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A REVIEW OF THE HISTORY, NATURAL HISTORY, AND STATUS OF COHO SALMON (*ONCORHYNCHUS KISUTCH*) IN CALIFORNIA

A LITERATURE REVIEW

by

Matthew Bettelheim
Central Valley Bay-Delta Branch

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INTRODUCTION

Coho salmon (*Oncorhynchus kisutch*) are a species of anadromous salmon with a widespread distribution throughout the northern Pacific Coast (McMahon, 1983; Laufle et al, 1986). Despite the dearth of quantitative historical data documenting the distribution of coho along the Pacific northwest, there is enough evidence today to suggest that present coho populations in California alone have declined to less than 6 percent of their abundance in the 1940's (Brown et al, 1994).

The National Marine Fisheries Service has identified six Evolutionary Significant Units (ESU) of Pacific coast coho populations in Washington, Oregon and California (Weitkamp et al, 1995). The Central California Coast ESU south of San Francisco Bay is State listed as endangered and federally listed as threatened; the Southern Oregon/Northern California Coast ESU is federally-listed as threatened and its habitat has been designated critical (Habitat Conservation Planning Branch [HCPB], 2001). At present, threats to the species include habitat degradation, genetic mixing, diseases, overexploitation, climate changes, and the effect of competition from hatchery fish. Recent studies suggest coho populations are still experiencing a downward trend (Santa Cruz Laboratory, 2001).

The purpose of this literature review is to provide an up-to-date overview of the history, natural history and status of California's coho salmon, as well as a compilation of the most recent data based on extant literature and research.

COHO SALMON

Life History

Coho salmon (*Oncorhynchus kisutch*), formerly known as silver salmon, are members of the Salmonidae family. In the past, coho have been referred to by common names such as jack salmon, dog salmon, sea trout, blueback, hookbill, and silverside (Shapovalov and Taft, 1954).

Coho are anadromous in that they spend a considerable amount of time growing and attaining sexual maturity within the ocean before reentering freshwater streams to spawn. Native coho exhibit a "homing instinct," where those that emigrated from freshwater environs to the ocean return again as adults to their parent stream to spawn. In contrast, young fish raised in hatcheries return as adults to the streams in which they were released instead of those from which their parents emigrated or those in which they were hatched (Shapovalov and Taft, 1954).

Spawning runs of coho enter parent streams between September and March, concentrated between November and January. The actual upstream migration has been noted to occur mainly during the daytime and males tend to predominate early in migration, although physical boundaries and seasonal precipitation influence their timing of entry and their upstream migration. A majority of California coastal streams are landlocked by sandbars during the dry season. Prior to the first heavy rains necessary to provide sufficient instream discharge to wash out obstructive sandbars, coho are at the whim of early rains, high tides, or winds to make streams temporarily accessible earlier (Shapovalov and Taft, 1954).

At Waddell Creek, Shapovalov and Taft (1954) noted that the time of stream entry fell between or after the first and permanent openings of the sandbar, suggesting that the fish are in the vicinity of the stream's mouth when entry becomes feasible.

Although other streams without obstructions are accessible year round, the majority of coho don't enter until the onset of the rainy season, nor do they enter in one short burst. Instead, spawning runs in both intermittent and permanently accessible streams occur in waves (Shapovalov and Taft, 1954).

During spawning activities, both males and females face upstream. Female coho select the nest sites and dig the redds unaided. Nest sites are usually located at the lower end of a pool near the head of a riffle, along the seam where the smooth water becomes disturbed. The gravels selected are usually small to medium sized. As the female proceeds to dig, a larger male, her future mate, accompanies her. Often some attending males will try to approach the female, but they yield to the dominant male. The future mate hovers immediately downstream and to one side as the female prepares the nest. Occasionally, the male will approach at which time they ritually quiver individually or separately (Shapovalov and Taft, 1954).

To prepare the redd, the female leans to one side and disrupts the streambed gravel with sharp, repeated thrusts of her tail until she forms a depression similar to her body in length and depth.

Often, female coho may dig more than one nest, with each subsequent redd located farther upstream. The complete spawning process may take as long as a week or more depending on the ripeness of the fish, potential interruptions, and instream conditions. On occasion, in what's known as superimposition, subsequent spawners overlap redd sites with those laid earlier (Shapovalov and Taft, 1954).

Coho exhibit semelparity in that they invest most of their energy into one reproductive bout. As soon as they've finished spawning, both males and females succumb to the degeneration of their gonads and other physiological changes that lead to their deaths (Shapovalov and Taft, 1954).

Coho salmon usually spawn completely so that the majority of eggs produced are deposited in the redds. It is also believed that 99 percent of eggs deposited are successfully fertilized (Shapovalov and Taft, 1954). Eggs are 4.5 to 6.0 mm in size and are red in color (Laufle et al, 1986).

The development and survival rates of fertilized eggs can vary not only between individual laying females, but also between subsequent redds of the same female. Environmental factors such as pH, siltation, dissolved oxygen levels, and water temperature also play a part in determining the likelihood of survival (Shapovalov and Taft, 1954).

The temperature requirements of coho as eggs and throughout their lifecycle vary considerably (Table 1). On average, the number of days from deposition to hatching at 51.3°F is 38 days and at 48.0°F approximately 48 days. An estimated 15-27 percent of the eggs deposited live long enough to emerge from the redds as fry. Coho fry begin to emerge from the gravel between two to three weeks after they hatch and continue for an additional two to seven weeks before the emergence is complete (Shapovalov and Taft, 1954).

Table 1. Temperature Requirements for various coho salmon life stages.

Life stage	**Temperature Range**	**Optimal Temperature Range**
Eggs	32-63 F	40-56 F
Larvae (alevins)	32-63 F	40-56 F
Juveniles (freshwater)	32-79 F	54-57 F
Juveniles (marine)	<59 F	✕
Adults (freshwater)	✕	✕

(PFMC, 1999) ✕ = data not available

Silting tends to be the restrictive element in redd emergence survival rates (Shapovalov and Taft, 1954), but eggs, alevin and pre-emergent fry are at the mercy of freezing, toxins, desiccation, predators, and stream bed scouring and shifting (Pacific Fishery Management Council [PFMC], 1999). Shallow burial, loose gravel, absence of silt, and high temperatures tend to catalyze emergence. Conversely, contrary conditions tend to impede emergence (Shapovalov and Taft, 1954). In looking into the relationship between gravel size, intragravel movement and emergence, Dill and Northcote (1970) showed that the larger interstices associated with bigger gravel allowed more extensive lateral and vertical movement for newly emerged alevins. Smaller gravel hindered the downward movement of alevins.

Most fry emerge at night once the young have completely absorbed the yolk sac. Upon emerging, the young fish tend to school, taking advantage of shallow graveled areas and stream margins. As they age, individuals break off and move up- and downstream, acquire territories, and drive away similarly sized intruders. During this time, they feed and grow generously (Shapovalov and Taft, 1954).

Shortly after, juvenile coho begin to engage in intraspecific aggressive behaviors in the form of territory defense and hierarchy establishment. The consequent agonistic lateral displays, nipping, fighting, submissive flight and aggressive displacement behaviors are thought to help instream population dynamics. As a result of such intraspecific aggression, juveniles spread out over a greater area. This in turn is thought to result in more copious food supplies for aggressors, help minimize the transmission of pathogens, and ensure higher survival rates (Chapman, 1962).

Newly emerged juveniles are occasionally swept downstream prematurely via current displacement or while shifting positions, induced perhaps by intraspecific aggression, or might succumb to their innate migratory instincts (Chapman, 1962).

Juveniles are sensitive to instream conditions. Sigler et al (1984) found that in comparison to coho juveniles exposed to chronic turbidity, those that were exposed to clear water conditions tended to be larger in length and weight and grew at faster rates. Coho juveniles in turbid waters were more likely to emigrate to clear waters.

As the fry grow, they move towards deeper waters and take larger food items. Come July and August, with maximum instream temperatures and minimal flows, the young fish adopt deeper pools and their food intake and growth rates taper off. Throughout late summer, up until around December and February, feeding and growth rates remain light during periods of high precipitation and low temperatures. All the while, fry suffer great losses from predators, drying stream channels, and disease (Shapovalov and Taft, 1954).

Bustard and Narver's (1975a) study of overwintering juveniles found age 0 coho occupied a wide range of depths greater than 15 cm while age 1+ coho preferred significantly deeper water. In turn, they found that as temperatures dropped with the encroaching autumn, coho juveniles moved into deeper waters. Age 0 and 1+ coho were also found to maintain an average distance of 25 and 27 cm from the stream bottom, respectively.

As water temperatures decreased from 9°C to 2°C (48°F to 36°F), Bustard and Narver (1975a) found that juvenile coho took shelter beneath overhanging banks, branches and snags, especially within the deep, slow water pools associated with upturned roots and logs.

In a concurrent study, Bustard and Narver (1975b) found that, given the option, juvenile coho preferred sidepool banks with overhanging cover compared to those without cover. They also showed a preference for clean rather than silted rubble streambed substrate. In March, as temperature and food abundance increases, coho juveniles resume feeding and rapidly increase in size. A year after their emergence, sometime between March and April, coho yearlings begin their downstream seaward migration (Shapovalov and Taft, 1954). At this time, each has attained a length of between 10-13 cm (HCPB, 2001). A number of influential and incidental environmental factors are thought to play a part in the coho's time of and size at migration, including flow, temperature, chemical factors, light, and food (Shapovalov and Taft, 1954).

The seaward migration is executed in schools of 10 to 50 individuals, and is thought to be a reflection of stream size and the population of migrants. Generally, the composition of individual fish within each school is of a similar size. Schooling coho tend to migrate downstream during crepuscular and nocturnal hours (Shapovalov and Taft, 1954). Based on the ratio of returning adults, Shapovalov and Taft (1954) estimated the sex ratio of downstream migrants to be an approximate 1:1. They also noted that at the onset of migration early migrant yearlings bore prominent parr marks, but as the season drew on, the yearlings adopted a "silvery" coloration with less noticeable parr marks. Identifying marks on juveniles include blue-green dorsal pigmentation, silvery sides, and 8 to 12 narrow, widely spaced parr marks bisected by the lateral line (Laufle et al, 1986).

When coho reach the ocean, they spend approximately 18 months at sea (up to 36 months in Alaska) before they reach maturity as adults (Shapovalov and Taft, 1954). Male "jacks" that mature early spend only 6 months at sea before returning to fresh water to spawn (PFMC, 1999). Those returning adult males that spawn the year following downstream migration are classified as age 1/1, one year in freshwater and one growing season in the ocean. Those males and females that spend two growing seasons in the ocean are classified as age 1/2 (Shapovalov and Taft, 1954). While in the ocean coho may travel several hundred miles, but they usually remain close to their river of origin. Coho are thought to live within the limits of the Continental Shelf in pelagic waters (Shapovalov and Taft, 1954; Hassler, 1987).

Upon reaching maturity, coho undergo a number of changes responsible for their common "hookbill" designation. Male coho develop an elongated, often times hooked upper jaw and a knobbed lower jaw, frequently to such a degree that it impedes closure. Female coho too develop elongated jaws, but rarely to the gross extant of their male counterparts. While in the ocean, coho salmon, much like other Pacific salmon, boast loosely attached silvery scales (Shapovalov and Taft, 1954). Adult coho pigmentation includes small black spots on the back and upper sides, at the base of the dorsal fin, and along the upper lobe of the caudal fin (Laufle et al, 1986). In freshwater and during spawning, the scales become firmly embedded, and larger male coho take on a bright red flush along their sides, while females take on a brassy green tinge (Shapovalov and Taft, 1954). Marine adult male coho have pale gums which can help to distinguish them from black gummed Chinook (*O. tshawytscha*). Additionally, coho spotting is confined to the upper lobe of the caudal fin, while Chinook exhibit spotting on both caudal lobes (Laufle et al, 1986). Between sexes, males tend to attain a slightly larger size than females. On average, adults attain fork lengths (FL) between 41 to 64 cm (Hassler, 1987).

The diet of coho salmon depends on factors such as life stage, fish size, location, time of year, and the relative abundance of food types. Throughout their geographic range, prey reportedly taken by young coho have included pink (*O. gorbuscha*), chum (*O. keta*), coho and Chinook fry and fingerlings; sticklebacks (*Gasterosteus aculeatus*); snails; and drifting and terrestrial insects such as ants, flies, beetles, and caddisfly and assorted larvae (Shapovalov and Taft, 1954).

In freshwater environs, the juvenile coho's primary predators include fellow coho, steelhead, sculpins (*Cottus asper*), dippers, giant water bugs (*Lethocerus americanus* and *Abedus hungerfordi)*, and garter snakes (*Thamnophis spp.*). As coho grow in size, kingfishers, blue herons, and striped bass (*Morone saxatilis*) become the primary predators; while at sea, adult coho run the risk of sea lion predation (Shapovalov and Taft, 1954).

Distribution, Abundance, and Status of Pacific Coast Coho Salmon ESUs

Coho are native to the northern Pacific Ocean. Their spawning and breeding distribution stretches from their southernmost range in Monterey Bay, California, to their northernmost range in Point Hope, Alaska, through the Aleutian islands, and then southward towards Korea and Japan along the Asiatic coast (McMahon, 1983; Laufle et al, 1986).

Although there is a remarkable absence of quantitative data concerning the historical distribution and abundance of coho salmon, Brown and Moyle (1991) surveyed all extant published and unpublished sources to piece together a historical projection. They found historic records of coho presence in 582 California streams between the Smith River near the Oregon border and the Big Sur River on the central coast. Of those streams identified, there were no current records for more than half of them. And of those remaining 248 streams with current data, 53 percent still had occurrences of coho salmon.

There is some debate in the historical record as to the existence of coho salmon in the Sacramento River. Brown and Moyle (1991) found that while historical documentation from 1881 to 1919 cite numerous accounts of coho presence in the Sacramento River, more recent reports designate occurring coho as strays. Either way, the California Department of Fish and Game tried to (re)introduce coho into the Sacramento River in 1956, but populations waned by 1963. Although some take this failure to suggest that perhaps coho were never supported in the Sacramento River system, Brown and Moyle (1991) assert that this premise is unlikely given the great physical changes that have occurred to the system over the years and that fact that there is little to suggest that other hatchery-propagated populations of coho in California might be self-sustaining if planting were discontinued.

Brown et al's (1994) review of historical population estimates in California found coho numbers to be between 200,000 and 500,000 in the 1940's, 100,000 in the 1960's, and 30,480 between 1984-1985. In 1987-1994 an average of 31,000 adult coho (~4,000 wild stock, ~9,000 natural stock, and ~18,000 hatchery stock) were estimated to have entered California streams each year to spawn. Further, the majority of coho caught in the ocean fisheries off the California coast are native to Oregon streams, predominantly the Columbia River. Only ten percent of the ocean caught California fish are northern California coho.

Overall, Brown et al (1994) estimated that the present-day wild, natural, and hatchery stock California coho abundance is less than six percent of its abundance in the 1940's.

In accordance with the Endangered Species Act (ESA), distinct population segments, or ESUs, may be listed individually if they demonstrate reproductive isolation and contribute substantially to the ecological/genetic diversity of the biological species. To determine an ESU, "natural" fish populations, those in which individuals of concern are the progeny of naturally spawning fish, are more heavily weighed. In turn, the ESA defines an endangered species as "any species which is in danger of extinction throughout all or a significant portion of its range." In 1993, the National Marine Fisheries Service (NMFS) identified ESU boundaries of six distinct Pacific coast coho populations and their extinction risk (Weitkamp, et al, 1995).

1. CENTRAL CALIFORNIA COAST – **Boundaries** extend from Punta Gorda in northern California south to and including central California's San Lorenzo River and tributaries to the San Francisco Bay, excluding the Sacramento-San Joaquin River system. **Extinction Risks** of natural coho populations rate in danger of extinction due to current low abundance compared to historical abundance, widespread local extinctions, downward trends in abundance, extensive habitat degradation and subsequent decreased carrying capacity, artificial propagation with non-native stocks, recent droughts and current ocean conditions.
2. SOUTHERN OREGON/NORTHERN CALIFORNIA COAST – **Boundaries** extend from Cape Blanco in southern Oregon to Punta Gorda in northern Oregon. **Extinction Risks** are negligible at this time but the population is likely to become endangered in the future due to a severe decline compared to historical run size, frequency of local extinctions, long-term downward trends, degraded habitat and subsequent decreased carrying capacity, widespread hatchery production of exotic stocks, recent droughts and current ocean conditions.
3. OREGON COAST – **Boundaries** include coastal drainages along most of the Oregon coast from Cape Blanco to the mouth of the Columbia River. **Extinction Risks** are negligible at this time but the population is likely to become endangered in the future due to recent low abundance estimates compared to historical abundance estimates, long-term downward trends, recent spawner-to-spawner ratios that are below replacement, extensive habitat degradation, hatchery production of coho, recent droughts and current ocean conditions.
3. LOWER COLUMBIA RIVER/SOUTHWEST WASHINGTON COAST – **Boundaries** historically probably included all Columbia River tributaries below the Klickitat River on the Washington side and below the Deschutes River on the Oregon side, including Willamette River as far upriver as the Willamette Falls, and coastal drainages in southwest Washington between the Columbia River and Point Grenville between the Copalis and Quinault Rivers. **Extinction Risks** weren't determined since no remaining natural populations of coho were identified, with the possible exception of the Clackamas River's late-run which might be a remnant of a lower Columbia River ESU which, while not presently in danger of extinction, is likely to become endangered in the future.
5. OLYMPIC PENINSULA – **Boundaries** are entirely within Washington, including coastal drainages from Point Grenville to and including Salt Creek west of the Elwha River. **Extinction Risks** are at present negligible due to the native, natural, self-sustaining population of coho which is not likely to become endangered in the future, although habitat destruction and hatchery practices are an area of concern.
6. PUGET SOUND/STRAIGHT OF GEORGIA – **Boundaries** include the drainages of Puget Sound and Hood Canal, the eastern Olympic Peninsula east of Salt Creek, and the Strait of Georgia from the eastern side of Vancouver Island and the British Columbia mainland north to and including Campbell and Powell Rivers, excluding the upper Fraser River above Hope. **Extinction Risks** include a likelihood of endangerment in the future due to risk factors such as widespread and intensive artificial propagation of non-natives, high harvest rates, extensive habitat degradation, a recent decline in adult size, and unfavorable ocean conditions.

In March 2001, the Southwest Fisheries Science Center at the Santa Cruz Laboratory (2001) published a status review update for the Central California Coast and Southern Oregon/Northern California Coast ESUs. There was evidence of coho presence in 877 California streams, a number which, compared to Brown and Moyle's (1991) 582 streams, they attribute to new historical records and intensified stream surveys. Nonetheless, between 1989 and 2000, they found that the percentage of streams in which coho were present declined. Further, they found there was a greater percentage of declines within the southernmost range of these ESUs. Overall, there was a downward trend in populations throughout the state. They confirmed that the Central California Coast ESU is in danger of extinction and the Southern Oregon/Northern California Coast ESU is likely to become endangered in the future.

At present, the Central California Coast ESU, restricted to coho south of San Francisco Bay, is State listed as endangered (December 31st, 1995), and federally listed as threatened (December 2nd, 1996). The Southern Oregon/Northern California Coast ESU is federally listed as threatened (June 5th, 1997) and critical habitat was designated February 16th, 2000 (HCPB, 2001).

More recently, attention has been drawn to the Southern Oregon/Northern California Coast ESU within the Klamath River's Klamath Project. In the 1800's, European settlers first began farming the Klamath basin. In 1905, U.S. Bureau of Reclamation (USBR) initiated the Klamath Project and, without the consent of the Native American Klamath Tribes, began draining lakes and wetlands to divert irrigation waters to farmlands. "Water rights" were issued to irrigators by state and federal governments, more so than were sustainable (Pacific Coast Federation of Fisherman's Association [PCFFA], 2001).

As a result, low flows, hydroelectric dams and runoff induced algae blooms have reduced some fish populations to dwindling numbers (Waterwatch). Resident Lost River (*Deltistes luxatus*) and shortnose (*Chasmistes brevirostris*) suckers have become federally endangered in the Upper Klamath Lake. Coho salmon in the Klamath River are federally threatened. Downstream commercial salmon fisheries have also felt the effects of decreasing water quality, increasing water temperatures, inadequate instream flows and the concurrent decline in coho population (PCFFA, 2001).

In the year 2000, USBR supplied farmers with 100 percent of their irrigation demands and set Klamath River flows at a fraction of that necessary to sustain coho populations. On April 5th, 2001, a federal court ruled that USBR knowingly and deliberately violated the Endangered Species Act because they did not consult with NMFS for a biological opinion for the 2000 year, a condition necessary to ensure that the continuing operation of the Klamath Project won't harm listed coho salmon. As a result, the court ordered USBR to halt water delivery to irrigators when water flows fell below a designated level to protect coho (Environmental News Service [ENS], 2001).

On April 6th, 2001, NMFS submitted to the USBR the opinion that "…the ongoing operation of the Klamath Project into the future, as proposed, is likely to jeopardize the continued existence of [Southern Oregon/Northern California Coast] coho salmon and adversely modify its designated critical habitat" (Lent, 2001).

Due to severe drought conditions in the Pacific Northwest in 2001, USBR severed water supplies to 200,000 acres of California and Oregon farmland served by the Federal Klamath Water Project to protect the listed species (Associated Press [AP], 2001). More than 1,000 farms lost access to irrigation water between April and July (Milstein, 2001).

After irrigation waters were shut off, questions arose concerning the science behind the decision. In August of 2001, Secretary of the Interior Gale Norton asked the National Academy of Sciences to review the biological opinion restricting USBR from delivering water to irrigators during the drought. Further, she gave USBR the go-ahead to release 75,000 acre-feet of surplus lake water from Upper Klamath Lake to be delivered to farmers (Coile, 2001; Milstein, 2001). To date, the review is pending.

In light of the conflicts that followed, Oregon State University set about producing a report covering the situation surrounding the Klamath Project, including history, community impacts, fish and wildlife, water resources and law, agricultural resources, economics, public policy issues, and alternative strategies for water allocation. The draft report (to be finalized early 2002) is available at: http://eesc.orst.edu/klamath/klamathdraft.pdf

History of Pacific Coast Hatcheries/Artificial Production

Hatcheries were originally intended to rebuild, reestablish and supply coho salmon populations to support commercial, sport and tribal fisheries. Most hatcheries were installed when wild salmon stocks were healthy and genetically diverse. In recent years, however, hatcheries have instead been implicated as a major contributor to the decline of wild salmon stock. The impacts of hatcheries on wild stock salmon include unnatural harvest rates, intraspecific competition, and genetic mixing (Flagg et al, 2000). Further, hatchery stock almost always include fish from outside the river system or outside California (Jensen, 1971; Brown and Moyle, 1991). The following section, *Threats to the Species*, discusses these impact issues in greater detail.

Coho and salmonid populations can be broken down into three stocks. Wild stock salmon are native fish populations that have little or no hatchery fish ancestry. Natural stock salmon are the naturally spawned progeny of populations that have mixed with hatchery fish. Hatchery stock salmon are populations that consist primarily of hatchery fish and which have minimal natural reproductive viability (Brown and Moyle, 1991).

Taken from Flagg et al 2000, some of the major differences between hatchery and wild stock salmon are summarized below:

	Wild Stock	**Hatchery Stock**
Survival		
Egg-smolt survival	lower	higher
Smolt-adult survival	higher	lower
Behavior		
Foraging ability	efficient	inefficient
Aggression	lower	higher
Social density	lower	higher
Territorial fidelity	higher	lower
Migratory behavior	disperse	congregate
Habitat preference	bottom	surface
Predator response	flee	approach
Morphology		
Juvenile shape	more variable	less variable
Nuptial coloration	brighter	duller
Kype size	larger	smaller
Reproductive Potential		
Egg size	smaller	larger
Egg number	lower	higher
Breeding success	higher	lower

To determine the magnitude of Pacific coast hatchery input, Weitkamp et al (1995) compiled coho salmon hatchery production numbers between 1987 and 1991 based on established ESU boundaries. Annually, hatcheries in the central California coast ESU released approximately 350,000 coho salmon; the southern Oregon/northern California coast ESU approximately 1.4 million; the Oregon coast ESU approximately 1 million (plus an annual private hatchery input of between 2.2 and 4.8 million); the lower Columbia River/southwest Washington coast ESU approximately 55 million; the Olympic Peninsula ESU approximately 4.8 million; and the Puget Sound/Strait of Georgia ESU approximately 43 million.

Of northern California's major spawning streams of coho salmon – the Smith, Klamath, Redwood, Mad, Trinity, Eel, Mattole, Noyo, Russian, Lagunitas, Waddell and Scott Rivers — the Klamath, Redwood, Trinity, Mad and Noyo Rivers all had hatcheries that have contributed to nonnative coho populations in significant numbers (Brown et al, 1994).

At present, only seven hatcheries in California are still producing coho salmon. In the Central California ESU there are the Monterey Salmon and Trout, Warm Springs, and Noyo Station hatcheries. Of these, the Noyo Station is the only significantly producing hatchery consistently in operation. In the California portion of the Southern Oregon/Northern California Coast ESU there are the Mad River, Trinity River, Irongate and Rowdy Creek hatcheries. Of these, the Trinity River, Irongate and Rowdy Creek hatcheries are the only main producers of coho (Santa Cruz Laboratory, 2001).

Threats to the Species

There have been a number of factors cited in the decline of coho and salmonid populations, mainly stream habitat loss, intraspecific genetic mixing of stock types, intraspecific competition between stock types, disease, overexploitation, and climate changes.

• **Stream Habitat Loss** – The disappearance of stream habitat, especially spawning and rearing habitat, has been widely cited as the key factor in declining coho and salmonid populations. Stream habitat loss has been attributed to damming, urbanization, agriculture, grazing, mining, water withdrawal, unscreened diversions, stream channelization, and other human activities (Brown et al, 1994; NMFS, 2001). In particular, habitat degradation has occurred due to changes in channel morphology, substrate changes, loss of instream roughness and complexity, loss of estuarine habitat, loss of wetlands, loss and/or degradation of riparian areas, declines in water quality, altered stream flows, impediments to fish passage, and elimination of habitat (NMFS, 2001). Forestry practices in particular have had deleterious effects on salmonid habitat. Watershed deforestation enhances runoff and siltation, introduces instream debris and blockage, and can increase water temperatures due to the absence of vegetative cover (Iwanaga and Hall, 1973). Logging roads and skid trails contribute notably to erosion and land slippage (Brown et al, 1994). Coho have been shown to prefer unsilted cobble substrates and stream banks with protective, vegetative overhang (Bustard, 1973).

• **Genetic Mixing –** Genetic mixing between hatchery and native fish can and has undermined the genetic integrity of coho salmon and salmonid populations. In introducing hatchery fish to native fish populations, the loss of genetic diversity characteristic of hatchery fish results in an overall loss of fitness in local populations. The absence of natural selective pressures in hatcheries (or rather, the unnatural selective pressures at work in hatcheries), and the subsequent change in mortality rates results in a genetic change in hatchery fish compared to those in the wild. The higher survival rates, unassociated with fitness, prove detrimental when introduced to natural populations. For smaller populations/stocks, inbreeding and genetic drift might also alter genetic integrity (Weitkamp et al, 1995).

• **Competition -** When hatchery fish are introduced into the natural environment, intraspecific competition occurs between hatchery, wild, and natural stocks, especially when fish densities are at high levels (Brown and Moyle, 1991). High levels of intraspecific competition have been noted to depress the return rate of adults (Shapovalov and Taft, 1954). Further, intraspecific competition at high fish densities for resources, territories, and prey items can alter juvenile responsiveness to predators and lead to higher mortality rates. Later in life, returning hatchery fish can compete with natural- and wild stock coho for spawning sites, further aggravated by the fact that hatchery fish are often less successful in producing smolts and returning adults (Brown and Moyle, 1991).

• **Disease –** The potential transmission of disease from hatchery fish to natural and wild stock salmonids could be problematic to local salmonid populations. A number of diseases such as the protozoan *Ceratomyxa shasta* induced Ceratomyxosis and viral *hemorrhagic septicemia* have been reported in hatchery salmonids (Brown et al, 1994). Other potential diseases known to affect salmon include *Renibacterium salmoninarum* induced bacterial kidney disease (BKD), *Aeromonas* *salmonicida* induced Furunculosis, *Flexibacter psychrophilus* induced bacterial coldwater disease (BCD), infectious hematopoietic necrosis virus (IHNV), herpes virus infections, and infectious pancreatic necrosis (IPNV) (Brown et al, 1994; Flagg et al, 2000).

• **Overexploitation –** Overfishing has contributed to coho and salmonid decline in that the continual harvest of depressed populations can prevent their recovery and might further reduce their genetic variability (Brown et al, 1994). When an abundance of hatchery stock are introduced into a population, the respectively higher harvest rates are detrimental to that population's wild stock component. Additionally, females are especially vulnerable to overfishing because they spend as many as three years in the ocean prior to returning, whereas males can spend as little as little as six weeks before returning to spawn (Brown et al, 1994). The oceanic predation of salmonids by California sea lions (*Zalophus californianus*) and Pacific harbor seals (*Phoca vitulina*) has also been implicated as an additional factor in the decline of salmonid populations (NMFS, 1997).

• **Climate –** Natural climatic events have also contributed to the decline in coho and salmonid populations. Severe droughts, inundating floods, oceanic upwelling and El Nino have played a role in the decline of quality habitat. While these factors have undoubtedly persisted throughout the past, they now serve to aggravate a situation already suffering from human related influences (Brown and Moyle, 1991; Brown et al, 1994).

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