A HISTORY OF THE SALMONID DECLINE IN THE RUSSIAN RIVER

& Rebecca V.

A Cooperative Project
Sponsored by

Sonoma County Water Agency
California State Coastal Conservancy
Steiner Environmental Consulting

Prepared by

Steiner Environmental Consulting

August 1996

Steiner Environmental Consulting
Fisheries, Wildlife, and Environmental Quality
P. O. Box 250 □ Potter Valley, CA 95469

A HISTORY OF THE SALMONID DECLINE IN THE RUSSIAN RIVER

A Cooperative Project
Sponsored By

Sonoma County Water Agency
California State Coastal Conservancy
Steiner Environmental Consulting

Prepared by

Steiner Environmental Consulting
P.O. Box 250
Potter Valley, CA 95469

August 1996

(707) 743-1815 (707) 743-1816 fax 103643.3310@compuserve.com

EXECUTIVE SUMMARY

BACKGROUND

Introduction

This report gathers together the best available information to provide the historical and current status of chinook salmon, coho salmon, pink salmon, and steelhead in the Russian River basin. Although the historical records are limited, all sources depict a river system where the once dominant salmonids have declined dramatically. The last 150 years of human activities have transformed the Russian River basin into a watershed heavily altered by agriculture and urban development. Flows in the main river channel river are heavily regulated. The result is a river system with significantly compromised biological functions. The anthropogenic factors contributing to the decline of salmonids are discussed.

Study Area

The 1,485 square mile Russian River watershed, roughly 80 miles long and 10 to 30 miles wide, lies in Mendocino, Sonoma, and Lake counties. The basin topography is characterized by a sequence of northwest/southeast trending fault-block ridges and alluvial valleys. Lying within a region of Mediterranean climate, the watershed is divided into a fog-influenced coastal region and an interior region of hot, dry summers. The mean annual precipitation is 41 inches, ranging from 22 to 80 inches, and primarily occurs from October to May. The pre-diversion runoff regime had episodic flows; high winter flows reflected the intensity and duration of storms and low summer flows were sustained by groundwater. Importation of water from the Eel River and two large reservoirs changed that regime, reducing winter flow peaks, protracting high winter flows, and greatly increasing summer flows.

Salmonid Life Histories

The anadromous chinook salmon, coho salmon, and steelhead are born in fresh water, live there for some time before migrating, then spend several years in the ocean. These fish return upriver as adults to spawn in their natal streams. Suitable spawning grounds must have clean, loosely compacted gravel in cool water with high dissolved oxygen and an intergravel flow sufficient to aerate the eggs. The lack of suitable gravel often limits successful salmonid spawning in many streams. The fertilized eggs hatch in 50 to 60 days. The alevin stay in the gravel for several weeks, emerging as fry once their yolk sac is nearly absorbed.

Russian river chinook salmon usually return as two to four year old adults, entering the river from August to January. They spawn primarily in the mainstem and

Dry Creek. The young chinook begin their outmigration soon after emerging from the gravel. Coho usually spend two years in the ocean, returning to the river to spawn from November into January. They currently spawn in the lower mainstem tributaries. The young spend one year in fresh water inhabiting cool pools with ample cover. Outmigration occurs in their second spring. Both chinook and coho die after spawning. Returning to the river December through April, most steelhead spawn high in the tributaries. Some adults return to the ocean after spawning to repeat the cycle as many as five times. The juveniles rear in freshwater from one to four years, preferring cool waters with abundant cover. Smolt outmigration typically occurs in the early spring.

POPULATION TRENDS

Decline in Russian River salmonid populations was noted as early as 1888. Today, Chinook salmon and coho salmon are considered at high risk of extinction. Whether chinook salmon were abundant historically in the Russian River is debated. Data is sparse and there were no population estimates until the 1960's following years of hatchery supplementation. Regardless of origin, there are very few chinook present in the basin today; those present are largely confined to the mainstem and Dry Creek. Coho, once so prevalent that they supported a commercial fishery, are now estimated at less than 1,000 for the entire basin. Their presence is much reduced because barriers and habitat degradation limit use of many creeks that were available historically. Pink salmon, once resident in the Russian River, are now nearly non-existent in the drainage. They were last reported spawning in 1955 and only the occasional fish has been reported since. As late as the 1950's, steelhead supported a world-class fishery in the Russian River. The species has since experienced such significant declines that it is currently proposed for federal listing as an endangered species. The significant decline in American shad and striped bass populations, both non-native species, further indicates the degradation of fisheries habitat throughout the Russian River watershed.

IMPACTS TO SALMONID POPULATIONS

Dams

Construction of two large dams, Coyote Valley on the East Fork in 1959 and Warm Springs on Dry Creek in 1982, formed absolute barriers to salmonid migration and trapped sediment. It is estimated that they blocked access to 86 to 169 miles of historically valuable spawning and rearing habitat, enough for about 8,000 to 14,000 steelhead adults and 100 coho adults. Loss of the 600,000 tons of sediment trapped annually behind the dams has caused a multitude of adverse morphological problems throughout the basin. Additionally, some smaller dams on the mainstem form barriers; for example, Healdsburg Recreational Dam blocks upstream salmonid migration at high and low flows and blocks all passage of American shad.

Extensive damming exists on tributaries. Over 500 small dams, mostly private, trap sediment, limiting recruitment of downstream spawning gravel. Most tributary dams also block the upstream migration of salmonids. Tributary dams and domestic or agricultural water diversions reduce downstream flows and increase water temperatures. These changes are of particular importance to juvenile steelhead and coho because they rely on small, shaded, cool streams for spawning and summer rearing. Loss and degradation of tributary habitat is considered a major limiting factor for Russian River salmonid populations.

Flows and Temperature Changes

Until 1908, the Russian River flowed unimpaired. Flows cycled with winter storms and were low in the summer. The 1908 diversion of Eel River water through the Potter Valley Power Project protracted the decline of spring flows, but did not augment late summer flows. The construction of Scott Dam in 1922 brought significant changes. Eel River water, stored in Lake Pillsbury and diverted to the East Fork of the Russian River, provided significant base flows throughout the year. Summer flows, regularly in excess of 125 cfs, eliminated stratified pools and other summer thermal refuges in the mainstem Russian River. Coyote Dam, completed in 1959 for water supply, flood control, and recreation, altered the mainstem flow patterns year-round. Dam operations dampened discharge peaks, prolonged winter high flows, and increased summer flows above Healdsburg to the range of 200 cfs. The new flow regime changed channel morphology basin-wide, compromising or destroying rearing habitat. Cool water released from the dam is warmed by ambient heating; summer water temperatures between Hopland and Cloverdale cause salmonid stress and approach lethal levels below Cloverdale. On Dry Creek, the benefit of high summer releases of cold water from Warm Springs Dam is offset by impaired habitat resulting from regulated flow. As a consequence, Dry Creek salmonid rearing is limited.

Altered Species Composition

Increased summer flows, lack of cold water refugia, the alteration of habitat by channelization, riparian vegetation removal, diversions and impoundments, and the introduction of non-native fish species have all worked to cause a major basin-wide shift toward warmwater species. Of these factors, the most critical element is the increased summer flows in the mainstem which now are 15 to 20 times the historic natural levels. Juvenile salmonid habitat has declined with increased flows. The flow increase, and the concomitant loss of habitat and thermal refuges, has created ideal warmwater fish habitat. As a consequence, the historical balance dominated by the native coldwater salmonids has shifted in favor of warmwater species. The Sacramento squawfish, a native warmwater species which competes with or directly preys upon juvenile salmonids, dominates much of the mainstem. Other established populations of introduced warmwater species adversely affect the salmonids by predation and through competition for habitat and food. Under present flow and temperature conditions, warmwater species will continue to dominate the mainstem, compromising salmonid rearing and juvenile migration.

Morphological Changes

Changes in the flow regime and sediment transport have dramatically transformed the Russian River and its tributaries. Loss of sediment load is attributable to retention behind the basin's large and small dams, and to gravel extraction in excess of replenishment. The response of the mainstem to a decreased sediment load has been to scour and to downcut which in turn increased bank erosion, created vertical banks, led to tributary downcutting, lowered the water table, and isolated flood plains. Loss of riparian vegetation, either through erosion, removal, or separation from the water table results in further erosion and vertical bank formation. Vertical banks prevent the natural succession that provides replacement for mature vegetation. Prolonged post-storm flood control releases from Coyote Dam exacerbate the failure of these vertical, erodable banks. Landowner stabilization measures in response to erosion tend to channelize the river and further disrupt the natural processes.

The result of these interlinked morphological changes, on-going today, is a simplified river system lacking the substrate, structure, cover and water quality necessary for salmonid habitat. In addition, channel degradation, often in combination with the presence of man-made structures, has created fish passage impediments in the mainstem and tributaries. Continued survival of salmonids requires reversal of the current trends in total erosion control, gravel extraction and maintenance of sustained flows.

Ocean Productivity Trends

Conditions during the marine phase, about half of a salmonid's life, impact growth rates and overall survival rates. Local hatchery return rates and chinook salmon escapement indices show parallel trends for many northern California and southern Oregon rivers. Most experienced a dramatic collapse in the late 1980's and early 1990's. These similarities across such a wide geographic area suggest that ocean productivity (food availability, predation, and harvest) may be a common influence of significant proportion.

Long-term cycles ranging from 30 to 100 years are believed to affect ocean productivity. Reduced growth rates, measured by mean fork lengths of returning adults, have been linked with El Niño activity. High ocean productivity might mask river system problems of habitat loss and degradation. If periods of low ocean productivity coincide with other factors which result in poor success, salmonid populations could be driven to critically low levels.

Hatchery Impacts

Since 1870, approximately 40 million hatchery-reared salmonids have been planted in the Russian River system: 8 million chinook salmon, 2 million coho salmon, and 30 million steelhead. In addition, from 1939 to 1971 juvenile chinook and steelhead rescued from drying streams in the Russian and Eel River systems were planted to the mainstem Russian. For the first century of hatchery supplementation, nearly all fish planted were from out-of-basin stocks. The majority of chinook and coho were from North Coast, Sacramento, Klamath, or Wisconsin hatcheries, while most steelhead came from North Coast hatcheries. Beginning in 1980, the concepts of ecological distinctness and genetic fitness of local stocks led to efforts at Warm Springs Hatchery to propagate locally returning fish. Since 1990, all steelhead planted in the Russian River basin are progeny of adults returning to Warm Springs Hatchery or Coyote Valley Fish Facility, all chinook planted are of a created source stock spawned and reared at Warm Springs, and 85 percent of coho planted are progeny of adults returning to Warm Springs.

Other hatchery and planting practices have changed over time. Larger fish are planted rather than eggs, embryos, or fry. Juveniles are imprinted at the release site to minimize straying when adults return. Some straying is a normal occurrence, the rate dependent upon environmental conditions. Many non-native fish species were also planted in the Russian River system, but today only brown trout continue to be planted, and they only above Lake Mendocino.

Consensus is growing that hatchery supplementation has had major negative impacts on the native or naturally reproducing salmonid populations. Hatchery selection processes, inbreeding, and interbreeding all lead to the loss of genetic diversity and loss of local adaptations. Russian River hatchery stocks, a melange of many different origins, are likely to be genetically less fit for survival in streams than wild fish. Remnant populations of genetically pure Russian River stock may exist in the more remote and relatively undisturbed tributaries. The release of large numbers of hatchery smolts may also negatively impact naturally spawned fish by displacement, predation, and competition for food in freshwater and the ocean. Successful hatchery returns increase angler pressure and incidental harvest of wild populations, a significant threat when wild populations are low. Disease continues to be a major problem with hatchery propagation and interbasin transfers. As hatcheries continue to adapt their practices, their function may evolve to one of genetic refugia, protecting stocks until river system restoration efforts assure the sustainablility of naturally reproducing populations.

LIST OF TABLES

LIST OF FIGURES

John Hawksworth - Report Preparation

David Menasian - Data Analysis, Report Preparation

Charles Suthard - Report Preparation

CALIFORNIA DEPARTMENT OF FISH AND GAME

Robert Coey - Draft Review

Bill Cox - Draft Review

Weldon Jones - Draft Review

Richard Macedo - Draft Review

Larry Week - Draft Review

PHILIP WILLIAMS AND ASSOCIATES

Joan Florsheim - Draft Review

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD

Robert Klamt - Draft Review

CIRCUIT RIDER PRODUCTIONS

Karen Gaffney - Draft Review

INDIVIDUALS

Mike Morford - Draft Review

1.1 Introduction

One hundred fifty years ago, the Russian River was the heart of a complex of interdependent ecological units. Well-developed floodplains, riparian forests, seasonal marshes, high-gradient woodland streams, oak grasslands, and coastal coniferous forests all worked in concert to support highly productive fishery and wildlife habitats. In the geologically brief time span since the mid-1800's, this system has been transformed from its natural condition and balance to what is now essentially a heavily controlled urban water conveyance. Two major dams, interbasin water transfers, channelization, water diversions, resource harvest, agricultural and urban land use practices, and lack of foresight in management practices have all contributed to a significantly compromised function of the biological systems. The changes in the Russian River basin present a classic case study of the modern anthropogenic impacts on interrelated ecological communities.

This report represents an extensive effort to collect the best available information on the historical and current status of chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), pink salmon (*O. gorbuscha*), and steelhead (*O. mykiss*) in the Russian River basin. Probable causes for the significant changes associated with these populations are discussed. Preliminary work on this topic was presented at the Russian River Workshop sponsored by the American Fisheries Society in February 1995. Since then, Steiner Environmental Consulting (SEC) has conducted significant research to provide additional details.

Records and information were collected from California Department of Fish and Game (CDFG) files in Yountville and Eureka, California; the California State Resources Agency and California State Government Publications libraries in Sacramento, California; the Mendocino County Water Agency; and the Sonoma County Water Agency. Interviews with CDFG wardens and biologists, long-time area residents, and newspaper sources supplemented agency data. Hatchery plant data were collected from Warm Springs Hatchery, Coyote Valley Fish Facility, Mad River Hatchery, and Silverado Fisheries Base.

During the information gathering process it became clear that the historical record for the Russian River fisheries is sparse. Federal and state agency records are often limited to brief field observations or gross estimates without significant substantiation. The earliest cannery records give a feel for the general magnitude of early salmon presence, but fail to elaborate on species composition. Anecdotal reports from sportswriters and others demonstrate a major presence of steelhead in the system, but lack the rigor of a population study. Early hatchery managers were interested in producing fish, not ledger pages. Hence, much of the planting history comes from highly summarized tables in biennial reports. Despite the lack of specificity, reports from all sources depict a system where the dominant salmonids have declined dramatically due to changes in the flow regime, loss of habitat, and numerous other anthropogenic factors.

[illegible]

The Institute (TI) [illegible] River was [illegible] We [illegible] and [illegible] conditions [illegible] support [illegible] and [illegible] since the [illegible] of the [illegible]

[illegible] by the American Fisheries Society in [illegible]. Since then, [illegible] detail.

[illegible] information [illegible] collected from California Department of Fish and Game (CDFG) [illegible] and [illegible], California; the California State [illegible] and California State Department [illegible] Services [illegible] Sacramento; the [illegible] County Water Agency, [illegible] County Water [illegible] and [illegible] agencies [illegible] collected [illegible]

[illegible]

1.2 Study Area

The Russian River watershed covers 1,485 square miles of northwestern California within Mendocino, Sonoma, and Lake counties (Florsheim and Goodwin 1993) (Figure 1.2-1). The basin is roughly 80 miles long, and varies from 10 to 30 miles in width (COE 1982). From its headwaters north of Ukiah, the river flows 69 miles in a southeastward direction. South of Healdsburg, the river makes an abrupt turn and flows west 41 miles to its outlet at Jenner on the Pacific Ocean. Major tributaries include Austin Creek, Mark West Creek, Maacama Creek, Dry Creek, Big Sulphur Creek, Pieta Creek, Feliz Creek, Robinson Creek, and the East and West forks.

Basin topography is characterized by a sequence of northwest/southeast trending fault-block ridges and valleys. Hills and mountains comprise 85 percent of the basin and alluvial valleys constitute the remaining 15 percent (COE 1982). Unstable Franciscan lithology underlies most mountainous regions, and landslides are common. Primary alluvial regions lie along the course of the mainstem and include the Ukiah and Sanel (Hopland) valleys in Mendocino County, Alexander Valley, and the Santa Rosa Plain in Sonoma County. Mount St. Helena, at 4,344 feet, is the highest point in the basin (Florsheim and Goodwin 1993).

The basin lies within a region of Mediterranean climate and is characterized by warm summers, mild winters, and winter-dominant precipitation regimes. Ninety-three percent of precipitation occurs between October and May, with snow uncommon. The basin is divided into two thermal regions: a fog-influenced coastal region and a drier interior region. The coastal region, characterized by cool summers and abundant summer fog moisture, extends 10 miles inland while the interior region experiences hot, dry summers. Basinwide mean annual precipitation is 41 inches with a range of 22 to 80 inches. The greatest precipitation occurs at high elevations near Mount St. Helena and in the coastal mountains near Cazadero, while the least amount falls in the southern Santa Rosa Plain (COE 1982).

Episodic flows characterized the basin's pre-diversion runoff regime. Steep slopes rapidly conveyed heavy winter precipitation into channels causing peak discharges many times larger than the mean annual flow. Duration of high flows depended on length and intensity of the preceding storm event. During summer, streamflows depended upon groundwater inputs, resulting in low baseflow conditions. These low baseflows continued until the first winter rains.

Augmentation from the Potter Valley Project and the regulating force of two large reservoirs have altered river discharge characteristics. Winter flow peaks are dampened under all but the highest flows. The discharge patterns from the two dams act to protract high water events. Summer flows are greatly augmented; once extremely low to intermittent, mean summer flows at Healdsburg are now approximately 200 cfs (EarthInfo 1994).

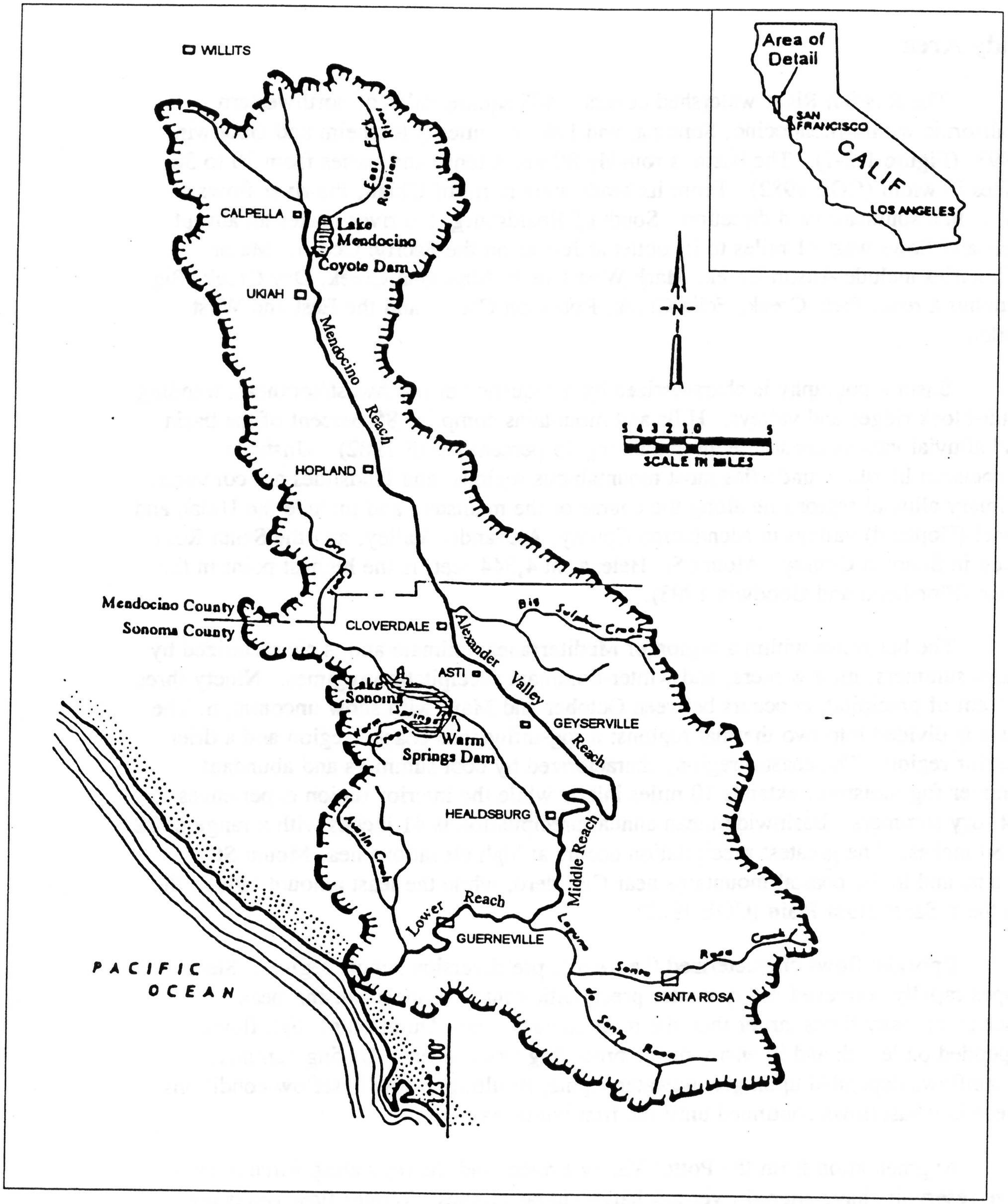

Figure 1.2-1: Map of the Russian River Basin (adapted from Florsheim and Goodwin 1993).

1.3 Salmonid Life Histories

The anadromous salmonids present in the Russian River are the coho salmon, chinook salmon, and steelhead. Anadromous fish are born and live in fresh water for a varying amount of time before migrating to the ocean. Once in the ocean, they spend a number of years before returning to fresh water to spawn. Anadromous salmonids have excellent homing mechanisms, usually returning to their natal stream to spawn. Using keen olfactory senses, a migrating salmonid may pass by and ignore many rivers and tributaries searching for their natal stream (Netboy 1974). Ideally, the upstream migration is timed to coincide with favorable flow and temperature conditions. Salmon and steelhead migrate up to 2,000 miles in the Yukon River, but 100 miles is the maximum distance in the Russian River (COE 1982).

Once steelhead or salmon have reached their natal stream, the search for suitable spawning grounds begins. Requirements for spawning include loosely compacted gravel (1.3 to 10.2 cm in diameter) relatively free of fine silt, sufficient intergravel flow to aerate the eggs, cool temperatures (4.4 to 9.4°C), and high dissolved oxygen levels (Meehan and Bjornn 1991). Suitable gravel is extremely important and is often a factor limiting salmonid populations on many streams (Reeves et al. 1991). The fish carefully choose their redd (nest) sites to minimize the possibility of high flows scouring out the redd. Spawning usually takes place in a pool tail just above a riffle or in a run-like habitat.

When a female fish finds a satisfactory area, the fish begin to form pairs. If the gravel is suitable, the female will begin digging the redd as the male swims nearby. Redds may reach dimensions of up to 10 square meters with depths of 30 to 40 cm (Meehan and Bjornn 1991). Once the redd is completed, the female moves into the pit and releases her eggs which are simultaneously fertilized by the male. The female then begins to dig immediately upstream, covering the eggs with gravel. Steelhead and salmon may repeat this sequence several times over several days. Chinook and coho die after one spawning migration, but steelhead may return to the ocean and then again return to fresh water to spawn in subsequent years, some up to five times (Netboy 1974; Shapovalov and Taft 1954). Eggs hatch in 50 to 60 days depending on water temperature and species (Fry 1979). The newly hatched alevin stay in the gravel until their yolk sac is nearly absorbed. They then move up through the gravel and emerge into the stream as fry. The fry then seek cover and begin the freshwater rearing stage of their life cycle (Meehan and Bjornn 1991).

Chinook Salmon

Chinook salmon begin returning to the Russian River as early as August, with the run continuing into January (Table 1.3-1) (Coey, CDFG, personal communication). Most spawning occurs in November and December. Average size at spawning is 20 pounds with some fish as large as 50 pounds (Fry 1979). Under current basin conditions, chinook spawn almost exclusively in the mainstem Russian River and in

Dry Creek. Generally, chinook juveniles begin migrating to sea shortly after emerging. Fresh water residence, including outmigration, usually ranges from two to four months, but occasionally chinook juveniles will spend one year in fresh water. Yearling residence is rare in California and increases in incidence further north (Moyle 1976a). Little data is available on juvenile chinook in the Russian River. Based on literature from other river systems, chinook move downstream from March to May (Reimers 1973; Moyle 1976a). For example, a regulated flow reach on the Eel River has a protracted chinook emigration due to unnaturally high and cool spring flows (SEC 1987). Chinook emigration in the Russian River may similarly be protracted due to regulated flows. Ocean residence is from one to seven years (COE 1982). Most chinook return to the Russian River as two-to four-year-old adults. Chinook, like coho, die soon after spawning.

Coho Salmon

Coho salmon begin entering the Russian River in November, with the run continuing into January (Table 1.3-1). Most spawning takes place in December. In California, adult coho average between 7 and 12 pounds (Fry 1979). The preferred coho habitat in California is a coastal stream with ample cover and cool temperatures (Hassler 1987). Of the spawning habitat now accessible in the Russian River basin, coho prefer the lower tributaries but will spawn in the main river under low flow conditions (COE 1982). After hatching, the young coho spend one year in fresh water. Juveniles favor pools with ample cover (large wood, root wads, and undercut banks) and cold water temperatures of 12 to 19°C (Moyle 1976a, Hartman 1965). Smolt outmigration usually takes place in the spring. After leaving fresh water, coho spend between one and three years in the ocean. Most Russian River coho spend two years in the ocean before returning to spawn and die (COE 1982).

Steelhead

Steelhead begin returning to the Russian River in December, with the run continuing into April (Table 1.3-1). Most spawning takes place from January through April, depending on time of freshwater entry. Steelhead usually spawn in the tributaries where fish ascend as high as flows permit (COE 1982). Under low flow conditions, steelhead will spawn in the main river (Daugherty, Louisiana Pacific, personal communication). After hatching, steelhead spend from one to four years in freshwater. Juvenile steelhead are extremely adaptable in their habitat selection, though upper tributary sites are most highly favored and productive. Most young-of-year fish prefer riffles, while larger (older) fish move into pools. Cover is extremely important in determining distribution; more cover leads to more fish (Meehan and Bjornn 1991). Preferred water temperatures are 13 to 21°C. Most outmigration is during the spring (January to June), but some outmigration may occur during any significant runoff event. Steelhead spend from one to three years in the ocean before first returning to the Russian River to spawn (COE 1982). Not all steelhead die after

Table 1.3-1: Timing of life history stages in the Russian River for chinook salmon, coho salmon, and steelhead trout.

	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sep
Chinook												
Upstream Migration	■	■	■	■								
Spawning		■	■	■								
Incubation		■	■	■	■	■						
Emergence					■	■						
Instream juvenile residence					■	■	■	■	■			
Smolt emigration						■	■	■	■			
Coho												
Upstream Migration		■	■	■								
Spawning			■	■								
Incubation			■	■	■							
Emergence					■	■						
Instream juvenile residence	■	■	■	■	■	■	■	■	■	■	■	■
Smolt emigration					■	■	■	■	■			
Steelhead												
Upstream Migration		■	■	■	■	■	■					
Spawning				■	■	■	■					
Incubation				■	■	■	■	■				
Emergence						■	■	■				
Instream juvenile residence	■	■	■	■	■	■	■	■	■	■	■	■
Smolt emigration				■	■	■	■	■	■			

spawning; some will return to the ocean and make one to four additional spawning migrations (Shapovalov and Taft 1954).

The salmonid life cycle is extremely complex. Impacts to fish at any one stage will affect the success of the entire brood class. Residence in both freshwater and the ocean expose anadromous fish to a myriad of possible impacts. Some problems associated with streams and oceans are preventable, but factors such as natural cycles in ocean productivity, floods, and droughts are beyond the scope of management capabilities.

2.0 Population Trends

Once, the Russian River contained four anadromous salmonid species: chinook salmon, coho salmon, pink salmon, and steelhead (Table 2.0-1) (Moyle 1976a). Each year the combined anadromous fish returns were in the tens of thousands. Since settlement of the Russian River Basin began in the 1850's, fish resources have suffered. As early as 1888, there was a noted decline in salmon populations (United States Bureau of Fish and Fisheries 1888). Pressure on the fisheries increased as the human population expanded in the basin.

As with other river basins on the West Coast, the Russian River has seen salmonid populations plummet (Figure 2.0-1) (Nehlsen et al. 1991). In the Russian River, chinook salmon are considered at high risk of extinction (Nehlsen et al. 1991). Coho salmon are considered at high risk of extinction (Higgins et al. 1992) and are a candidate for federal listing (Weitkamp et al. 1995). Pink salmon are now functionally extinct in the system. Steelhead runs have decreased significantly and are proposed for federal listing as endangered under the Endangered Species Act (Figure 2.0-2) (NMFS 1996).

Chinook Salmon

The extent of naturally-occurring historic chinook salmon (also known as king salmon) in the Russian River is debated. Cannery records from before 1890 indicate that most salmon harvested were too small to be chinook, the largest of these weighing only about 20 pounds. Unfortunately, this is the only data available for the status of salmon populations prior to the Potter Valley Power project completion in 1922. The next references to Russian River chinook populations came decades after this project was in place. Shapovalov (1946, 1947, and 1955) stated in several correspondences that there were few, if any, chinook in the Russian River. He recommended using Sacramento River stock for introducing a run of chinook in the Russian River due to the similarity in the fauna of each basin. Murphy (1945 and 1947) also stated there were few if any chinook in the Russian River, citing: "Reports from liverymen and wardens indicate that there is a possibility that other species of salmon [other than coho] occasionally penetrate the Russian River in small numbers". Pintler and Johnson (1956) stated, "Although king salmon are sometimes caught in the winter in the lower river, they are rare." Fry (1979) reported there were no chinook in the Russian River prior to supplementation. Several other reports and communications claim chinook were a greater part of the Russian River's fauna. Lee and Baker (1975) stated chinook historically spawned in the upper drainage. Jones (CDFG, personal communication) states chinook were regularly harvested by local tribes in Coyote Valley prior to construction of Coyote Dam.

There are no chinook population estimates until the 1960's. Documented returns appear strongly associated with periods of sustained hatchery supplementation (Section 3.6). Estimated chinook escapement in 1966 was 1,000 (CDFG 1966) and estimated escapement in 1982 was 500 (COE 1982). (Escapement is the number of adult fish successfully returning to a river system to spawn.) Heavy planting in Dry Creek during the 1980's did not result in establishment of a viable run. Returns to Warm Springs from 1980 to 1996 range between 0 and 304 chinook, with the highest count in 1988 (Table 2.0-2) (Cartwright, CDFG, personal communication; Estey 1982-84, 1986; Gunter 1988, 1990, 1991). A single chinook arrived at Coyote Dam in both 1993 and 1994, and no chinook arrived in 1995 and 1996 (Duran, CDFG, personal communication; Fortier 1995, unpublished data). Historic spawning distribution is unknown, but suitable habitat formerly existed in the upper mainstem and in low gradient tributaries. Current spawning is primarily in the mainstem and Dry Creek. Views differ as to where in the mainstem spawning may predominate. Recently, there have been reports of chinook spawning in Mill Creek, Sonoma County (Coey, CDFG, personal communication). Low chinook escapements, variable water years, and spotty data preclude an accurate estimate of spawning distribution. Regardless of origin, hatchery or wild, there are very few chinook presently in the Russian River basin.

Coho Salmon

Coho salmon (also known as silver salmon) were once so prevalent in the Russian River that they supported a commercial fishery (United States Bureau of Fish and Fisheries 1888). Cannery records give no mention of species, but fish weighed between 8 and 20 pounds, suggesting coho were a large part of the catch. In 1888, 183,597 pounds of fish were caught near Duncan Mills for cannery and personal use (United States Bureau of Fish and Fisheries 1888). Assuming an average fish weight of 12 pounds, 15,300 fish were taken. Undoubtedly, many of these fish were coho. Since there is no indication of how many fish escaped capture and continued upstream, the cannery records by themselves may significantly underestimate salmon populations. No further data exist on coho populations until 1975. Lee and Baker (1975) estimated 1975 Russian River coho escapement at 7,000. The COE (1982) estimated 1982 escapement at 5,000. Dry Creek supported an estimated 300 coho salmon before Warm Springs Dam was built in 1982 (COE 1982). By the early 1990's, estimates of combined wild and hatchery coho numbers for the entire Russian basin were under 1,000 (Cox, CDFG, personal communication).

Current coho distribution in the Russian River is much reduced from historic range. Coho once inhabited tributaries to the West Fork such as Forsythe, Mill, Jack Smith, Howard, and Redwood creeks. These creeks provided ideal habitat: dark, deep, shaded pools. Barriers now impede access to these creeks. There are records of juvenile coho in the West Fork during the last five years, but no records of adult spawning (Jones, CDFG, personal communication). In the lower river, coho once inhabited Austin and Mark West creeks. There are no recent records of coho in Austin Creek and few have been reported in Mark West Creek. Currently in the lower river, only Willow Creek, tributaries to Austin Creek, Santa Rosa Creek, and Maacama Creek remain inhabited by coho (Cox, CDFG, personal communication).

Pink Salmon

Pink salmon once inhabited the Russian River, but are now thought to be functionally extinct (Nehlsen et al. 1991). The last spawning was seen in 1955. Only sporadic angler catches have been reported since then (Moyle 1976a; Coey, CDFG, personal communication). Prior to 1955, pink salmon returned in "good" numbers (various anecdotal accounts indicate this may have been in the hundreds) in 1949, 1951, and 1953 (Wilson 1954). The Russian River run represented the pink salmon's southernmost distribution (Moyle 1976a). No reason for decline or extirpation is presented in the literature, but the run probably was small, and cumulative watershed degradation resulted in conditions no longer favorable for continued existence.

Steelhead

Prolific Russian River steelhead runs once ranked as the third largest in California behind the Klamath and Sacramento rivers (COE 1982). This is no longer the case; current Russian River populations have plummeted from historic levels (Figure 2.0-2). Early population estimates are lacking, but anecdotal evidence alludes to large steelhead runs throughout the entire Russian River drainage (Jones, CDFG, personal communication; Anonymous 1893). During the 1930's and on through the 1950's, the Russian River was renowned as one of the world's finest steelhead rivers. A healthy economy thrived on the sport fishing activity (COE 1982). Burghduff (1937) estimated the 1936 sport catch of steelhead at 15,000, and Christensen (1957) estimated the 1956/57 sport catch at 25,000. In 1957 there were an estimated 57,000 steelhead in the Russian River (Prolysts 1984).

Construction of Coyote Dam in 1959 blocked anadromous fish from the East Fork Russian River. Prior to the dam, the East Fork and its tributaries contained some of the best spawning and rearing habitat in the Russian River system (Prolysts 1984). The augmented summer flows from the Potter Valley Project undoubtedly created artificial steelhead rearing habitat. According to newspaper accounts, many limits of "trout" were taken from the East Fork during the 1950's (Prolysts 1984). Adult steelhead population estimates for the East Fork prior to Coyote Dam were 2,213 to 7,684 (Prolysts 1984), 36 to 1,292 (U.S. Fish and Wildlife Service 1982), and 5,000 to 10,000 (Mendocino County 1982). Regardless of the estimate chosen, the loss of access to East Fork steelhead habitat was significant.

There have been no basin-wide estimates since 1957, but hatchery returns fail to approach historic levels. Since 1981, combined return numbers for Warm Springs and Coyote dams range between 333 and 10,310 (Figure 2.0-3). The large return in 1995, about 10,000 hatchery fish, is likely the result of improved ocean conditions and large-scale hatchery plants at both Warm Springs Hatchery and Coyote Valley Fish Facility (Section 3.5 and 3.6).

Other Species

Other species experiencing notable decline in the Russian River are American shad (*Alosa sapidissima*) and striped bass (*Morone saxatilis*). American shad were once numerous with a range extending up to Ukiah (Jones 1993). In 1971, there were an estimated 11,000 to 22,000 shad in the Russian River (COE 1982). Currently, shad distribution is blocked by Healdsburg Dam and periodically limited by other seasonal mainstem dams depending on flow conditions (COE 1982). There are no population estimates since 1971, but limited distribution and degraded habitat conditions have undoubtedly contributed to decreased numbers. Striped bass once supported a significant sport fishery in the Russian River (Shapovalov 1944). In 1924, striped bass weighing 28 and 72 pounds were taken from the Russian River (Metcalf, undated). In 1936, the sport catch was 9,838 fish (Burghduff 1937), and in 1941 was 59,000 fish (Shapovalov 1944). No population estimates exist since 1941. Currently, small numbers of striped bass are caught in the lower river (Coey, CDFG, personal communication), and Reynolds (1991) claims the current striped bass population is not self-sustaining. Both American shad and striped bass are not native to the Russian River and support only small fisheries, but their decline serves to demonstrate the overall decline in the Russian River system.

Table 2.0-1: Indications of population size for chinook, coho, and pink salmon and steelhead in the Russian River at various times in history.

PERIOD	SALMON				STEELHEAD
	PINK	COHO	CHINOOK	TOTAL	
1880's to 1920's				-8,000 to 15,000 taken annually in commercial harvest below Duncan's Mills (1).	-Steelhead spawning in all small tributaries (2). -Many fish in the East Branch in Potter Valley (2).
1930's to 1950's	-Regular small runs; good runs in 1949, 1951, 1953 (3). -Last run in 1955 (4).				-Renowned as one of the world's finest steelhead rivers (5). -Supports strong sport fishing economy (5).
1960's to 1970's		-5,000 (5) to 7,000 (6).	-500 thought to be in river (5).	-5,500 to 7,500.	-Estimated 57,000 (5) to 62,000 (6) adults. -Heavy planting (Section 3.6). -Sport fishery begins noticeable decline (10).
1980's to 1996	-Anecdotal reports of infrequent angler catch of individual fish.	-162 to 578 hatchery returns annually (7,8). -Few fish in river.	-41 to 125 hatchery returns annually (8,9). -Few fish in river.	-500 to 1,000 salmon estimated in total system.	-Approximately 500 to 10,000 hatchery returns annually (9). -Heavy planting (Section 3.6).

REFERENCES:

1. United States Bureau of Fish and Fisheries 1888.
2. Anonymous 1893.
3. Wilson 1954.
4. Nehlsen et al. 1991.
5. COE 1982.
6. Lee and Baker 1975.
7. Cox 1993 Personal Communication.
8. Estey 1982 to 1986 and Gunter 1988 to 1991.
9. Cartwright 1996 Personal Communication, and Duran 1996 Personal Communication.
10. Prolysts 1984.

Table 2.0-2: Adult salmonid returns to Warm Springs Hatchery and Coyote Valley Fish Facility[A].

WARM SPRINGS HATCHERY

	Steelhead Trout				Coho Salmon				Chinook Salmon			
Year	Male	Female	1/2 lb	Total	Male	Female	Grilse	Total	Male	Female	Grilse	Total
1980/81	148	185	0	333	0	0	0	0	0	0	0	0
1981/82	124	235	0	359	2	2	0	4	0	0	0	0
1982/83	322	242	0	564	515	277	194	986	1	0	1	2
1983/84	1039	923	0	1962	0	1	8	9	2	1	1	4
1984/85	369	468	0	837	32	44	0	76	7	1	0	8
1985/86	812	484	4	1300	0	0	0	0	65	0	0	65
1986/87	519	696	36	1251	139	5	328	472	50	25	36	111
1987/88	660	375	10	1045	164	155	257	576	176	4	124	304
1988/89	453	421	17	891	219	139	176	534	151	61	21	233
1989/90	428	260	15	703	35	35	100	170	8	6	3	17
1990/91	239	181	3	423	100	87	90	277	67	0	32	99
1991/92	750	834	7	1591	53	20	89	162	77	46	2	125
1992/93	1378	1289	2	2669	250	113	215	578	15	22	3	40
1993/94	856	895	9	1760	110	62	277	449	8	0	13	21
1994/95	3561	4525	14	8100	310	392	63	765	59	9	17	85
1995/96	2135	1958	12	4105	13	13	36	62	18	12	3	33

COYOTE VALLEY FISH FACILITY

	Steelhead Trout				Coho Salmon				Chinook Salmon			
Year	Male	Female	1/2 lb	Total	Male	Female	Grilse	Total	Male	Female	Grilse	Total
1992/93	182	120	8	310	0	0	0	0	1	0	0	1
1993/94	229	198	13	440	5	2	1	8	1	0	0	1
1994/95	854	737	5	1596	0	1	0	1	0	0	0	0
1995/96	1132	982	6	2120	0	0	0	0	0	0	0	0

A. Sources: Cartwright 1992 and 1994, Estey 1982 to 1986, Gunter 1988 to 1991, Cartwright 1996 Personal Communication, and Duran 1996 Personal Communication.

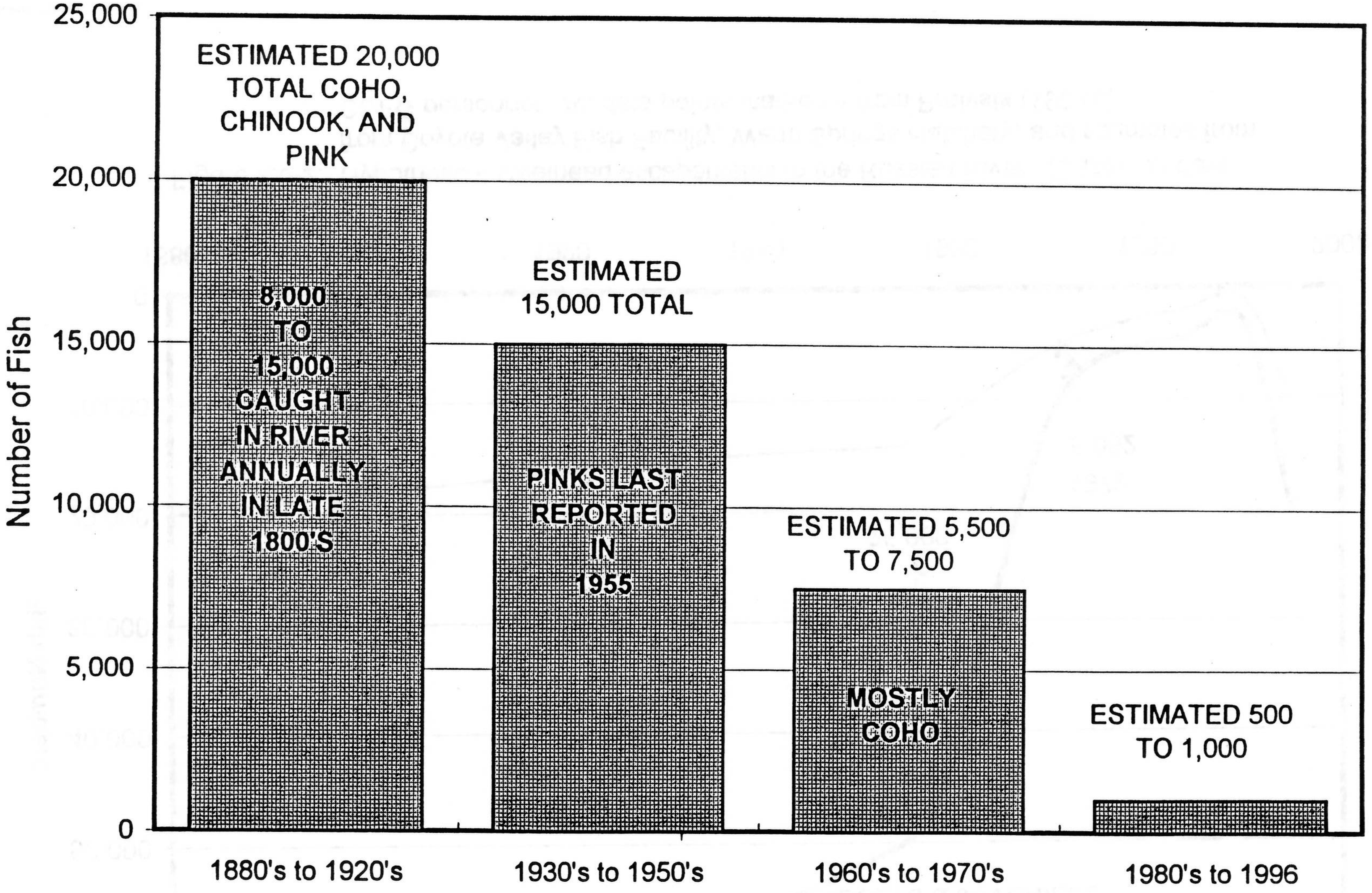

Figure 2.0-1: Hypothetical escapements to the Russian River for all species of salmon. [Estimates based on conservative expansion of U.S. Bureau of Fish and Fisheries (1888), Warm Springs Hatchery return numbers, and anecdotal CDFG reports.]

33\projects\ruserivr\SALMON.XLS\Chart1

8/23/96

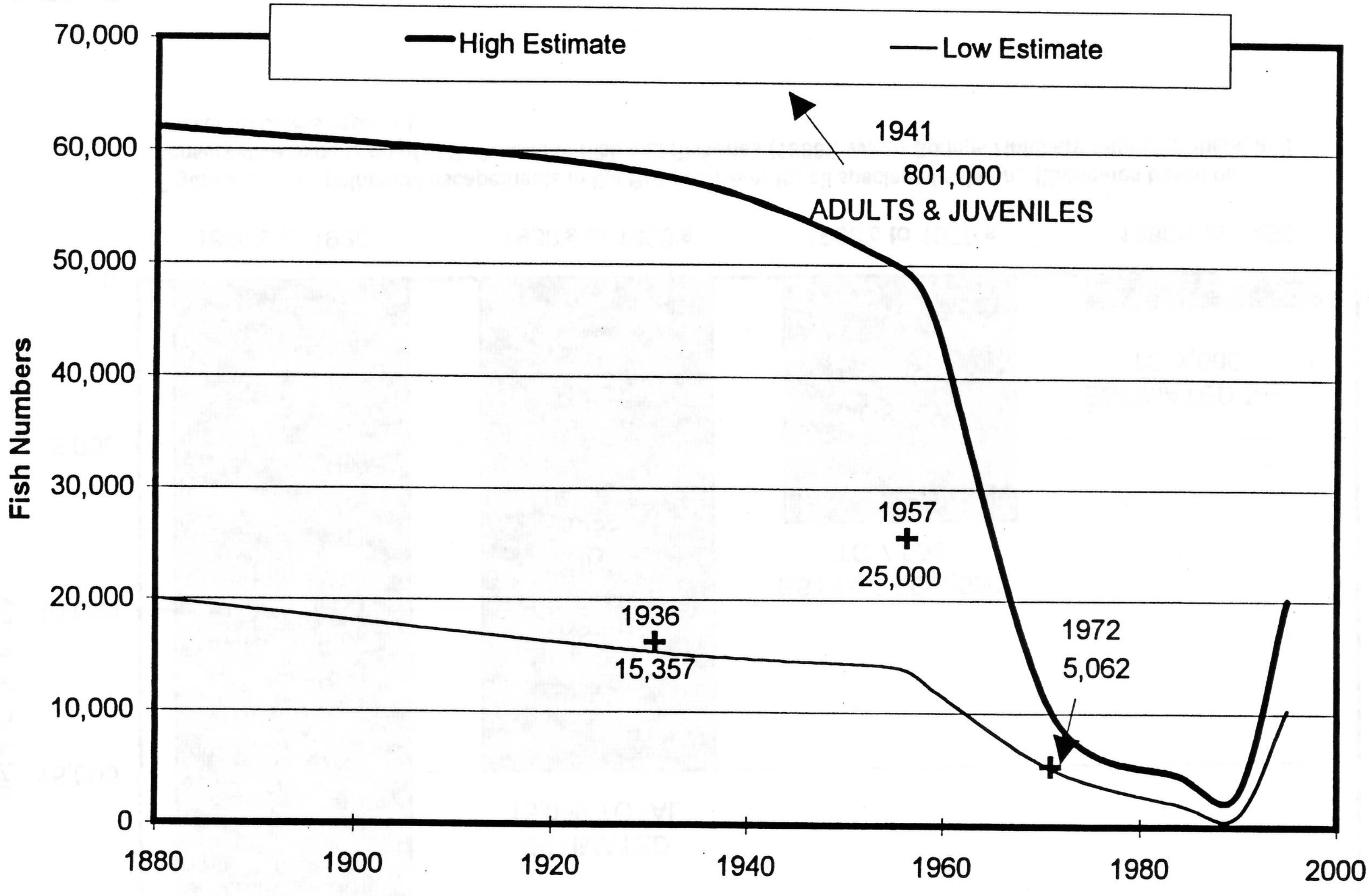

Figure 2.0-2: Hypothetical steelhead escapements to the Russian River. [Based on data from Coyote Valley Fish Facility, Warm Springs Hatchery, and estimates from CDFG personnel. All data points marked + from Prolysts (1984).]

33\projects\russriver\RUSSIAN.XLS\pop ests

8/23/96

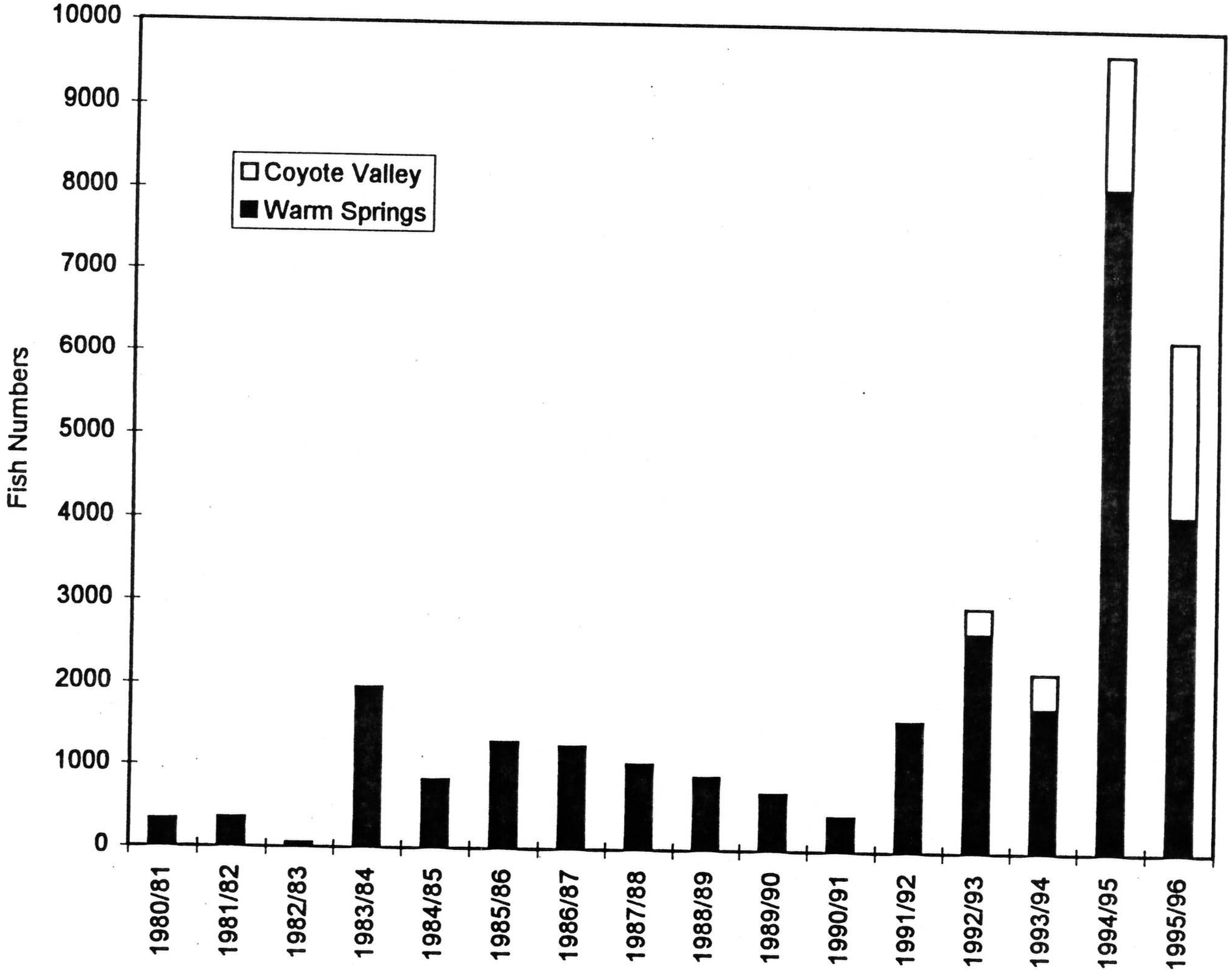

Figure 2.0-3: Combined steelhead returns to Warm Springs Hatchery and Coyote Valley Fish Facility. (Data compiled from CDFG files.)

3.0 IMPACTS TO SALMONID POPULATIONS

Human impacts on the Russian River are highly varied but have had a cumulative effect on the river and its fisheries. Two major dams and numerous tributary structures have led to significant habitat loss and changed channel morphology. Augmented flow with its inherent temperature modification, introduced fishes, gravel mining, increased sport and commercial harvest, land use practices (logging, road building, agriculture, and urbanization), and an increase in hatchery production all have played a part in the basin-wide decline in native salmonid populations.

3.1 Impacts Due To Dams

There are two major dams in the Russian River watershed: Coyote Dam on the East Fork Russian River (Ukiah) completed in 1959 (Florsheim and Goodwin 1993) and Warm Springs Dam on Dry Creek (Geyserville) completed in 1982. The estimated capacity behind Coyote Dam in 1985 was 88,447 acre feet (SCWA 1985), while the original estimated capacity behind Warm Springs Dam was 381,000 acre feet (COE 1973). Designed to provide flood control, recreation, irrigation, and drinking water to Mendocino and Sonoma counties, both structures completely block access to upstream habitat for anadromous salmonids. Estimates of habitat lost vary depending on methodology. Coyote Dam estimates of lost habitat range from 36 miles (Cramer et al. 1995) to 64 miles (Prolysts 1984). For Warm Springs Dam, estimates range from lows of 50 miles (Cox, CDFG, personal communication) and 55 miles (COE 1973) to a high estimate of 105 miles (Cramer et al. 1995).

The areas blocked by these two dams historically were valuable habitat for steelhead and coho salmon. Before Coyote Dam, the East Fork Russian River and associated tributaries provided some of the best steelhead habitat in the entire basin and accounted for an "appreciable portion of the Russian River spawning" (USFWS 1948). Estimates of steelhead denied access to the area above Coyote Dam range from 2,213 to 7,685 fish per year (Prolysts 1984). According to the final environmental impact report prepared by the US Army Corps of Engineers (1973), Warm Springs Dam blocks access to spawning habitat for estimated populations of 6,000 steelhead and 100 coho.

In addition to physically blocking upstream access to anadromous salmonids, these dams also block downstream sediment movement. Coyote Dam blocks approximately 200,000 tons of sediment yearly (Sonoma County Water Agency 1985) and Warm Springs Dam blocks approximately 400,000 tons of sediment annually (COE 1973). Decreased downstream sediment transport causes a myriad of downstream morphological problems (Florsheim and Goodwin 1993) (Section 3.4). Loss of spawning gravels is a direct impact affecting salmonids in the system.

Coyote and Warm Springs dams are not the only dams in the Russian River basin impacting fish populations. There are also five smaller impoundments on the mainstem, and hundreds of lesser dams on tributaries, totaling 509 licensed or permitted dams in the Russian River basin (State Water Resources Control Board, unpublished data). Healdsburg Recreational Dam, constructed in 1952, illustrates the problems caused by small mainstem dams (COE 1982). Originally constructed at grade, the dam blocked migration only when the flashboards were installed for summer recreation. By 1969, however, downcutting necessitated extensive rip-rap installation below the dam (CDFG, unpublished data). This rip-rap, combined with the downcutting, produced a seasonal fish migration impediment. The dam is a barrier to upstream salmonid migration at the higher and lower flows and is a permanent barrier to upstream shad migration (COE 1982; Jones, CDFG, personal communication).

Most dams in the Russian River basin are on tributaries where they degrade the most important salmonid habitat. Tributaries are preferred by steelhead and coho for spawning and over-summer rearing. Anecdotal reports claim, "innumerable tons of salmon ... spawning far up every stream in the county" (Anonymous 1893), and numerous other accounts allude to historic heavy spawning in Mendocino County tributaries (SEC, unpublished data). Historically, tributaries (especially those facing north or east) with summer flow and healthy riparian vegetation likely supported significant populations of salmonids. Most of the small tributary dams are private projects, many done without permit or application; as a result, few records of design or size are available. Extensive tributary damming exists in the more populated areas of Sonoma and Mendocino counties, as exemplified by Redwood Valley. A Febraury 1995 aerial flight over that valley revealed dams and farm ponds on most tributaries to the West Fork Russian River with many drainages accommodating multiple dams.

In general, dams and water diversions in small streams tend to decrease available habitat and increase water temperatures downstream (Prolysts 1984). Habitat is lost either by decreased downstream water flow resulting from diversion or by migration blockage. This adversely affects salmonids, particularly steelhead and coho which rely on tributary habitat for summer rearing. Small tributary dams also block the movement of sediments, limiting the recruitment of necessary spawning gravel downstream. Tributaries are much smaller than the mainstem and thus more sensitive to environmental changes (COE 1982). According to the COE (1982), the loss of tributary habitat is the primary factor limiting the recovery of the anadromous fishery in the Russian River.

3.2 Flow and Temperature Changes

Changes in flow and temperature resulting from dams and diversions have significantly impacted Russian River salmonid populations. Mainstem Russian River flow regimes fall into four distinct time periods: prior to 1908, the river flowed unimpaired; from 1908 to 1922, there was seasonal augmentation from the Eel River; between 1922 and 1959, there was significant year-round augmentation from the Eel River; and after 1959, Coyote Dam further regulated and stabilized flows (COE 1982).

Prior to 1908, the Russian River flowed unimpaired, tending to follow concurrent precipitation patterns (Florsheim and Goodwin 1993). Winter flows were high, cycling with storm events, and summer flows were low or intermittent (McGlashan and Dean 1913). Domestic, municipal, and agricultural users withdrew water. Spot measurements taken in September 1905 showed discharges of 2.2 cubic feet per second (cfs) in the East Fork near Ukiah (McGlashan and Dean 1913). Estimated summer flows at Healdsburg were 10 to 15 cfs (Cox, CDFG, personal communication). Low summer flows could have resulted in high water temperatures, but the mainstem river contained many deep pools with lower layers cooled by intergravel flow. Salmonids survived summer by seeking refuge in the these stratified pools, near springs and seeps, at sites of intergravel flow, and near cooler tributary inflow (Circuit Rider Productions 1994a).

In 1907, Snow Mountain Water and Power Company completed Cape Horn Dam, forming Van Arsdale Reservoir on the Eel River. A tunnel from Van Arsdale Reservoir to the East Fork Russian River was finished in 1908, allowing water diversion for power production (COE 1982). Due to Van Arsdale Reservoir's limited capacity, 700 acre feet, this diversion was primarily run-of-the river, and likely had little effect on flows other than prolonging spring flows in the East Fork Russian River (Figure 3.2-1). The duration and intensity of prolonged spring flows depended on snowpack in the Eel River Basin, but seldom extended through July. Continuous flow records from this period are lacking, but one spot discharge of 6.6 cfs was recorded near Cloverdale in August 1910, and 17 cfs was recorded near Healdsburg in August 1911 (McGlashan and Dean 1913). Historical unimpaired flows for the Eel River from 1911 to 1967 show that, on average, only 17 cfs was available for diversion during August (Anderson 1972). Undoubtedly, a large portion of these early diverted flows were used for irrigation and, hence, did not significantly alter summer flow in the Russian River. Minor flow augmentation from the Eel River continued until 1922.

Completed in 1922, Scott Dam impounded Lake Pillsbury (original capacity 86,000 acre feet) 12 miles upstream of Cape Horn Dam (DWR 1976). Lake Pillsbury provided regulated flow between Scott and Cape Horn dams allowing year-round diversion of Eel River water into the East Fork Russian River (COE 1982). The average summer base discharges in the Russian River increased dramatically, with summer flows generally exceeding 125 cfs (Figure 3.2-2) (COE 1982).

Increased summer base flows eliminated the formation of stratified pool habitat in the mainstem Russian River. Stratified pools form when currents are too weak or inflow of cold water is too great to allow mixing of waters of contrasting temperatures (Nielson et al. 1994). In the Eel River at flows of 44 cfs, DWR (1976) found temperature differences of 11.1°C between surface and bottom waters in pool habitat 16.5 feet deep. DWR (1976) then found that when flows were increased to 83 cfs, stratification failed to occur, resulting in uniform water column temperatures of 27.8°C. The augmented summer flow regime in the Russian River after 1922 eliminated potential salmonid rearing habitat in marginal thermal reaches by maintaining flows at levels too high to allow pool stratification.

The construction of Coyote Dam in 1959 significantly altered downstream flows. During the rainy season, storage for water supply and flood control dampens or eliminates discharge peaks, particularly in fall and early winter as the water supply pool is filling. This attenuation occurs again in the spring when incursion in the flood control pool is allowed to maximize water storage. After storm events, releases from the flood control pool generally sustain high flows for extended periods of time, unlike natural systems. Summer flows also increased significantly after completion of Coyote Dam (Figure 3.2-2). Lake Mendocino enabled maintenance of stable base flows regardless of diversion flows from the Eel River. Current base flows are set by order of the State Water Resources Control Board (D1610). The mainstem is used as a water conduit to supply downstream agricultural, domestic, and industrial needs; releases to satisfy demands are in addition to the base flow. Two hundred cfs is now the approximate mean summer flow at Healdsburg, compared with the historic unimpaired flows of 20 cfs or less (Figure 3.2-2). Coyote Dam's ability to further alter natural flows in the Russian River added to the growing problems of changed channel morphology, impeded migration, and compromised rearing habitat (Section 3.4) (COE 1982; Prolysts 1984; Florsheim and Goodwin 1993).

Cool water release from Coyote Dam was intended to benefit salmonids in summer, but the influence diminishes below Hopland due to ambient warming as the water moves downstream (Hopkirk and Northen 1980; Prolysts 1984). Preferred temperatures for steelhead are between 13 and 21°C (Brown and Moyle 1981), for coho, 11.8 to 14.6°C (Laufle et al. 1986), and for chinook, 12 to 13°C (Brett 1952). Kubicek (1977) described effects of high temperature on juvenile salmonids. At temperatures above 20°C, salmonids suffer stress (decreased metabolic activity and utilization of food, reduced competitive ability, and increased vulnerability to predation and disease). Between 23 and 26°C, salmonids suffer chronic physiological stress. Temperatures sustained for 100 minutes above 28°C are lethal. Summer temperatures between Hopland and Cloverdale cause salmonid stress, and high temperatures prevent juvenile salmonids from utilizing the river below Cloverdale (Hopkirk and Northen 1980; Prolysts 1984; COE 1982). Mean daily temperatures reach 20°C at Healdsburg in late April and exceed 23°C by June 1. By June 1, even minimum temperatures at

Healdsburg exceed 20°C, creating thermally stressful conditions for salmonids (Figure 3.2-3).

In 1982, Warm Springs Dam was completed on Dry Creek, resulting in regulated flows and a loss of rearing habitat below the dam. Cool water released from Warm Springs Dam keeps temperatures below 16°C, limiting warmwater fish intrusion into Dry Creek and creating favorable temperatures for salmonids. This positive effect is offset, though, by impacts to channel morphology from regulated flows (Section 3.4). Before Warm Springs Dam, summer flows in Dry Creek were between 1 and 5 cfs. Present summer flows are approximately 90 cfs at the confluence with the Russian River and significantly higher immediately below the dam. Regulated flow coupled with gravel extraction has caused channel incision, channelization, diminished gravel recruitment, riparian encroachment, and habitat simplification. Temperatures are favorable for salmonid rearing, but lack of riffles, cover, and instream structure severely limits salmonid production in Dry Creek (City of Healdsburg 1996).

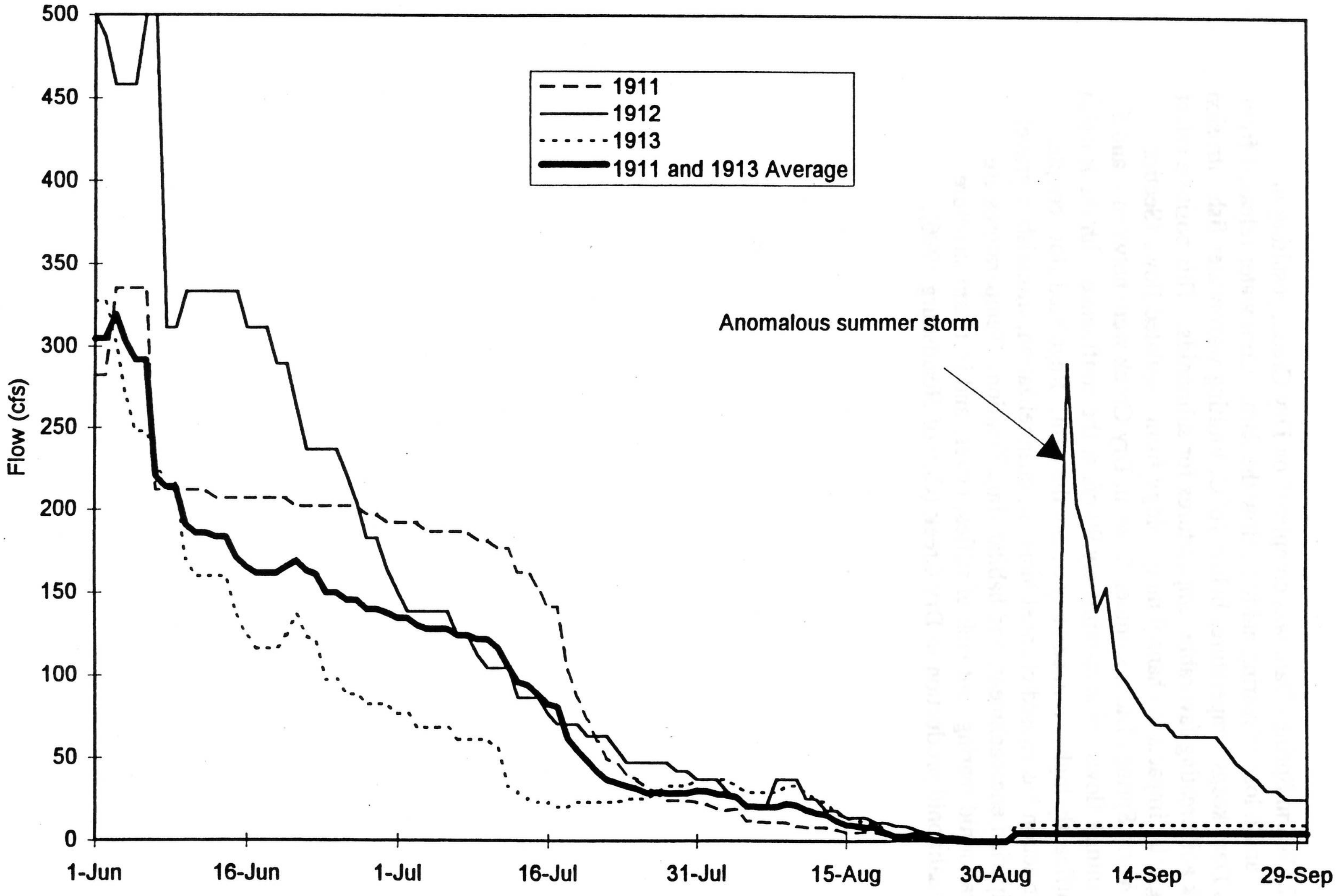

Figure 3.2-1: Mean daily discharge in the Russian River near Geyserville for three years prior to the construction of Scott Dam including the average of mean daily discharges for 1911 and 1913. [All flow data from EarthInfo (1994).]

super\histflow\russian\CSHOPL.XLS\geyser cht

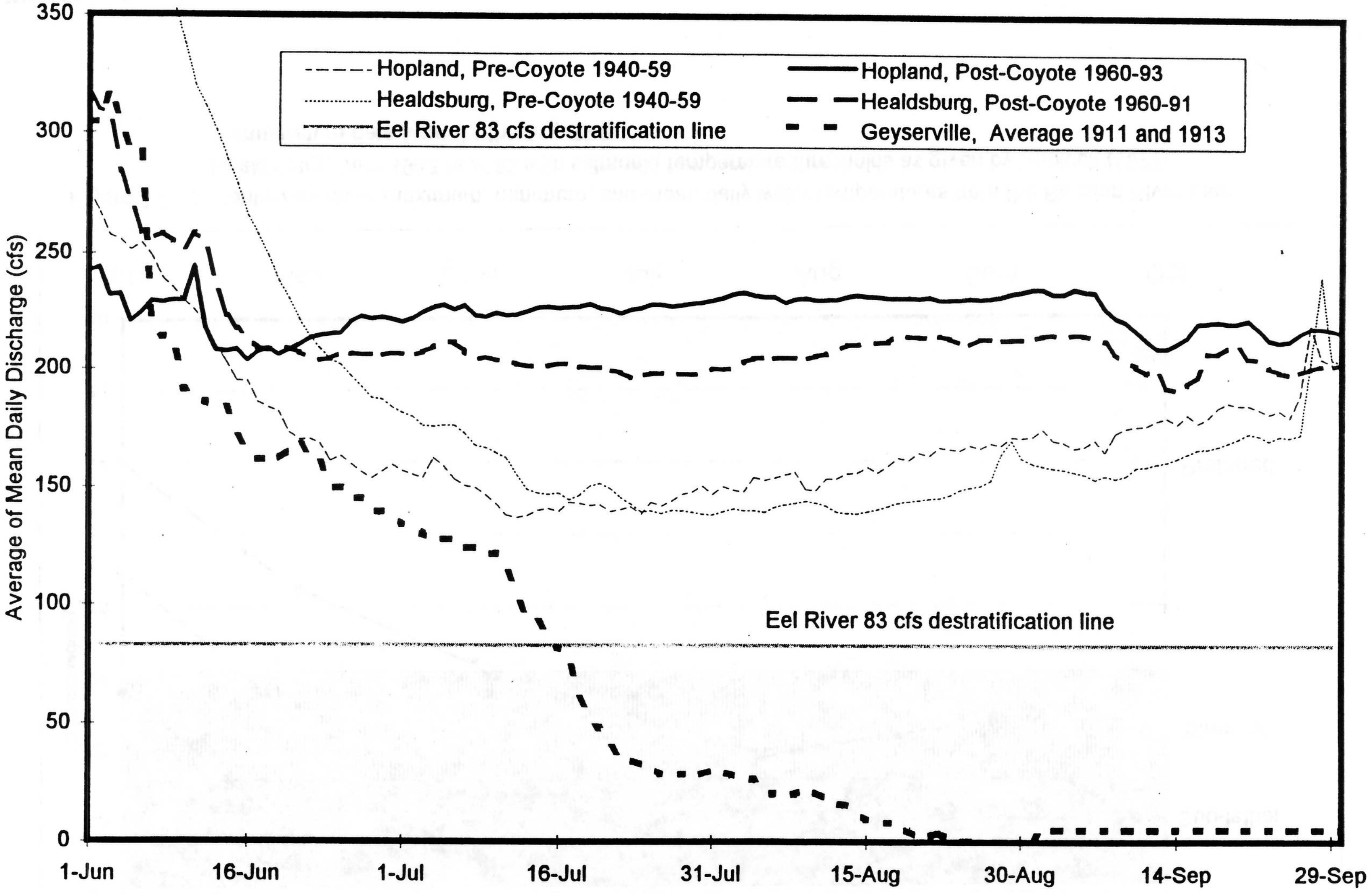

Figure 3.2-2: Average mean daily discharges near Hopland and Healdsburg (pre- and post-Coyote Dam) and average near Geyserville (1911 and 1913) between June 1 and September 30. [The 83 cfs destratification line is taken from DWR (1976). All flow data from EarthInfo (1994).]

\super\hstflow\russian\CSHOPL.XLS\hop+heald grf

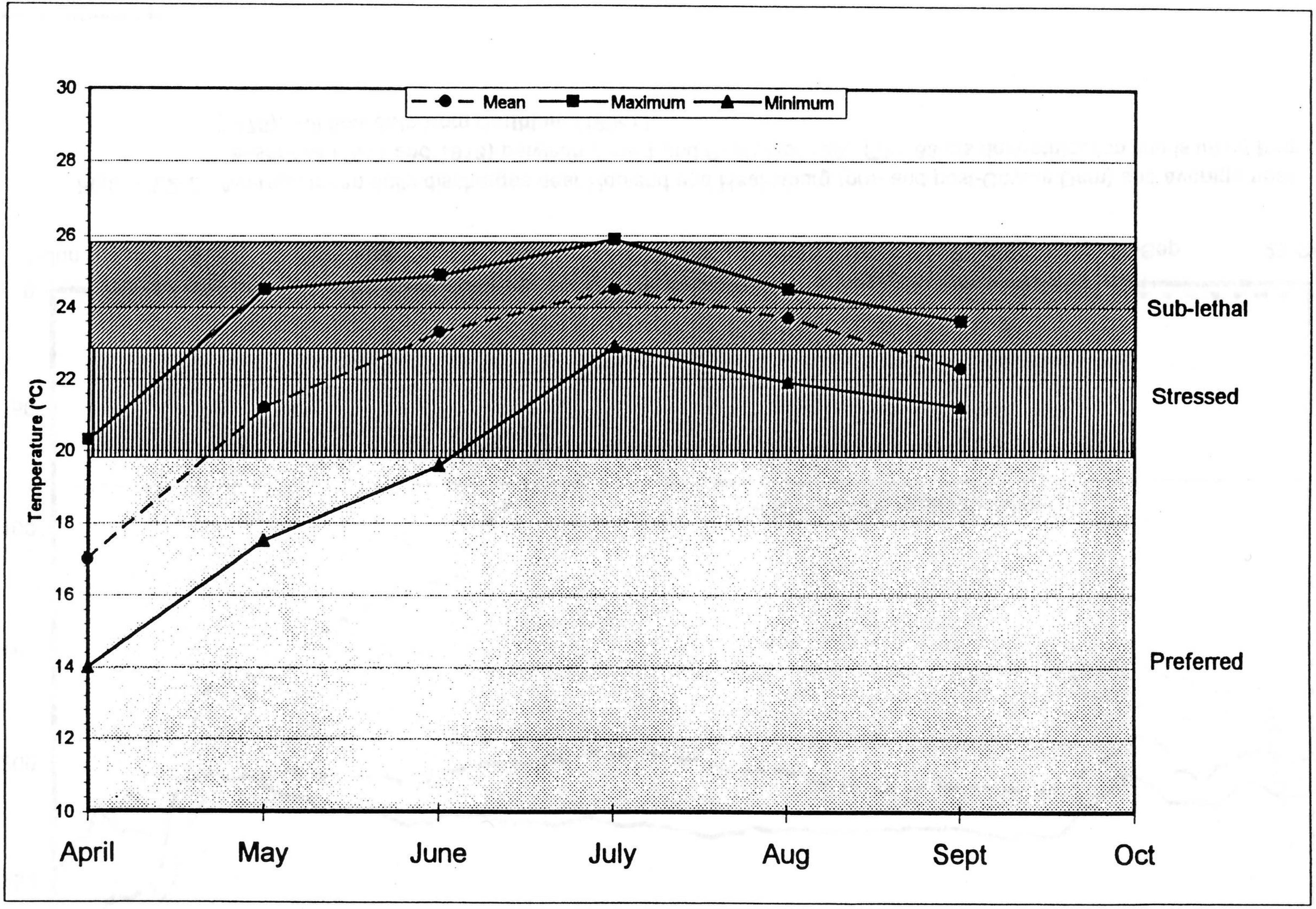

Figure 3.2-3: Monthly average maximum, minimum, and mean daily water temperatures from the Russian River near Healdsburg, from 1966 to 1993 with salmonid temperature thresholds as given by Kubicek (1977). [Temperature data from EarthInfo (1994).]

p90\tempsupr\HLDSTMP.XLS\apr-sep grf

8/23/96

3.3 Altered Species Composition

Russian River water management and habitat disturbance have worked in concert with the introduction of exotic species to cause major shifts or declines in fish populations throughout the basin. Possibly the most critical feature of the altered hydrograph is the increased summer flows. The mainstem Russian River historically had summer flows in the range of 0 to 20 cfs. The salmonids endemic to the system were well adapted to historic conditions and dominated over warmwater species (Cox, CDFG, personal communication). During summer low flow conditions, salmonids actively sought cool water refuge. Many juvenile coho and steelhead found shelter in the tributaries where temperatures were moderated by steep topography and dense vegetation. Some salmonids may have spent the summer in mainstem scour pools where waters were cooled by intergravel flows, groundwater seeps, tributary inflow, pool stratification, and riparian shading (Cox, CDFG, personal communication; Circuit Rider Productions 1994a).

After the Eel River diversion and the construction of Coyote Dam, mainstem summer flows increased 15 to 20 times (Section 3.2). Contrary to expectations, increased summer flows actually decreased salmonid rearing habitat by inundating cover and increasing water velocities (COE 1982). The COE (1982) speculated 20 cfs was the optimum flow for summer salmonid rearing in the mainstem Russian River based on available resting habitat (Figure 3.3-1). Summer flows since 1922 have significantly exceeded 20 cfs and have generally remained above 125 cfs (Figure 3.2-2). Two hundred cfs has been the approximate mean summer flow at Hopland and Healdsburg since Coyote Dam became operational in 1959. At these flows, nursery habitat is theoretically eliminated in the lower (Healdsburg to mouth) and middle (Cloverdale to Healdsburg) reaches and reduced 70 percent in the upper (above Cloverdale) reach (COE 1982).

Co-existence of salmonids and warmwater fish species commonly occurs, but anthropogenic influences alter the balance of these interactions. In northern California, increased summer flows favor warmwater species over coldwater species (Hopkirk and Northen 1980). Under historic conditions, salmonids generally dominated, but since 1922, the increased summer flows and temperatures in the mainstem Russian River not only decreased salmonid habitat but actually created ideal warmwater habitat. Under pre-existing natural conditions, the warmwater Sacramento squawfish (*Pthychocheilus grandis*), a species native to the Russian River, co-existed with native salmonids and they interacted without significant compromise to either species. Now, squawfish impact salmonids in two ways. First, they are known fish predators that consume juvenile salmonids. Secondly, Brown and Moyle (1981) found that squawfish will behaviorally displace salmonids in altered habitats such as those resulting from channelization, riparian removal, and impoundment. All of these conditions are prevalent on the Russian River. Since flow augmentation, squawfish have become the most widespread predator in the basin (Pintler and Johnson 1956; Holman 1968), frequently displacing salmonids from preferred summer rearing habitat. Two wellorchestrated warmwater fish eradication efforts in the 1950's failed to displace the squawfish from its dominance in the Russian River mainstem (Pintler and Johnson 1956).

Of the 48 fish species present in or lost from the Russian River, 29 are introduced, either intentionally or inadvertently (Table 3.3-1). The introduced fish were perceived as valuable sport or forage fish, but most were predatory by nature. Introduction of non-native fishes began in 1872 with the first known introductions of predatory species in 1899 (Table 3.3-2) (State of California 1891,1907). Predatory species introduced in the Russian River were largemouth bass (*Micropterus salmoides*), smallmouth bass (*M. dolomieui*), striped bass (*Morone saxatalis*), channel catfish *(Ictaluras punctatus)* and green sunfish (*Lepomis cyanellus*) (EIP Associates 1994).

In disturbed and altered systems such as the Russian River, non-native species tend to out-compete native species, both by direct predation and by competition for space and food (Moyle 1976b). The introduced predator species tend to occupy the warmer, lower reaches of the Russian River, posing little threat to salmonids except during the spring outmigration from tributaries and hatcheries. The heaviest predation is usually associated with structures that provide habitat; human "improvements"–bridges, bank armoring, dams, and diversions–are generally sites with the greatest impacts. A true irony of the shift in species dominance to predatory non-salmonids occurred during the 1940's, and on through the 1960's. During the summers of those years, literally millions of young steelhead and thousands of salmon were "rescued" from tributary sites in the Russian and Eel basins. The young fish were then transported to the flowing waters of the Russian mainstem, where unbeknownst to their rescuers, they probably became feed for the flourishing warmwater fishery.

Introduced non-predatory fish species can also have adverse impacts on juvenile salmonids by competing for available food and habitat (Moyle 1976b). Such species in the Russian River include bluegill (*Lepomis marginatus*), crappie (*Pomoxis spp*)., American shad (*Alosa sapidissima*), and redear sunfish (*Lepomis microlophus*) (EIP Associates 1994). At temperatures above 20°C, warmwater species will dominate over salmonids (Moyle 1976a). Reeves et al. (1987) found redside shiner (*Richardsonius balteatus*) out-competed trout for food and space in warm water (19-20°C) resulting in a 54 percent reduction in trout production. In cool water (12-15°C), trout out-competed shiner with no change in trout production or habitat utilization. Present temperatures and flows in the middle and lower reaches of the Russian River favor warmwater species over salmonids, effectively limiting salmonid utilization.

It was initially envisioned that augmented mainstem flows would benefit the Russian River salmonid fisheries by increasing summer habitat (COE 1982; Prolysts 1984). Time has shown, however, that these increased flows actually decrease salmonid habitat and create conditions more suitable for warmwater species. The introduction of warmwater species, both predatory and non-predatory, exacerbated that effect. Under present flow and temperature conditions, warmwater species will continue to dominate the mainstem Russian River at the expense of salmonid populations.

Table 3.3-1: A list of 48 native and introduced fish species documented to exist or have existed in the Russian River. (Data compiled from CDFG records, Hopkirk and Northen 1980, Lassen 1969, Moyle 1976 Robbins et al. 1991, Cox 1994 Personal Communication, and Jones 1993.)

Common Name	Scientific Name	Native/Introduced	Status[A]
River Lamprey	*Lampetra ayresi*	N	?
Western Brook Lamprey	*Lampetra richardsoni*	N	?
Pacific Lamprey	*Lampetra tridentata*	N	C,S
Green Sturgeon	*Acipenser medirostris*	N	R
White Sturgeon	*Acipenser transmontanus*	N	R
California Roach	*Hesperoleucus symmetricus*	N	C
Hitch	*Lavinia exilicauda*	N	?
Hardhead	*Mylapharadon conocephalus*	N	C
Sacramento Squawfish	*Ptychocheilus grandis*	N	C
Sacramento Sucker	*Catostomus occidentalis*	N	C
Pink Salmon	*Oncorhynchus gorbuscha*	N	PE
Coho Salmon	*Oncorhynchus kisutch*	N	R,S
Steelhead Trout	*Oncorhynchus mykiss*	N	C,S
Chinook Salmon	*Oncorhynchus tshawytscha*	N	R,S
Threespine Stickleback	*Gasterosteus aculeatus*	N	C
Coastrange Sculpin	*Cottus aleuticus*	N	C
Prickly Sculpin	*Cottus asper*	N	C
Riffle Sculpin	*Cottus gulosus*	N	C
Russian River Tule Perch	*Hysterocarpus traski pomo*	N	R
American Shad	*Alosa sapidissima*	I	S
Goldfish	*Carassius auratus*	I	C
Carp	*Cyprinus carpio*	I	C
Sacramento Blackfish	*Orthodon microlepidotus*	I	?
White Catfish	*Ameiurus catus*	I	?
Black Bullhead	*Ameiurus melas*	I	?
Brown Bullhead	*Ameiurus nebulosus*	I	?
Channel Catfish	*Ictalurus punctatus*	I	?
Lake Whitefish	*Coregonus clupeaformis*	I	PE
Cutthroat Trout	*Oncorhynchus clarki*	I	PE
Atlantic Salmon	*Salmo salar*	I	PE
Brown Trout	*Salmo trutta*	I	R
Eastern Brook Trout	*Salvelinus fontinalis*	I	PE
Lake Trout	*Salvelinus namaycush*	I	PE
Western Mosquitofish	*Gambusia affinis*	I	R?
Inland Silversides	*Menidia beryllina*	I	?
Striped Bass	*Morone saxatilis*	I	R
Sacramento Perch	*Archoplites interruptus*	I	?
Green Sunfish	*Lepomis cyanellus*	I	C
Bluegill	*Lepomis macrochirus*	I	C
Redear Sunfish	*Lepomis microlophus*	I	?
Smallmouth Bass	*Micropterus dolomieu*	I	C
Largemouth Bass	*Micropterus salmoides*	I	C
Splittail	*Pogonicthys macrolepidotus*	I	?
Fathead Minnow	*Pimephales promelas*	I	?
Golden Shiner	*Notemigonus crysoleucus*	I	?
White Crappie	*Pomoxis annularis*	I	?
Black Crappie	*Pomoxis nigromaculatus*	I	?
Yellow Perch	*Perca flavescens*	I	PE

A: C=common, R=rare, PE=probably extinct, S=seasonal, ?=status uncertain.

Table 3.3-2: Exotic fishes planted in the Russian River for which actual records have been found. (All information compiled from CDFG files.)

Non-Salmonid	Carp	Catfish spp	Lake Whitefish	Largemouth Bass	Smallmouth Bass	Yellow Perch	Bluegill & Green Sunfish	Sacramento Perch	Striped Bass	Crappie spp.
1870-79	5	39,000	10,000	---	---	---	---	---	---	---
1880-89	---	---	---	---	---	---	---	---	---	---
1890-99	---	---	---	6	13,000	10	---	---	---	---
1900-09	---	---	---	---	4,500	---	---	---	---	---
1910-19	---	---	---	---	---	---	18	18	---	18
1920-29	---	---	---	---	---	---	---	---	---	---
1930-39	---	---	---	100	11,045	---	---	---	---	---
1940-49	---	---	---	---	---	---	---	---	---	---
1950-59	---	---	---	---	5,000	---	---	---	---	---
1960-69	---	---	---	---	---	---	---	---	3,000	---
1970-79	---	---	---	---	---	---	---	---	---	---
1980-89	---	---	---	---	---	---	---	---	---	---
1990-95	---	---	---	---	---	---	---	---	---	---
TOTAL:	5	39,000	10,000	106	33,545	10	18	18	3,000	18

Salmonid	Brook Trout	Brown Trout	Cutthroat Trout	Lake Trout	Atlantic Salmon
1870-79	29,000	---	---	---	---
1880-89	---	---	307,000	---	---
1890-99	100,000	770,000	925,000	47,500	---
1900-09	---	---	---	---	---
1910-19	4,000	24,000	---	---	---
1920-29	711,000	4,130,500	---	---	18,000
1930-39	---	1,120,000	---	---	12,000
1940-49	---	---	---	---	---
1950-59	---	---	---	---	---
1960-69	---	---	---	---	---
1970-79	---	44,052	---	---	---
1980-89	---	85,756	---	---	---
1990-95	---	160,586	---	---	---
TOTAL:	844,000	6,334,894	1,232,000	47,500	30,000

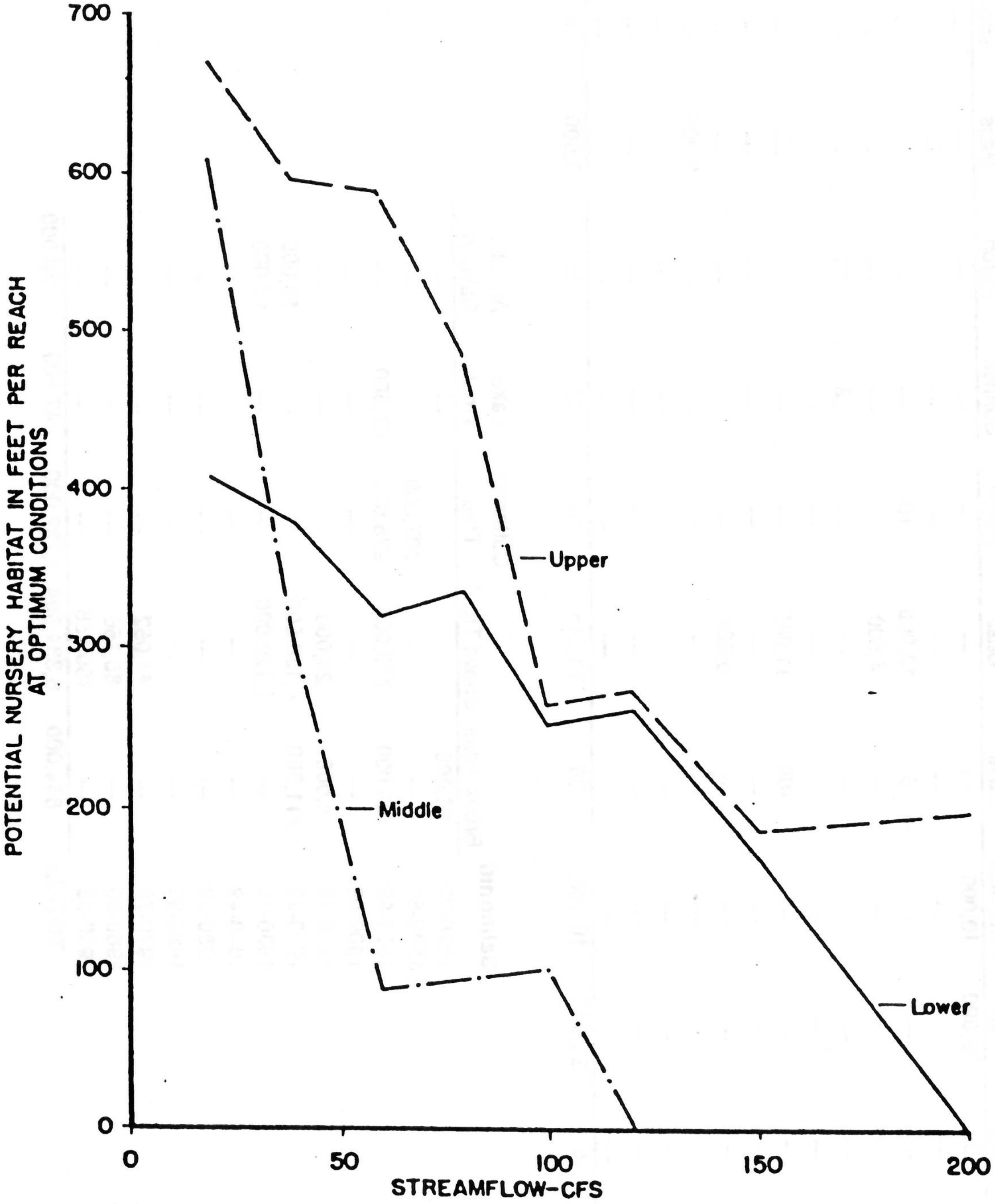

Figure 3.3-1: Maximum potential nursery habitat on mainstem Russian River vs streamflow (COE 1982).

3.4 Morphological Changes

Naturally flowing rivers are dynamic systems prone to change. Rivers are constantly acting to achieve "dynamic equilibrium", a delicate balance between the flow of water, the sediment transported, and the form of the river. In attempting to reach equilibrium, a river will balance the flood flows and sediment supply by adjusting various features of the river channel, mainly slope, geometry, and roughness (Leopold et al. 1964). The dynamic equilibrium is delicate and any change in the flow or sediment load will initiate a change in the channel form. Sediment load is often reduced in regulated (dammed, diverted, controlled flow) rivers. Lack of sediment results in changes to the channel and flow characteristics (Florsheim and Goodwin 1993). Channel and flow changes often result in downcutting, channelization, fish passage problems, loss of habitat diversity, and decrease in fish populations (Moyle 1976a; Florsheim and Goodwin 1993).

Prior to flow regulation, the aquatic and riparian habitats of the Russian River were quite different from present conditions. The river was shallower and wider, meandering across its alluvial valleys. These meanders created oxbows and side sloughs which, coupled with seasonal wetlands and backwater marshes, created seasonal habitats for waterfowl and for rearing steelhead and coho salmon (Florsheim and Goodwin 1993; Circuit Rider Productions 1994a). Extensive areas once existed along the Russian River where the riparian was dominated by large trees, shrubs, and vines. These areas, connected by a riparian corridor, created wildlife habitat and contributed extensively to instream fish habitat. Fallen trees and root wads provided deep scour pools in the channel which, during the summer, were likely utilized by rearing steelhead and coho (Cox, CDFG, personal communication; Circuit Rider Productions 1994a).

Changes in the flow regime and sediment transport have caused significant morphological changes in the Russian River channel (Florsheim and Goodwin 1993). Dams decrease flow fluctuations and cut off downstream sediment supply. Together, Coyote and Warm Springs dams are the primary source of the river's long-term sediment deficit, blocking transport of an estimated 600,000 tons of sediment per year (Sonoma County Water Agency 1985; COE 1973). Decreased sediment load initially causes the river to increase in depth, resulting in extensive bank erosion (Florsheim and Goodwin 1993). Bank erosion is further exacerbated by riparian vegetation removal and in-stream gravel extraction. To counteract this erosion, bank revetment structures are often installed, channelizing the river and further interrupting natural processes. Riparian vegetation removal also prevents large woody debris from entering the river and creating fish habitat (Reynolds 1991). The result is a simplified system lacking the substrate, structure, cover, and water quality necessary for salmonid habitat.

Gravel mining is the second major cause of sediment deficit in the Russian River basin. In the basin there are three gravel mining methods: in-channel, terrace or pit, and quarry mining. In-channel mining removes material directly from the stream channel. Gravel is often skimmed from bars or excavated directly from the channel. Terrace or pit mining removes gravel from historic or active flood plain deposits. The pits are separated from the river by alluvial separators. Some pits are up to 44 feet deeper than the adjacent river channel elevation (Gahagan and Bryant Associates, Inc. 1994). Quarry mining utilizes sites away from the stream, and has little effect on the stream channel. The greatest stream impact from quarries is demand for water, up to 20,000 gallons per day for washing and related activities(Florsheim and Goodwin 1993). From 1981 to 1990, 51 million tons of gravel were removed from the Russian River basin: 19 percent in-channel, 47 percent terrace, and 34 percent from quarries (EIP Associates 1994).

In-channel and terrace mining each have unique problems, but both remove gravel from a sediment-starved system, further decreasing sediment supply. Lake Mendocino blocks approximately 200,000 tons of sediment per year (SCWA 1985), and Warm Springs Dam blocks approximately 400,000 tons of sediment per year (COE 1973). In-channel mining removes gravel at rates significantly in excess of replenishment, hence contributing to channel incision. In the Mendocino Reach (Figure 1.2-1), an average of 100,000 tons of gravel per year were extracted in the 1980's and an average of 45,000 to 60,000 tons of gravel per year were extracted in the early 1990's. This rate of extraction led to a net sediment loss in the reach of 97,000 to 200,000 tons per year. Since the United States Army Corps of Engineers (COE) surveys conducted in the 1940's, the channel in the Mendocino Reach has degraded 10 to 18 feet (Florsheim and Goodwin 1993). In the Alexander Valley Reach, an average of 726,500 tons of gravel per year were extracted between 1982 and 1991. This extraction led to an average sediment loss in the reach of 630,000 tons per year. From 1991 to 1995, an average of 496,000 tons of gravel per year were extracted, leading to a sediment loss of 395,000 tons per year (Sonoma County, unpublished data). In the Middle Reach, an average of 164,000 tons per year were extracted. Natural recruitment there averages 128,000 tons per year, and the reach suffered a net sediment loss of 36,000 tons per year (EIP Associates 1994). Sustained overharvest as well as deep dredge mining of the channel in the 1960's and 1970's led to channel degradation of 10 to 20 feet in the Middle Reach channel since the 1940's (EIP Associates 1994).

Negative impacts from terrace (pit) mining are related less to removal of in-channel gravel and more to potential impacts from breaching. The large pits are separated from the river channel by alluvial separators which are non-engineered gravel banks. The bottom of the pits are well below river channel elevations. When the separator is breached, either quickly in one flood event or more slowly from bank erosion, the river channel can migrate into the pit, causing "capture". When this occurs, riverine habitat changes to lacustrine (lake-like) habitat as the river channel incorporates the pit. Pit capture can result in extreme downcutting both upstream and downstream. Many pits contain warmwater predator fish species. As the separators breach and the river flows through the pits, warmwater fish dominate the captured pit, impacting salmonid populations. Breached pits may also attract salmonids during spring emigration and trap them with no chance of survival once flows decline (Circuit Riders 1994a).

Sonoma County gravel demand from the Russian River through 2010 is projected to equal, if not exceed, current extraction rates. The low estimate for 1991 through 2010 is 75 million tons, 3.9 million tons per year. The moderate estimate is 109 million tons, 5.7 million tons per year. The high estimate is 171 million tons, 9.0 million tons per year (EIP Associates 1994). Natural replenishment from all sources is estimated at 484,000 tons per year, well below demand. Continued extraction at these rates will significantly exacerbate existing geomorphic problems.

In response to gravel mining concerns, both Sonoma and Mendocino counties have created gravel management plans. In 1994, Sonoma County implemented their Aggregate Resources Management Plan and accompanying Environmental Impact Report. This is a twenty-year plan which aims to monitor river cross sections and determine yearly sediment budgets based on actual replenishment (EIP Associates 1994). To prevent degradation of the river channel, mining in excess of measured replenishment would not be allowed; the only sediment available for mining would be that which the river deposits over a set baseline year. Recently, Shamrock Materials was granted a ten-year permit to remove up to 131,000 tons per year from the Alexander Valley Reach. Several other ten-year permit applications are pending which, when added together, could far exceed the most recently monitored sediment deposition amounts (Sonoma County Water Agency, unpublished data). The Mendocino County plan for the Russian River is expected by end of summer, 1996. This plan will discuss natural inputs, past extractions, projected extractions, and permitting processes (Slota, Mendocino County Water Agency, personal communication).

Decreased sediment supply causes shifts in a river's equilibrium that lead to channel changes. With a decreased sediment load, the ability of water to carry sediment is greater than the actual sediment supply. To compensate for this discrepancy, the "hungry" water picks up sediment from the channel. This constant scour causes the channel to downcut. Mainstem river downcutting causes bank erosion, tributary downcutting, and a drop in associated ground water levels. Anecdotal evidence claims the Russian River was an aggrading system in the 1930's (Circuit Rider Productions 1994b). Since the first Corps of Engineers surveys in 1940, reaches of the Russian River near Ukiah (Lake Mendocino Drive) have downcut approximately 20 feet and reaches in the Alexander Valley and Middle Reach have downcut from 12 to 20 feet (Florsheim and Goodwin 1993). These changes in bed elevation have undermined bridge supports and other structures. For example, the Highway 101 bridge in Healdsburg requires premature replacement due to extensive undermining of the bridge pilings caused by downcutting.

Tributary downcutting is a significant problem in the Russian River system. As mainstem channel elevation drops, tributary channels will increase velocity and scour, dropping their channel elevations (Florsheim and Goodwin 1993). Tributary downcutting causes the streams to widen, become shallower, and lose gravel substrate, decreasing fish habitat and passage (Circuit Rider Productions 1994b). Gravels necessary for salmonid spawning frequently scour out, leaving fewer sites of lesser quality. Forsythe Creek near Ukiah has downcut as much as 10 feet near the Highway 101 bridge since 1949. Extensive tributary downcutting necessitated the replacement of the Uva Drive Bridge in 1990 (Florsheim and Goodwin 1993). Lower Forsythe Creek now flows over clay substrate and has highly erodable vertical banks (COE 1982). Feliz Creek, near Hopland, has downcut five feet since 1979 which has exposed buried pipelines (Florsheim and Goodwin 1993). Ackerman and Hensley creeks in Ukiah required major grade stabilization structures to protect upstream bridges.

As channels downcut and drop in elevation, the water table also drops. In the Middle Reach, the water table has dropped 5 to 10 feet coincident with channel incision of up to 20 feet (Florsheim and Goodwin 1993). Near Forsythe Creek, the water table level has also dropped coincident with a channel elevation drop of up to 10 feet (Florsheim and Goodwin 1993).

As rivers downcut, vertical banks are created. These banks occur along many reaches of the Russian River and are very susceptible to erosion (COE 1982; Florsheim and Goodwin 1993). The winter release schedule from Coyote Valley Dam may exacerbate the failure of these vertical, erodable banks. Coyote Dam operational procedures require sustained discharges up to 7,500 cfs for many days following storm events (COE 1986). The banks along much of the Russian River are composed of fine alluvium. During the extended high flow period, this porous soil saturates. When flows decline, the saturated banks are prone to mass failure causing significant erosion and land loss. Landowner response is to armor the banks, creating more channelization and compromising the remaining riparian habitat.

Channel incision causes an interruption between the active river channel and its associated flood plains (Circuit Riders 1994a). Vertical bank formation effectively cuts off natural floodplain function. In a "natural" situation, the floodplain acts to slow down water velocity and dissipate energy during high discharges. Floodplains also act as water retention features. Water from a floodplain is slowly returned to the channel, and retained water may create seasonal wetland habitat. Floodplains isolated from the river by channel incision are only inundated on very large flows; in most flow events they fail to slow water velocity or retain water, and hence, downriver flooding increases.

Removal of riparian vegetation increases erosion and vertical bank formation, decreasing the interface between the river and floodplain. Vertical banks prevent the natural succession of riparian plant species. Without establishment of pioneer riparian species, there is no successive replacement for the mature vegetation as it dies or is washed away (Circuit Riders 1994b). Channel incision and the accompanying drop in the water table also may separate mature riparian species from summer water causing die-off; a complete loss of riparian habitat may result as is occurring below Coyote Dam. Urbanization and agricultural development are also responsible for the direct removal of riparian vegetation. Since European settlement, total riparian area in the Russian River basin has declined 70 to 90 percent (Circuit Riders 1994a).

Channelization and downcutting can create fish migration problems. In the Russian River, downcutting combined with instream structures has created several migration impediments. Healdsburg Recreation Dam presents a total upstream migration barrier during the summer base flow period and is an intermittent barrier to adult salmonids during winter's higher flows. By 1969, the river channel below the dam's concrete sill had scoured severely enough to require the placement of rail cribbing and large boulder rip-rap to control scour and maintain stability (CDFG, unpublished data). By 1991, downcutting had created a 14-foot difference in the river channel elevations immediately upstream and downstream of the dam, further exacerbating passage problems (Florsheim and Goodwin 1993). Willow Creek Diversion Dam in Ukiah also creates a fish migration barrier under certain flow conditions (COE 1982). Downcutting has dropped the channel elevation 10 feet below the concrete spillway, forming a barrier under high and low flows (Florsheim and Goodwin 1993).

Morphological changes and manmade structures in the tributaries have also created fish passage problems. Tributaries to the Russian River contain at least 500 small impoundments, most without fish ladders (State Water Resources Control Board, unpublished data). The fisheries impacts of these structures are unknown, but many are likely to pose migration impediments during both adult and juvenile life stages. Most tributaries are channelized to varying degrees. The most significant channelization is associated with urban areas, where streams are often confined with concrete and rip-rap (Florsheim and Goodwin 1993). Doolin Creek in Ukiah has passage problems due to urban encroachment and channelization. Gibson Creek, at Leslie Street in Ukiah, has a cement box culvert blocking access to spawning habitat under most flow conditions, a problem exacerbated by downcutting (Jones, CDFG, personal communication). Rip-rap grade stabilization structures on Ackerman and Hensley creeks have both required modification with fish ladders in an attempt to improve salmonid access. These tributary problems are attributable to downcutting in the mainstem and a system-wide trend towards channel degradation. The preponderance of the usable salmonid habitat in the Russian River basin lies in the tributaries, and the COE (1982) calls the degradation of the tributaries the single greatest factor limiting salmonid populations. Accessible and healthy tributaries are vital to the maintenance of healthy salmonid populations.

Channel morphology and the physical processes of the river system control all aspects of the biological system. Changes in sediment load or flow will cause channel adjustments. Continued gravel extraction compounds existing problems caused by reservoir sediment retention and past gravel extraction. The Russian River will never regain its form of a hundred years ago. Instead, it will constantly seek equilibrium based on the current variables of channelization, reduced sediment supply, and regulated flows. Continued survival of salmonids, much less any approach toward historic population levels, will require some reversal of practices that currently encourage riparian vegetation removal, total erosion control, gravel extraction, and sustained unnatural flows. Habitat and migration conditions for salmonids are generally best in systems where hydrologic, geomorphic, and riparian aspects most closely reflect unimpaired conditions.

3.5 Ocean Productivity Trends

Salmonids spend approximately half of their life in the ocean, and therefore, conditions during the marine phase of life play an important role in determining overall growth and survival of these fish from smolt to spawning adult. Historical records and relevant literature were reviewed to explore possible relationships between population variation and ocean productivity.

The rate at which adult salmonids return to hatcheries is an important indicator of ocean productivity. Warm Springs Hatchery steelhead return rates for emigration years 1982 through 1994 were calculated from the total number of smolts released into Dry Creek as yearlings in a given year (Table 3.6-1) and the total number of adults, excluding half-pounders, returning two years hence (Table 2.0-2). The resulting data set was graphed for emigration years 1982 to 1994 (Figure 3.5-1). The lowest return rate, 0.18 percent, occurred in 1990/91, which corresponds to the emigation year of 1989 (Figure 3.5-1). Hatchery steelhead from the Eel River and hatchery chinook from the Trinity River also had relatively low rates for that return year. The parallel trend between hatcheries suggests that one or more factors common to both species and to all three drainages influenced survival rates. The variable most common to all these systems was ocean productivity, a term used here to encompass the availability of food, impacts from predation, and rate of harvest. Although these return rate data sets are limited to relatively few drainages and cover a short span of years, similar trends are seen in steelhead, coho salmon, and chinook salmon return rates from river systems as far north as British Columbia. Fisher and Pearcy (1994) conclude that ocean conditions were the primary factor.

The strength of wild salmonid runs returning to their natal streams to spawn (escapement) is an additional indicator of ocean influences. Chinook salmon escapement indices for several drainages in northern California and southern Oregon, compiled from Pacific Fisheries Management Council data, reveal similar long-term patterns (Figure 3.5-2). Each annual index value was normalized as a percentage of the historical average for that river. The resulting trend lines showed peaks in adult returns for most drainages in the mid- to late 1980's and dramatic collapses for all 13 drainages by 1991. Together with the hatchery return rate analysis, chinook escapement trends reinforce the hypothesis that the major decline in population in 1990/91 was driven by environmental factors common to the river systems. Climatic regimes affecting juvenile and adult migrations were probably of minor importance because many of the river systems had regulated flows, and local weather patterns varied considerably from central California to Oregon. Hence, ocean productivity emerges as the most common variable.

Shifts in ocean productivity that span decades have been linked to cyclical changes in the strength and direction of major ocean currents. Hollowed and Wooster (1991), Tabata (1991), and Francis (1992) studied patterns of climatic and marine influence. Their models incorporated effects of broad-based climatic variables, including north Pacific atmospheric pressure, sea surface temperature, and the more remote El Niño Southern Oscillation phenomenon (El Niño). These climatic variations were linked to the north-south split of the trans-Pacific Current as it diverges upon approaching the Pacific west coast. The pattern of the split influences the relative strengths of the Alaska and California currents. The overall conclusion emerging from the various oceanic studies was that there was a demonstrated relationship between the ocean currents and ocean productivity as reflected by salmon populations. When the split of the trans-Pacific current favored the north-flowing Alaska Current, salmon populations were strong in the Gulf of Alaska and weaker off Washington, Oregon, and California. By contrast, when the current splits sending most of the flow south with the California Current, salmon populations increased along the coast but were depressed off Alaska. The cycle lasted approximately three decades. The primary mechanisms linking shifts in ocean current patterns with changes in biological productivity throughout the food web generally are thought to be coastal upwelling (or downwelling) and advection (Ward 1993) in marine deposits offshore from Santa Barbara, California.

Marine sediment records reveal even longer cycles in ocean productivity. Fish scale deposition rates for the Pacific sardine and northern anchovy from A.D. 270 through 1970 were measured by Soutar and Isaacs (1969) in marine deposits offshore from Santa Barbara, California. A detailed analysis by Baumgartner, Soutar, and Bartrina (1992) revealed cyclical variations in population levels with periods of approximately 60 to 100 years. Collapse and recovery were apparently normal events throughout the 1700 years of record. The recovery that began in the late 1970's was considered to be quite similar to those of the past. Because at least one of the two species, the anchovy, is a principal diet item for salmon (Petrovich 1970), it is reasonable to assume that this species' population cycles would be reflected in salmonid population trends as well.

Ocean productivity can influence growth rates as well as survival. Shapovalov and Taft (1954) documented relatively short mean fork lengths for adult steelhead and coho salmon returning to Waddell Creek in 1941/42, a year that has been associated with significant El Niño activity. Chinook salmon mean fork lengths for the upper Eel River in 1984/85 revealed significantly reduced growth rates, attributed to effects of the 1982/83 El Niño (SEC, unpublished data). Pearcy (1992) also documented the shortest mean fork lengths of record for maturing coho salmon caught off the Oregon coast during 1983. Since smaller adult salmonids generally produce fewer eggs, suppressed growth rates probably reduced the reproductive potential of these spawning populations.

Multiple-drainage trends and longer-term cyclical variations clearly demonstrate that ocean productivity must be taken into account when interpreting year-by-year changes in salmonid population levels. If Russian River coho salmon or steelhead populations were already low due to other causes, a subsequent downturn in ocean productivity might have deleterious effects, possibly driving numbers to critical levels.

Conversely, high ocean productivity might mask problems associated with habitat loss or degradation, management practices, or other factors. Documentation of marine influences affirms that factors responsible for determining historical salmonid population trends in the Russian River are varied and complex, by no means limited to the geographic confines of the watershed.

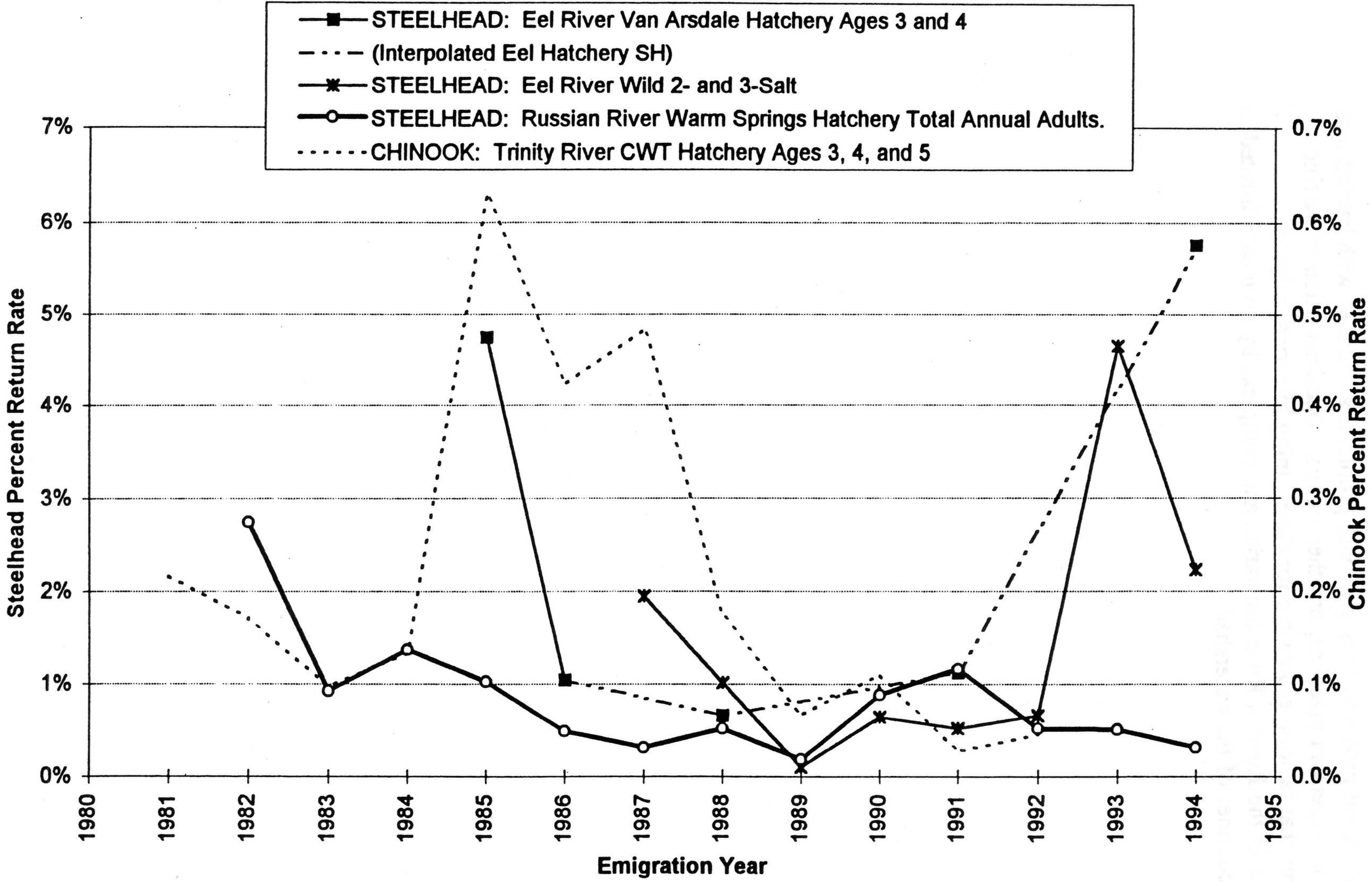

Figure 3.5-1: Salmonid return rates for three North Coast rivers. (Returns for the 1994 emigration year are limited to 2-salt years only.)

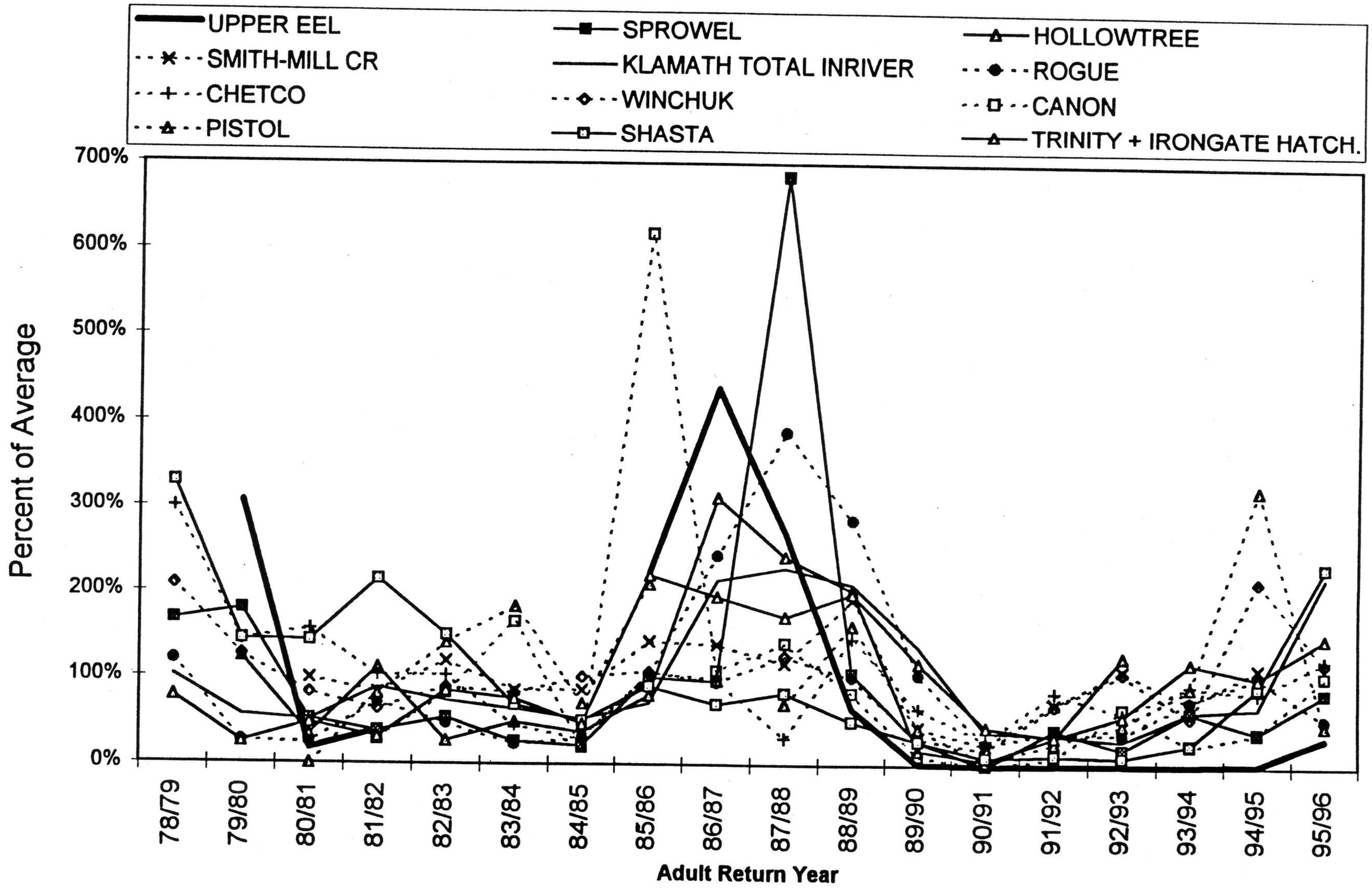

Figure 3.5-2: Normalized chinook salmon escapements for northern California and south-migrating Oregon stocks expressed as percents of the historical average of each respective index.

10\4\BMULTIAVG.XLS\RUSSIAN

8/23/96

3.6 Hatchery Impacts

The use of state-funded fish hatcheries in California dates back to 1870. Since their inception, the purpose of these facilities has been "to stock and supply streams, lakes, bays with both foreign and domestic fish" (Leitritz 1970). The intent of stocking has been to provide fish for sport and commercial fishing, for restoration, and for mitigation. To these ends, hatcheries have provided the state's citizens with untold millions of sport and commercial fish, predominantly salmon and trout. From a biological perspective, hatchery supplementation is, at best, a symptomatic treatment for underlying problems of habitat loss and degradation, overharvest, and other chronic conditions.

Hatchery programs have added substantial numbers of young salmonids to the Russian River system. Since 1870, approximately 30 million hatchery-reared steelhead, 8 million chinook salmon, and 2.1 million coho salmon have been were planted in the basin. In addition, a large number of rescued fish (moved from drying streams), many from the Eel River basin, were moved to the Russian River mainstem between 1939 and 1971. Large-scale artificial plantings such as these can impact native salmonid populations through loss of genetic material, inbreeding, run-time change, competition, and predation. Disease can also result from heavy and continued hatchery supplementation programs.

History of Hatchery Plants

Hatchery plant data were compiled from published and unpublished documents covering the period between 1872 and 1995. The records consisted of biennial reports of the California Department of Fish and Game Commission; the quarterly publication "California Fish and Game" (1914 to 1994); annual reports to the Fish and Game Commissioner (1972 to 1993); "Outdoor California" (1964 to 1969); actual planting receipts from Silverado Fisheries Base, Mad River Hatchery, and Warm Springs Hatchery; annual reports from Warm Springs Hatchery (1982 to 1995); annual reports from Coyote Valley Fish Facility (1993 and 1994); and other California Department of Fish and Game documents. Some records were incomplete with certain years unobtainable, so data gaps exist. When possible, the missing information was obtained from other documents. Where duplicate data existed, planting dates, locations, and numbers were carefully compared to avoid duplicate entries. Any numbers not specifically referenced are part of the database compiled by SEC.

The reliability of compiled data depends on the strength of the underlying source documents. Documents varied in reporting methods and level of detail. For example, some records described the exact date and planting location, whereas others listed only the year and county. This compilation of supplementation records is intended to convey the general magnitude rather that the exact amount of hatchery plantings to the Russian River through the last century.

This section contains the following technical terms with specific definitions important to the discussions presented. *Stock* is fish that spawn in a particular river system (or portion of it) at a particular season, and that do not interbreed to any substantial degree with any group spawning in a different place, or in the same place at a different season (Ricker 1972). *Native* describes fish descended from original stocks present prior to land use development activities (Nehlsen et al. 1991). *Out-of-basin stocks* are fish brought into one basin from another basin. *Naturally spawning* is a term loosely applied to any fish naturally reproducing in the river system, whether of native or hatchery origin.

The most notable recent trend in hatchery management has been the move away from using non-native salmonid stocks while moving towards planting progeny of locally returning adults. Prior to 1980, stocks from diverse origins were commonly planted in the Russian River. Historically, at least 6 chinook salmon, 5 coho salmon, and 7 steelhead stocks were introduced into the Russian River from other basins. Hatchery stocks were not limited to the basin where the hatchery was located, and hatcheries often incorporated the practice of cross-breeding fish of different stock origins. Most steelhead planted in the Russian River were supplied by hatcheries in the North Coast region, while chinook and coho came from North Coast, Sacramento River, and Wisconsin hatcheries. Due to decades of out-of-basin stock introductions, many native Russian River sub-stocks may be genetically lost. The predominant fish in the Russian River today is likely a locally adapted stock derived from many stocks, but which still carries some native Russian River genetic material. During the 1980's and 1990's, the concept of the ecological distinctness and genetic fitness of local stocks gained strength. As a consequence, efforts have increased to protect these specific adaptations by propagating locally returning fish to their respective drainages.

Over time, the age and size of planted fish has changed. Early in the century, eggs, embryos, and fry were planted in large numbers. These attempts suffered high mortality, and gradually the practice changed in favor of planting larger fish which are more likely to survive than the smaller juveniles (Smith et al. 1985*)*. On the Russian River, this trend is difficult to verify due to the lack of fish size data; however, the few references prior to 1920 indicate egg and fry planting predominated. Steelhead plantings from 1939 to 1970 were dominated by fingerlings (young-of-year fish) from "rescue" operations. Since 1971, planting policy has varied by species. Generally, chinook are planted as fingerlings in their first spring, coho as yearlings (one-year-old fish), while steelhead are planted both as fingerlings and yearlings. The current state policy is to plant steelhead as yearlings no smaller than 20 to the pound with younger surplus fry being released throughout the year.

Fish culturists have come to understand the importance of imprinting, the rapid and irreversible learning process by which juvenile salmonids learn the navigational cues to help them return to their natal streams (Slatick et al. 1981). The individual odors of a stream are believed to be the primary sensory cues adult fish follow. Successful hatchery returns to a specific release site are maximized and straying reduced if fish are held at the release site long enough to imprint with the site. Operationally, 10 to 14 days are considered minimal holding periods for successful imprinting to occur.

The Coyote Valley Fish Facility (CVFF) was opened in 1992 as a fish imprinting and egg taking facility. The primary objective of this facility was to increase the number of adult steelhead returning to the upper Russian River, thereby mitigating the loss of habitat upstream from Coyote Dam. Adult fish trapped at CVFF are spawned and eggs are transported to Warm Springs Hatchery for hatching and rearing. After one year, the reared fish are returned to CVFF for imprinting and release. Typically, the fish are held for 30 days prior to release (Fortier, CDFG, unpublished data).

Straying of salmonids between river systems is a natural and regular occurrence. Straying rates are influenced by environmental conditions, and vary annually. Under normal conditions straying is minimal (Cramer et al. 1995). Smith (1994) found steelhead straying rates of only 2.3 to 6.6 percent in Waddell Creek when the mouth of Scott Creek was open, but when the mouth of Scott Creek was closed, straying to Waddell Creek increased to 22.9 percent. Leider (1989) found the percentages of strays in an adjacent, non-impacted tributary increased from 16 to 45 percent in response to ash fallout impacting a tributary below the Mount St. Helens volcano. Chinook straying rates are slightly higher than steelhead due to likelihood of encountering low flow conditions. Major et al. (1978) found an average chinook straying rate of 8.4 percent for several hatcheries on the Columbia River.

In 1992/93, eight steelhead were recorded at CVFF with fin clips matching those given to Eel River smolts in 1991. According to CDFG personnel, as many as 100 clipped steelhead were captured at the facility, but no formal records or tissue samples were kept. These clipped fish led to speculation that straying from the Eel River was due to the input of Eel River water to the Russian River from the Potter Valley Project. Examination of state-wide planting records showed at least 400,000 steelhead smolts with the same clip were released in the state during 1990 and 1991 with only 41,900 of these being released to the Eel River (SEC 1994). Unfortunately, no genetic studies were conducted to determine the source of the stray fish. Since 1992/93, more detailed records have been kept at CVFF and there is yet no documented occurrence of a clipped Eel River fish returning to CVFF. It is more likely that hatchery fish from the Sacramento system would stray into the Russian River due to the relatively close proximity of the rivers' mouths.

Chinook Salmon

The first recorded attempt to artificially increase the chinook salmon population in the Russian River basin occurred over a century ago. In 1881, 15,000 chinook were planted in the mainstem (State of California 1883). Since 1881, over eight million chinook have been introduced into the system, all hatchery reared except 2,382 "rescued" from the Eel River in 1939 (Figure 3.6-3) (CDFG 1939). Early efforts were sporadic until 1949 when a consistent program began. Though continuing until 1970, that program failed to establish a viable population.

Prior to 1980, all chinook salmon planted were progeny of out-of-basin stocks (Figure 3.6-4). Source stocks included the Sacramento River, Eel River, Mad River, Klamath River, Silver King Creek, and Wisconsin Strain (Green River, WA) (Table 3.6-3). Facilities providing these stocks included Ukiah (1916), Shasta (1959-60), Nimbus (1962), Coleman (1963-64), and Darrah Springs (1969-70) hatcheries (Leitritz 1970). The failure of earlier planting efforts (1949-1962) was attributed to the use of "fall" run chinook that have an early spawning run. Returning to the river as early as July, the spawners from these stocks found adversely high water temperatures which caused spawning females to ripen and lose their eggs prematurely (Gunter, CDFG, personal communication). Furthermore, summer dams erected for recreational purposes hindered upstream migration. Efforts after 1963 used a later "winter" run stock in hopes that returning adults would encounter cooler water and no summer dams (CDFG 1964).

In 1982, systematic efforts were made to establish a source stock that might consistently return to the system. Warm Springs Hatchery imported chinook from Wisconsin, the Eel River, and the Mad River. A gradual trend towards planting progeny of local returns also began in 1982. From 1980 to 1989 only 15 percent of the chinook plants were progeny of Warm Springs adult returns, but since 1990, all chinook plants have conformed to the local-return stock selection policy.

All attempts to establish a chinook run in the Russian River have been marginally successful, at best. Establishing a significant wild or hatchery chinook population appears unlikely as the Russian River may no longer posses appropriate conditions. For that matter, it is not clear if historic conditions ever favored large numbers of chinook (Section 2.0). Probably of greatest importance is the fact that Withler (1982) found no successful case of establishing a new run of anadromous salmonids by interbasin transfer.

Coho Salmon

Approximately 2.1 million coho have been planted in the Russian River (Figure 3.6-5). The first recorded plants occurred in 1937 when 171,500 fish were released, primarily in Mendocino County. No further coho were planted until 1963 when consistent plants began. From 1963 to 1995, approximately two million coho were planted. From 1940 to 1980, over 137,000 coho were rescued, 44 percent of which were out-of-basin stocks, mainly from North Coast sources (Table 3.6-1) (CDFG, unpublished data).

Before 1980, all coho planted in the Russian River were from out-of-basin stocks (Table 3.6-3). Noyo River and Iron Gate Hatchery (Klamath River) strains were the dominant source stocks accounting for approximately 1 million planted coho, 57 percent of the total for all out-of-basin stocks (Figure 3.6-6). Other source stocks included Alsea River in Oregon and Soos Creek in Washington. Hatcheries providing these stocks included Cold Creek (1937), Darrah Springs (1969-76), and Mad River (1980-81).

Warm Springs Hatchery began development of a basin-adapted strain for the coho stocking program in 1980. Source stocks included Noyo River, Iron Gate, Eel River, Alsea River (OR), and Soos Creek (WA). Between 1980 and 1989, 15 percent of coho planted were progeny of fish returning to Warm Springs Hatchery. From 1990 to the present, 85 percent of planted coho have been progeny of fish returning to Warm Springs Hatchery.

Steelhead

A review of hatchery records revealed that at least 30 million steelhead have been planted in the Russian River since 1870 (Figure 3.6-1). Three major steelhead planting periods exist. The first period, from 1890 to 1939, peaked in 1920 to 1929 when 5,647,400 steelhead were planted. The second period fell between the loss of the Cold Creek Hatchery in 1939 and the commissioning of the Mad River Hatchery in 1971. During this second period, the Russian River was primarily stocked with steelhead "rescued" from summer-intermittent streams (Table 3.6-1) (CDFG 1939; CDFG 1972), and very few hatchery steelhead were planted. Shapovalov (1944) noted that "all" stocking carried out at that time used rescued fish, 28 percent of which were from other basins, most notably the Eel River. The third period, 1980 to the present, corresponds to the construction of Warm Springs Dam and its associated fish hatchery. Over 15 million steelhead have been planted in the drainage since 1980, with nearly 14 million coming from Warm Springs Hatchery (Table 3.6-2).

Almost all steelhead planted prior to 1980 were from out-of-basin stocks (Table 3.6-3). Documented stocks include Eel River, Prairie Creek, Mad River, San Lorenzo River, Scott Creek, and Washougal River (Washington) (Figure 3.6-2). Fish were hatched and reared by a succession of North Coast facilities including Ukiah (1897-1927), Cold Creek (1928-1937), and Mad River (1971-1980) hatcheries. In 1980, CDFG planting policy shifted to planting progeny of adults returning to Warm Springs Hatchery. From 1980 to 1989, progeny of Warm Springs Hatchery returns comprised 93 percent of the steelhead planted to the Russian River. Since 1990, all hatchery steelhead planted are progeny of adults returning to Warm Springs Hatchery and Coyote Valley Fish Facility.

Other Plants

Many non-native fish species have been planted in the Russian River system. Introduced game species include brown trout (*Salmo trutta*), largemouth and smallmouth bass (*Micropterus dolomieu* and *salmoides*), and *Lepomis* spp. (Table 3.3-2). These fish offered many attractive attributes. Bass were known as excellent game fish with a good culinary reputation. The large size of Brown trout made them attractive to anglers, and their ease of adaptation to hatchery conditions enhanced their popularity with fisheries managers. Among exotics, only brown trout planting continues. From 1890 to 1995, roughly 6 million brown trout were planted (Figure 3.6-7). The vast majority were planted prior to 1940 with only 290,000 having been planted since 1970. Prior to 1978, brown trout plants were distributed between Mendocino and Sonoma counties, but since then, all plants have been to the East Fork Russian River above Lake Mendocino.

From the 1870's to present, rainbow trout have been planted to support a put-and-take fishery in the Russian River (Figure 3.6-7). The domesticated fish used for this planting are the product of CDFG broodstock programs at various hatcheries around the state. Records indicate that approximately five different strains of rainbow trout were planted. Since 1978, approximately 21,000 fish have been planted annually in the East Fork Russian River (CDFG, unpublished data). These fish do not contribute to the anadromous steelhead runs in the Russian River since they are planted above Lake Mendocino. No catchable rainbow trout have been planted in the mainstem since 1958. California Department of Fish and Game policy forbids the planting of catchable trout in waters supporting anadromous fish (Week, CDFG, personal communication).

Impacts of Hatchery Plants

Consensus is forming that hatchery supplementation has resulted in major negative impacts to salmonids including loss of genetic diversity, displacement of native stocks, and disease transfer (Nehlsen et al. 1991; Higgins et al. 1992; Cramer et al. 1995). These effects are manifested in many ways and can vary dramatically from species to species and between years. Quantifying impacts is often difficult due to the complexity of both salmonid life cycles and aquatic systems. Given the magnitude of planting in the Russian River over the past century, it is likely that these impacts were experienced by salmonids in this system.

The loss of genetic diversity through selective breeding, inbreeding and interbreeding concerns many fish biologists as this can compromise the ability of both wild and hatchery fish to adapt to environmental change (Weitkamp et al. 1995). Selective breeding for individual characteristics such as large size or early run timing can diminish a hatchery stock's genetic variability. Weitkamp et al. (1995) note hatcheries tend to select their spawners from earlier portions of the run, leading to advanced and compressed run timing.

Inbreeding also causes a loss of genetic diversity. Hatchery gene pools are small, and repeated inbreeding tends to create a homozygous population. Small, homozygous gene pools lack the natural elasticity necessary to adapt to changing environmental conditions. Inbreeding may also cause depressed fertility. Iron Gate Hatchery coho experienced a low 38 percent fertility rate which was attributed to inbreeding (Higgins et al. 1992).

Interbreeding is the third possible cause of genetic diversity loss. Hatcheries often crossbreed stocks from different basins creating a "mongrel fish" poorly adapted to any specific location (Hillborn 1992; Stickney 1994). The offspring from out-of-basin stocks are commonly released into basins inhabited by native stock. If hatchery and native stocks interbreed, native gene stock dilution is possible (Cramer et al. 1995). Large hatchery plants may overwhelm native stocks leading to "genetic swamping" or loss of local adaptations (Altukhov and Salmonkuva 1986).

Hatchery stocks are genetically less fit for survival in streams than wild fish (Hillborn 1992). Hatchery stocks are adapted to hatchery conditions and are often less successful at locating spawning gravels, avoiding predators, or finding natural food. Negative impacts of hatchery rearing are not limited to one generation; studies have consistently found the progeny of hatchery fish have a considerably lower survival rate than those of wild fish (Smith et al. 1985). Cramer et al. (1995) state that hatchery practices have led to a lack of genetic fitness on the North Coast.

Russian River salmonids have likely suffered hatchery-related genetic impacts. Prior to 1980, many different stocks were introduced to the system. The present Russian River hatchery stock is likely a mélange of many different origins. Warm Springs steelhead stock has been statistically shown to have far more in common with Eel River stocks (Cramer et al. 1995) than the native Russian River stocks. Based on this genetic similarity, Cramer concluded that the Dry Creek stock is descended from Mad River Hatchery (Eel River stock) smolt releases in 1979 and 1981. Due to the current hatchery stock's out-of-basin lineage, fish planted from Warm Springs hatchery production are likely less suited to Russian River conditions than native stocks.

The status of genetically pure Russian River stocks is unknown, but it is possible that remnant populations remain in some of the more isolated headwaters. Anecdotal and agency reports of fish spawning in larger tributaries are relatively common, especially in wetter years. Fry and larger fish are commonly reported rearing in tributaries where summer flow and riparian vegetation provide suitable habitat. Many remote and relatively undisturbed drainages still retain viable "natural" populations, including Pieta Creek (Rich 1991), Big Sulphur Creek (McMillan 1985), Mark West Creek, Santa Rosa Creek (Cox, CDFG, personal communication), Maacama Creek, and Austin Creek (Coey, CDFG, personal communication).

Another potential negative impact of hatchery plants is the displacement of native stocks through density-dependent competition. Because they are released in high numbers, in discrete pulses, and at a large size, hatchery plants may outcompete and displace naturally spawned fish. Displaced fish are at a disadvantage in establishing territories, acquiring food, and resisting predation (Smith et al. 1985), and suffer increased mortality relative to natural conditions (Hillborn 1992). The hatchery-reared fish are, however, poorly adapted for long-term survival, and depressed populations may result from the loss of native or locally adapted stocks (Weitkamp et al. 1995). The large salmonid numbers released into the Russian River most certainly have resulted in competition. For reasons of practicality, hatchery plants are concentrated in one area, creating localized high densities of fish. Since 1985, large numbers of steelhead juveniles have been released at or near Warm Springs and Coyote dams. At Warm Springs Dam, annual steelhead plant numbers have ranged between 121,000 and 1.6 million fingerlings and between 53,000 to 363,000 yearlings (Cartwright, CDFG, personal communication; Estey 1982-84, 1986; Gunter 1988, 1990, 1991). At Coyote Dam, 165,469 yearlings and 120,914 sub-yearlings were released in 1993 (Fortier, CDFG, unpublished data). In 1994, the numbers were even larger with 213,872 yearlings released at Coyote Dam, and 227,313 fingerlings released "below" the dam. A stated goal of the Coyote Valley project is to have 4,000 adult steelhead return to Coyote Dam (Morford 1994). To achieve this goal would necessitate the release of approximately 400,000 smolts annually. Such point-source planting can be expected to create locally overpopulated situations with attendant problems for naturally spawning fish.

Additional competition between hatchery and native stocks takes place in the ocean. Marine productivity changes with variations in oceanic circulation patterns (Section 3.5) (Cramer et al. 1995). In some years, low ocean productivity may prove limiting to salmonid populations. Several studies illustrate that salmonids suffered density-dependent mortality during periods of weak oceanic upwelling, while other studies indicated diminished oceanic fish growth under high-density conditions (Pearcy 1992). Oceanic fish density effects are still debated, but it remains possible that hatchery releases increase oceanic competition, decreasing success for both wild and hatchery fish.

Large aggregations of hatchery steelhead smolts can present a significant predation threat to smaller salmonids. Hatchery releases are typically done in large blocks and sometimes occur outside normal steelhead smolt departure windows. Under natural conditions, steelhead smolts emigrate from late winter through spring. Chinook salmon move later, from mid- to late spring, minimizing migratory interaction between the species. Steelhead released during chinook emergence and outmigration can opportunistically prey on the fry and smolts. Under natural conditions, a 1992 Snake River study found steelhead smolts did consume chinook fry, but in relatively low numbers (3.2 percent predation rate) (Cannamella 1993). Under certain water conditions (low flows, high visibility) releases of hatchery steelhead during peak chinook fry outmigration could result in significant predation on chinook smolt populations.

The Russian River, once a world-class fishery, remains a popular stream for recreational anglers, largely due to hatchery planting programs. This artificially maintained sport harvest may result in unintentional reductions of wild steelhead populations. Angling pressure often increases in stocked streams, and angler harvest may include a substantial number of native fish (Cramer et al. 1995). Many studies state more wild salmonids may be harvested than would have occurred under a "no-plant" scenario. This incidental wild fish take increases in significance when wild populations are already at depressed levels. During periods when wild fish populations are critically low, the harvest of even a few fish can dramatically limit the gene pool.

Disease is another major hatchery concern. Unlike the wild setting, hatchery propagation forces fish into tight confinement, virtually assuring that any communicable disease will be spread to the entire population. A naturally spawned population may possess a given disease, but generally in a smaller portion of the population. Interaction between a relatively healthy natural population and a heavily infected hatchery population can spread diseases, resulting in unnaturally high incidences of infection or mortality. Out-of-basin stocks may bring disease with them. Noyo River coho salmon are known carriers of bacterial kidney disease (BKD), a horizontally transmitted (fish to fish) disease (Post 1987) that results in the loss of normal liver and kidney function, severely limiting survival (Kaatori et al. 1989). Widespread use of Noyo River stock may have resulted in interbasin BKD transfer (Higgins et al. 1992). Bacterial kidney disease is now present at Warm Springs Hatchery. Though the origin of the BKD at Warm Springs Hatchery is unknown, Noyo River coho are the suspected carrier as they were used to establish a source stock at the hatchery. Out-of-basin stocks may also lack immunity to localized diseases and/or strains. If these introduced fish spawn with locally adapted or native stocks, all fish may suffer decreased immunity to localized diseases (Higgins et al. 1992).

The growing body of evidence from the Russian River and other systems suggests that hatchery operations have been counterproductive, damaging the very resource they were attempting to augment. While Warm Springs Hatchery and CVFF have achieved some production success, the presence of hatchery fish may have masked or contributed to the worsening condition of the native or adapted stocks. Behavioral adaptations to the basin's specific hydrology, morphology, and climate patterns are at risk of being lost or suppressed. The decade-long attempt of the Warm Springs Hatchery to replicate evolutionary processes and create locally adapted stock for chinook and coho salmon has had limited success. Planting steelhead smolts at inappropriate times or densities may have resulted in significant competition with or predation on naturally spawned salmonids. Disease has been spread by interbasin transfer, and immunity to drainage-specific diseases may have been weakened. Hatcheries have gradually changed their methodology as these problems have become apparent, but it is clear that hatchery supplementation can never be viewed as a replacement for natural production. The present function of hatcheries should be to provide refugia, maintaining local reproductive populations while habitats and systems undergo restoration (Stickney 1994).

Table 3.6-1: Basin origins and planting totals for rescued chinook salmon, coho salmon, and steelhead planted into the Russian River.

RESCUED STEELHEAD

RESCUE LOCATION	YEARS	FISH TOTALS
RUSSIAN RIVER	1939,44,49-50,55-72	4,598,912
EEL RIVER	1939,42,49-50,58-61,65	189,562
NORTH COAST	1942-45	1,646,746
TOTAL		**6,435,220**

RESCUED CHINOOK

RESCUE LOCATION	YEARS	FISH TOTALS
EEL RIVER	1939	2,382
TOTAL		**2,382**

RESCUED COHO

RESCUE LOCATION	YEARS	FISH TOTALS
RUSSIAN RIVER	1963,68-71	76,524
NORTH COAST	1944	60,510
TOTAL		**137,034**

Table 3.6-2: Number of steelhead planted into Russian River which were progeny of Warm Springs Hatchery or Coyote Valley Fish Facility.

Fiscal Year	Warm Springs Hatchery Progeny		Coyote Valley Fish Facility Progeny	
	Fry [a]	Smolts [b]	Fry	Smolts
1981	460,056	0		
1982	362,136	53,380		
1983	226,710	102,622		
1984	444,850	124,146		
1985	314,520	148,830		
1986	426,917	212,365		
1987	1,316,469	235,413		
1988	646,279	224,963		
1989	578,780	233,979		
1990	347,447	212,769		
1991	111,326	243,881		
1992	1,182,663	341,181		
1993	145,809	1,737,362		
1994	1,116,076	924,205		
1995	637,835	495,762	70,424	92,133
1996*	178,385			
TOTAL:	8,496,258	5,290,858	70,424	92,133

* Data for 1996 are incomplete

[a] Fry are defined as fish smaller than 20 per pound.

[b] Smolts are defined as fish larger than 20 per pound.

Table 3.6-3: Basin origins and planting totals for hatchery chinook salmon, coho salmon, and steelhead planted into the Russian River.

HATCHERY STEELHEAD

SOURCE STOCK	YEARS	FISH TOTALS
RUSSIAN RIVER	1959,81-95	14,770,143
EEL RIVER	1914-19,21-23,58-59,72	4,900,843
MAD RIVER	1975-76,78-79,81	324,101
PRAIRIE CREEK	1927	249,000
SAN LORENZO CREEK	1973	83,350
SCOTT CREEK	1911	433,458
UNKNOWN		8,934,122
WASHOUGAL (WA)	1980-81	270,360
TOTAL		**29,965,377**

HATCHERY CHINOOK

SOURCE STOCK	YEARS	FISH TOTALS
RUSSIAN RIVER	1985,87-90,92-95	476,765
EEL RIVER	1982,84,86-89	171,537
KLAMATH RIVER	1955-56	1,000,000
MAD RIVER	1953	9,250
SACRAMENTO RIVER	1956,59-60,62-64	3,283,295
SILVER KING CREEK	1982-83	70,000
UNKNOWN		2,265,292
WISCONSIN*	1982-86	1,337,624
TOTAL		**8,613,763**

* Originated from Green River, WA.

HATCHERY COHO

SOURCE STOCK	YEARS	FISH TOTALS
RUSSIAN RIVER	1983,85-95	632,972
ALSEA RIVER (OR)	1972	58,794
EEL RIVER	1987,90	25,112
KLAMATH RIVER	1975,81-83,86-88	451,370
NOYO RIVER	1970,72-74,82-84,86-91	563,651
SOOS CREEK (WA)	1978	8,420
UNKNOWN		403,340
TOTAL		**2,143,659**

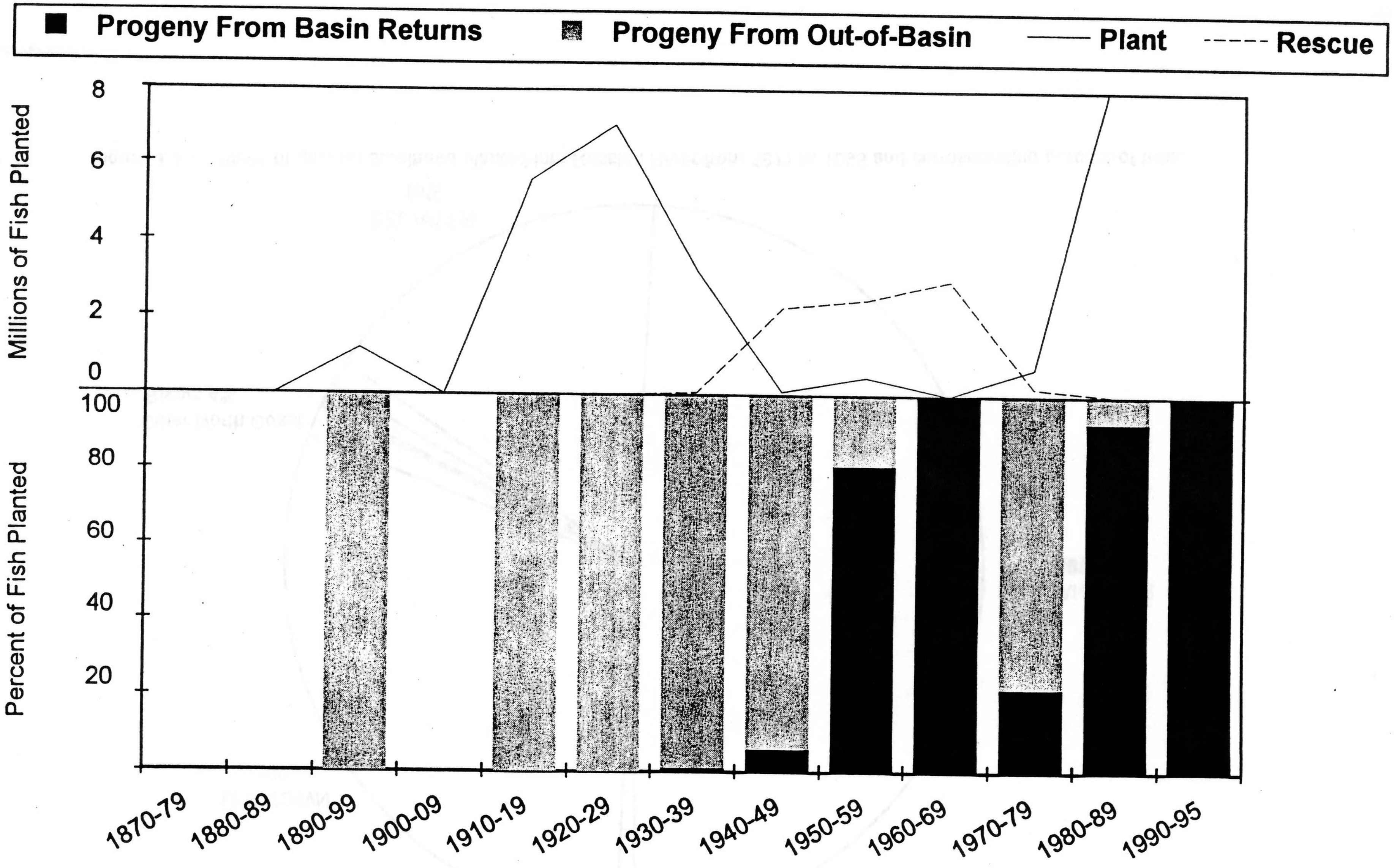

Figure 3.6-1: Number of steelhead planted and rescued into the Russian River and the corresponding percent contributed from local returns and out-of-basin sources.

p90\tempsupr\ruspapr.sgx

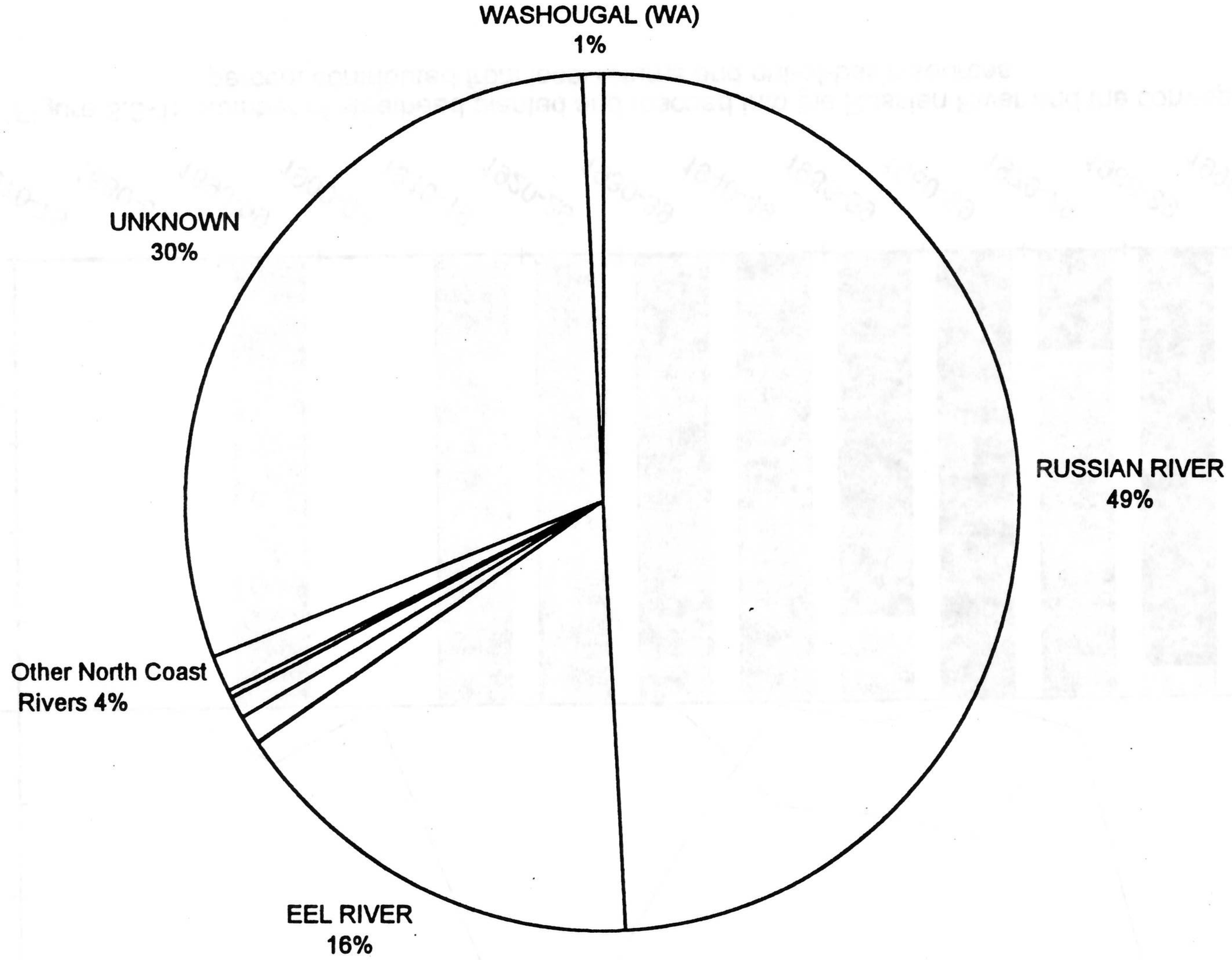

Figure 3.6-2: Basin origins for steelhead planted into Russian River from 1911 to 1995 and corresponding percent of total.

STKSRC.XLS\SH percent of total

8/23/96

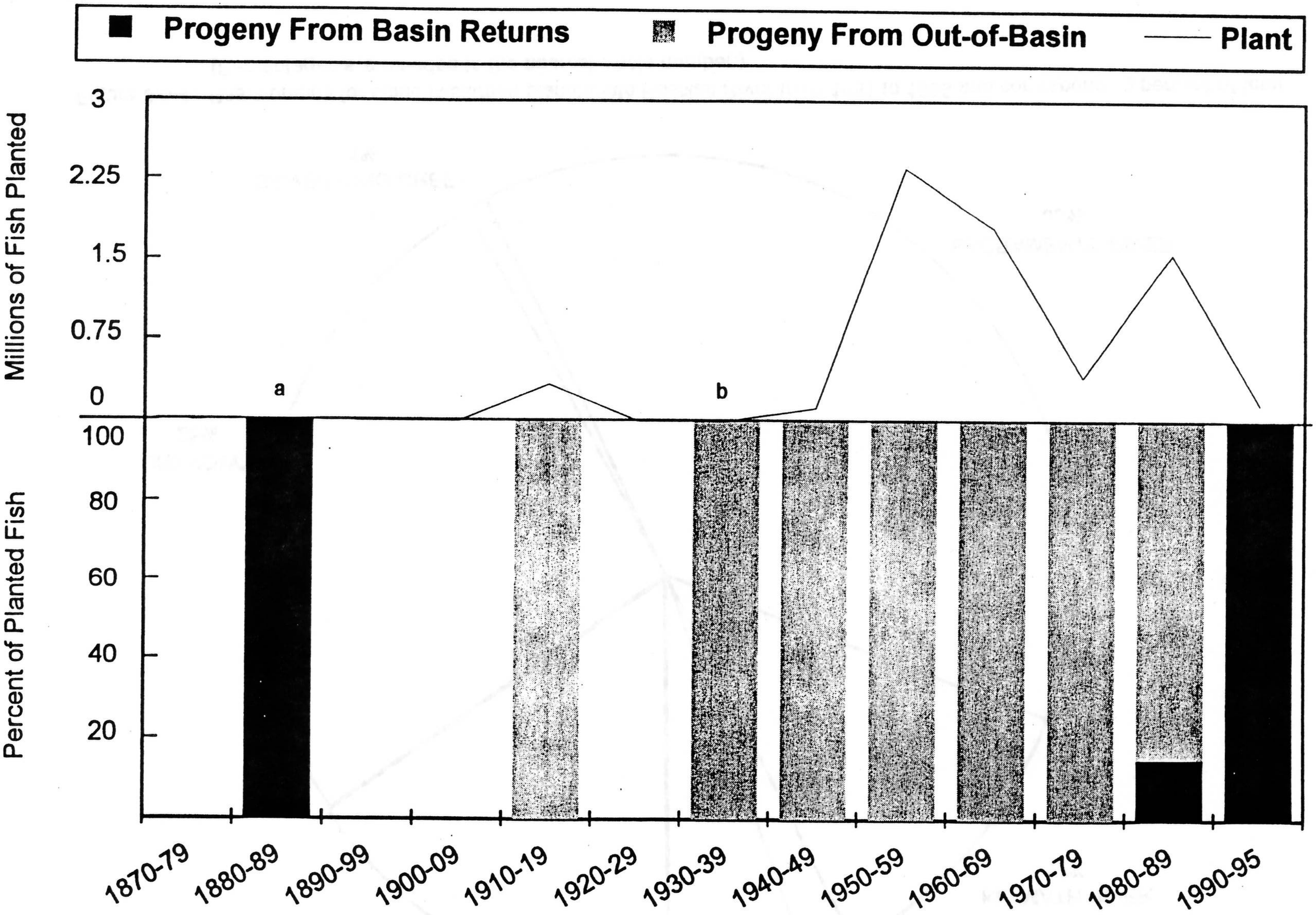

Figure 3.6-3: Number of chinook salmon planted and rescued into the Russian River and the corresponding percent contributed from local returns and out-of-basin sources.

a 15,000 planted in 1881.
b 2,382 rescued between 1930 and 1939.

p90\temps\upr\ruspepr.sgx

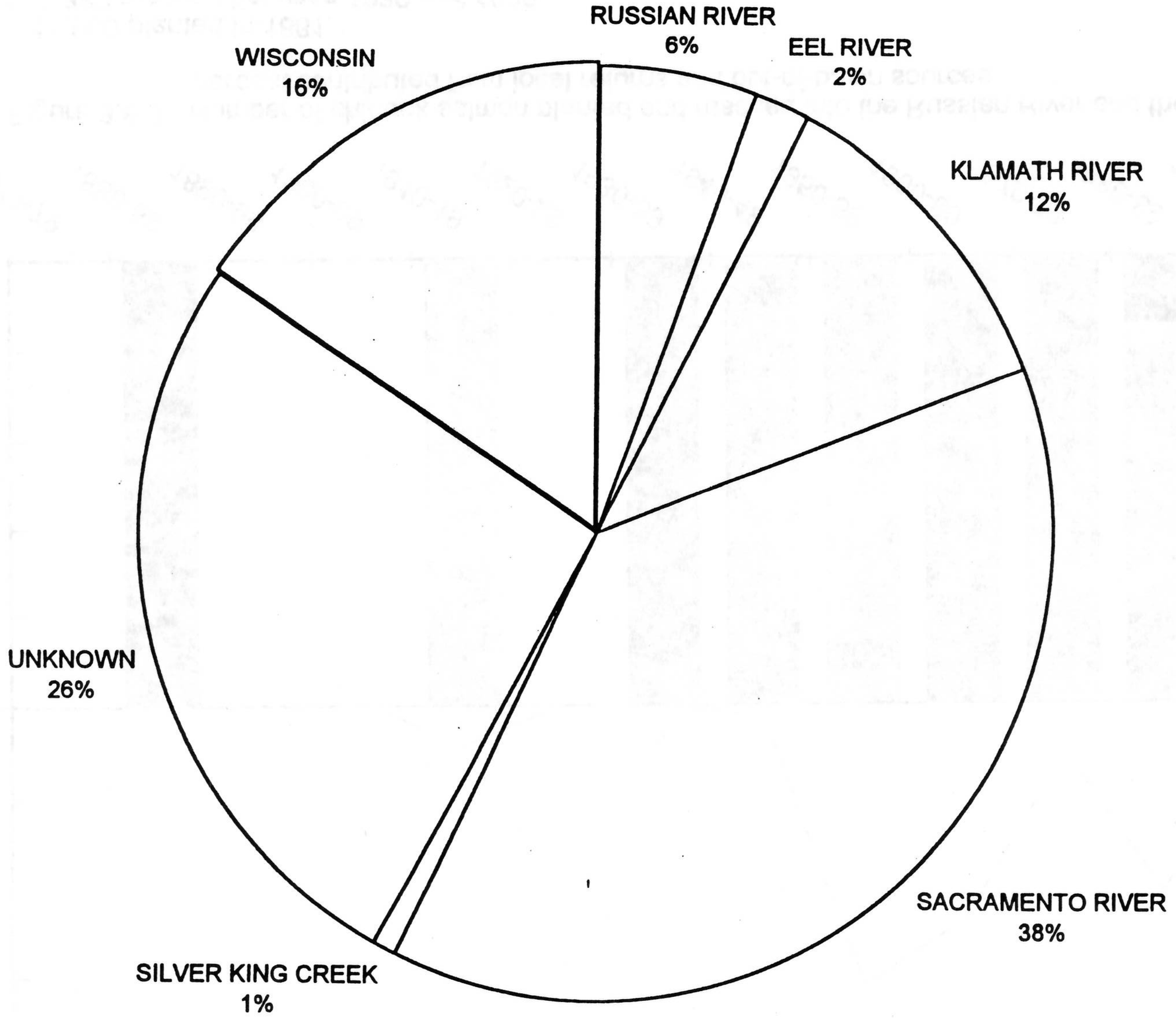

Figure 3.6-4: Basin origins for chinook salmon planted into Russian River from 1881 to 1995 and corresponding percent of total. (Percentages are rounded to the nearest whole number.)

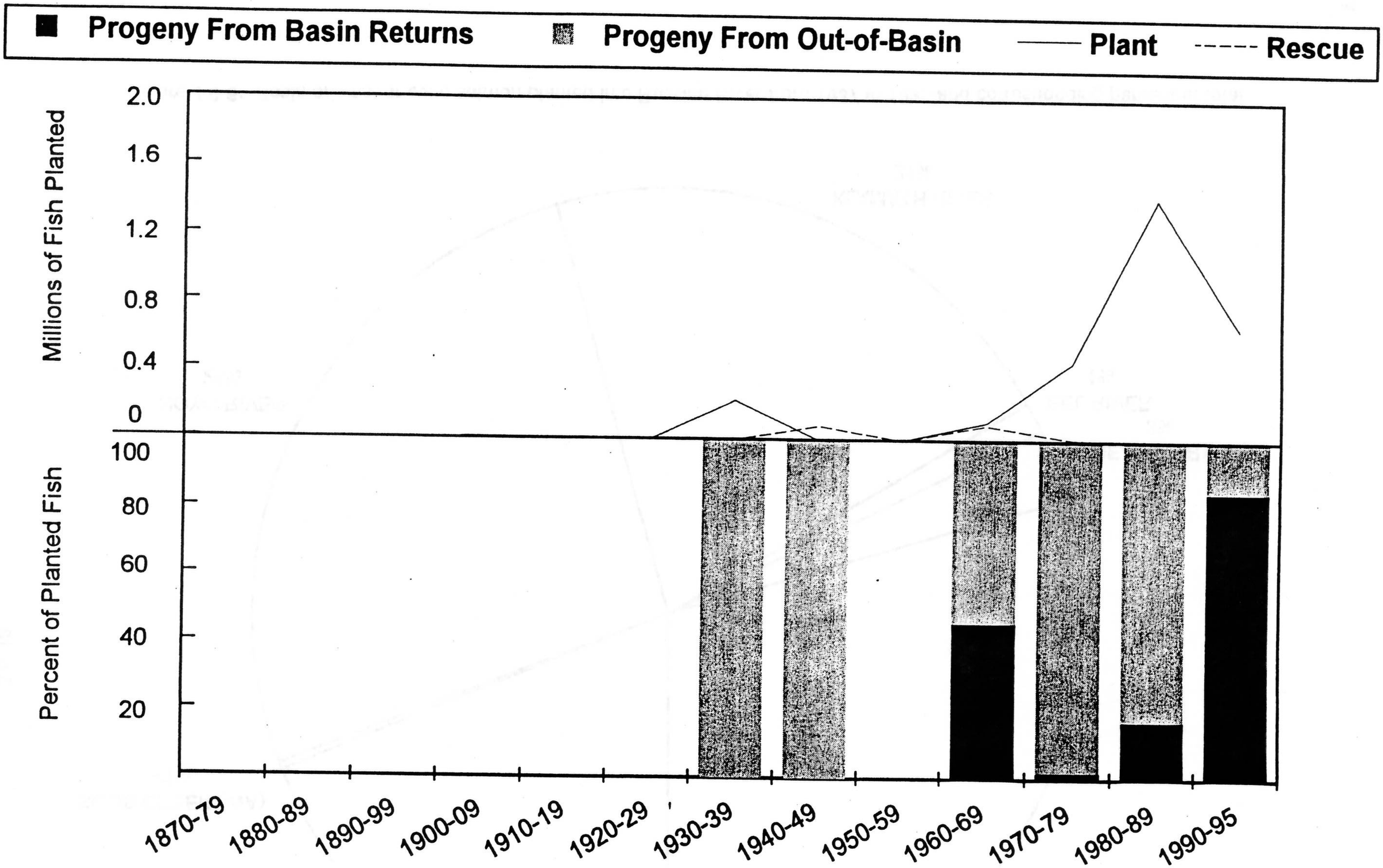

Figure 3.6-5: Number of coho salmon planted and rescued into the Russian River and the corresponding percent contributed from local returns and out-of-basin sources.

p90\tempsupr\ruspapr.sgx

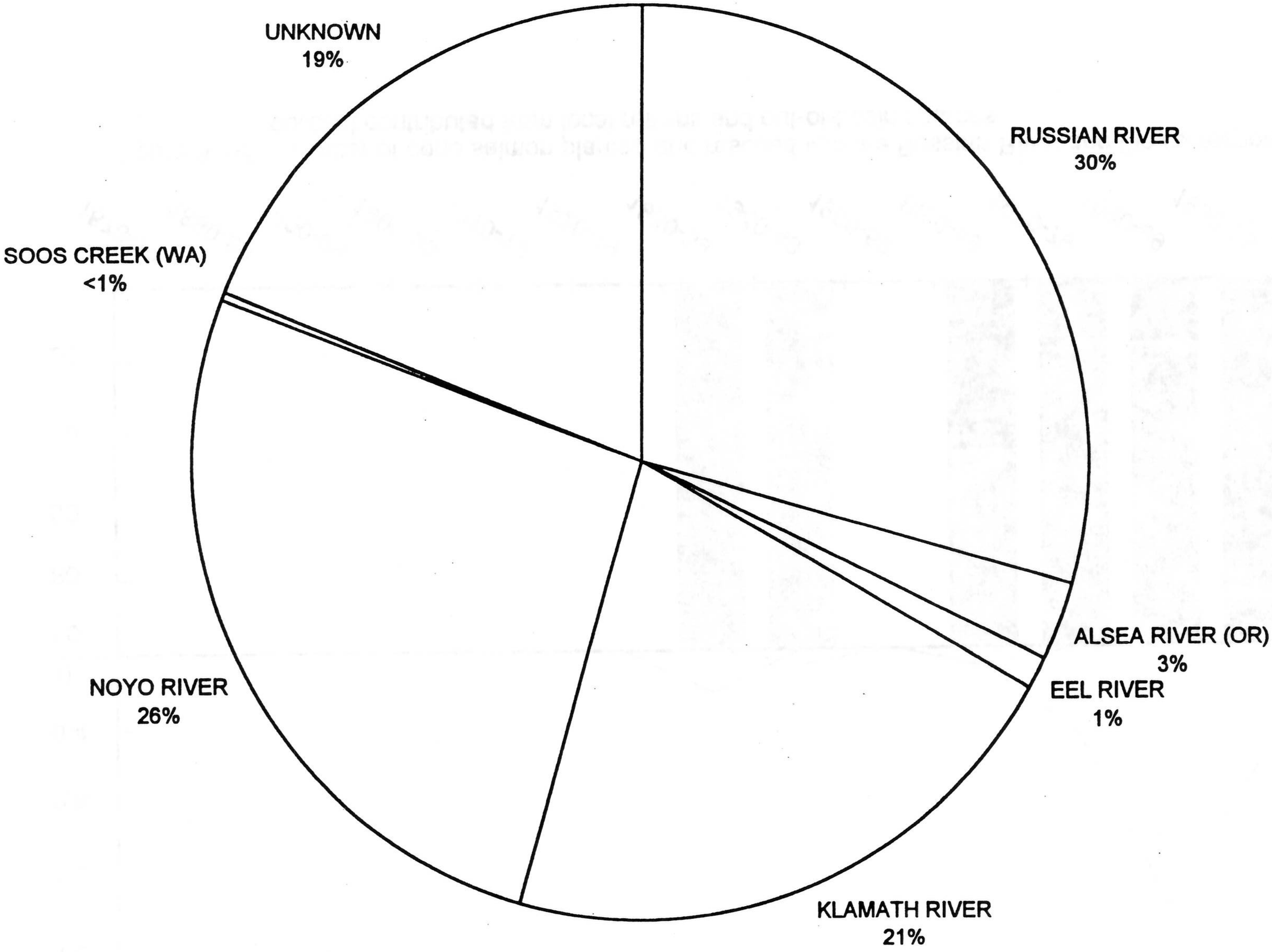

Figure 3.6-6: Basin origins for coho salmon planted into Russian River from 1937 to 1995 and corresponding percent of total.

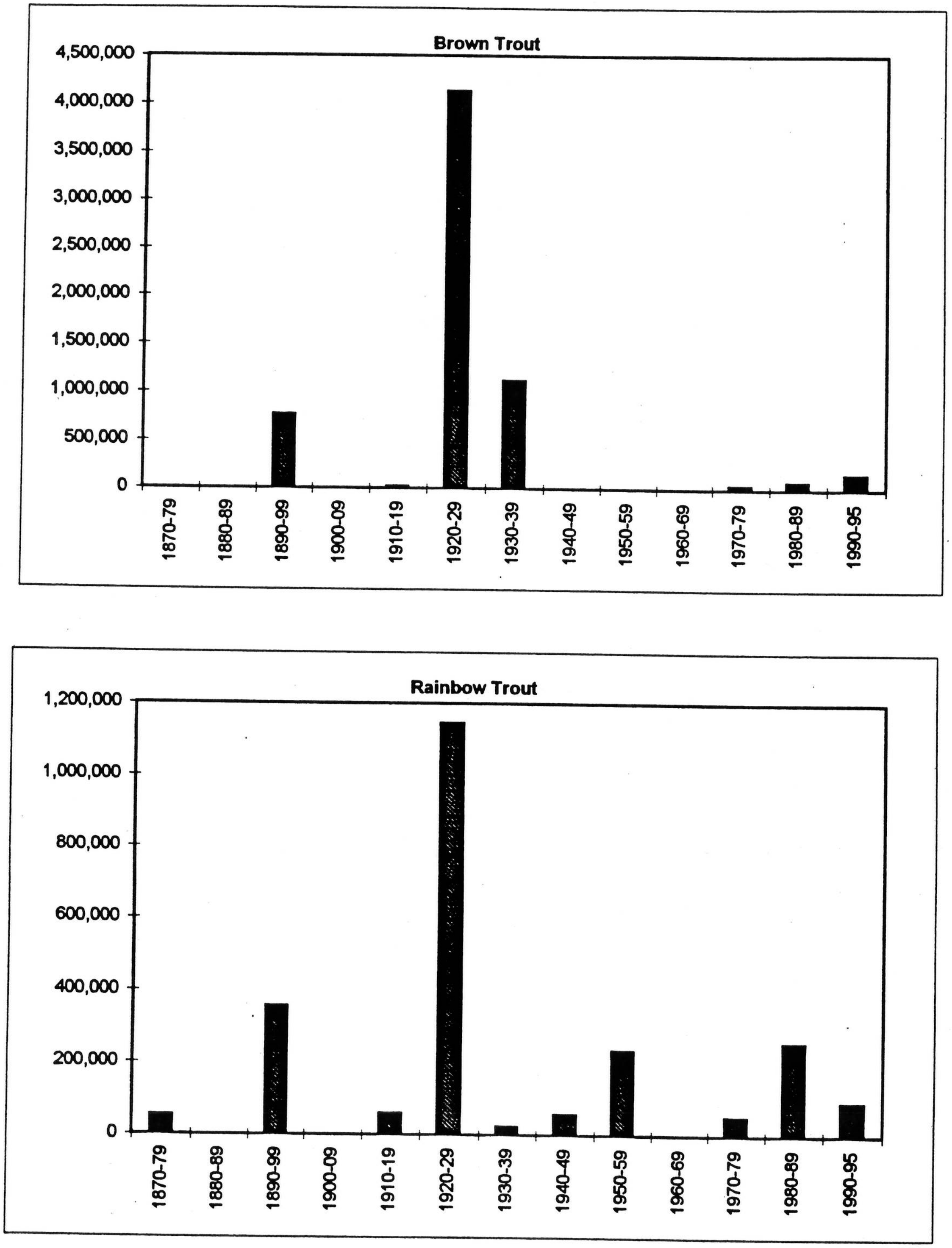

Figure 3.6-7: Number of brown and rainbow trout planted into the Russian River. (Rainbow trout are domestic brood stock not intended to supplement anadromous returns. All rainbow trout planted after 1958 are into the East Fork Russian River. All data compiled from CDFG records.)

3.7 Other Implicated Causes

Dams, habitat loss, flow and temperature changes, altered species composition, morphological changes, ocean conditions, and hatcheries are major impacts to salmonids in the Russian River. These are not, however, the only factors impacting salmonids. Other human activities–agriculture, timber harvest, urbanization, unprotected water diversions, and fish harvest–chronically and cumulatively impact the Russian River, all contributing to salmonid decline.

Agriculture has impacted the Russian River since the late nineteenth century. By 1900, most land near the Russian River was already under cultivation (Jones 1993). Early agriculture filled in sloughs and side channels, and removed riparian vegetation. These practices continued until the late 1940's when few wetlands remained (Florsheim and Goodwin 1993). During this time, the river valley was leveled and creeks were channelized, altering drainage and increasing runoff. Agricultural operations removed riparian vegetation, small in-channel islands, and gravel bars to increase arable acreage and achieve flood control. Since European settlement in the basin, an estimated 70 to 90 percent of the Russian River riparian habitat has been lost (Circuit Rider 1994a). Vegetation removal and channel destabilization accelerated erosion. In response to increased erosion, bank stabilization measures began in the 1850's and continued as cultivated acreage increased. Stabilization measures increased channel straightening which expedited channel downcutting. In addition to changing river morphology, agricultural practices decreased water quality by releasing fertilizers and pesticides into the river (Florsheim and Goodwin 1993). Enrichment from manures was also a problem where barns and livestock were close to streams.

Urbanization has had profound effects throughout the watershed. Development encourages gravel harvest from stream beds and also increases water withdrawal. Initially, as urban centers develop, there is an influx of sediment into streams from erosion. Once rapid building is complete, large areas of concrete and asphalt increase and concentrate runoff, increasing flooding and stream bank erosion (Florsheim and Goodwin 1993). Roofs dramatically increase the impervious area, adding more rapid runoff. Roads may pose the greatest threat of urbanization to streams. Road construction and unpaved roads cause significant direct sediment input to streams. Poorly designed road cuts frequently result in major slippage. Many road designs channelize natural stream courses, and all roads increase runoff (Meehan 1991).

Since 1900, human population in the Russian River basin has increased rapidly. In 1950, there were 65,000 people in the basin, while in 1980 there were 215,800 people. Estimates predict 346,000 people in the basin by 2000 (COE 1982). As the population in the basin expands, demand for gravel and water increases proportionately. As a consequence, stream channels are altered and habitat degraded, either directly or through cumulative negative impacts to the river system. As easier sites are exhausted, more marginal areas are brought into production. Utilization of these sites often requires increased levels of habitat disruption. Stream pollution increases with higher human density, degrading water quality for both people and wildlife (Florsheim and Goodwin 1993). Tributaries suffer from channelization, rerouting, and pollution; many urbanized Russian River tributaries no longer support salmonid populations.

Timber harvest has had a major influence on the Russian River basin. The redwood forests of the lower 20 river miles were heavily logged near the turn of the century and again after World War II (Reynolds 1991). Tributary watersheds in the western hills of the basin were also periodically harvested, though their timber reserves were not as extensive as those of the lower river. During peak timber harvest periods, logging practices were largely unregulated. Hillslope and streambank erosion was accelerated by tractor logging on steep slopes, clearing of riparian zones, and logging road construction. The eroded sediments ended up in streams, silting gravels, diminishing invertebrate populations, and generally reducing spawning and rearing habitat (Reynolds 1991). Additionally, riparian canopy loss often elevated stream temperatures and diminished nutrient and invertebrate inputs from the riparian zone.

"Conversion", the harvesting of timber, burning what remained, and preventing re-growth through heavy grazing pressure, was and remains a commonly espoused and followed practice in the Russian River basin. For example, 90 percent of the Dry Creek watershed redwood and Douglas fir forests were transformed to other habitat types (COE 1973). This conversion to other vegetation types and the fragmentation of the remaining conifer forests likely reduced salmonid populations. Botkin et al. (1995) found that, in Oregon, steelhead and chinook populations were larger in conifer forests than in brush and grassland habitats. Furthermore, forest fragmentation statistically correlated with diminished steelhead and chinook populations. They concluded that forest conditions were a major factor controlling salmonid abundance. Habitat conversion will continue to impact salmonids as long as habitats are held at their altered successional levels.

Another form of timber harvest existed in the Russian River basin which may have impacted the fisheries. Entire stands of trees were removed and reduced to charcoal, then transported by rail to population centers in the San Francisco Bay Area. During a period believed to peak in the 1920's and 1930's, considerable pressure was put on oak and madrone forests in the hills between Cloverdale and Ukiah. Based on artifact and remnants recovered, one ranch north of Hopland owned by Malcomb King (personal communication) was the site of at least nine charcoal camps. Mr. King stated that he remembered the whole area being severely cut over. One ridge, Largo Ridge, was completely cleared of all madrones at least twice in his memory. The implications for impacts from hardwood harvest are similar to those for coniferous timber harvest. Roads and siltation, loss of riparian habitat, and changes in nutrient cycling all have the potential to cumulatively impact the fisheries resources.

Unprotected water diversions in the Russian River can impact young salmonids. Young fry are easily drawn into water pumps (entrained) or become stuck against the pumps' screened intakes (impinged). California Department of Fish and Game policy states that all intakes will be screened where salmonids are present. Criteria for screens state they will have a pressed wire mesh with openings of 5/32 inches or less and an approach velocity to that mesh of less than 0.33 feet per second (Jones, CDFG, personal communication). A 1991 survey between Lake Mendocino Drive near Ukiah and the Highway 101 bridge south of Hopland found 63 pumped diversions; eight with proper screen size but unacceptable approach velocities, 51 with improper screens, and four with no screens at all (CDFG, unpublished data). Unscreened or inadequately screened diversions predominate on the Russian River. On the Sacramento River system, screening issues are of great concern because juvenile salmonids are present all year (Vogel and Marine 1991). The Russian River situation is less critical since juvenile salmonids are present primarily in the spring months. During this period, pumping is intermittent with the primary uses being frost protection and early irrigation. This is not to imply that no problem exists. During a frost event, most pumps would run simultaneously, presenting a cumulative withdrawal of large proportions. Any juvenile outmigration occurring at this time could experience significant loss.

In-river sport fishing has directly impacted spawning and rearing salmonid populations. Throughout the twentieth century, the Russian River has been a popular angling stream. The winter steelhead run was internationally famous, and its proximity to the San Francisco Bay Area made the Russian River accessible to millions of people (Prolysts 1984). With the advent of improved transportation networks, angling popularity intensified, and local economies benefited from the recreational trade. As the number of anglers increased, however, steelhead populations decreased, escalating harvest pressure when fish numbers were low. Only limited catch data are available, but a declining trend is evident. From the 1930's to the 1950's, anglers caught many steelhead, more than 15,000 in 1936. Under exceptionally favorable conditions in 1957, they caught approximately 25,000. By 1971/72, however, angler harvest had dropped to approximately 5,000 fish. By the 1980's, angler success had diminished to the point that fish derbies were no longer held in Mendocino County (Prolysts 1984).

Extremely low salmon and steelhead populations observed in the early 1990's stimulated concern about angler harvest of adults in the Russian River and other North Coast streams. Concern was most strongly directed at the diminishing populations supported by natural spawning. Angler pressure has been shown to have a significant impact on already depressed salmonid populations. These small populations can sustain little or no harvest (Cramer et al. 1995). Annual harvest estimates for adult steelhead in California range from 12 to 56 percent of the species population, with greater proportions taken in more southerly watersheds. A higher proportion of small salmonid escapements are caught in California streams during low water years. On the Eel River, situations often occur where discharge is sufficient to attract adult salmonids upstream, but inadequate to allow passage into tributary streams (SEC, unpublished data). These fish concentrate in pools as they wait for high flows, making them easy targets for anglers. The same situation occurs on the Russian River. Concerns about overharvest contributed to the 1995 closure of the mainstem Eel River to fishing (CDFG 1994) but no similar action has been proposed for the Russian River.

Juvenile salmonid populations are also affected by freshwater harvest. Substantial numbers of yearling steelhead are caught by anglers who call them "trout'. A study of the Big Sur River found that the majority of emigrating wild juvenile steelhead were caught before they made it downstream (Cramer et al. 1995). In the Russian River basin, tributary fishing is prohibited, yet harvest of "trout" (juvenile steelhead) remains a significant source of loss for some rearing steelhead populations. Tributaries in urban areas, such as Ukiah, are especially vulnerable as anglers are often uninformed or unconcerned about regulations.

Ocean harvest is a significant source of salmonid loss (Cramer et al. 1995). In addition to targeted harvest, oceanic salmonids are taken unintentionally during harvest of other types of fish (bycatch), or are taken through high seas drift net fishing. Both bycatch and drift net fishing are suspected of affecting oceanic salmonid populations, but impacts are difficult to quantify (Higgins et al. 1992).

Many anthropogenic factors impact salmonids. Individually, the factors may not be significant, but cumulatively they are formidable. Watersheds, for example, are affected by nearly all human endeavors. An impact in one area manifests itself throughout the watershed. Salmonid recovery requires lessening of all impacts, including seemingly minor ones. Community cooperation is necessary to protect entire watersheds, not just streams or forests, if a salmonid fishery is to remain viable.

4.0 References Cited

Anderson, K.R. 1972. Report to the Federal Power Commission on the fish and wildlife aspects of the relicensing of the Potter Valley Hydroelectric Project (F.P.C. Project No. 77), Lake and Mendocino Counties, California. California Department of Fish and Game. Sacramento, California.

Anonymous. 1893. A few personal remarks - about Mendocino's interests and people - fishing at Potter. Ukiah Republican Press, March 17. Ukiah, CA.

Altukhov, Y.P. and E.A. Salmenova. 1986. Stock transfer relative to natural organization, management, and conservation of fish populations. In: Ryman and Utter *eds*. Population Genetics and Fisheries Management. University of Washington Pres. Seattle, WA.

Baumgartner, T.R., A. Soutar, and V. Ferreira-Bartrina. 1992. Reconstruction of the history of Pacific sardine and northern anchovy populations over the past two millennia from sediments of the Santa Barbara Basin, California. California Cooperative Oceanic Fisheries Investigations. Report 33:24-40.

Botkin, D.B., K. Cummins, T. Dunne, H. Regier, M. Sobel, L. Talbot, and L. Simpson. 1995. Status and future of salmon of western Oregon and northern California: Overview of findings and options. The Center for the Study of the Environment. Santa Barbara, CA.

Brett, J.R. 1952. Temperature tolerance in young Pacific salmon, genus *Oncorhynchus*. Journal of the Fisheries Board of Canada 9:265-323.

Brown, L.R. and P.B. Moyle. 1981. The impact of squawfish on salmonid populations: A review. North American Journal of Fisheries Management 1:104-111.

Burghduff, A.E. 1937. Russian River improvement. California Department of Fish and Game. Sacramento, CA.

CDFG (California Department of Fish and Game). 1939. Biennial Report for the years 1936-1938. State of California. Sacramento, CA.

__________. 1964. Russian River gets winter-run kings. Outdoor California 25:12.

__________. 1966. Fish and wildlife problems and study requirements in relation to North Coast water development. Water Projects Branch Report No. 5. Sacramento, CA.

__________. 1972. Annual Report to the Fish and Game Commission. California Department of Fish and Game. Sacramento, CA.

__________. 1994. Initial statement of purpose for regulatory action: Amend Section 7.50(b)(63) Title 14, California Code of Regulations. California Department of Fish and Game. Sacramento, CA.

__________. Unpublished Data. Sacramento, CA.

Cannamella, D.A. 1993. Hatchery steelhead smolt predation of wild and natural juvenile chinook salmon fry in the upper Salmon River, Idaho. Idaho Department of Fish and Game. Boise, ID.

Cartwright, W.F. 1992. Annual Report Warm Springs salmon and steelhead hatchery 1990-91. California Department of Fish and Game. Sacramento, CA.

__________ 1994. Annual Report Warm Springs salmon and steelhead hatchery 1991-92. California Department of Fish and Game. Sacramento, CA.

Christensen, W. 1957. Steelhead season longest in history. Press Democrat, February 10. Santa Rosa, CA.

City of Healdsburg: Department of Public Works. 1996. Proposed municipal water wells on Dry Creek Healdsburg, California. Draft Environmental Impact Report. Healdsburg, CA.

Circuit Rider Productions. 1994a. Riparian Habitat Status Report. Technical Report to Coastal Conservancy. Russian River Resource Enhancement and Public Access Plan in preparation. Oakland, CA.

Circuit Rider Productions. 1994b. Enhancement Alternatives: Middle Reach, Russian River. Technical Report to Coastal Conservancy. Russian River Resource Enhancement and Public Access Plan in preparation. Oakland, CA.

COE (United States Army Corps of Engineers). 1973. Warm Springs Dam and Lake Sonoma project Russian River Basin, Sonoma County, California. Final Environmental Impact Statement. Office of the Chief of Engineers Department of the Army. Washington, D.C.

__________. 1982. Northern California Streams Investigation Russian River Basin study. Final Report. San Francisco, CA.

Cramer, S.P., S.W. Alley, J.E. Baldrige, K. Barnard, D.B. Demko, D.H. Dettman, B. Farrell, J. Hagar, T.P. Keegan, A. Laird, W.T. Mitchell, R.C. Nuzum, R. Orton, J.J. Smith, T.L. Taylor, P.A. Unger, and E.S. Van Dyke. 1995. The status of steelhead populations in California in regards to the Endangered Species Act. S.P. Cramer and Associates, Inc. Gresham, OR.

DWR (Department of Water Resources). 1976. Eel-Russian Rivers streamflow augmentation studies. Bulletin No. 105-5. Department of Water Resources. Sacramento, CA.

__________. 1984. Upper Russian River gravel and erosion study. Sacramento, CA.

EarthInfo. 1994. USGS Daily Values West1 1994. CD-ROM under product license agreement. EarthInfo Inc. Boulder, CO.

EIP Associates. 1994. Sonoma County aggregate resources management plan and environmental impact report. Prepared for Sonoma County Planning Department, Santa Rosa, CA.

Estey, D.F. 1982. Annual Report Warm Springs salmon and steelhead hatchery 1980-81. California Department of Fish and Game. Sacramento, CA.

__________ 1982. Annual Report Warm Springs salmon and steelhead hatchery 1981-82. California Department of Fish and Game. Sacramento, CA.

__________ 1984. Annual Report Warm Springs salmon and steelhead hatchery 1982-83. California Department of Fish and Game. Sacramento, CA.

__________ 1986. Annual Report Warm Springs salmon and steelhead hatchery 1984-85. California Department of Fish and Game. Sacramento, CA.

Fisher, J.P. and W.G. Pearcy. 1994. Interannual trends in steelhead abundance and in ocean conditions. S.P. Cramer and Associates, Inc. Gresham, OR.

Florsheim, J.L., and P. Goodwin. 1993. Geomorphic and hydrologic conditions in the Russian River, California: historic trends and existing conditions. Prepared for the California State Coastal Conservancy and the Mendocino County Water Agency.

Fortier, R. Unpublished Data. California Department of Fish and Game. Yountville, CA.

Francis, R.C. 1992. Climate change and salmonid production in the North Pacific Ocean. Pages 33-44 in K.T. Redmond and V.L. Tharp eds. Proceedings of the Ninth Annual Pacific Climate (PACLIM) Workshop. Asilomar, CA.

Fry, D.H. 1979. Anadromous Fishes of California. California Department of Fish and Game. Sacramento, CA.

Gahagan and Bryant Associates, Inc. 1994. Preliminary engineering investigation of alluvial separators on the Middle Reach, Russian River. Prepared for California State Coastal Conservancy. Oakland, CA.

Gunter, E.R. 1988. Annual Report Warm Springs salmon and steelhead hatchery 1985-86. California Department of Fish and Game. Sacramento, CA.

__________ 1988. Annual Report Warm Springs salmon and steelhead hatchery 1986-87. California Department of Fish and Game. Sacramento, CA.

__________ 1990. Annual Report Warm Springs salmon and steelhead hatchery 1987-88. California Department of Fish and Game. Sacramento, CA.

__________ 1990. Annual Report Warm Springs salmon and steelhead hatchery 1988-89. California Department of Fish and Game. Sacramento, CA.

__________ 1991. Annual Report Warm Springs salmon and steelhead hatchery 1989-90. California Department of Fish and Game. Sacramento, CA.

Hartman, G.F. 1965. The role of behavior in the ecology and interaction of underyearling coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada 22:1035-1081.

Higgins, P., S. Dobush, and D. Fuller. 1992. Factors in northern California threatening stocks with extinction. Humboldt Chapter of the American Fisheries Society. Arcata, CA.

Hillborn, R. 1992. Hatcheries and the future of salmon in the Northwest. Fisheries 17:(1)5-8.

Hollowed, A.B. and W.S. Wooster. 1991. Year class variability of marine fishes and winter ocean conditions in the northeast Pacific Ocean. ICES Variability Symposium. Paper Number 33, Session 3.

Holman, G. 1968. Russian River fisheries sampling. Internal memorandum. California Department of Fish and Game. Sacramento, CA.

Hopkirk, J.D. and P.T. Northen. 1980. Technical report on fisheries of the Russian River. Prepared for the Sonoma County Planning Department, Santa Rosa, CA.

Jones, W. 1993. Fishery resources of the upper Russian River drainage, Mendocino County: A general overview of the fishery resources; current and historical. California Department of Fish and Game. Yountville, CA.

Kaatari, S., P. Turaga, and G. Wiens. 1989. Development of a vaccine for bacterial kidney disease in salmon. Final Report. U.S. Department of Energy. Bonneville Power Administration. Portland, OR.

Kubicek, P. 1977. Summer water temperature conditions in the Eel River system, with reference to trout and salmon. M.S. Thesis. Humboldt State University. Arcata, CA.

Lassen, R.W. 1969. The Russian River Drainage- a summary report on the fish and wildlife resources and their problems. California Department of Fish and Game. Sacramento, CA.

Laufle, J.C., G.B. Pauley, and M.F. Shepard. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)--coho salmon. U.S. Fish and Wildlife Service Biological Report 82(11.48). U.S. Army Corps of Engineers, TR EL-82-4.

Leitritz, E. 1970. A history of California's fish hatcheries. Fish Bulletin 150. California Department of Fish and Game. Sacramento, CA.

Lee, D.P. and P.H. Baker. 1975. Eel - Russian Rivers Streamflow Augmentation Study: Reconnaissance Fisheries Evaluation. California Department of Fish and Game. Sacramento, CA.

Leider, S.A. 1989. Increased straying of adult steelhead trout, *Salmo gairdneri*, following the 1980 eruption of Mount St. Helens. Environmental Biology of Fishes 24(3):219-229.

Leopold, L.B., M.G. Wolman, and J.P. Miller. 1964. Fluvial Processes in Geomorphology. W.H. Freeman and Co. San Francisco, CA.

Major, R.L., J. Ito, and H. Godfrey. 1978. Distribution and origin of chinook salmon (*Oncorhynchus tshawytscha*) in offshore waters of the North Pacific Ocean. Bulletin Number 38. International North Pacific Fisheries Commission. Vancouver, B.C.

McGlashan, H.D. and H.J. Dean. 1913. Stream measurements in the Great Basin and Pacific Coast river basins. Water-Supply Paper 300. United States Geologic Survey. Washington, D.C.

McMillan, L.E., Editor. 1985. Geysers-Calistoga KGRA-ARM Program. 1982-83 Annual Report.

Meehan, W.R. 1991. Introduction and overview. American Fisheries Society Special Publication 19:1-16.

Meehan, W.R. and T.C. Bjornn. 1991. Habitat requirements of salmonids in streams. American Fisheries Society Special Publication 19:83-139.

Mendocino County. 1982. *in* Prolysts, Incorporated and Beak Consultants, Incorporated. 1984. Coyote Valley Dam fish mitigation study. Prepared for the U.S. Army Engineer District, Sacramento, CA.

Metcalf, F. Undated. Twelve months of reel fun on the Russian River. Unknown source. California Department of Fish and Game. Yountville, CA.

Morford, M.D. 1994. Proposal by Mendocino County Fish and Game Commission to the U.S. Army Corps of Engineers, Sacramento, District for Leasing of Federal Land Coyote Valley Project. Mendocino County, CA.

Moyle, P.B. 1976a. Inland Fishes of California. University of California Press. Berkeley, CA.

Moyle, P.B. 1976b. Fish introductions in California: History and impact on native fishes. Biological Conservation 9:101-118.

Murphy, G.I. 1945. Internal Correspondence. California Department of Fish and Game. Yountville, CA.

__________. 1947. Field Correspondence. California Department of Fish and Game. Yountville, CA.

Nehlsen, W., J.E. Williams, J.A. Lichatowich. 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16:(2)4-21.

Netboy, A. 1974. The Salmon: Their Fight for Survival. Houghton Mifflin Company. Boston, MA.

Nielsen, J.L., T.E. Lisle, and V. Ozaki. 1994. Thermally stratified pools and their use by steelhead in northern California streams. Transactions of the American Fisheries Society 123:613-626.

NMFS (National Marine Fisheries Service). 1996. Endangered and threatened species: Proposed endangered status for five ESUs of steelhead and proposed threatened status for five ESUs of steelhead in Washington, Oregon, Idaho, and California. August 9. Federal Register 61:155, pp 41541-41561.

Pearcy, W.G. 1992. Ocean Ecology of North Pacific Salmonids. University of Washington Press. Seattle, London.

Petrovich, A. 1970. Biota of near-shore waters off Humboldt Bay and Trinidad Head, 1960-1964, as shown by diet of Pacific salmon. M.S. Thesis. Humboldt State University. Arcata, CA.

Pintler, H.E. and W.O. Johnson. 1956. Chemical control of rough fish in the Russian River drainage, California. California Department of Fish and Game. Sacramento, CA.

Prolysts, Incorporated and Beak Consultants, Incorporated. 1984. Coyote Valley Dam fish mitigation study. Prepared for the U.S. Army Engineer District, Sacramento, CA.

Post, G. 1987. Textbook of Fish Health. TFH Publications. Neptune City, NJ.

Reeves, G.H., F.H. Everest, and J.D. Hall. 1987. Interactions between redside shiner (*Richardsonius balteatus*) and the steelhead trout (*Salmo gairdneri*) in western Oregon: The influence of water temperature. Canadian Journal of Fisheries and Aquatic Sciences 44:1603-1613.

Reeves, G.H., J.D. Hall, T.D. Roelofs, T.L. Hickman, and C.O. Baker. 1991. Rehabilitating and modifying stream habitats. American Fisheries Society Special Publication 19:519-558.

Reimers, P.E. 1973. The length of residence of juvenile fall chinook salmon in Sixes River, Oregon. Research Reports of the Fish Commission of Oregon 4(2).

Reynolds, F. 1991. Russian River salmon and steelhead trout restoration plan. California Department of Fish and Game. Sacramento, CA.

Rich, A.A. 1991. Pieta Creek Basin Stream Assessment. Prepared for Mendocino County Resource Conservation District. Ukiah, CA.

Ricker, W.E. 1972. Hereditary and environmental factors affecting certain salmonid populations. Pages 19-160 *in* R.C. Simon and P.A. Larkin, eds. The stock concept in Pacific salmon. University of British Columbia, Vancouver.

Robbins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1991. Common and Scientific Names of Fishes from the United States and Canada. Fifth Edition. Special Publication 20. American Fisheries Society. Bethesda, MD.

Shapovalov, L. 1944. Preliminary report on the fisheries of the Russian River system, California. California Department of Fish and Game. Sacramento, CA.

__________. 1946. Internal Correspondence. California Department of Fish and Game. Yountville, CA.

__________. 1947. Field Correspondence. California Department of Fish and Game. Yountville, CA.

__________. 1955. Internal Correspondence. California Department of Fish and Game. Yountville, CA.

Shapovalov, L. and A.C. Taft. 1954. The life histories of the steelhead rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*) with special reference to Waddell Creek, California, and recommendations regarding their management. Fish Bulletin 98. California Department of Fish and Game. Sacramento, CA.

Slatick, E., L.G. Gilbreath, and J.R. Harmon. 1982. Imprinting steelhead for homing. Pages 247-264 in E.L. Brannon and E.O. Salo, eds. Proceedings of Salmon and Trout Migratory Behavior Symposium. Seattle, WA.

Smith, E.M., B.A. Miller, J.D. Rodgers, M.A. Buckman. 1985. Outplanting anadromous salmonids: A literature survey. U.S. Department of Energy Bonneville Power Administration. Portland, OR.

Smith, J. 1994. Status of Steelhead in Central California.

Sonoma County. Unpublished Data. Santa Rosa, CA.

Sonoma County Water Agency. 1985. Lake Mendocino Siltation Study Results and Area Capacity Tables. Santa Rosa, CA.

__________. Unpublished Data.

Soutar, A. and J.D. Isaacs. 1969. History of fish populations inferred from fish scales in anaerobic sediments off California. California Cooperative Oceanic Fisheries Investigation Report 13:63-70.

State of California. 1883. Journal of the Senate and Assembly. California State Legislature, 25th session. Sacramento, CA.

__________. 1891. Journal of the Senate and Assembly. California State Legislature, 29th session. Sacramento, CA.

__________. 1907. Biennial Report for the years 1905-1906. State of California. Sacramento, CA.

State Water Resources Control Board. Unpublished Data. Santa Rosa, CA.

SEC (Steiner Environmental Consulting). 1994. Potter Valley Project Monitoring Program (FERC No. 77, Article 39) Effects of Operations on Upper Eel River Anadromous Salmonids, 1992-93 Progress Report. Prepared for Pacific Gas and Electric Company. San Ramon, CA.

__________. Compiled Unpublished Data.

Stickney, R.S. 1994. Use of hatchery fish in enhancement programs. Fisheries 19:6-13.

Tabata, S. 1991. Annual and interannual variability of baroclinic transports across Line P in the Northeast Pacific Ocean. Deep Sea Research 38:5221-5245.

United States Bureau of Fish and Fisheries. 1888. Fisheries of the Pacific Coast. Report of Commissioner of Fish and Fisheries for 1888. Washington, D.C.

USFWS (United States Fish and Wildlife Service). 1948. *in* Prolysts, Incorporated and Beak Consultants, Incorporated. 1984. Coyote Valley Dam fish mitigation study. Prepared for the U.S. Army Engineer District, Sacramento, CA.

__________. 1982. *in* Prolysts, Incorporated and Beak Consultants, Incorporated. 1984. Coyote Valley Dam fish mitigation study. Prepared for the U.S. Army Engineer District, Sacramento, CA.

Vogel, D.A. and K.R. Marine. 1991. Guide to upper Sacramento River chinook salmon life history. Prepared for U.S. Bureau of Reclamation, Central Valley Project.

Ward, M.B. 1993. The physical dynamics of the Subarctic Front of the North Pacific Ocean and its relation to salmon (*Oncorhynchus* spp.) production. Masters thesis. University of Washington, Seattle, WA. 109 pp.

Weitkamp, L.A., T.C. Wainwright, G.J. Bryant, G.B. Milner, D.J. Teel, R.G. Kope, and R.S. Waples. 1995. Status review of coho salmon from Washington, Oregon, and California. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-24.

Wilson, J.B. 1954. Field Correspondence. California Department of Fish and Game. Sacramento, CA.

Withler, F.C. 1982. Transplanting Pacific Salmon. Canadian Technical Report of Fisheries and Aquatic Sciences 1079.

Personal Communications

Cartwright, W. 1996. California Department of Fish and Game. Warm Springs Fish Hatchery. Healdsburg, CA.

Coey, R. 1996. California Department of Fish and Game. Inland Fisheries Division. Healdsburg, CA.

Cox, W. 1993, 1994, and 1996. California Department of Fish and Game, Region 3. Yountville, CA.

Daugherty, T. 1996. Louisiana Pacific Corporation. Calpella, CA.

Duran, D. 1996. California Department of Fish and Game. Coyote Valley Fish Facility. Ukiah, CA.

Gunter, R. 1995. California Department of Fish and Game. Warm Springs Fish Hatchery. Healdsburg, CA.

Jones, W. 1995. California Department of Fish and Game, Region 3. Yountville, CA.

King, M. 1996. Area Landowner. Ukiah, CA.

Slota, D. 1996. Mendocino County Water Agency. Ukiah, CA.

Week, L. 1995. California Department of Fish and Game. Region 3. Yountville, CA.