). This incidental or “collateral” mortality is also treated as bycatch in this review.

Globally, bycatch has been identified as a major problem area in commercial fisheries. It was estimated in the early 1990s that marine discards sum to between 18 and 40 million tons of marine life per year worldwide, representing approximately one-third of wild fishery landings (Alverson et al. 1994). In addition to comprising a large share of marine productivity, bycatch has also led to the decline of numerous non-target animals including sharks, sea turtles, and seabirds such as albatrosses. The unintentional destruction of marine life represents one of the most significant but least-documented pathways that fisheries impact marine ecosystems.

Very little specific information was found for this review with respect to the quantity and composition of discarded bycatch in salmon fisheries. In general, the gear types used in commercial and recreational salmon fisheries (trolls and gill-nets) are among the more selective types of fishing gear. As a result of this selectivity, overall *levels* of bycatch are generally quite low in salmon fisheries, relative to other marine fisheries. In addition, the discard mortality rates (percentage of discard animals that die) associated with hook-and-line and gill-nets are typically lower than the mortality rates linked with gears such as trawls and dredges. One reviewer noted that “all major fishing gear types involve some degree of injury to fish by internal and external wounding, crushing, scale loss, and hydrostatic effects, with the severity of injury dependant on gear type. Contact among fish in gear ranges from little in hook and line and gill-netting to moderate in traps and abundant in trawling and purse-seining with brailing” (Davis 2002).

While the overall level of bycatch is low in salmon fisheries, the industry's bycatch can include species with low or threatened populations. In particular, mid-water gillnets, which are not attached to the seafloor, have among the worst bycatch effects on seabirds, sharks, and marine mammals (Chuenpagdee et al. 2003). Because even bycatch at low levels can contribute to the demise of these at-risk species, it represents a significant concern. The remainder of the analysis in this criterion focuses on the accidental capture of threatened animals including seabirds, groundfish, and listed salmonids.

### **Seabird and Marine Mammal Bycatch**

The majority of the U.S. wild salmon harvest in Alaska, Oregon, and Washington is landed using gillnets and purse seines. In Alaska, a variety of these nets are used throughout coastal waters, while trolling is only a small contributor to landings in Southeast Alaska.

In the Pacific Northwest, gillnets are seasonally employed in a number of coastal areas including Willapa Bay, Puget Sound, Gray's Harbor, and the lower Columbia River. According to NMFS landing statistics, in 1999 and 2000, over 80% of the Chinook salmon harvest in Washington State was taken using nets. Similarly, almost all of the sockeye, chum, and pink salmon landings are captured in gillnets and seines. In contrast, California's landings come almost exclusively from trolling and just 20% of Oregon landings were taken in nets in 1999 and 2000.

Seabird bycatch in the Pacific Northwest is most frequently associated with the use of gillnets targeting sockeye and pink salmon, particularly in Puget Sound. Gillnets are up to 1,500 feet long and can ensnare diving seabirds (Melvin et al. 1999). The long nets, typically set at dusk or dawn, are released to drift for a set period of time (e.g., "soak" times in OR and WA are typically limited to 45 minutes). Seabirds, unable to see gillnets, can become entangled and drown.

In the mid-1990s, attention was focused on seabird bycatch in Puget Sound, because one of the affected birds, the marbled murrelet, is a listed species (Sanford 2004). The gillnet fishery for sockeye salmon bound for the Fraser River captured marbled murrelets in some areas, though the most commonly entangled seabirds were common murrelets (*Uria aalge*) and rhinoceros auklets (*Ceroghinca monocerata*). Melvin et al. (1999) estimated in 1999 that seabird bycatch in this fishery could be reduced up to 75% by pursuing a three-fold strategy of gear modifications, restrictions on time-of-day fishing, and abundance-based fishery openings. A combination of closed areas and gear modifications (making the top of gillnets more visible) was implemented in the late 1990s to reduce bycatch (Sanford 2004).

In general, the populations of common murrelets and rhinoceros auklets appear to be relatively healthy. Murrelets are among the most numerous seabirds in the northern hemisphere, and populations have generally been on the rise over the past half-century (Gaston et al. 2003). Rhinoceros auklets are distributed along the northern half of the Pacific Rim. In North America, most of the population is found in British Columbia, with smaller numbers in Southeast Alaska, Washington, and Oregon. In California, these birds are a species of special concern, only recently returned after being extirpated in the 1860s (Gaston and Dechesne 1996).

Purse seines and hook-and-line gear, in contrast, have a comparatively small rate of seabird entanglement (Milward 2004, Sanford 2004). Troll gear (hook-and-line gear) in PFMC-regulated

waters use a maximum of four to six spreads per line and single point, single shank, barbless hooks. Trolls remain close to the boats and do not use real bait; as such, some observers have never seen a bird hooked (Milward 2004). Chum salmon fisheries in the Pacific Northwest also occur at a different time of the year when seabirds are not as concentrated.

With respect to marine mammals, data from 1991 to 1993 indicate that drift gillnets in Washington and Oregon killed an estimated 200 harbor seals per year. Most of the mortalities were observed in the Columbia River, with lower levels reported from Grays Harbor and Willapa Bay. However, the extent of gillnet fishing effort was much higher in the early 1990s than it is today, and therefore is not particularly representative. At a population of around 20,000 seals, this level of mortality is unlikely to have significant negative effects. Moreover, populations of marine mammals in the Pacific Northwest have generally been on the rise, and are posing difficulties to endangered species, such as endangered fish attempting to pass through Ballard Locks (Sanford 2004).

No information on bycatch or mortality of seabirds or marine mammals is available for Alaska, though fishery managers maintain that it is “very low” (Plotnick 2004).

### **Non-Salmonid Fish Bycatch**

In addition to seabirds, various fish species are incidentally hooked in trolls and caught in gillnets. Of greatest concern on the West Coast are groundfish, which have undergone significant population declines over recent decades (BRT 2003). Several species of groundfish are caught incidentally in salmon fisheries, when trolls are set in deeper waters. Because Chinook salmon generally are found and fished at greater depths than coho, rockfish incidental catch is highest when targeting Chinook.

Of the eight overfished groundfish species under the Pacific Fishery Management Council’s jurisdiction, three (darkblotched rockfish, Pacific Ocean perch, and cowcod) occur in habitat outside of salmon trolling areas and as such are unlikely to be taken incidentally or discarded. Of the remaining five, as of 2001 incidental catch in the salmon fishery was only a small fraction of estimated optimum yields (OYs) (Table 3.1). The largest effect of salmon trolling on groundfish appears to occur in the canary rockfish fishery. In 2004, troll gear targeting salmon landed an estimated 1.6 mt of canary rockfish, or 3.4% of the 47 mt optimum yield (PFMC 2004a). More generally, landings of overfished rockfish in salmon fisheries totaled less than 1% of rockfish optimum yields.

**Table 3.1. Landings of overfished groundfish in the PFMC commercial salmon fishery (PFMC 2004a).**

	Species					
	Lingcod	Bocaccio	Canary	Widow	Yelloweye	All Groundfish
<b>Landings (mt) (2000)</b>	0.31	0.20	1.53	0.09	0.16	15.62
<b>Landings (mt) (2001)</b>	0.27	0.01	0.84	0.12	0.10	12.9
<b>OY (2004)</b>	651.00	250.00	47.00	240.00	22.00	-
<b>Percent of OY (average)</b>	0.04%	0.04%	2.52%	0.04%	0.59%	< 1%

In general, landings of overfished groundfish appear to be relatively infrequent, and exploitation rates are unlikely to be high enough to threaten the recovery of groundfish species, relative to directed commercial fisheries. The PFMC describes average annual groundfish catch in the salmon fishery as “very low,” such that adjustments and changes to the salmon fishery “do not substantially alter the projections for harvest-related mortality in the groundfish fishery (projections made as part of the development of the groundfish annual specifications)” (PFMC 2004). Moreover, most groundfish bycatch are allowed to be landed rather than discarded.<sup>21</sup> As a consequence, the incidental landings are not officially considered “bycatch” *per se*. To avoid redundancy, groundfish landings in commercial salmon trolls ought to be addressed in reviews of rockfish.

With respect to other fish species hooked in salmon fisheries, such as halibut, highly-migratory species, and coastal pelagic species, the PFMC notes that “co-occurrence rates for salmon and these other Council-managed species is low, as well as for non-Council-managed species.... At present, these other non-salmon stocks are not the subject of overfishing concerns” (PFMC 2004a).

In state waters, gillnets and purse seines in Washington generally have low levels of bycatch. The most frequently discarded species is reportedly dogfish (Ames 2004). One report of a gillnet fishery in Willapa River reported discards of anchovy, sardine, shad, crabs, and dogfish (Vander Haegen et al. 2002).

### **Salmonid Bycatch**

In contrast to seabirds and groundfish, there is significant concern over bycatch and incidental landings of non-target salmonids. In West Coast salmon fisheries this concern centers on the capture of salmonids from threatened and endangered ESUs. As discussed in the first two criteria, many salmon ESUs are in exceedingly poor health. As a result, bycatch or incidental landings of salmon from these ESUs in the mixed-stock fishery can negatively affect the species' abundance, even if non-target fish comprise only a small portion of total landings.

<sup>21</sup> Certain restrictions apply. For example, in Alaska black rockfish bycatch cannot be sold in specific areas. More generally, harvest limits exist and groundfish under a minimize size or out of season must be discarded.

For many of the ESUs (such as threatened coho and steelhead ESUs), non-retention regulations have been put in place and the fish are released when caught. For other non-target ESUs, such as endangered winter-run Chinook, it is difficult to differentiate between target and non-target stocks. As a consequence, fish from the non-target ESUs are likely to be retained and landed. Both the discards and incidental landings have the potential to impact listed stocks and can negatively affect the health of non-target populations (MacCall and Wainwright 2003). Because the West Coast salmon fishery is a mixed-stock fishery, and landings can unintentionally include stocks listed under the Endangered Species Act, the review characterizes all non-target salmon landings (whether discarded or retained) as bycatch. In contrast, the health and abundance of targeted salmon ESUs, such as the Sacramento River fall Chinook, have been addressed in the Stock Status criterion.

### ***Data Availability***

Data for bycatch of listed salmon stocks is imprecise for a number of reasons. Many affected fish are not landed and there is no available and definitive means of differentiating between subspecies of fish that are landed. As a consequence, for many ESUs it remains unclear to what extent the recovery of listed stocks is hindered by fisheries exploitation. As discussed in the analysis under the Inherent Vulnerability criterion, ESA-listed Pacific salmon populations are depleted for numerous reasons, including, but not limited to, habitat loss, habitat degradation, unfavorable oceanic conditions, and historical overfishing (MacCall and Wainwright 2003). While the primary reason for these declines has typically been the degradation and loss of fresh water spawning, rearing, and migration habitats, the continued harvest of these species may be a contributing factor impeding the recovery of multiple West Coast salmon populations. The uncertainties involved are generally too large to quantify blame. As the National Marine Fisheries Service (NMFS 1998) notes: “No single factor is solely responsible for this decline, though every factor... has contributed to the decline in varying degrees. Given the complexity of this species' life history and the ecosystem in which it resides... it is impossible to accurately quantify the relative contribution of any one factor to the decline of a given Chinook salmon [stock].” With respect to bycatch in particular, the uncertainties surrounding non-target landings significantly complicate management efforts (Alverson et al. 1994).

One of the major unknowns in managing bycatch is the discard mortality rate, or the percentage of bycatch released back into the ocean that die due to injuries, stress, or reduced survival skills as a result of the interaction. Discard mortality rates vary with several factors including the specific gear used and species landed, as well as “environmental conditions (light conditions, temperature, air exposure, anoxia, sea conditions, and pressure changes) and biological factors (fish size and species, behavior, and physiology)” (Davis 2002). Mortality can be immediate or delayed, occurring later due to subsequent predation, physiological stress, or disease. In addition, some fish, termed “dropoffs,” encounter fishing gear but escape prior to landing and subsequently die or are consumed by predators. Captured salmon are often physically exhausted, and can be damaged from fishing gear or simply stressed, which can weaken a fish’s immune system “either directly through the endocrine system or via energy shunting” (Farrell et al. 2000, Davis 2002).

In light of the considerable uncertainties, a range of estimates exist for salmon discard mortality rates. Buchanan et al. (2002) comment that total discard mortality in traditional gill-nets is

estimated to be 35-70% for coho salmon (Buchanan et al. 2002). An empirical study of a Willapa River gillnet fishery observed immediate mortality of 9.2% for coho and 12.8% for Chinook salmon; delayed mortality was not estimated (Vander Haegen et al. 2002). The NMFS Biological Review Team (BRT) employs estimates of hooking mortality rates of 13% for recreational fisheries and 24% for commercial fisheries, while tacking on an additional 5% for dropoffs.<sup>22</sup> Recent studies of coho caught by hook and line under optimal handling conditions (and employing the use of on-board recovery tanks) have recorded salmon mortality rates of less than five percent (Farrell et al. 2001a, Farrell et al. 2001b).

Given the considerable uncertainties involved, progressive fisheries management ought to seek a precautionary approach that minimizes the bycatch or incidental landings of ESA-listed species. The remainder of this section documents available evidence on the health and bycatch rates for each endangered or threatened salmon ESU on the West Coast. When not otherwise specified, this review has relied on the findings summarized by the most recent Biological Review Team status assessments (BRT 2003). Summaries are provided in Table 3.2 and Table 3.3, which list the current assessment of ESU health and management estimates of fishing-related mortality.

In Alaska, the situation is improved by virtue of the fact that Alaskan salmon runs are in considerably better health than their counterparts in the contiguous United States (see the Stock Status criterion). Fisheries are less likely to incidentally harvest salmon of endangered or threatened runs simply because there are no listed salmon ESUs in Alaska, though some Chinook salmon from listed stocks in the Pacific Northwest are presumably landed in the Chinook troll fishery in Southeast Alaska, where Chinook migrate seasonally from as far south as California. According to a recent study of troll-caught salmon in Southeast Alaska, there are a number of major contributors to Chinook harvests in this region. These include mid- and north-Oregon stocks, Columbia River fall and summer stocks, Washington coastal Chinook, Chinook from British Columbia, and Chinook from rivers in Southeast Alaska (Templin and Steeb 2003). However, the harvest rate of listed stocks taken in Alaska is small in comparison to harvest in British Columbia, Washington, Oregon and California (Chaffee et al. 2007). For example, exploitation rates of ESA-listed Snake River fall Chinook in the southeast Alaska fishery are about 4.5%, exploitation rates of upper Willamette spring Chinook are about 5.1%, and exploitation rates of Puget Sound Chinook are approximately 0.4% (Chaffee et al. 2007). In contrast to the higher harvest rates in British Columbia and the lower states, these low levels of exploitation in the Southeast Alaska fishery pose only a moderate risk to endangered and threatened salmon. Fisheries in other parts of Alaska are not believed to take listed salmon.

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<sup>22</sup> The recreational fisheries estimates are in line with the 12.2% mortality rate estimated in a recent experimental study of catch-and-release Willamette River Chinook (Lindsay et al. 2004).



**Table 3.2. Salmon species listed under the Endangered Species Act.**  
**(Sources: NMFS website 2004, California Department of Fish & Game, Oregon Department of Fish & Wildlife, and NMFS Biological Review Team (BRT), 2003).**

ESU	Known Range	Federal Listing	State Listing	BRT Conclusions
<b>Chinook</b>				
Sacramento River Winter	CA	<b>Endangered</b>	<b>Endangered (CA)</b>	<b>“in danger of extinction”</b>
Central Valley Spring	CA	Threatened	Threatened (CA)	“likely to become endangered”
Central Valley Fall/Late Fall	CA	Species of Concern	Species of Special Concern (CA)	
California Coastal	CA	Threatened		“likely to become endangered”
Upper Klamath Trinity River	CA	Not Warranted		
Southern OR & N. CA Coastal	CA/OR	Not Warranted		
Oregon Coast	OR	Not Warranted		
Upper Willamette River	OR	Threatened		“likely to become endangered”
Deschutes River Summer/Fall	OR	Not Warranted		
Lower Columbia	OR/WA	Threatened		“likely to become endangered”
Middle Columbia River Spring	OR/WA	Not Warranted		
Snake River Spring/Summer	OR/WA	Threatened	Threatened (OR)	“likely to become endangered”
Snake River Fall	OR/WA	Threatened	Threatened (OR)	“likely to become endangered”
Upper Columbia River Summer/Fall	WA	Not Warranted		
Upper Columbia River Spring	WA	<b>Endangered</b>		<b>“in danger of extinction”</b>
Puget Sound	WA	Threatened		“likely to become endangered”
Washington Coast	WA	Not Warranted		

**Table 3.2 (Continued). Salmon species listed under the Endangered Species Act. (Sources: NMFS website 2004, California Department of Fish & Game, Oregon Department of Fish & Wildlife, and NMFS Biological Review Team (BRT), 2003).**

ESU	Freshwater Range	Federal Listing	State Listing	BRT Conclusions
<b>Coho</b>				
Central California Coast	CA	<b>Endangered</b>	<b>Endangered (CA)</b>	<b>“in danger of extinction”</b>
Southern Oregon/Northern California	CA/OR	Threatened	Threatened (CA)	“likely to become endangered”
Interior Fraser	BC	<b>Endangered</b>		N/A
Oregon Coast	OR	Threatened		“likely to become endangered”
Lower Columbia River/ Southwest WA	OR	Threatened	<b>Endangered (OR)</b>	<b>“in danger of extinction”</b>
Puget Sound/Strait of Georgia	WA	Species of Concern		
Olympic Peninsula	WA	Not Warranted		
<b>Chum</b>				
Hood Canal Summer Run	OR/WA	Threatened		“likely to become endangered”
Lower Columbia River	OR/WA	Threatened		“likely to become endangered”
<b>Sockeye</b>				
Snake River	ID	<b>Endangered</b>		<b>“in danger of extinction”</b>
Lake Ozette	WA	Threatened		“likely to become endangered”
Cultus Lake	BC	Threatened		N/A
Sakinaw Lake	BC	<b>Endangered</b>		N/A
<b>Steelhead</b>	CA/OR/WA	Variable: Includes Endangered and Threatened	Variable: Includes Endangered and Threatened	Variable: 3 stocks <b>“in danger of extinction,”</b> 7 stocks “likely to become endangered”

**Table 3.3. Harvest rates of Endangered and Threatened salmon ESUs (PFMC 2004c, updated for SRWC and Lower Columbia Chinook with NMFS 2010c and C. Tracy, pers. comm.).**

ESU	BRT Conclusions	Exploitation Rate
Sacramento River Winter Chinook	<b>"in danger of extinction"</b>	<b>15-21% in 2000-2007</b>
Central Valley Spring Chinook	"likely to become endangered"	< 27% in 2001, based on Central Valley harvest index (CVI)
California Coastal Chinook	"likely to become endangered"	Unknown; "Low"
Upper Willamette River Chinook	"likely to become endangered"	Unknown; 1980-99 mean 48%.
Lower Columbia Chinook	"likely to become endangered"	<b>~37.5% limit, post-season analysis suggests actual rates have been lower</b>
Snake River Spring/Summer Chinook	"likely to become endangered"	Unquantified: "Generally Low"; 1980-99 mean: 8% spring, 3% summer.
Snake River Fall Chinook	"likely to become endangered"	<b>20-40%</b> (since 1990); 1980-99 mean 62%.
Upper Columbia River Spring Chinook	<b>"in danger of extinction"</b>	Unknown. Previously 20-40% before management actions. 1980-99 mean: 9%
Puget Sound Chinook	"likely to become endangered"	<b>44% 5-year average; 26-63% range</b>
Central California Coast Coho	<b>"in danger of extinction"</b>	<b>3-12%</b>
Interior Fraser Coho	<b>"in danger of extinction"</b>	<b>6.5%</b>
Southern Oregon/Northern California Coho	"likely to become endangered"	<b>3-8%</b>
Oregon Coast Coho	"likely to become endangered"	<b>7-12%</b>
Lower Columbia River/Southwest WA Coho	<b>"in danger of extinction"</b>	<b>~10%</b>
Hood Canal Summer Run Chum	"likely to become endangered"	<b>4% (1998-2002 mean: 1-13% range)</b>
Lower Columbia River Chum	"likely to become endangered"	<b>&lt; 10%</b>
Snake River Sockeye	<b>"in danger of extinction"</b>	Undocumented - Presumably low
Lake Ozette Sockeye	"likely to become endangered"	Undocumented - Presumably low
Cultus Lake Sockeye	<b>"in danger of extinction"</b>	Undocumented - Presumably low
Sakinaw Lake Sockeye	<b>"in danger of extinction"</b>	Undocumented - Presumably low
Steelhead (all)	Variable: 3 stocks <b>"in danger of extinction"</b>	Steelhead bycatch = "Rare event" in ocean fisheries; common in some freshwater fisheries. 1980-99 mean 12-36% by listed run in Columbia and Snake Rivers.

### **Chinook Salmon Bycatch**

West Coast Chinook salmon includes nine Chinook ESUs which have been determined to be Endangered or Likely to Become Endangered by the current Biological Review Team (BRT) status review. Because of this listing status, each of the nine ESUs is considered a non-target species and treated as bycatch in this assessment. Non-target Chinook salmon are primarily landed in commercial Chinook fisheries.

The Chinook salmon fishery off California primarily targets Sacramento River fall-run Chinook. The fall-run fishery has been constrained to meet the Salmon Fishery Management Plan (FMP) escapement goals and in-river allocation objectives for Klamath River fall Chinook. In addition, NMFS consultation standards under the ESA for listed Sacramento River winter Chinook and three other listed ESUs have affected this fishery. Based on these restrictions the commercial and recreation Chinook fishery have decreased substantially since 1990. It is believed that the harvest rates on listed ESUs are less than those occurring on Central Valley fall Chinook, though precise data are often absent. This lack of harvest rate estimates for even the targeted fall run requires the PMFC and NMFS to address recovery of weak stocks through “adaptive management” strategies. Such strategies include in-season adjustments that reflect newly acquired data on surrogate populations.

The Oregon and Washington ocean Chinook fisheries target a range of stocks including California Sacramento River fall and Klamath River fall Chinook, Oregon Coastal Chinook, and Columbia River tule Chinook stocks. These fisheries can affect listed Chinook salmon ESUs in California as well as several in Oregon and Washington.

Alaska does not have any listed Chinook stocks. As such, Chinook salmon of Alaskan origin are not addressed under the Bycatch criterion. However, Alaskan fisheries, such as the Southeast Alaskan Chinook troll fishery, contribute to landings of Chinook of some threatened runs.

### ***Sacramento River Winter Chinook***

#### ***Population Status: In Danger of Extinction***

Sacramento River winter-run Chinook are officially listed as an endangered species, and represent one of the most endangered of the salmon ESUs. Whereas summer- and fall-run Chinook populations are common in many areas, winter-run Chinook salmon are limited to the Sacramento River (Waples et al. 2004). Historic populations upwards of 200,000 fish declined four orders of magnitude to under 200 fish by the 1980s (Lindley and Mohr 2003). In the most recent years, Sacramento River winter Chinook spawner escapements have increased marginally. Escapements of endangered winter Chinook in 2003 were estimated at 6,200 adults, ten times the extremely low 600 adult escapements observed three years earlier, but well below the initial recovery goal of 10,000 female spawners per year and a lambda (growth rate) of 1.0 calculated over 13 years of data. As of 2003, the quasi-extinction risk was estimated at 28% for the run (BRT 2003).

#### ***Bycatch Rates***

Historically “overfishing” and “unsustainable harvest rates” have contributed to the demise of the Sacramento River winter-run Chinook ESU (BRT 2003). As with most fisheries, data on the ocean harvest rate of the stock is not well known. In the case of winter Chinook, harvest rates are

estimated using the Central Valley Chinook ocean harvest index (CVI), defined as the ratio of ocean catch south of Point Arena to the sum of this catch and the escapement of Chinook to Central Valley streams and hatcheries. The CVI varied between 0.55 and 0.80 from 1970 to 1995, when management actions were instituted to protect winter run populations. In 2001, the CVI fell to 0.27, implying that marine exploitation of winter-run Chinook is less than 27%. For the years 2000-2007, the exploitation rate range was 15-21% (NMFS 2010c).

### ***Upper Columbia Spring Chinook***

#### ***Population Status: In Danger of Extinction***

Upper Columbia spring Chinook salmon runs also remain in very poor health, and appear to be continuing to deteriorate. Columbia spring Chinook are particularly unusual, in that, unlike Chinook salmon in other regions, in the interior Columbia River Basin, spring-run Chinook populations are notably genetically divergent from summer- and fall-run populations. This difference represents an older evolutionary event (Waples et al. 2004). Unfortunately, long-term trends in spawning escapement are negative in all three of the main spawning areas (Wenatchee River, Entiat River, and Methow River) for spring-run Chinook. The BRT (BRT 2003) reports: “The Wenatchee River spawning escapements have declined an average of 5.6% per year, the Entiat River population at an average of 4.8%, and the Methow River population an average rate of 6.3% per year since 1958.” These declining population trends continued through 2001. Similarly, short-term trends in population size (1990-2001) were also negative for all three upper Columbia River spring Chinook populations, on average falling between 3% and 16%. Average spawning escapement from 1997 to 2001 fell to between 8% and 15% of target delisting levels. One study estimates that there is over a 50% chance Upper Columbia River spring Chinook will be extinct in fifty years, and greater than a 95% chance that the population will suffer a decline more than 90% (McClure et al. 2003).

#### ***Bycatch Rates***

Uncertainty regarding Chinook populations and their ocean harvest rates make it difficult to assess the status of the stock. Exploitation rates of Upper Columbia River Chinook salmon spring-run in the lower-river commercial fishery are estimated to have been around 30-40% through the early 1970s, primarily from main-stem fisheries below McNary Dam and recreational fisheries. No current data are available, but this rate has been reduced substantially (BRT 2003). The PFMC estimates that Council-managed ocean fisheries harvest less than 2% of summer- and spring-run Columbia River Chinook (this does not include in-river exploitation or British Columbia and Alaskan ocean salmon fisheries).

### ***California Central Valley Spring Chinook***

#### ***Population Status: Likely to Become Endangered***

Only three populations of California Central Valley spring-run Chinook salmon with consistent spawning runs remain: Mill Creek, Deer Creek, and Butte Creek. Despite historically supporting runs in the range of 700,000 spawners, during the 1980s populations fell to a few hundred fish on average. Spring-run salmon have been eliminated from most of the Central Valley, including all San Joaquin River tributaries.

Following changes in management and some habitat improvements in the early 1990s,

populations in the three remaining runs started to rebound. Both long- and short-term growth rates in the population of these runs are positive, with maximum returns in the last five years of ~6,000 fish.

#### *Bycatch Rates*

As with winter-run Chinook, bycatch rates of Central Valley spring-run Chinook are estimated through the Central Valley Chinook salmon ocean harvest index (CVI). The CVI ranged between 0.55 and 0.80 from 1970 to 1995. In 2001, the CVI fell to 0.27, implying that spring Chinook exploitation rates are under 27%. This reduction is presumed to be partly responsible for the rebound in spring-run populations. No more specific estimates of spring-run exploitation rates are available.

#### *California Coastal Chinook*

##### *Population Status: Likely to Become Endangered*

Data on the abundance and distribution of the California Coastal Chinook ESU are sparse. The stock was listed as threatened in previous reviews due to several concerns including low and declining abundance, as well as a reduced geographic range. In the mid-1960s, the already highly degraded habitat supported an estimated 70,000 spawners. Today, abundance in independent populations of California Coastal Chinook salmon appears depressed to just a few thousand fish in the few basins where they are monitored. In addition, many populations no longer exist. The BRT (2003) notes: “Reduction in geographic distribution, particularly for spring-run Chinook salmon and for basins in the southern portion of the range, continues to present substantial risk.”

There has been a recent increase in returns to the Russian River, with between 1,300 and 5,500 spawners over the past three years of data; however, the genetic composition of these runs is uncertain (i.e., they may be of hatchery origin, rather than wild fish), such that their relevance to the overall status of the ESU remains unclear.

#### *Bycatch Rates*

Incidental landings of California Coastal Chinook have not been explicitly estimated. In 2000, NMFS concluded that ocean salmon fishing in accordance with the Salmon Fishery Management Plan (FMP) was likely to jeopardize the continued existence of California Coastal Chinook. Harvest rates have been reduced and the PFMC considers it likely that “current restrictions on harvest of Klamath River fall Chinook maintain low ocean harvest of Chinook salmon from the California Coastal ESU” (BRT 2003). In other words, restrictions on the ocean fishery targeting Klamath River Chinook have reduced the exploitation of California Coastal Chinook.

#### *Upper Willamette Chinook*

##### *Population Status: Likely to Become Endangered*

Little information is available for Upper Willamette Chinook runs, which are obviously in poor health. The BRT concisely notes: “Most natural spring Chinook populations are likely extirpated or nearly so. The only population considered potentially self-sustaining is the McKenzie. However, its abundance has been relatively low (low thousands) with a substantial number of these fish being of hatchery origin. The population has shown a substantial increase in the last couple of years, hypothesized to be a result of improved ocean survival” (BRT 2003).

### *Bycatch Rates*

No estimates are provided by the PFMC for Upper Willamette Chinook. However, an independent analysis (McClure et al. 2003) found that “changes in the harvest levels could have relatively large effects on the population growth rates of the Upper Willamette River, Snake River fall, and Lower Columbia River Chinook ESUs. These three ESUs are subject to harvest both in the ocean and in-river, resulting in higher overall harvest rates than those seen in other ESUs.”

### ***Lower Columbia River Chinook***

#### ***Population Status: Likely to Become Endangered***

Lower Columbia River Chinook are threatened, with wild spawner abundances continuing to decline since 1998 and short and long-term population growth rates negative. Spring-run Chinook have largely been extirpated due to habitat loss from hydroelectric facilities. Fall runs have fared only marginally better, with populations diluted through large-scale hatchery releases as well as “relatively high harvest and extensive habitat degradation” (BRT 2003). Only one remaining run, the Lewis River late fall Chinook run, maintains a significant probability of being self-sustaining.

### *Bycatch Rates*

An estimated 40% of Lower Columbia River adults in the runs that have not been extirpated are harvested. The BRT (2003) characterizes these rates as “relatively high.” Reductions in fishery exploitation could have significant positive effects on the growth rate of this ESU (McClure et al. 2003).

### ***Snake River Spring/Summer Chinook***

#### ***Population Status: Likely to Become Endangered***

Historic abundance of spring- and summer-run Chinook in the Snake River may have totaled more than 1.5 million spawners per year. By the late 1960s returns were closer to 100,000, and have continued to decline. In recent years, less than 5,000 summer-run salmon have been recorded in the Snake River, and spring-run returns passing over Lower Granite Dam have generally remained well under 20,000 fish. As such, long-term population growth rates since the 1960s are less than 1.0. While year 2001 spawner abundances were substantially higher than in past years (more than 17,000 naturally-produced spring Chinook), hatchery fish appear to have excessive influence on the stock, with an estimated 88% of hatchery origin (BRT 2003).

### *Bycatch Rates*

No quantitative estimates of landings of Snake River spring/summer Chinook runs are available. The Biological Review Team simply asserts that “harvest impacts on Snake River spring Chinook are generally low. Ocean harvest rates are also low” (BRT 2003). Feist, Steel et al. (2003) comment that, for the Snake River spring/summer Chinook ESU, “there is an enormous urgency to reverse their population decline. Hatchery supplementation and harvest pressure reductions (currently estimated at ~8%...) apparently have not reversed population declines.”

### ***Snake River Fall Chinook***

#### ***Population Status: Likely to Become Endangered***

Snake River fall-run Chinook salmon have suffered major declines in abundance since as late as the 1970s. However, since the mid-1990s Snake River fall runs have improved, due in large



measure to increased hatchery production. Long-term growth rates are masked in part by the presence of hatchery fish, but appear to be somewhere between 0.90 and 1.02 (declining or stable). Wild salmon returns were estimated at 2,600 fish in 2001, with a 5-year average of 870 fish, well shy of the delisting abundance criteria for Snake River fall Chinook (an 8-year average of 2,500 natural spawners).

#### *Bycatch Rates*

Previous reviews of Snake River fall Chinook identified the “relatively high aggregate harvest impacts in ocean and in-river fisheries” as one of the main causes for concern in this ESU (BRT 2003). Snake River fall Chinook are landed in a number of fisheries because of their pattern of ocean distribution and the timing of their spawning run up the Columbia River. Since 1990, landings of Snake River fall Chinook have eliminated between 20% and 40% of returning fish (BRT 2003). The current allowable total exploitation rate on Snake River fall fish is 50%. Statistical analysis indicates that reductions in the harvest level of Snake River Chinook could have relatively large positive effects on the population growth rates of the ESU (McClure et al. 2003).

#### ***Puget Sound Chinook***

##### *Population Status:* **Likely to Become Endangered**

Historically, the Puget Sound area supported Chinook salmon runs of nearly 700,000 fish. By the early 1990s, the average run size had been reduced to 24,000 fish—less than 4% of its traditional breadth. Nine of the thirty-one known runs appear to have been completely eliminated, and at present populations in half of the remaining runs are declining, while populations in the remaining half are increasing. Over the past decade, salmon populations have fared less poorly and many have halted the declines in their numbers, though these recoveries may be attributable in part to hatchery fish. If hatchery fish spawn at the same rate as wild fish, then half of the runs have continued to decline over the past decade (BRT 2003).

#### *Bycatch Rates*

The BRT characterizes the exploitation of the Puget Sound stocks over the past two decades as “quite high,” with average exploitation on natural stocks in the 1980s between 65% and 85%, exceeding 90% for specific stocks. Over the most recent five years for which data is available, harvest rates on Puget Sound Chinook populations averaged 44% overall, but ranged between 26% and 63% by population.

#### **Coho, Chum, and Sockeye Salmon, and Steelhead**

As with Chinook salmon, several other salmon stocks are in very poor shape. For example, of the six coho evolutionarily significant units (ESUs) identified for California, Oregon, and Washington, the Biological Review Team has listed two coho ESUs as endangered (Central California Coast coho and Lower Columbia River/Southwest Washington coho) and two coho ESUs as likely to become endangered (Southern Oregon/Northern California Coastal coho and Oregon Coast coho). Interior Fraser coho in British Columbia has been listed as endangered by Canadian authorities. Similarly, two chum stocks, two U.S. sockeye stocks, two Canadian sockeye stocks, and numerous steelhead stocks are listed as endangered.



Bycatch represents a potential threat to fish in these ESUs, which can be caught in commercial and recreational salmon fisheries. Unlike Chinook salmon, directed commercial fisheries for these non-target fish have been closed for several years. However, wild fish are still caught accidentally in Chinook fisheries and recreational coho fisheries in the Pacific Northwest.

The Pacific Fisheries Management Council (PFMC) has made several efforts to reduce coho and other salmon landings and discards. The 1999 Supplemental Biological Opinion and Incidental Take Statement for coho required the following: 1) no directed coho fishing in all commercial and recreational fisheries off California; 2) marine fishery impacts on threatened coho stocks must be no more than 13%; and 3) fishery impacts on Oregon Coastal stocks should not exceed levels permitted by the Salmon FMP, which was 15% in 2003. In 2003 the PFMC prohibited all retention of coho in fisheries south of Humbug Mountain, Oregon (Figure 2.14). Seasons were also adopted for the rest of the fishery that would result in exploitation rates of 9.6% of Rogue/Klamath coho and 14.4% for Oregon Coastal coho. Chinook fishery closures and gear restrictions were also used to reduce Oregon Coastal impacts.

Despite the non-retention regulations, some discard mortality continues. Studies of adult coho salmon indicate that fish captured in various gear types (troll, gillnet, and seine) arrive on board “in a state of severe metabolic exhaustion,” with minimal physiological differences observed between salmon caught in different gear types (Farrell et al. 2000). Following a literature review, the PFMC adopted an estimate of the hooking mortality rates of 13% for recreational fisheries and 24% for commercial fisheries. On top of these rates, the PFMC assumed that dropoff mortalities occur, and estimated the number to be 5% of the number of fish landed (BRT 2003).

As with Chinook, the following section documents existing information on the current population status of endangered and threatened ESUs for both various non-target salmonids

### ***Central California Coast Coho***

#### ***Population Status: In Danger of Extinction***

Best guesses indicate that spawning populations of Central California Coast (CCC) coho were in the range of 200,000 to 500,000 fish in the 1940s, well after substantial habitat damage had occurred. By the late 1980s, wild coho in this ESU are thought to have declined to less than 7,000 fish. The California Department of Fish and Game reports that CCC coho are no longer present in 58% of the streams they historically inhabited, and that occupancy trends continued to decline between 1987 and 2000, though they increased in 2001. With state coho populations at just 6-15% of levels in the 1940s, the California Fish and Game Commission voted in August 2004 to list coho south of Punta Gorda as endangered under the California Endangered Species Act, and coho north of Punta Gorda as threatened.

#### ***Bycatch Rates***

Retention of coho is prohibited in both recreational and commercial troll fisheries in California and southern Oregon in an effort to reduce impacts. North of Humbug Mountain in Oregon, selective fishing is allowed for hatchery-marked coho. The recent status reviews note that despite non-retention regulations, some mortality may be associated with coho incidentally-caught in the Chinook fishery, or through poaching. The numbers incidentally taken and released are not well known. The BRT reports that “total estimated incidental and illegal harvest of coho salmon has not exceeded 1000 fish in any year since non-retention regulations were put in place” (BRT

2003). Inferred exploitation rates of this stock, from 1998 to 2002, still range from 3-12%. These exploitation rates are below the threshold goal of 13% set by the PFMC.

### ***Interior Fraser Coho***

#### ***Population Status: In Danger of Extinction***

Interior Fraser coho are one of three Canadian salmon stocks listed as endangered. There are no estimates of the abundance of Interior Fraser coho salmon prior to the arrival of Europeans. Abundance in the 1920s and 1930s has been estimated at roughly 400,000 fish. In recent years, the total population of spawners has been reduced to around 24,000 fish, roughly 15% of which are of hatchery origin (Irvine 2002). In 1991, 1995, 1997, and 1998, productivity was so low that the ESU was unable to sustain itself even with no fisheries exploitation.

#### ***Bycatch Rates***

Canadian fishery managers report that “coded wired tags from coho salmon that were spawned in the interior Fraser River have been recovered in fisheries from Alaska to Oregon. Most were gathered during troll and sport fisheries off the West Coast of Vancouver Island and in the Strait of Georgia” (Irvine 2002). Even recently, exploitation rates were historically very high. From 1987 to 1996 the estimated annual exploitation rate for Interior Fraser coho salmon (U.S. and Canada) was 68%. Following management action the rate was reduced ten-fold to 6.5% from 1998 to 2000 (Irvine 2002).

### ***Southern Oregon/Northern California Coho***

#### ***Population Status: Likely to Become Endangered***

Abundance data for the Southern Oregon/Northern California Coast (SONCC) coho population are sparse, particularly for the California share of the ESU. Generally, annual spawner populations are known to have declined from several hundred thousand fish in the 1940s, to an estimated 7,000 SONCC fish in California in the late 1980s. From the late 1980s to 2000, the estimated percentage of streams in the SONCC for which coho were detected ranged between 36% and 61%. There was generally a decline in occupancy rates over the past decade, the significance of which is unclear.

#### ***Bycatch Rates***

As with Central California Coast coho, retention of non-hatchery SONCC coho is prohibited. Any fishing mortality is presumably either incidental mortality or from poaching. No reliable numbers are available for the number of coho killed incidentally. The majority (93-97%) of ocean fishing mortality of SONCC coho appears to occur in Chinook-directed fisheries in California and Oregon, south of Humbug Mountain, rather than in hatchery coho-directed fisheries. The PFMC determines mortality by proxy via mortality on Rogue and Klamath River (RK) hatchery stocks. Current exploitation rates on these stocks are low; they are estimated to generally lie in the range of 3-8%, comfortably below the management target of <13% (BRT 2003).

### ***Oregon Coastal Coho***

#### ***Population Status: Likely to Become Endangered***

As with other salmon ESUs, spawning escapements of Oregon Coastal coho have declined substantially over the past century, and may have sunk to less than 5% of historical abundances.

The decline in average spawner abundance appears to have halted in the late 1970s; however, the decline in pre-harvest abundance has continued. In 1996, the five-year average spawner abundance for the Oregon Coastal coho ESU was roughly 50,000 fish, an order of magnitude less than abundance a century prior, and one-third the abundance seen in the 1950s. Long-term trends in escapement, run size, and recruits-per-spawner are all declining.

#### *Bycatch Rates*

Bycatch occurs in both recreational fisheries for hatchery-marked coho and in commercial Chinook trolling fisheries. From 1998 to 2002, fishery exploitation was estimated to be between 7% and 12%, considerably below pre-ESA listings of exploitation rates as high as 70%. However, the BRT comments: “There is concern that these rates may be underestimates, and that actual mortalities may be greater. It is difficult to assess the risk to these stocks resulting from harvest at these levels” (BRT 2003).

#### *Lower Columbia River Coho*

##### *Population Status: In Danger of Extinction*

Lower Columbia River coho salmon are in extremely poor health, and remain in imminent danger of extinction. Over 90% of the historical populations in the Lower Columbia River have been effectively extirpated, with just two populations (the Clackamas and Sandy River) supporting runs. Both the Clackamas and Sandy River runs reflect “low abundance, declining trends and failure to respond after a dramatic reduction in harvest” (BRT 2003). In the Clackamas River, the native run is at a high risk of extinction, while the Sandy River coho population has also failed to recover. A slight rebound seen in 2000 and 2001 was not repeated in 2002. In summary, BRT (2003) states: “Of the 21 putative populations, most were considered extirpated, or nearly so, during the low marine survival period of the 1990s (reviewed in NMFS 2001a). Of the two populations where natural production can be evaluated, both have experienced recruitment failure over the last decade. Recent abundances of the two populations are relatively low (especially the Sandy River), placing them in a range where environmental, demographic and genetic stochasticity (sic) can be significant risk factors.” The stock was downlisted to “Threatened” in 2005.<sup>23</sup>

#### *Bycatch Rates*

In the last three seasons, the harvest rate for Clackamas River natural-origin coho is estimated to be approximately 10%. This exploitation rate is significantly below rates above 60% that were the rule prior to 1994. The BRT provided no analysis on the effects of the harvest rate on population stability.

#### *Hood Canal Summer Run Chum*

##### *Population Status: Likely to Become Endangered*

The Hood Canal summer-run chum ESU is listed as threatened, and remains listed as likely to become endangered. Of the sixteen historic populations of summer-run chum in the Hood Canal ESU, half no longer exist. Abundance trends in the remaining eight are negative for all but two runs (the Quilcene and Union Rivers), with the median late indicating a decline of 6% per annum. Short term trends in abundance have been more positive, with seven of the eight remaining populations growing between 1990 and 2002.

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<sup>23</sup> <http://www.nmfs.noaa.gov/pr/species/esa/fish.htm#note>

### *Bycatch Rates*

In the 1997 BRT review, one of the several threats identified to the continued existence of summer-run Hood Canal chum salmon was a high incidental harvest in salmon fisheries in Hood Canal and the Strait of Juan de Fuca. The mean exploitation rate from 1979 to 1997 was 36%. Following changes in fisheries management, the estimated exploitation rate has dropped substantially. From 1998 to 2002, the estimated fishery exploitation rate for Hood Canal summer-run chum varied from 1% to 13% by population, with a mean exploitation rate for remaining populations of 4%. The BRT does not provide an estimate for the effects of the remaining harvest on recovery prospects.

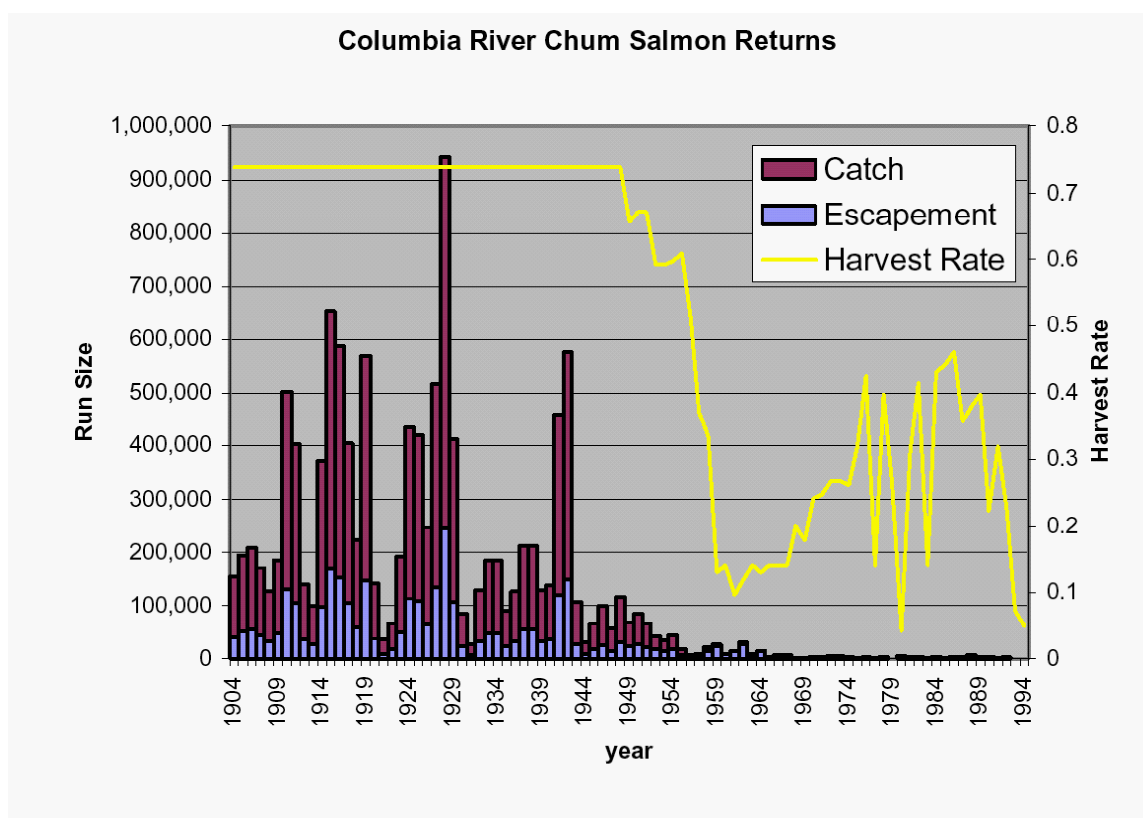
### ***Lower Columbia River Chum***

#### ***Population Status: Likely to Become Endangered***

The Lower Columbia River chum salmon ESU has also been decimated over the past century. Historical runs approaching one million fish per year have averaged just a few thousand fish over the past half century. Of the 16 known historical populations, only two remain (Grays River and the Lower Gorge). For the Grays River run, long-term trends in abundance have been negative since 1950 and over the short-term as well. Similarly, in the Lower Gorge, available data indicate that since 1950 there has been a downward trend in populations and low abundances up to 2000. Year 2002, however, witnessed a substantial increase in spawner abundance.

### *Bycatch Rates*

As with other stocks, no information is available on estimated harvest rates for Lower Columbia River chum. Historical estimates of harvest rates over the past century (through 1994) are provided in Figure 3.1. They are estimated/presumed to have been at 80% in the earlier half of the century. In the 1960s, most chum salmon were caught incidentally in fisheries targeting hatchery coho salmon. Recent harvest rates have presumably remained below 10%. Incidental catch of chum salmon in the Lower Columbia River commercial fishery has been less than 100 fish per year since 1993 (WDFW 2002a). No estimates of the effects of these harvest rates have been provided.



**Figure 3.1. Columbia River chum salmon returns (BRT 2003).**

### *Snake River and Ozette Lake Sockeye*

Population Status: **Ozette Lake: Likely to Become Endangered**

**Snake River: In Danger of Extinction**

Of the six or seven sockeye salmon ESUs on the West Coast, two have been listed under the U.S. Endangered Species Act (ESA). Neither the Snake River nor the Ozette Lake sockeye salmon ESUs are faring well. In the case of the Snake River, just sixteen naturally-produced adult fish have returned to spawn since 1991, and all sixteen were immediately placed into the captive spawner program. The BRT unanimously voted that the Snake River ESU is in danger of extinction.

The Ozette Lake sockeye salmon ESU was listed as threatened in 1999. Historic run sizes of 3,000-18,000 fish have been reduced to five-year averages of fewer than 1,000 fish in the early 1990s and 2,270 fish most recently, with a substantial portion of these fish of hatchery origin.

### *Bycatch Rates*

While past over-exploitation was a contributor to the decline of the Snake River and Ozette Lake ESUs, current ocean harvest has not been identified as a current factor in either ESU's decline. No more information is available.

### *Cultus Lake and Sakinaw Lake Sockeye*

Population Status: **Cultus Lake: In Danger of Extinction**

**Sakinaw Lake: In Danger of Extinction**

In addition to U.S. sockeye, British Columbia has two endangered populations of sockeye that may occasionally be landed by U.S. fisheries. Both the Cultus Lake and Sakinaw Lake populations are officially listed as endangered. Both lakes historically supported modest populations of sockeye salmon; though, today, they are severely depleted. The most recent estimates indicate that Cultus Lake sockeye populations have been reduced from a historical abundance of about 20,000 fish to roughly 500 fish in 2004 (CSRT 2004). The declines in Sakinaw Lake are even more severe. From 1947 to 1987, returns averaged 5,000 fish. In 2002, only 78 fish were counted entering the Sakinaw Lake. In 2003, only 3 fish entered, just one of which was observed spawning (SSRT 2004).

### *Bycatch Rates*

Over-exploitation prior to 1995 was the primary cause of the population collapses in Cultus and Sakinaw lakes. Currently, some fish from the lakes may be incidentally landed. Cultus and Sakinaw Lake sockeye spend two years offshore in the Gulf of Alaska before returning to British Columbia (B.C.) to spawn. "Cultus sockeye are part of a convoy of maturing adults from several Fraser populations, all of which can be intercepted by mixed-stock fisheries along the coast of B.C. and in the Fraser River" (CSRT 2004). The ocean distribution of Sakinaw Lake sockeye is largely unknown. The Recovery Team report comments: "Mixed stock fisheries can unintentionally kill adult Sakinaw sockeye during their return migration. Little information is available on the migratory route or timing of Sakinaw sockeye so precautionary management of the mixed-stock remains controversial and challenging" (SSRT 2004). Overall, current exploitation rates of Cultus and Sakinaw Lake sockeye are low, with most exploitation appearing to come from coastal B.C. and in-river fisheries rather than from U.S. fishermen.

### *Steelhead*

Population Status: **3 ESUs In Danger of Extinction**

**7 ESUs Likely to Become Endangered**

Steelhead is the name commonly given to anadromous rainbow trout (*Oncorhynchus mykiss*). The distribution of this species extends from Alaska to Southern California on the eastern side of the Pacific. As with salmon, the most southerly populations of steelhead have been decimated by a number of factors over the past two centuries. The most recent BRT assessed ten steelhead ESUs, of which three were considered in danger of extinction and seven were declared likely to become endangered. As most of the rivers that support salmon also support steelhead, and there is also overlap in use of coastal waters, there is the potential for steelhead bycatch from directed salmon fisheries.

### *Bycatch Rates*

Reportedly, for Northern California steelhead, “ocean harvest is a rare event, so effects on extinction risk are negligible” (BRT 2003). No numerical data have been provided by NMFS. However, bycatch rates from in-river harvest are not negligible. For example, the Columbia River summer Chinook fishery is limited by steelhead bycatch.

### **Synthesis**

Due largely to the selective nature of the gear, discards in commercial salmon trolls and gill-nets, as well as in recreational salmon fisheries, appear to be at relatively low levels (i.e., < 10% of landings). The bycatch of sea-birds occurs in the fishery (more common to gill-netters than to trolls), and incidental takes of groundfish and other non-salmonids also occur, but all appear to be at relatively low levels (i.e., < 1% of groundfish optimal yields) and are not impacting populations of non-target species.

Of considerably greater concern is the regular presence of listed salmon in the landings of the mixed-stock fishery. This includes both fish that are discarded, including coho, and those that are retained, such as several Chinook stocks. Data on the regularity of these landings and their implications for the recovery of listed stocks are sparse. The lack of actual data on harvest impacts and the diversity of other impacts on listed stocks make it difficult to assess the effects of ocean fishing on these stocks. Certainly fishing effort in the salmon fishery has been drastically reduced in the past 20 years. In addition, strong management actions have been put in place to address overfishing and bycatch. Yet many of the listed stocks continued to decline. As Table 3.3 indicates, where data are available current exploitation rates of listed stocks vary from a few percent up to forty percent. Almost all of the threatened and endangered fish undergo some fishing pressure, and in several cases there is strong evidence that this exploitation is constraining recovery or contributing to continuing declines.

The Seafood Watch wild-capture fisheries methodology considers a bycatch rate that is “a contributing factor in limiting the recovery of a species of special concern” to have severe population consequences. While the jeopardy standard for bycatch of endangered or threatened species is also based on population impacts, a “severe” bycatch ranking in a Seafood Watch® evaluation is more precautionary than the jeopardy standard. This reflects the Monterey Bay Aquarium’s strong conservation ethic and the fact that fisheries with “severe” bycatch can still receive an overall recommendation of “Good Alternative”. Thus, bycatch mortality levels that are not high enough to appreciably decrease the likelihood of survival and recovery (satisfying the jeopardy standard) may still be ranked severe if they are sufficient to slow or limit the extent of the population’s recovery.

Geographically, the endangered and threatened salmon ESUs are located in California, Oregon, Washington, and British Columbia. In Alaska, the general health of salmon populations has meant that incidental mortality of non-target salmon is addressed as landings rather than as bycatch. However, Alaskan fisheries may capture fish from listed stocks in the Pacific Northwest. It is likely that there are some regular landings of listed fish in the Alaskan Chinook salmon fishery in Southeast Alaska. For example, Snake River fall-run Chinook (threatened) are harvested in the Alaskan fishery. Because harvest rates of endangered and threatened salmon

stocks in Alaska are low, and are not believed to constrain recovery or to contribute to declines in these stocks, bycatch of listed salmon in Alaska's fishery is considered a moderate conservation concern.



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### Primary Bycatch Factors to Evaluate

Quantity of bycatch, including any species of “special concern” (i.e., those identified as “endangered,” “threatened,” or “protected” under state, federal or international law):

#### *Alaska*

- **Quantity of bycatch is low (< 10% of targeted landings on a per number basis) AND does not regularly include species of special concern** 
- **Quantity of bycatch is moderate (10–100% of targeted landings, by number) AND doesn't regularly include species of special concern OR unknown** 

#### *California, Oregon, Washington*

- **Quantity of bycatch is high (> 100% of targeted landings by number) OR bycatch regularly include threatened, endangered, or protected species** 

Population consequences of bycatch:


#### *Alaska (except Chinook)*

- **Low: Evidence indicates quantity of bycatch has little or no impact on population levels** 

#### *Alaska (Chinook only)*

- **Moderate: Conflicting evidence of population consequences of bycatch OR unknown** 

#### *California, Oregon, Washington*




- **Severe: Evidence indicates quantity of bycatch is a contributing factor in driving one or more bycatch species toward extinction OR is a contributing factor in limiting the recovery of a species of “special concern”** 

Trend in bycatch interaction rates (adjusting for changes in abundance of bycatch species) as a result of management measures (including fishing seasons, protected areas, and gear innovations):

#### *California, Oregon, Washington*




- **Trend in bycatch interaction rates is down** 

#### *Alaska*

- **Trend in bycatch interaction rates is flat OR unknown** 
- **Trend in bycatch interaction rates is up** 
- **Not applicable because bycatch is low** 

### Secondary Factor to Evaluate

Evidence that the ecosystem has been or likely will be substantially altered (relative to natural variability) in response to the continued discard of the bycatch species:

- **Studies show no evidence of ecosystem impacts** 
- **Conflicting evidence of ecosystem impacts OR unknown** 
- **Studies show evidence of ecosystem impacts** 

## Evaluation Guidelines

Bycatch is “**Minimal**” if:

- 1) Quantity of bycatch is <10% of targeted landings AND bycatch has little or no impact on population levels.

Bycatch is “**Moderate**” if:

- 1) Quantity of bycatch is 10-100% of targeted landings OR
- 2) Bycatch regularly includes species of “special concern” AND bycatch has little or no impact on the bycatch population levels AND the trend in bycatch interaction rates is not up.

Bycatch is “**Severe**” if:

- 1) Quantity of bycatch is > 100% of targeted landings OR
- 2) Bycatch regularly includes species of “special concern” AND evidence indicates bycatch rate is a contributing factor toward extinction of such species or limiting their recovery AND trend in bycatch is down.

Bycatch is considered a **Critical Conservation Concern** and the species is ranked “Avoid,” regardless of other criteria if:

- 1) Bycatch regularly includes species of special concern AND evidence indicates bycatch rate is a factor contributing to extinction of such species or limiting their recovery AND trend in bycatch interaction rates is not down OR
- 2) Quantity of bycatch is high AND studies show evidence of ecosystem impacts.

### *Conservation Concern: Nature and Extent of Discarded Bycatch*

#### **Pacific Salmon in AK (except Chinook)**

- Low (Bycatch Minimal) 

#### **Chinook Salmon in AK**

- Moderate (Bycatch Moderate) 

#### **Pacific Salmon in CA, OR, and WA**

- High (Bycatch Severe) 

#### **Criterion 4: Effect of Fishing Practices on Habitats and Ecosystems**

*Guiding Principle: A sustainable wild-caught species maintains natural functional relationships among species in the ecosystem, conserves the diversity and productivity of the surrounding ecosystem, and does not cause irreversible ecosystem state changes.*

##### **Direct Habitat Effects from Fishing Gear**

In addition to the direct effects of fishing gear on target and non-target animals, large-scale fishing is capable of generating a broader set of impacts on habitats and associated ecosystems. Most of the work on the habitat effects of fisheries has examined the physical alterations of benthic habitats resulting from contact with mobile gear and the removal of various biotic components of the ecosystem. Auster and Langton (1999) synthesized the results of more than 90 gear impact studies: the vast majority documented some degree of habitat impact from mobile fishing gear, typically involving a reduction in habitat complexity, an alteration of community structure, and some change in ecosystem processes.

The salmon fisheries discussed in this report predominantly employ three types of gear: seines, gillnets, and hook-and-line gear (Figure 4.1). Unlike bottom otter-trawls and dredges, seines, mid-water gillnets, and hook-and-line gear have minimal contact with the sea floor.<sup>24</sup> According to several recent reviews of the effects of fishing gear (Gordon et al. 1998, Johnson 2002, Morgan and Chuenpagdee 2003) hook-and-line gear (i.e., trolling) has little to no physical impact on the benthic environment. Similarly, seines and mid-water gillnets (which are not grounded) have little documented effect. According to a recent NMFS technical memorandum, however, few studies have looked at the direct effects of nets on habitat. In those studies that did examine the issue, the only identified effects involved the entanglement of nets in hard bottom areas, particularly in corals. A larger number of studies have examined the role of lost gillnets in “ghost fishing.” The technical review summarizes:

Lost gillnets, in particular, often get caught on and damage or cover hard bottoms and reefs. However, these nets are quickly covered by encrusting epifauna, and eventually blend into the background habitat (Carr et al. 1985, Cooper et al. 1988, Erzini et al. 1997, ICES 2000). Erzini et al. (1997) observed that lost gillnets became incorporated into the reef and provided a complex habitat that was attractive to many organisms. Carr and Milliken (1998) noted that in the Gulf of Maine, cod reacted to lost gillnets as if they were part of the seafloor. Thus, other than damage to coral reefs, effects on habitat by gillnets are thought to be minimal (ICES 1991, 1995, Stephan et al. 2000, (Johnson 2002)

In summary, the evidence indicates that salmon fishing gear has no significant direct physical effect on marine or freshwater habitats. Mid-water gillnets, seines, and hook-and-line gear were all ranked among the least damaging gear types by a panel of experts (Chuenpagdee et al. 2003).

Indirectly, however, there is substantial evidence to indicate that the commercial salmon fishery *system* does affect aquatic habitats. First, the *removal* of salmon stocks that have been overfished

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<sup>24</sup> Set gillnets are also used in some areas (e.g., Bristol Bay). They are also thought to have small to moderate habitat impacts.

or otherwise depleted can affect productivity and disturbance in freshwater habitats. Second, the *supplementation* of salmon through hatchery programs significantly alters both the freshwater and marine habitats of wild salmon.<sup>25</sup>



**Figure 4.1. Driftnet and troll gear types ([www.goldseal.ca/](http://www.goldseal.ca/)).**

### **Habitat Effects of Salmon Removal**

As the Inherent Vulnerability criterion catalogued, salmon populations in numerous watersheds have undergone severe population declines over the past two centuries. These declines are due in part to historic, and in some cases present, fisheries exploitation. Studies indicate that the reduction in spawner populations can alter freshwater habitat in these watersheds through at least two pathways.

First, due to their anadromous and semelparous nature, salmon runs transfer significant quantities of marine nutrients (via carcasses) to freshwater ecosystems. The fundamental concern is that declines in spawning salmon stocks may represent an important loss of nutrient and energy inputs to many freshwater systems. In addition to returning salmon forming an important component of the seasonal food web, the nutrients in salmon carcasses can increase the productivity of some freshwater bodies. By reducing the number of returning spawners, fisheries concomitantly diminish the input of high-quality marine nutrients into lake systems. In oligotrophic systems, the decrease in nutrient inputs may suppress the overall productivity of the freshwater body (Finney et al. 2000). Empirical analysis indicates that salmon carcasses can influence the primary productivity of forested stream ecosystems (Johnston et al. 2004). The authors found that sockeye spawner abundance raised stream-water nutrient concentrations and chlorophyll *a* concentrations in the summer and fall when peak primary production occurred in the tested oligotrophic streams (Johnston et al. 2004).

<sup>25</sup> The apparent contradiction between claiming that habitat effects emerge from both the addition and subtraction of salmon is recognized, but is largely superficial. To some extent, conservation-oriented hatcheries may offset the habitat effects of the removal of wild salmon (e.g., reductions in freshwater productivity and the physical disturbances associated with digging redds) but these supplementations have neither been universal nor necessarily balanced. However, the deleterious habitat effects of salmon supplementation involve the degradation of the *ecological* habitat of wild salmon (e.g., density-dependent mortality effects, competition for food and space, alterations to the gene pool). Whereas increases in the populations of wild salmon are positive outcomes for ESUs, increases in hatchery-origin salmon can be markedly detrimental.

Experimentally, the presence of carcasses has been associated with faster growth rates (and presumably higher survival rates) of coho salmon and related salmonids such as cutthroat trout and Dolly Varden (Wipfli et al. 2003). Similarly, a second set of authors have speculated that observed density-dependent mortality suffered by juvenile Chinook in heavily depleted areas such as the Snake River Basin may be in part due to a shortage of nutrients previously delivered by salmon carcasses (Achord et al. 2003). The magnitude of these losses is uncertain, and clearly depends on the size of the run and the freshwater system, among other factors.

Second, spawning salmon physically alter freshwater benthic habitats. Most notably, female Pacific salmon dig nests (known as redds) to deposit their eggs. Depending on the species, as well as size and location of the fish, a single redd may range between 1 m<sup>2</sup> and 17 m<sup>2</sup> in size and be up to 35 cm deep (Moore et al. 2004). Reductions in the size of spawning runs clearly reduces the density of redds, the significance of which—if any—has not been well documented. However, it has been noted that redd construction alters the substrate in spawning grounds and hastens sediment transport, with the added speculation that these actions may reduce the immediate abundance of benthic algae and invertebrates (Johnston et al. 2004).

As noted in the Inherent Vulnerability criterion, declines in the abundance of West Coast salmon are not solely attributable to salmon fisheries. To the extent that the declines are attributable to other factors, fisheries ought not be held culpable for habitat alterations in freshwater systems.

### **Habitat Effects of Salmon Supplementation**

Unlike most marine fisheries, the commercial salmon industry extensively benefits by using hatcheries to augment landings (see the Stock Status criterion). As these hatcheries represent part of the salmon system, the habitat effects of artificially propagated fish also need to be analyzed.<sup>26</sup> The following section summarizes the extent of the current hatchery system and the effects of the hatchery system on habitats.

#### ***Extent and Distribution of Salmon Hatcheries***

Since the 1860s, salmon hatcheries have been established in the western United States for fishery augmentation and later for mitigating habitat loss and degradation. Despite little evidence of their utility, half a billion artificially propagated salmon were released annually along the Pacific Coast in 1910 (Lichatowich et al. 1999).<sup>27</sup> In the recent past, the Pacific Rim nations released an estimated 5-6 billion hatchery-raised salmon (Noakes et al. 2000, Kelly 2001). Summary estimates compiled by Kelly indicate that:

- Japan has among the most advanced hatchery programs in the world, releasing close to two billion salmon annually. The Japanese primarily cultivate chum salmon, with some pink and masu salmon (*Oncorhynchus masou*) as well.

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<sup>26</sup> This discussion is primarily concerned with those hatcheries whose primary purpose is fisheries enhancement. Hatcheries existing purely for conservation-related goals may still affect habitat, but unlikely to have a significant detrimental effect.

<sup>27</sup> Prior to the 1960s, a combination of disease and malnutrition meant that few juvenile salmon actually survived to recruitment (Lichatowich et al. 1999).

- The United States releases in the range of one and a half to two billion fish per annum, which includes mainly pink and chum salmon (in Alaska), with some Chinook, coho, and sockeye salmon, and steelhead (from California through Alaska).
- As of the mid-1990s, Russia released a half billion salmon annually, roughly half chum and half pink salmon.
- Canada propagated just over 400 million salmon in 1998; mainly chum and sockeye.
- South Korea has a minor hatchery program for chum salmon, typically releasing fewer than 15 million fish per year.

With respect to the domestic hatchery industry, around 80% of U.S. salmon hatchery production occurs in Alaska. The remainder is split between Washington, California, Oregon, and Idaho.

#### *California, Oregon, and Washington*

In 1995, an estimated 470 million hatchery salmon were produced in the contiguous U.S. Nearly two-thirds (159 million Chinook, 59 million chum, 57 million coho, 16 million sockeye, and 11 million steelhead) were released in Washington (Kelly 2001). The remainder of salmon hatchery releases were mostly Chinook in Oregon (80 million fish), California (67 million fish), and Idaho (17 million fish). The statistics do not differentiate between hatchery propagation for conservation purposes, mitigation, and for fisheries augmentation.

The predominance of hatchery-fish is most notable in the Columbia River Basin. At present, the majority of returning spawners in the Columbia are hatchery-raised fish, originating at the ~170 hatcheries active in the basin. It is estimated that these hatcheries release about 200 million salmon and steelhead into the Columbia and Snake Rivers annually (Levin and Williams 2002). While only a third of the hatcheries report the number of fish that return, data from the mid-1990s indicates that hatchery fish accounted for four of every five salmon returning to the Columbia River (Robinson 2004, Stetkiewicz 2004). As of 1996, hatchery-reared fish in the Columbia River Basin comprised more than 95% of the coho,<sup>28</sup> 80% of summer-run Chinook, 70% of spring-run Chinook and steelhead, and 50% of fall-run Chinook (NRC 1996).

#### *Alaska*

Following a period of low salmon harvests in the mid-1970s, Alaska instituted a fisheries-augmentation oriented hatchery program that has grown to be among the world's largest. The state contains twenty-nine private, two state, and two federal hatcheries, which released nearly 1.5 billion salmon in 2002, resulting in 26 million fish harvested (Farrington 2003).<sup>29</sup> Hatcheries generated 23% of Alaska's commercial harvest in 2002. By species, Alaskan hatchery salmon releases are roughly the inverse of those in the Pacific Northwest, with a large majority of pink (938 million), chum (451 million), and sockeye salmon (67 million), and only relatively small releases of coho (20 million) and Chinook salmon (8 million) (Farrington 2003).

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<sup>28</sup> With respect to coho salmon, 70 million coho were released from Pacific Northwest hatcheries in 1995 (Kelly 2001). In GLOBEC trawl cruises off of Oregon in the summer of 2000, hatchery coho represented around half of the juvenile coho taken in the survey trawls (Brodeur et al. 2004).

<sup>29</sup> The two state hatcheries mainly produce salmon targeted in sport fisheries, while the private operations harvest adult fish to recoup their costs (Kelly 2001).

Geographically, Prince William Sound and Southeast Alaska are the primary regions in Alaska affected by hatchery programs (Farrington 2003). In 2002, half of Alaska's hatchery salmon releases were in Prince William Sound and nearly 30% were in Southeast Alaska, with the remainder split between Cook Inlet (9%) and Kodiak Island and the Alaska Peninsula (12%) (Farrington 2003). Nearly a third of the releases (400 million pink salmon) originated with one non-profit aquaculture corporation, the Prince William Sound Aquaculture Corporation (PWSAC) (Kelly 2001).

### ***Effect of Hatcheries on Habitat***

A small portion of the existing literature on hatcheries focuses on the impacts of hatchery salmon on wild salmon populations. Considerable scientific evidence demonstrates that the presence of hatchery-raised salmon can degrade wild salmon habitat. Cultured fish change the habitat of wild fish by competing for food resources and space, and by enhancing predator populations (OPR 2004). While the effects of hatcheries can be reduced through proper management, in many instances these effects are not adequately considered in the design of salmon hatchery programs (NRC 1996). Robert Lohn, regional administrator of NMFS, recently remarked: "The hatchery system is just not integrated with wild runs" (Robinson 2004). Lohn noted that on the West Coast, hatchery fish have an "adverse effect" on 13 or more of the 26 stocks of Pacific salmon protected under the Endangered Species Act (Robinson 2004). Similarly, a report by the University of Alaska-Anchorage exploring Alaskan salmon hatchery operations concluded that industrial-scale hatchery operations may be jeopardizing the long-term viability of Alaska's wild salmon (Kelly 2001).

While there are other pathways through which hatchery fish can affect wild fish, with respect to habitat, the addition of hatchery fish effectively alters the carrying capacity of freshwater and marine systems. Where they co-occur, cultured fish compete with wild salmon for food and space, effectively lowering the resources available to wild fish. Additionally, large numbers of hatchery releases can enhance predator populations, potentially increasing mortality effects on wild salmon (Kelly 2001, Myers et al. 2004). While it is possible to release hatchery salmon in tandem with changes in the carrying capacity and the population status of wild fish, Kelly (2001) observes that "hatchery fish are seldom released in numbers that are related to the carrying capacity of the receiving stream. The pre-smolt juveniles and any residuals will compete with their wild counterparts and lower the wild fish success by changing optimum habitat use of the wild fish."

Wild salmon may react to this changing environment in a number of ways, some of which are detrimental. A recent study on interactions between wild and hatchery Chinook salmon parr found that the behavior of wild fish (e.g., aggressiveness and habitat preference) changed markedly when hatchery fish were present, depending on the size of the hatchery salmon. It is speculated that these behavioral shifts could increase exposure to predators and increase the energy expenditures of wild salmon (Peery and Bjorn 2004).

More significantly, analysis by Levin, Zabel et al. (2001) statistically documents the detrimental competitive effects of hatchery salmon in the marine environment. Their work indicated that large numbers of hatchery-raised Chinook salmon decrease ocean survival rates of threatened wild Snake River spring Chinook. Marine mortality for salmon ranges 90-99%, with the highest

levels of mortality occurring during the early phases when wild and hatchery-raised juveniles co-occur in coastal waters. The strong, negative relationship between the wild Chinook survival and the number of hatchery fish released extends for a quarter of a century, and is particularly evident during periods of poor ocean conditions. Levin, Zabel et al. (2001) state: “When hatchery releases are high and poor ocean conditions result in reduced productivity, competition for limited food resources may occur. The pattern we observed of reduced survival of wild fish during ENSO events that coincide with large hatchery releases is consistent with this hypothesis.”

Levin and Williams (2002) have also demonstrated that the survival of Chinook salmon in the Snake River is negatively affected by hatchery releases of steelhead and salmon regardless of climatic conditions (Levin and Williams 2002). Again, hatchery releases are believed to generate density-dependent mortality on wild salmon.

In Alaska, concern over alteration of the ecological landscape by hatcheries centers on Prince William Sound, where four hatcheries release a half billion pink salmon each spring. Competition for food in the near shore environments of the Sound is likely to be fierce, as hatchery pinks outnumber wild pink salmon by a factor of two (Willette 2001, Willette et al. 2001). These competitive interactions may occur over a large geographic scale. For example, Alaskan sockeye salmon and Asian pink salmon populations interact in the Bering Sea. Sockeye salmon have lower survival rates during years when Asian pink salmon populations are higher, highlighting the potential habitat effects of hatchery releases for wild fish (Ruggerone et al. 2003). However, this review found no empirical documentation of negative impacts of hatchery fish on wild Alaskan stocks, as the apparent health of Alaskan stocks belies such effects. Even critics of Alaskan hatcheries have noted that “with respect to fish-culture practices, Alaska’s hatcheries are among the best in North America. The main reasons for this are both fortuitous and purposeful. By concentrating on pink and chum salmon, Alaska’s ocean-ranching program has avoided many of the attenuated problems (e.g., domestication and ecological) with long-term rearing species like steelhead trout and coho salmon. Given the late date at which Alaska’s ocean-ranching program was established, the state was able to benefit from mistakes made elsewhere. The program started on better footing by having genetic oversight of operations through fish transport permits, hatchery siting, egg takes, broodstock development, etc.” (Kelly 2001). Moreover, recent reductions in wild pink salmon runs in Prince William Sound appear to be primarily attributable to environmental factors, with the remaining escapement above management targets.

### **Synthesis**

The fishing gears used in salmon fisheries have minimal direct effects on physical and biogenic habitats. As the pelagic environment is highly resilient to the use of hook-and-line gear, seines, and gillnets, there are no lasting effects to evaluate.

Indirectly, salmon fisheries do alter habitats. First, the depletion of salmon runs appears to affect freshwater habitats both by reducing the transfer of marine nutrients, and by decreasing the physical disturbance created by spawning female salmon. The extent and implications of this phenomenon are neither well documented nor clearly attributable to current salmon fisheries (relative to habitat loss and other causes of salmon population declines), but represent an



important area for further study. Some analysts have estimated reductions in nutrient inputs from salmon up to 90% (Gresh et al. 2000); however, the ramifications of this finding in light of other anthropogenic changes (i.e., eutrophication, increases in biogeochemical cycles, reductions in the biomass of large predators, etc.) are poorly understood.

More significantly, the addition of artificially propagated salmon from the extensive West Coast hatchery complex affects the competitive landscape faced by wild salmon and other wildlife. In some situations, hatchery salmon may reduce the abundance of food available to wild fish, and may increase populations of predators. While the evidence has been limited to date, initial statistical work indicates that hatchery fish reduce survival rates of some runs of wild salmon—including endangered runs—particularly during periods where the ocean conditions are poor.

The wild fisheries criteria as written do not adequately accommodate a review of the effects of hatcheries. To address this limitation, the indirect effects of both wild stock depletions and hatchery augmentation have been incorporated into the review under the ecosystem effects factors. The reduced productivity of oligotrophic freshwater systems where salmon have been depleted or extirpated in California, Oregon, and Washington indicate that the removal of the targeted species may have disrupted freshwater ecosystem dynamics. In addition, there is strong evidence to suggest that the augmentation of hatchery salmon throughout the contiguous West Coast has affected the habitat of wild salmonids via competitive effects. In Alaska, the effects of the augmentation program are a matter of important concern, but due to the apparent strength of wild runs, the effects remain unclear.

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### Primary Habitat Factors to Evaluate

Known (or inferred from other studies) effect of fishing gear on physical and biogenic habitats

- **Minimal damage (i.e., pelagic longline, midwater gillnet, midwater trawl, purse seine, hook and line, or spear/harpoon)**
- Moderate damage (i.e., bottom gillnet, bottom longline or some pots/traps)
- Great damage (i.e., bottom trawl or dredge)



For specific fishery being evaluated, resilience of physical and biogenic habitats to disturbance by fishing method

- High (e.g., shallow, sandy habitats) OR benthic habitats not impacted
- Moderate (e.g., mud bottoms or deep-water sandy habitats)
- Low (e.g., corals, shallow or deep water rocky bottoms)
- **Not applicable because gear damage is minimal**




If gear impacts are moderate or great, spatial scale of the impact

- Small scale (e.g., small, artisanal fishery or sensitive habitats are strongly protected)
- Moderate scale (e.g., modern fishery but of limited geographic scope)
- Large scale (e.g., industrialized fishery over large areas)
- **Not applicable because gear damage is minimal**



### Primary Ecosystem Factors to Evaluate

Evidence that the fishery system has or will likely substantially disrupt the food web

- The fishery and its ecosystem have been thoroughly studied, and studies show no evidence of substantial ecosystem impacts 




*Alaska*

- **Conflicting evidence of ecosystem impacts OR unknown** 

*California, Oregon, Washington*

- **Ecosystem impacts of the fishery system demonstrated** 

Evidence that the fishing method has caused or is likely to cause substantial ecosystem state changes, including alternate stable states

- **The fishery and its ecosystem have been thoroughly studied, and studies show no evidence of substantial ecosystem impacts** 
- Conflicting evidence of ecosystem impacts OR unknown 
- Ecosystem impacts from fishing method demonstrated 

### Evaluation Guidelines

The effect of fishing practices is “**Benign**” if:

- 1) Damage from gear is minimal AND resilience to disturbance is high AND both Ecosystem Factors are not red.

The effect of fishing practices is “**Moderate**” if:

- 1) Gear effects are moderate AND resilience to disturbance is moderate or high AND both Ecosystem Factors are not red; OR
- 2) Gear results in great damage AND resilience to disturbance is high OR impacts are small scale AND both Ecosystem Factors are not red.

The effect of fishing practices is “**Severe**” if:

- 1) Gear results in great damage AND the resilience of physical and biogenic habitats to disturbance is moderate or low; OR
- 2) One or more Ecosystem Factors are red.

Habitat effects are considered a **Critical Conservation Concern** and a species receives a recommendation of “**Avoid,**” regardless of other criteria if:

- 1) Four or more of the Habitat and Ecosystem factors rank red.

*Conservation Concern: Effect of Fishing Practices on Habitats and Ecosystems*

**Pacific Salmon in AK**

- Low (Fishing Effects Benign)



**Pacific Salmon in CA, OR, WA**

- Moderate (Fishing Effects Moderate)



**Criterion 5: Effectiveness of the Management Regime**

*Guiding Principle: The management regime for a sustainable wild-caught species implements and enforces all local, national, and international laws and utilizes a precautionary approach to ensure the long-term productivity of the resource and integrity of the ecosystem.*

**Management Structure**

The primary management bodies for the U.S. Pacific salmon fisheries are the relevant state fisheries agencies: the Alaska Department of Fish and Game, the Washington Department of Fish and Wildlife, the Oregon Department of Fish and Wildlife, and the California Department of Fish and Game. Additionally, several Native American tribes have jurisdiction and fishing rights over salmon. Each state and tribal agency is responsible for managing salmon fisheries in their territorial waters, and for establishing fisheries regulations to manage concerns such as bycatch, habitat conservation, and hatchery supplementation. Additionally, state agencies bear the primary responsibility for monitoring and enforcement of regulations. State agencies typically collect a range of data including catch and fishing effort information, escapement, ocean conditions, and coded wire tag recoveries.

Because salmon frequently move across state and national borders, two coordinating bodies with regulatory authority also exist. First, the U.S. is required to observe international agreements on salmon existing between the United States and Canada. In March 1985, the U.S. and Canada agreed to cooperate in the management of Pacific salmon stocks of mutual concern. The Pacific Salmon Commission (PSC) was created as a bilateral commission addressing salmon originating from the Yukon River as far south as southern Oregon. The Pacific Salmon Commission dictates allowable harvest levels and allocation for a number of fisheries such as in-river Fraser River sockeye and Chinook in Southeast Alaska.<sup>30</sup>

Second, the Pacific Fishery Management Council (PFMC) is responsible for managing ocean salmon fisheries off the coasts of California, Oregon, and Washington. The PFMC is one of eight regional fishery management councils established by the Magnuson-Stevens Fishery

<sup>30</sup> At present, the U.S. is allocated 16.5% of the total allowable catch of Fraser River sockeye, and Canada the remaining 83.5%, which in turn is split between recreational, aboriginal, and various commercial sectors ((McRae and Pearse 2004)).

Conservation and Management Act for the purpose of managing offshore fisheries. The PFMC has established a Salmon Fishery Management Plan (FMP) for Chinook and coho salmon in California and the Pacific Northwest, which sets goals for spawner escapement in the major stocks and allocates planned harvests between commercial, recreational, and tribal fisheries. The FMP establishes conservation objectives to achieve optimum yield, prevent overfishing, and assure the rebuilding of salmon stocks whose abundance has been depressed to an overfished level. The stated harvest-related objective of the Pacific Salmon FMP is to “establish ocean exploitation rates for commercial and recreational salmon fisheries that are consistent with requirements for stock conservation objectives, specified ESA consultation standards, or Council adopted rebuilding plans” (Lohn 2004). The PFMC recommends annual management measures based on annual stock forecasts to achieve the conservation and allocation objectives of the framework plan. Implementation of the annual measures is through the Department of Commerce and National Marine Fisheries Service (NMFS).

In addition to the PSC and PFMC, the U.S. Endangered Species Act (ESA) places any management actions that affect endangered stocks under federal jurisdiction. Since 1990, West Coast salmon fisheries have been modified to accommodate requirements of listed salmon species under the ESA. The ESA requires agencies whose actions may jeopardize listed salmon to consult with NMFS, which conducts internal consultations with respect to the effects of ocean harvest on listed salmon. The consultation standards and recovery plans are put in place to stabilize the listed populations until freshwater habitats can be restored.

NMFS provides guidance to the PFMC on protective measures for species listed under the ESA. The ESA is triggered when a species’ survival is in doubt and a “status review” is done by NMFS to determine if the species is threatened or endangered. If the status review indicates that the species’ survival is imperiled, NMFS must publish a proposal to protect the species. Under section 7 of the ESA, federal agencies must consult with NMFS on any action that is likely to adversely affect a threatened or endangered species. In doing this, NMFS must issue a “biological opinion” that explains how the federal action affects the species and lays out what actions should be taken to protect the species. Section 4(d) of the ESA applies to state, tribal, and local jurisdiction or individuals and prohibits the “take” of an endangered species without ESA authorization. This section requires NMFS to issue regulation to provide for protection of the species. If the action that is being reviewed does not interfere with the long-term survival and recovery of the species, the action can be authorized under section 4(d) of the ESA. Thus, in order to be authorized, all salmon fisheries must be in accordance with Section 7 consultations and 4(d) rules (though this does not necessarily mean that the population consequences of bycatch are benign in a Seafood Watch® evaluation (see Criterion 3 synthesis for more information)).

### **California, Oregon and, Washington**

Since 1977, the Pacific Fisheries Management Council (PFMC) has managed salmon fisheries off the coast of California, Oregon, and Washington. The ocean salmon fisheries in the U.S. Exclusive Economic Zone (EEZ), 3-200 miles offshore, are managed under a fishery management plan entitled the Pacific Coast Salmon Plan (Salmon FMP). This plan was developed in accordance with the Magnuson-Stevens Fishery Conservation and Management

Act, which authorized the creation of the PFMC and the subsequent development and implementation of these plans.

The PFMC consists of voting members representing management agencies and stakeholders from the states of California, Oregon, Washington, and Idaho, as well as NMFS and a tribal representative. It is organizationally structured with Council members that include a Chairman, a Vice Chairman, a Council staff, and various committees and advisory bodies. There are a total of nineteen Council members in the PFMC, fourteen of whom are eligible to vote on matters brought before the Council. The Council staff is responsible for the administration and execution of Council operations. Advisory bodies are composed of individuals knowledgeable about West Coast fisheries matters and serve the purpose of providing expert advice to the Council on matters related to the Council purpose. They consist of both scientific/technical bodies, and industry/stakeholder bodies.

With respect to salmon, the PFMC essentially controls the process for Chinook and coho salmon fisheries in California and the Pacific Northwest. To inform Council decisions, the Salmon Technical Team exists to analyze fisheries and abundance data and assess the impacts of proposed regulations. Additionally, the Salmon Advisory Subpanel is comprised of seventeen individuals representing commercial and recreational fisheries as well as a single public representative and a single conservation representative.

Every year, the Council with the help of the Salmon Technical Team, Salmon Advisory Panel, NMFS, and the state agencies develops a stock abundance analysis for ocean salmon fisheries. This includes an analysis of fishery-dependent and independent data.

According to the PFMC, most target salmon stocks are managed such that escapement generally exceeds the Maximum Sustainable Yield (MSY) level or conservation objective. Because of the mixed-harvest nature of the fishery, “the Salmon FMP is structured such that in setting annual management measures, most stocks exceed their conservation objectives, while one or a few stocks constrain harvest because they approach their conservation objectives, without exceeding them. In theory then, most stocks experience escapement above the average MSY level (or other criteria) set as their conservation objective, while only the constraining stocks experience optimal escapement levels.” (PFMC 2004a).

In recent years, however, four stocks have failed to meet the escapement goals for three or more consecutive years. The four stocks are the Sacramento River fall Chinook (SRFC), Grays Harbor coho, Queets coho, and Western Strait of Juan de Fuca (SJF) coho. According to the Pacific Coast Salmon Plan (PFMC 2003), this could “signal the beginning of a critical downward trend (e.g., Oregon coastal coho) which may result in fishing that jeopardizes the capacity of the stock to produce MSY over the long term if appropriate actions are not taken to ensure the automatic rebuilding feature of the conservation objectives is achieved.” In lieu of clearer criteria for making “overfishing”, “overfished”, and “approaching overfished” determinations (currently being addressed in Amendment 16 to the Pacific Salmon Plan), a failure to meet escapement goals in three consecutive years is currently considered the “overfished” threshold (NMFS 2010c). Three of these stocks – SRFC, Grays Harbor coho and Queets coho – have since achieved their conservation objective and have been recommended to be removed from the list of

overfished stocks (C. Tracy, pers. comm.). The Western SJF stock has been combined with the Eastern SJF stock since 2009; under the new criteria the combined stock has also met the escapement goal (see below).

The SRFC run, historically the largest and most commercially important run in California, failed to meet its escapement goals from 2007 to 2009. Moreover, estimated escapement in 2008 and then 2009 was the lowest on record. As a result, the PFMC closed nearly all Chinook-directed fisheries in 2008 and 2009, and requested NMFS conduct an investigation into the cause of the low returns in 2007 and 2008 (NMFS 2010c). That review found that the reasons for the collapse of the SRFC run include habitat degradation, poor ocean conditions, climate variability, and a bias in management's forecast model (Lindley et al. 2009). The review also noted that although overfishing is not considered a primary reason for the stock's decline and low escapement, the Overfishing Concern and record low escapement highlights the weak stock status, and fishing pressure would further reduce escapement of depleted stocks (Lindley et al. 2009).

The 2010 forecast of ocean abundance for SRFC was 245,500 adults (NMFS 2010c), a great improvement over estimated returns for the previous three years and significantly above the upper end of the conservation objective for the stock (180,000 fish). NMFS guidance to the PFMC in 2010 was "Given the recent declines in adult escapement and inherent scientific uncertainty, NMFS believes that the Council should adopt a conservative approach to management of SRFC in 2010 by structuring potential fisheries to target escapement around the upper end of the SRFC conservation objective range." (NMFS 2010c) The PFMC reopened the Chinook fisheries south of Cape Falcon with an escapement goal of the upper end of the 122,000-180,000 fish range stipulated in the Pacific Salmon Plan in order to reduce the risk of the stock continuing to fall below 122,000 fish (C. Tracy, pers. comm.). Thus, although the estimated 2010 escapement (125,353) was just above the minimum escapement goal for the stock, it was below the PFMC's 2010 target of 180,000.

As noted in "Criterion 2: Status of Wild Stocks", one consistent problem appears to be the high uncertainty of estimates from forecast models. The PFMC predicted a 2007 escapement of 265,000 Sacramento River fall Chinook adults, but actual escapement in 2007 was only 87,900. Because of this overly optimistic prediction, fishing in the 2007 season was not constrained as much as would be appropriate for such a depleted stock, further exacerbating the problem of low escapement (Lindley et al. 2009). Thus, while the fishery's management was not the primary cause of the decline in the SRFC run, it did contribute to the failure to achieve the SRFC escapement goal in 2007 (Lindley et al. 2009). Although the bias in the model that caused the overly optimistic prediction has since been corrected (Lindley et al. 2009), there is still cause for concern. The PFMC model predicted escapement of 122,050 fish in 2009, yet only 39,530 adults returned to the river, despite the fishery closures of 2008-2009 (PFMC 2010b). In 2010, the preseason forecast of 245,483 adults was 1.6 times the postseason estimate (PFMC 2011a). Given the highly uncertain escapement forecasts over the past few years and that the 2009 SRFC escapement was the lowest on record, management should have been more precautionary and not opened the fishery for the 2010 season, according to Seafood Watch®.

Grays Harbor coho and Queets River coho also recently failed to meet escapement goals for three years in a row, from 2006-2008. Both stocks exceeded the goal in 2009, however (PFMC 2011c). The Salmon Technical Team (STT) concluded that from 2006-2008, overfishing of Queets coho occurred and that Queets coho were overfished, but did not believe that the stock abundance levels in those three years was significantly depressed and would represent a concern for producing maximum sustainable yield on a continuing basis. Pending a review of the preseason and terminal abundance methodologies, the STT believes the rebuilding feature of the FMP is sufficient, and development of a separate rebuilding plan is not necessary at this time (PFMC 2010a).

The Western SJF coho stock failed to meet its conservation objective for four consecutive years (2005-2008), despite a preseason expectation the conservation objective would be met (PFMC 2010c). The cause of this failure is depressed adult ocean abundance due to poor marine survival, which may have been intensified by the limited capacity of the habitat to produce smolts. Even if exploitation rates had been reduced to zero, the Western SJF stock would still have failed to meet its conservation objective from 2005-2008. Therefore, the STT concluded that overfishing on the Western SJF coho stock did not occur, and that the stock is depressed, but not overfished (PFMC 2010c). In 2009 the PFMC modified the Salmon FMP, combining the eastern and western stocks into a single stock. The combined stock met the escapement objectives in 2009 (C. Tracy, pers. comm.). At the time of the current update to this report, however, the western SJF stock is still listed as overfished by NMFS, and in 2009 fell short of the management objective under the old FMP criteria (11,044 with an objective of 11,900) (C. Tracy, pers. comm.).

Apart from the PFMC and NMFS, the Washington Department of Fish and Wildlife (WDFW) plays a significant role in salmon fishery management in the Pacific Northwest. The WDFW remains the primary body managing chum, sockeye, and pink salmon, which are generally not landed outside of Washington State waters. According to state managers:

The annual process of setting scientifically sound fishing seasons begins each year with a pre-season forecast of the abundance of various individual fish stocks. These forecasts are based on estimates of the number of juvenile wild salmon produced in a river system, surveys of adult fish spawning in the wild, counts of fish returning to hatcheries, and samples from fisheries in 'terminal' areas.... The forecast is added to a base of information on the historic run-size strength and fishery impacts for the various fish populations.... After the biological information and data gleaned from coded wire tags is agreed to by the co-managers, they are assembled into a computer model that offers a snapshot of an upcoming season's fishery under various regulation options. The results from these computer simulations are then compared to conservation goals, obligations under U.S-Canada treaties, allocations for tribes and protection requirements for some wild fish population under the Endangered Species Act. (WDFW 2002b)

In general, abundance of salmon in California, Oregon, and Washington has declined for a number of reasons typically outside of management's direct control, such as habitat degradation, poor ocean conditions, and climate variability (Lindley et al. 2009), although abundance appears to be rebounding in 2011 to near recent year averages.

***Bycatch***

In 1997, due to the ESA status of many salmon runs in California, Oregon and Washington, Amendment 12 of the Pacific Salmon FMP implemented procedures for governing retention of salmon bycatch in trawl nets and management objectives for ESA listed salmon species (PFMC 2003). The primary constraints under the Salmon FMP at present vary by region. South of Point Arena, California, exploitation of endangered Sacramento River winter Chinook is the limiting factor. Targeted Klamath River fall Chinook salmon are limiting south of Cape Falcon, Oregon. North of Cape Falcon, incidental landings of threatened lower Columbia River tule fall Chinook are the constraining factor. Additionally, management goals for wild coho salmon limit fisheries across the entire West Coast (PFMC 2011a) The effectiveness of the non-retention restrictions is unclear. In some cases, bycatch has been reduced and in other cases, bycatch rates are still high. None of the salmonid species that were listed under the ESA in 2004 have been delisted. “Criterion 3: Nature and Extent of Discarded Bycatch” outlines several ESUs that are harvested at levels that may be retarding their recovery.

***Habitat***

There are no significant physical effects of salmon fishing gear on aquatic habitat. As discussed in the Habitat Effects criterion, the main indirect effect of the salmon fishery system is that hatchery fish can degrade habitat for wild fish. Management’s treatment of hatchery-origin salmon has been a major point of debate recently; specifically, NMFS’ new hatchery policy requires wild and hatchery salmon to both be included in ESU listings despite the recommendations of a scientific advisory panel (Myers et al. 2004). The opinion of Myers, Levin et al. (2004), authors of a recent article in *Science*, was unequivocal about the harms of this policy: “To avoid the dysgenic effects of domestication, even conservation hatcheries should be strictly temporary and should not prevent protection of wild populations under the Endangered Species Act.... The danger of including hatchery fish as part of any ESU is that it opens the legal door to the possibility of maintaining a stock solely through hatcheries. However, hatcheries generally reduce current fitness and inhibit future adaptation of natural populations” (Myers et al. 2004).

This perspective is countered in part by a recent article in *Fisheries*, which contends that in many cases artificially propagated fish ought to be allowed to reproduce in the wild (Brannon et al. 2004). However, even the defense of hatcheries concludes that substantial reforms in the current system are warranted. Brannon, Amend et al. (2004) note that Pacific salmon hatcheries “have had negative impacts on wild conspecifics because management decisions and hatchery operations were unrelated to the biological needs of either the introduced or the recipient populations. Reforms, therefore, are necessary in the management of fisheries that will address the biological needs of anadromous salmonid populations, and reforms are necessary in hatchery programs that will assure hatchery fish are compatible genetically and behaviorally with the recipient population.”

***Enforcement***

The fishery is enforced through the local management authorities (states, tribes) and the use of fish tickets, logbooks, catch cards, and similar management measures (PFMC 2003).



## Alaska

Alaskan salmon fisheries are overseen by the Alaska Department of Fish and Game (ADFG), which regulates harvest and all salmon rehabilitation and enhancement projects. Unlike the PFMC to the south, the North Pacific Fishery Management Council (NPFMC) does not play an active role in salmon fisheries. Similarly, Alaskan salmon fisheries are not regulated by PFMC decisions, nor has NMFS played a large role in Alaskan salmon management to date. However, the Pacific Salmon Commission (PSC) affects Alaskan salmon in Southeast Alaska, where it sets exploitation rates for Chinook salmon (Delaney 1994). Currently, the Southeast Alaska Chinook fishery is managed to achieve the annual harvest quota set by the PSC through a plan established by the Alaska Board of Fisheries.

Overall, the task of salmon management in Alaska is enormous. The state estimates that there are over 15,000 streams and rivers throughout the state that support anadromous salmon. In Southeast Alaska alone there are over 5,000 streams with anadromous fish runs, roughly 60% of which are principal salmon streams. Moreover, coho, pink, and chum salmon co-exist in almost all of the streams (Kelly 2001). While the state monitors the most productive and important areas, it is clearly difficult to have complete coverage. For example, in Prince William Sound alone, the Department of Fish and Game currently monitors 150-200 out of the 800 streams for salmon escapement (Kelly 2001). According to ADFG: “State of Alaska management has been intensive, conducted on a real-time basis with regulations imposed inseason by local biologists who have a clear conservation mandate and authority to open or close fisheries as needed. Delegated emergency authority provides for immediate management decisions by area biologists. When runs are strong, managers liberalize harvest regulations to utilize surpluses. When runs are poor, managers close fisheries to provide for predetermined escapement needs which ensure long-term sustainable yields” (ADFG 2003).

An obvious difficulty with salmon management is that the sizes of salmon runs naturally fluctuate, a factor that makes it difficult to accurately forecast the size of salmon returns (although actual return estimates may be more accurate than for many other stocks due to the relative ease in counting salmon). Salmon models are typically based on an empirical stock-recruitment relationship, modified by other factors such as environmental conditions. Assessments of previous models have shown that even the best examples have an average error of approximately 35%, and are likely to be off by a factor of two (Adkinson and Finney 2003). As a consequence, Alaskan salmon management currently relies on conservative preseason estimates and inseason management to adjust for these effects. Adkinson and Finney (2003) comment: “The health of Alaska’s salmon runs depends on maintaining its conservation oriented management goals. A widely-accepted goal of meeting escapement objectives coupled with intensive inseason management has helped to maintain the health of salmon stocks for decades, even through dramatic declines in abundance such as occurred in the early 1970s.”

With respect to salmon management in Alaska, the state management body has an excellent track record. Alaskan salmon stocks have not always been healthy as they appear to be today. Prior to Alaska statehood in 1959, overfishing under federal management may have contributed to declines in salmon stocks. Since 1959 the state management agencies have pursued a path of conservation and careful planning that has largely protected the productivity of salmon populations, such that recent harvests were roughly five times the size of those in 1959 (ADFG

2003). The current health of Alaskan salmon runs and habitat attests to the relative success of the state's management regime. However, the state has also been aided by favorable environmental conditions. If conditions were to decline, the state may have to revisit its hatchery policies.

### ***Bycatch***

Little information is available about management of bycatch in Alaskan salmon fisheries. ADFG officers insist that if bycatch were a problem area, the management body would collect more detailed information (Plotnick 2004).

### ***Habitat***

Alaska currently has a number of protections regulating development of freshwater habitat. According to the Alaska Department of Fish and Game (ADFG 2003), the "Anadromous Fish Act (AS 16.05.870) requires approval for any in-stream construction activities in salmon streams." Similarly, Alaska's "Forest Practices Act" (41.17.010) requires the presence of buffer zones between actively logged areas and salmon streams. Additionally, the "Water Use Protection Act" (AS 46.15) protects stream flows needed for salmon and allows the ADFG Commissioner to purchase water rights for the purpose of protecting salmon runs (ADFG 2003). While over 100 dams exist in Alaska, the number remains small relative to the state's size.

As with salmon in the Pacific Northwest, the main concern with respect to habitat in Alaska is the presence of the extensive hatchery system—most notably the pink salmon hatchery complex in Prince William Sound. As noted in the Habitat Effects criterion, significant unknowns exist with respect to Alaskan salmon. While even critics of the Alaskan hatcheries have noted that they are better-managed and regulated than most hatchery systems, the sheer scale of the system may be causing detrimental effects on wild salmon habitat, particularly in Prince William Sound and Southeast Alaska (Kelly 2001). There is a lack of information and data necessary to evaluate the effects of the hatcheries on wild salmon.

There have also been some recent changes in management in Alaska. The ADFG's Habitat Division and all of its functions have been transferred to Alaska's Department of Natural Resources (ADNR), the state's resource development agency. The Habitat Division had primary responsibility for permit issuance and other measures to protect anadromous fish streams. Additionally, Bristol Bay has been opened to oil and gas exploration (a move which will not necessarily harm salmon runs). These changes may or may not signal a broader political willingness to put salmon habitats at risk in Alaska.

### ***Synthesis***




Managers of U.S. West Coast salmon fisheries assess stocks on a timely basis, typically issuing pre-season abundance forecasts and updating regulations as the season progresses. Managers regularly assess fisheries-dependent data, such as landings, and fisheries-independent data, such as run size, ocean conditions, and fish age, to determine stock status and fishing levels. Management does not have a track record of setting catch quotas over what its scientific advisors have recommended. Managers require specific gear types and employ closed areas to reduce wasteful discards, and actively craft fishing seasons and regulations to reduce harmful impacts on endangered or struggling stocks. However, the effectiveness of the bycatch reduction measures is not clear, as bycatch of some species has decreased, while bycatch of other species

remains high, including bycatch of some ESA-listed salmonids. Alaska salmon regulations also limit gear sizes (including mesh size as well as boat and gear length) and limit the time during which gear can be in the water. Management has not prevented the long-term declines of many salmonids in Washington, Oregon and California. Many of the contributing factors (e.g., habitat loss, pollution, introduced species, etc.) are outside of fishery managers' control; however, management's escapement forecast models have been highly inaccurate and overly optimistic for the past few years, and as a result, fishing for SRFC in the 2007 season was not constrained as much as would be appropriate for such a depleted stock, further exacerbating the problem of low escapement. Thus, while the fishery's management was not the sole cause of the decline in the SRFC run, it did contribute to the failure to achieve the SRFC escapement goal in 2007. In addition, given the highly inaccurate escapement forecasts over the past few years and that the 2009 SRFC escapement was the lowest on record, management could have been more precautionary for the 2010 season. Nonetheless, the SRFC conservation objective was met in 2010, and other (non-ESA) stocks of concern have also recently met their conservation objectives.




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### Primary Management Factors to Evaluate




**Stock Status:** Management process utilizes an independent scientific stock assessment that seeks knowledge related to the status of the stock

- **Stock assessment complete and robust** 
- Stock assessment is planned or underway but is incomplete OR stock assessment is complete but out-of-date or otherwise uncertain 
- No stock assessment available now and none is planned in the near future 



**Scientific Monitoring:** Management process regularly involves the collection and analysis of data with respect to the short and long-term abundance of the stock



- **Regular assessment of fishery-dependent AND independent data** 
- Regular collection of fishery-dependent data only 
- No regular collection or analysis of data 

**Scientific Advice:** Management has a well-known track record of consistently setting catch quotas beyond those recommended by its scientific advisors and other external scientists





- **No** 
- Yes 
- Not enough information available to evaluate OR not applicable because little or no scientific information is collected 

**Bycatch:** Management implements an effective bycatch reduction plan




- Bycatch plan in place and reaching conservation goals (deemed effective)   
*California, Oregon, Washington, and Alaska Chinook troll*
- **Bycatch plan in place but effectiveness is not yet demonstrated or under debate** 

- No bycatch plan implemented or bycatch plan implemented but not meeting its conservation goals (deemed ineffective) 
- Alaska (except Chinook troll)*
- **Not applicable because bycatch is “low”** 

Fishing practices: Management addresses the effect of the fishery system on habitats and ecosystems

- Mitigative measures in place and deemed effective 
- **Mitigative measures in place but effectiveness not yet demonstrated or under debate** 
- No mitigative measures in place or measures in place but ineffective 
- Not applicable because fishing method is moderate or benign 

Enforcement: Management and appropriate government bodies enforce fishery regulations



- **Regulations regularly enforced by independent bodies, including logbook reports, observer coverage, dockside monitoring, and similar measures** 
- Regulations enforced by fishing industry or by voluntary/honor system 
- Regulations not regularly and consistently enforced 

Management Track Record: Conservation measures enacted by management have resulted in the long-term maintenance of stock abundance and ecosystem integrity

*Alaska*

- **Management has maintained stock productivity and limited ecosystem change OR has fully recovered the stock from an overfished condition** 

*California, Oregon, Washington*

- **Stock productivity has varied but management has responded quickly OR stock has not varied but management has not been in place long enough to evaluate its effectiveness** 
- Measures have not maintained stock productivity OR were implemented only after significant declines and stock has not yet fully recovered 

### Evaluation Guidelines

Management is deemed to be “**Highly Effective**” if four or more management factors are green AND the remaining factors are not red.

Management is deemed to be “**Moderately Effective**” if:

- 1) Management factors “average” to yellow OR
- 2) Management factors include one or two red factors

Management is deemed to be “**Ineffective**” if three individual management factors are red, especially those for Stock Status and Bycatch.

Management is considered a **Critical Conservation Concern** and a species given a recommendation of “**Avoid**,” regardless of other criteria if:

- 1) There is no management in place OR
- 2) The majority of the management factors rank red.

*Conservation Concern: Effectiveness of Management*

**Pacific Salmon in AK, WA, OR, CA**

- Low (Management Highly Effective)



#### **IV. Overall Evaluation and Seafood Recommendation**

In Alaska, the salmon stocks are inherently resilient to fishing pressure and have healthy abundance levels, and the salmon fisheries have a low to moderate bycatch concerns, low habitat impacts, and highly effective management. Therefore, Alaskan salmon receives an overall Seafood Watch® ranking of **Best Choice**. In Washington and Oregon (north of Cape Falcon), the salmon stocks are moderately vulnerable to fishing pressure and have moderate abundance levels, and the fishery has high bycatch concerns, moderate habitat effects, and highly effective management. This results in Washington salmon receiving an overall Seafood Watch® ranking of **Good Alternative**. In California and Oregon (south of Cape Falcon), the moderate status of the stocks and the high bycatch concerns result in an overall Seafood Watch® ranking of **Good Alternative**.

#### **Table of Sustainability Ranks**

Sustainability Criteria	Conservation Concern			
	Low	Moderate	High	Critical
Inherently Vulnerability	√ (AK)	√ (CA, OR, WA)		
Status of Wild Stocks	√ (AK)	√ (WA, OR, CA)		
Nature of Bycatch	√ (AK except Chinook)	√ (AK Chinook)	√ (CA, OR, WA)	
Habitat Effects	√ (AK)	√ (CA, OR, WA)		
Management Effectiveness	√			

### Evaluation Guidelines

A species is given the overall recommendation of “**Best Choice**” if it has a total of three or more green criteria AND the remaining criteria are not red.

A species is given the overall recommendation of “**Good Alternative**” if:

- 1) Criteria “average” to yellow OR
- 2) There are four green criteria and one red criteria OR
- 3) Stock Status and Management criteria are both ranked yellow and remaining criteria are not ranked red.

A species is given the overall recommendation of “**Avoid**” if:

- 1) It has a total of two or more red criteria OR
- 2) It has one or more criteria of **Critical Conservation Concern**.

### Overall Seafood Recommendation:

#### Alaska:



#### Washington, Oregon and California:



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*Scientific review does not constitute an endorsement of Seafood Watch® on the part of the reviewing scientists. The Seafood Watch® staff is solely responsible for the conclusions reached in this report.*

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## **Supplemental Information**

Consumption advice on the Seafood Watch® pocket guides is provided by Environmental Defense. Environmental Defense applies the same risk-based methodology as the U.S. Environmental Protection Agency (EPA) to data from government studies and papers published in scientific journals. The Environmental Defense Fund has a consumption advisory for Washington and Oregon salmon for PCBs contamination. Consumption of salmon from Washington should be limited to one meal per month for men and women of childbearing age, one meal per month for children between the ages of 6-12, and less than one meal per month for children under the age of 6. Consumption of salmon from Oregon should be limited to two meals per month for men and women of childbearing age, and one meal per month for children under the age of 12. A meal size is considered to be 8 ounces for men, 6 ounces for women, 4.5 ounces for children ages 6 to 12, and 3 ounces for children under 6. More detailed information about the Environmental Defense advisory can be found at [www.edf.org/seafoodhealth](http://www.edf.org/seafoodhealth).

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**VI. Appendix 1**

This report was most recently updated in May 2011. Major changes made at that time are:

- Stock status of CA and OR (south of Cape Falcon) from red to yellow, reflecting the improved stock status of the Sacramento River Fall run Chinook
- Management of CA, OR, and WA stocks from yellow to green, reflecting the efforts to rebuild the SRFC and several other stocks to conservation objectives in 2009 and 2010.
- As a result of the above, the overall recommendation for CA and OR (south of Cape Falcon) salmon was changed to Good Alternative.