

**HISTORICAL REVIEW OF EEL RIVER ANADROMOUS
SALMONIDS, WITH EMPHASIS ON CHINOOK SALMON, COHO
SALMON AND STEELHEAD**

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**Ronald M. Yoshiyama and Peter B. Moyle
Center for Watershed Sciences
University of California, Davis
Davis, CA 95616**

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**Ronald M. Yoshiyama and Peter B. Moyle
Center for Watershed Sciences,
University of California, Davis, CA 95616**

EXECUTIVE SUMMARY

The Eel River basin once possessed significant populations of at least five distinct kinds of anadromous salmonids, including fall-run Chinook salmon, coho salmon, winter and summer steelhead, and coastal cutthroat trout. In addition, there were small populations of chum and pink salmon and possibly spring Chinook salmon. It is likely that an even greater number of seasonal runs or life-history variants within some species previously co-existed in the Eel River system. The historical plentitude of salmon in the Eel River motivated the establishment of a commercial salmon fishery as early as 1854, along with associated canning operations. Salmon canneries operated on the Eel River during the late-19th and early-20th centuries, producing a peak output of 15,000 cases of canned salmon during 1883. The cannery data can be roughly translated into minimal population estimates which average about 93,000 fish per year during the period 1857-1921 and evidently approached 600,000 fish in the peak year 1877, mostly Chinook salmon. Given that the cannery records result in a very conservative estimate of Chinook numbers, the records suggest that historic runs of Chinook salmon probably ranged between 100,000 and 800,000 fish per year, declining to roughly 50,000-100,000 fish per year in the first half of the 20th century.

Probably the most realistic points of reference for past population levels of Eel River salmonids are the abundance estimates reported during the mid-1960s in the California Fish and Wildlife Plan and updated through the 1970s. While the salmonid populations at that time had already experienced more than a half-century of commercial harvest and decades of increasingly disruptive habitat alteration, their numbers still were at fairly high levels—e.g., tens of thousands of spawners in the South Fork Eel River alone. In the 1960s Chinook salmon were estimated to have averaged 56,000 spawners annually in the entire Eel River basin and coho salmon averaged 14,000 spawners annually. Steelhead numbers during the early-1960s were estimated to have been 82,000 spawners for the entire Eel River system. Counts of up-migrating (adult) steelhead at the Van Arsdale Fish Facility in the upper mainstem Eel River during the period 1967-1977 ranged from 2 fish (1976) to 1,863 fish (1970), averaging about 725 fish annually.

After the great floods of 1955 and 1964, annual Chinook salmon runs were generally considerably less than 10,000 fish. The most recent numbers suggest that less than 1,000 wild adults per year have returned to the Eel River basin in recent years. The listing of the California coast Chinook salmon ESU as a threatened species by NMFS indicates that the decline is continuing

For coho salmon, historic numbers of spawning adults were probably in the 50,000-100,000 fish per year range. There still may have been runs of 20,000-40,000 fish in the first half of the 20th century, based on angler reports. By the 1960s, the number of spawners was likely less than 15,000 fish, with numbers dropping by about 5-10% of spawners per year in subsequent years. Coho salmon thus appeared headed for extirpation from the Eel River basin by 2025 if not sooner.

Both winter and summer steelhead have also undergone severe declines in the basin. Based on habitat availability and the few population estimates that exist, historic numbers were likely 100,000-150,000 adults per year (both runs combined), declining to 10,000-15,000 by the 1960s. Present numbers are probably considerably less than 1,000 fish in both runs.

The causes of the Eel River salmonid declines are multiple. The Eel River system has undergone profound changes—in physical and biological aspects--over the century and a half since the start of Euro-American settlement in the region. In the 19th century, the primary cause was probably over harvest of fish migrating up the river but degradation of the landscape from logging

and grazing undoubtedly was also degrading spawning and rearing habitat in the river. Logging debris caused stream blockages that impeded or prevented the movements of salmonids. Denuded watersheds resulted in abnormal levels of erosion and sedimentation that filled in pools, reduced spawning areas, smothered benthic stream organisms that served as salmonid food, and hastened the closing of stream mouths during low-water periods. The denuded areas also promoted quick runoff of storm water, thus causing floods during the wet season and abnormally low water levels during the dry season. This degradation intensified again with post-WW II logging and was greatly exacerbated by the great floods of 1955 and 1964, which acted on a naturally fragile landscape.

At the same time dams provided complete (Scott Dam) or partial (Cape Horn) barriers to migration, as did reduced flows from the Potter Valley Project diversions. However, accurate quantification of the degree of salmonid population limitation due to the dams and associated features remains elusive even to the present time. An additional major blow came from the introduction of Sacramento pikeminnow around 1980, a salmon predator whose population exploded through the watershed, becoming extremely abundant in the main stems of the Eel and all its forks. Pikeminnow predation and competition has increased the difficulty of detecting recovery of salmon and steelhead populations that should be occurring as the watershed recovers, albeit slowly, from the effects of the great floods. All of these factors had incrementally negative effects on the salmonids and most factors had synergistic (i.e., compounded) interactions with the other factors; e.g., logging effects created good habitat for pikeminnow. However, the lack of study and complexity of change make it difficult to understand the relative importance of each factor.

The distribution of salmon and steelhead in the Eel River basin has not changed as much as their abundance, although many populations are now missing. Remnant populations, especially of winter steelhead, remain in much of the historic habitat.

We conclude that coho salmon, Chinook salmon, and steelhead are all on a trajectory towards extinction in the Eel River basin, with only winter steelhead being widely enough distributed and abundant enough to persist beyond the next 50 years. Historically, it is likely that in wet periods with good ocean conditions, the Eel River support runs of well over a million salmon and steelhead (800,000 Chinook, 100,000 coho, and 150,000 steelhead), with about half that number being present in less favorable years. At present, the numbers seem to be, on average, about 3,500 fish total (+/-1,000) per year (1,000 Chinook, 500 coho, and 2,000 steelhead). These numbers are very approximate, but they are the best that can be supported by existing information. Regardless, they represent a 99% decline in numbers.

Considering the historic importance of the Eel River in supporting both commercial and sport fisheries for salmon and steelhead, it is astonishing both that we know so little about what is going on in the watershed or why salmon and steelhead are headed towards extinction. The Eel River system has been largely ignored in terms of fisheries management during recent decades; there have been no significant management activities since the late-1930s to 1940s. This lack of attention for the Eel River appears to have been largely due to its relatively isolated location, the lack of any urban centers in the basin, and the rapidity and completeness of loss of fish resources. This state of affairs is entirely due to human actions.

Accomplishing even a partial recovery will be extraordinarily difficult and require the focused energy of many people and organizations, as well as a genuine commitment of governmental agencies to a major restoration program. The Eel River is considered "lost" by many; finding it again, however, could produce many ecological and economic rewards.

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I. INTRODUCTION

The Eel River is the third largest river basin in California and once supported some of the largest runs of salmon and steelhead along the North Coast. Despite this, the historical distribution and abundance of its anadromous salmonids is poorly understood, an artifact of its remoteness and huge loss of habitat and fisheries first from fisheries, and then the great floods of 1955 and 1964. This report is an effort to provide the historical background needed to create a fuller understanding of the biological diversity and former abundance of anadromous fishes in the Eel River basin. Of particular interest are the major salmonids such as Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*) and steelhead (*O. mykiss*) that have played prominent roles in the economic and cultural history of humans in the region and that also once served important biological functions in the riverine ecosystem. The significance of the Eel River system for anadromous fishes was noted by the California Department of Fish and Game (CDFG 1972: p.33):

“The Eel River is one of California’s most important anadromous fish streams, ranking second in silver [coho] salmon and steelhead trout production and third in king [Chinook] salmon production.”

There are several major themes in the conjoined history of salmonids (and other anadromous fishes) and humans in the Eel River system. First, there is the largely unknown story (or stories) of the relationship between Native Californian peoples and the fish in the various parts of the Eel River basin. That story no doubt had great richness but now presents the deepest mystery because of the loss of most traditional cultural information from the native tribes as the result of their extirpation by Euro-American immigrants and their diseases, as settlement of the region intensified. Then came the heavy, uncontrolled exploitation of resources of the basin, especially the forests and the salmon, during the late 19th century. Closely related to commercial harvesting were the supplementation activities conducted by federal and state agencies in conjunction with hatcheries and fish-planting operations centered in the California Central Valley region, particularly the northern Sacramento River basin. Then, during the first half of the 20th century, the recreational fisheries developed--most prominently represented by steelhead trout fishing that laid claim to size-records during a brief period of time. At the same time, dams were built, most prominently the Potter Valley Project, but the remoteness of the watershed prevented other development. After World War II, the watershed was devastated by logging and other human activities and the fish populations collapsed.

These major historical themes can be viewed as distinct yet interrelated chapters of the Eel River story. We have separated them to facilitate our study and discussion of the Eel River anadromous fishes. Such topical categories are convenient for discourse, but in reality the history of the Eel River and its fisheries constitutes one seamless and ongoing panorama with multiple, interacting facets. However, the common theme in the recent history of salmon and steelhead in the Eel River has been continuous decline. As we will show here, the decline was rapid, in large part because of human abuse of the fragile landscape through which the Eel River flows, but also poorly recorded. The Eel has been called part of the “Lost Coast” of California because its remoteness and absence of urban centers, making it easy to ignore. As filmmaker Justin Coupe says in the introductory remarks to his documentary film *Rivers of a Lost Coast* (Skinnyfist Productions 2009, produced with Palmer Taylor, p. 38):

“So here we stand... 100 years after John Benn, William Carson, and other Eel River pioneers first began casting flies to the sea-going trout they were calling steelhead. 90 years after San Francisco anglers spent two days traveling through damp and dangerous redwood forests for a chance to hook a tackle-busting Eel River King. 80 years since the Eel was noted in national sporting magazines as one of the finest angling streams in the country. 75 years since the Eel captured 1st through 5th place in the annual Field and Stream Big Fish Contest, earning the title “River of Giants.” 70 years since Sam Wells and Jim Pray’s fly shops were graced by steelhead-seeking ex-presidents and

congressmen. 65 years since returning WWII servicemen rushed to the river to experience one of the greatest seasons the Eel would ever produce. Less than 55 years since Bill Schaadt flipped his car on an Eel River gravel bar in his mad pursuit to get down to the giant schools of fish. And only 50 years since Nelson Rossig hooked three King Salmon on five consecutive mornings, all within the short hour he had to fish before leaving for work. So now we stand, at the dawn of a new era where all species of salmon, steelhead, and cutthroat trout of the Eel River are listed as either threatened or endangered. Where the steelhead and salmon returns are so dismal, no angler is allowed to keep a single fish. Where, when the river's flows are low enough, the Eel is closed to all fishing, including catch and release."

The great productivity of the Eel River system was noted by many early observers, for example:

"... Eel River, like the headwaters of the Sacramento, has no predatory fish except the trout to devour the salmon fry. The water of the river from the mouth of Price Creek to the ocean flows through deep pools, with very little current. The salmon fry find perfect conditions in this stretch of water, and enter the ocean with very little loss and in fine condition." (Shebley 1922: p.76)

"It takes less fry to stock Eel River and maintain the run of salmon than any other river on the coast, as there are few natural enemies of the young of the salmon to be found in the river. There are no predatory fishes, no diverting canals to carry off the water where fry are lost, or overflow basins, and very few water snakes or other natural enemies. If only a few million eggs can be collected and the resulting fry planted each season, the run of salmon in Eel River can be easily maintained, provided the fishing at the mouth of the river is regulated as well as the ocean fishing, where large numbers of salmon are taken each season." (Shebley 1922: p.80)

The Eel River system is considered by the CDFG to have historically supported four native anadromous salmonid species (viz., Chinook and coho salmon, steelhead-rainbow trout and coastal cutthroat trout), two native sturgeon species (green and white sturgeons), three native lampreys (Pacific, river, and Pacific brook lampreys), the native and somewhat anadromous eulachon (a smelt species), and the introduced American shad (CDFG 1997, Appendix D). The early historical populations of Chinook and coho salmon were very large compared with later time periods, and this was probably the case for steelhead trout to a lesser degree. The Pacific lamprey population(s) also was (were) of substantial size, but the two sturgeon species probably occurred in relatively low numbers.

With regard to the sturgeon species, the CDFG (1997: p.2) noted that:

"Populations of both white and green sturgeon, which are important remnant stocks, also occur in this [mainstem Eel River] basin. In both 1995 and 1996, sturgeon were observed during [C]DFG field census dives in this reach."

Green sturgeon evidently were fairly abundant in an earlier period, as noted by a CDFG report (CDFG 1972: p.4):

"At one time green sturgeon supported an important sport fishery in the Eel River, occurring upstream as far as Rio Dell. In recent years, however, only an occasional green sturgeon is seen in the river and little if any fishing takes place for them."

Furthermore, CDFG (1972, their Table 1) denoted green sturgeon as "common" but stated that "The number of green sturgeon in the Eel River is unknown; however, they are not as abundant as [American] shad." The CDFG report also listed the introduced American shad as being "common" and estimated "that from 5,000 to 10,000 American shad annually enter the Eel River" (CDFG 1972: p.36). Coastal cutthroat trout were considered to be "uncommon," while

Chinook and silver (coho) salmon and “steelhead rainbow trout” were considered to be “abundant” at that time. At the same time, CDFG regarded Pacific lamprey as being “abundant” and the river lamprey as “uncommon” in the Eel River (CDFG 1972, their Table 1). Although these anadromous non-salmonids (especially Pacific lamprey) were likely historically numerous and formerly culturally important to Native Californian people, we have very limited information on them and therefore do not consider them further in the present report.

In this report, we first describe the Eel River watershed and its fishes, with a brief overview of its history. Next, we discuss the factors affecting salmon and steelhead abundance, the trends in abundance, and trends in their distribution in the watershed. We then draw conclusions on the future of the fish from the scattered information and make management recommendations.

II. METHODS

General Methods

Our first step in preparing this report was assembling information from as many sources as possible, starting with the collection of reports and other documents from the library of the junior author, mainly assembled during the 1980s when he led a project surveying the fishes of the watershed. The next step was to search data bases and contact outside sources, including looking through the files of California Department of Fish and Game in Eureka.

In preparing this report we quoted extensively from the reviewed documents. We generally retained the original spelling, punctuation and terminology within quoted passages to maintain accuracy, except for a few egregious cases. Where minor changes were made, we enclosed the changes in square brackets [].

Information Sources

Our project relies on information derived from several main types of sources: (1) reports by public agencies and private-sector consultants that collectively give general overviews of the Eel River watershed, status assessments of salmonid species, and environmental assessments of certain human-related impacts; (2) federal and state fish agency reports and bulletins that provide summaries of fisheries activities; (3) scientific literature, and (4) general literature on the watershed and its people. These diverse sources supply historical information with varying degrees of accuracy and all must be viewed with appropriate circumspection to ensure historical veracity. Yet, they all contribute in some manner to the larger historical picture that is the story of the Eel River fisheries.

Public Agency and Consultant Reports

This body of information forms the core of our knowledge about the Eel River anadromous fisheries. The amount of information encompassed in reports by public agencies and private consulting firms is large and collectively spans decades of studies. Some recent reports are comprehensive and very informative, at least in terms of indicating broad population trends and status of specific salmonid species over the past half-century, but they are all hampered by highly incomplete time-series of population data, especially for the most recent decades. Many of the reports are based on earlier sources and served as launching points from which to further explore the primary (original) historical documents. However, many of these documents were not readily available so the reports themselves provided the best understanding of the past and present states of the Eel River system.

We realize that there may be some question about our heavy reliance at times on reports written by consultants writing on behalf of the Pacific Gas and Electric Company, because of their potential bias in favor of water projects. However, we found these reports to generally reflect a high level of scholarship and objectivity. Especially useful was the report by Steiner

Environmental Consulting (SEC 1998), which accurately summarized much of the early literature. Where we disagree with conclusions, we say so.

Federal and State Fish Commission Serial Reports

The serial reports of the U.S. Fish Commission (annual) and California State Fish Commission (biennial) provide the earliest regular documentation on fisheries management activities by public agencies in California and the western United States. Those reports provide unparalleled information on historical fisheries for certain rivers—viz., the McCloud and Upper (Little) Sacramento rivers, Battle and Mill creeks in the Sacramento River system. In contrast, the coverage of California coastal fisheries activities is much more limited although certain activities are periodically mentioned—e.g., salmon and steelhead egg-collections for hatcheries. We anticipated that the amount of information from these government serial reports would be small, judging from our past reviews. Nonetheless, information such as the egg-collections from specific coastal localities—including the Eel River system—are official documents that show when and where certain salmonid species were present in abundance.

Scientific Literature

The peer-reviewed scientific literature on the Eel River is not abundant, a reflection in part of the difficulty of getting into the watershed from public universities and research institutions (although there is a valuable collection of unpublished Master's theses at Humboldt State University) and the general lack of interest in the basin compared to the Klamath and Sacramento-San Joaquin river systems. Most of the peer-reviewed literature is fairly recent and includes publications by (1) the junior author of this report (e.g., Brown et al. 1994, Brown and Moyle 1997; Moyle et al. 2008), (2) scientists at the USFS Redwood Sciences Laboratory and Humboldt State University (e.g., Lisle 1982; White and Harvey 2001, 2003; Reese and Harvey 2002; Harvey et al. 2004) and (3) scientists working at the University of California's Angelo Coast Range Reserve (on the South Fork Eel River), especially the team led by Mary E. Power of UC Berkeley (e.g., Folt et al. 1998, Power 2001, Finley et al. 2002, Power and Dietrich 2002, Power et al. 2008). It is ironic that some of the most globally significant work in basic stream ecology has taken place on the Eel River, while little effort has been made to apply this science to managing the overall watershed.

The part of the peer-reviewed literature we have not used much are academic studies on California Native American groups ("tribes") that inhabited various parts of the Eel River watershed and neighboring areas in some cases. These papers and reports, although few, provide the core of what we know about the relationships of Native Californian people to salmonids and other fishes. They probably are the most reliable sources that extend back in time for a century or so.

General Literature

This body of literature comes from sources such as historical and environmental books, personal-family journals, and collections of magazine or newspaper articles. It provides information that varies widely in accuracy and reliability but it nonetheless comprises an essential foundation on which to base our understanding of the ecological and historical significance of the Eel River anadromous fishes. In certain respects, these documents encompass some of the most interesting and entertaining materials even when they are of questionable historical accuracy. Such writings convey the perceptions of their authors and, thereby, reflect the environmental and social conditions of those earlier times that may help us interpret and better understand other data that are available from contemporary sources.

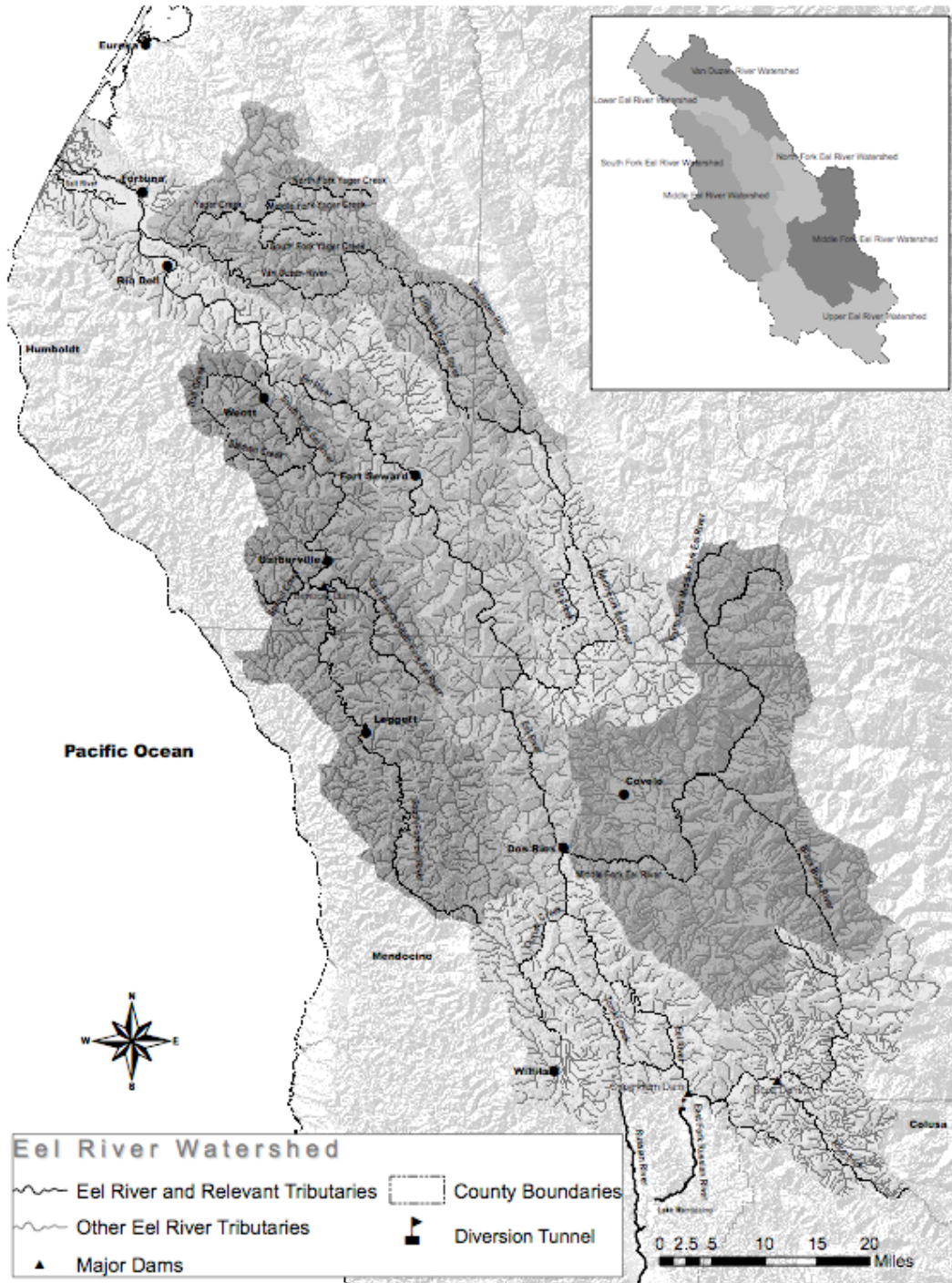


Figure 1. Map of the Eel River basin. Locations of the three major dams are indicated: Benbow Dam on the South Fork Eel River and Cape Horn Dam and Scott Dam on the upper mainstem Eel River.

III. THE EEL RIVER AND ITS FISHES: OVERVIEW

The Eel River system is the third largest river system in California, comprising a total watershed area of 3,684 square miles and four major subbasins—viz., the Van Duzen River and North, Middle and South Forks Eel River—in addition to the mainstem Eel River which extends approximately 100 miles from its headwaters near Bald Mountain (Mendocino County, maximum elevation about 600 m) downriver to its ocean terminus at the southern edge of Humboldt Bay (Kubicek 1977, SEC 1998) (Figure 1). The average annual runoff from precipitation in the entire Eel River watershed during the period 1951-1993 was 6.5 million acre feet (SEC 1998, citing EarthInfo 1994). As a reflection of the Mediterranean climate of the region, almost all precipitation falls as rain in winter, resulting in rapid rise and fall of the hydrograph following storms. There is virtually no rain in summer, so low flows occur May through October.

The climate was described by Kubicek (1977: p.9) as follows:

“The climate of the Eel River system has been described as Mediterranean with subregional variations (California Department of Water Resources 1966). The watershed can be divided into three general climate zones. A Mediterranean cool summer with fog extends from the mouth of the Eel River in a band southward along the western edge of the watershed. This zone, known as the “fog belt”, contains the lower portions of the Eel and Van Duzen Rivers and much of the South Fork Eel River. Winters are mild and wet. Summers are cool and foggy. Fogs reduce incoming solar radiation and increase precipitation efficiency.”

“A Mediterranean cool summer without fog is found directly east of the “fog belt” and covers most of the Eel River system. Due to the changing topography and increased distance from the coast, wider temperature ranges occur in this zone. Most of this area receives some snow, which accumulates only at the higher elevations in the eastern part of the watershed. Summers are usually hot and dry.”

“A Mediterranean warm summer occurs in an oval-shaped area encompassing the Eel River from Island Mountain to Fort Seward and in a circular area containing Covelo and the lower portion of the Middle Fork Eel River. This climate zone is similar to that found over most of the Sacramento and San Joaquin Valleys, but with a greater amount of winter precipitation. Summers are hot and dry.”

The Environment—Geology and Vegetation

Eel River is underlain by the Franciscan terrane that dominates most of California's North Coast. This geologically active, complex terrane produces a subsurface of steep, rapidly-uplifted mountains with layers of fragile rock. This subsurface and the thin soil that covers it, are highly erodible, especially once stabilizing vegetation is removed. According to Kubicek (1977: p.6-10).

“The topography of the system is characterized by long, rugged, steep-sided canyons. The Eel River and its major tributaries are of steep gradient only in their extreme headwaters and are of moderate gradient throughout most of their lengths. Smaller tributaries are of steeper gradient, and many follow short, tortuous routes to the main streams. Flood plains begin to appear in the middle and lower portions of major tributaries of the system and progressively widen on the main stem to extensive gravel bars as the river approaches the coast.”

Sloan et al. (2001: p.33) note:

“The combined effects of high seasonal rainfall, easily eroded bedrock, and high relief make this area one of the most rapidly eroding landscapes in the United States... Excluding rivers with

glacial or active volcanic sources, the Eel River has the greatest mean annual suspended load_23 million tons_21 million metric tonnes.per year.of any basin its size in the U.S....The Eel River basin lies in the tectonically active region of the Mendocino Triple Junction. Uplift, which began in the late Miocene and continues to the present, has generated northwest-trending folds and faults. Dated stream terraces document uplift rates of about 4 m per 1000 years at Scotia Bluffs... This high rate of uplift affects the rate of incision and the formation of terraces along the Eel River.”

Historically, the vegetation at the upper elevations was pine forest, with oak woodlands and hilly savannah at lower elevations. The lower mainstem and the South Fork Eel, however, are located mostly in the coastal fog belt, where the forest was dominated by dense forests coastal redwood, *Sequoia sempervirens*, and other large trees. The mouth of the river ended in a large multi-channeled wetland and estuary, presumably covered with a mixture of marsh plants and forests. Kubicek (1977) summarized the vegetation as follows:

“The distribution of vegetative types in the Eel River system forms four roughly defined and discontinuous belts running in a northwest-southeast direction (California Department of Water Resources 1966). Along the western side of the watershed coinciding with the “fog belt” region, grow forests of coast redwoods, *Sequoia sempervirens*. The redwoods are concentrated in a large area surrounding the lower reaches of the Eel and Van Duzen Rivers and occupy most of the western drainage of the South Fork Eel River.”

“The forest belt directly east of the redwoods, extending from Kneeland south through Willits, is predominantly Douglas fir, *Pseudotsuga taxifolia*, but includes grasslands and scattered stands of pines, *Pinus* spp.”

“The third belt of vegetation is generally a woodland-grassland vegetative group. It is less readily defined but includes a variety of hardwoods, mixed conifers, and chaparral in the central and southern parts of the watershed.”

“The fourth vegetative belt consists of pines and Douglas fir. This forest type covers the higher elevations of the eastern and southern parts of the watershed, extending over the headwaters of all the eastern drainage.”

Human History

The inhabitants of the Eel River basin and adjacent areas at the time the Euro-Americans arrived were various groups such as the Wiyot, Sinkyone, Lassik, Nongatl, Yuki and Wailaki peoples (Heizer 1978). Collectively, those groups utilized a variety of anadromous fishes—largely salmon but also steelhead, sturgeon and lamprey (Kroeber and Barrett 1962, Heizer 1978). While the native peoples exploited the fishes and other resources and probably used fire to manage the landscape (Lightfoot and Parrish 2009), their cumulative impact on the landscape was comparatively small. Starting in the 19th century, the Eel River basin had a long history of abusive land use by Euro-Americans which devastated the watershed and its fishes. The first wave of logging took place in the 19th century, when easily-accessible groves of large trees were mowed down, often with stream beds serving as conduits or roadways for moving the logs to mills or railroads. Most of the low, flat areas were converted to farms and pasture, while the upland areas that had been logged were left to regenerate on their own and often heavily grazed as well by cattle and sheep. The effects of this landscape change on the salmon and steelhead is not known, in part because any effects would have been masked by large in-river fisheries. These fisheries supported canneries at the mouth of the Eel for a few years, when as many as 600,000 salmon may have been taken in a single year. The depletion of the fish is reflected in the closure of the canneries in 1912 and banning of commercial salmon fishing in the Eel River in 1926 (State of the Eel 1995, citing Brown and Haley 1974).

The partial recovery of the watershed from logging and fisheries was reflected in the fame that the Eel River attained in the early 20th century as one of the best angling streams for salmon and steelhead in the USA (Coupe and Taylor 2009). However, in 1908, Cape Horn Dam was built on the mainstem Eel, along with a tunnel to allow water to be diverted into the Russian River. Scott Dam was built upstream in 1922, creating Pillsbury Reservoir to store water in order to make the diversion continuous year around, along with hydropower production. Today the entire project (Potter Valley Project) is operated by the Pacific Gas & Electric Company (PG&E) and includes the mainstem Eel River from Scott Dam [at river kilometer 271 (river mile 168) and elevation 1,818 feet] downstream to Van Arsdale Reservoir [river kilometer 252 (rm 157), elevation 1,443 feet] (Steiner Environmental Consultants (SEC) 1998).

Following WWII, mechanized logging came to the watershed, making virtually every tree accessible. Given the near-absence of regulations to protect the fragile landscape, large swaths were clear-cut and subject to highly-erodible road construction on steep hillsides. This set up the watershed for massive erosion as the result of record rainfall and floods in 1955 and 1964 (Sloan et al. 2001). The erosion resulted in 10-20 m of sediment being deposited in the main river channels, filling in most deep pools (Lisle 1982). River channels became wide and shallow, with little riparian vegetation for stabilization or shade. Following the massive 1964 flood, populations of anadromous fish did not recover, a recovery made even more difficult by the illegal introduction and explosive population expansion of the predatory Sacramento pikeminnow in 1979 (Brown and Moyle 1997).

The first major protection for the Eel River came in 1971, when the plan of the Army Corps of Engineers to build Dos Rios Dam on the Middle Fork Eel was abandoned (Hundley 2001). The dam would have flooded Round Valley (including Native American lands) and sent the water into the Central Valley. In 1972, protection of the Eel River and its forks from new dams was more or less assured by declaring much of it to be a state Wild and Scenic River, a status adopted by the federal government in 1981. Headwaters of the Eel River were protected by designation by Congress of the Yolla Bolly Eel River Wilderness area in 1964, the North Fork Wilderness in 1984, and the South Fork Eel Wilderness in 2006 (<http://www.fs.fed.us/r5/mendocino/recreation/>). In addition various stands of redwood forest were protected in state and national parks, as well as in preserves.

Today, land use in the watershed is a mixture of private and public, including Mendocino and Six Rivers National Forests and wilderness areas. The predominant use is grazing and logging, with patches set aside for recreation, agriculture, and other uses. Although the remaining 'old growth' redwood forest is protected in state and national parks and reserves, most of the historic forest has been removed and is now either in its second or third round of growth for harvest or the land has been converted to pasture and other uses (e.g., diked farmland on Eel River estuary).

The Fishes

There are 27 kinds of fishes recorded from the Eel River watershed in recent years, 10 of them alien species (Table 1). Historically, the Eel River was remarkable for its complete dominance by anadromous fishes; only one 'true' freshwater species was present, the Humboldt (Sacramento) sucker (Moyle 2002). Today, all of the 11 species of completely anadromous fishes are either extirpated from the basin, very rare, or in serious decline. All of the anadromous salmon and steelhead stocks are either listed as threatened species or qualify for listing (Moyle et al. 2008). Most abundant of those salmonid stocks were: fall-run (and possibly spring-run) Chinook salmon, coho salmon, winter and summer steelhead, and coastal cutthroat trout. In addition, small runs of chum (*O. keta*) and pink salmon (*O. gorbuscha*) evidently occurred in the Eel River at least occasionally (Berg Associates 2002, citing NMFS 2000, Moyle et al. 2008). In this section, however, we focus only on the "major" anadromous salmonids Chinook salmon, coho salmon, and steelhead.

Table 1. Fish fauna of the Eel River. Abbreviations for status are: A = abundant, C = common, D = declining, R =rare, T = listed as a threatened species under the ESA; for life history: Anad = anadromous, Res = resident. See Brown and Moyle (1997) for additional records.

Species	Status	Life history	Notes
Native species			
Pacific lamprey, <i>Entosphenus tridentatus</i>	D	Anad	Namesake of Eel River
River lamprey, <i>Lampetra ayresi</i>	R	Anad	
Pacific brook lamprey, <i>L. richardsoni</i>	R	Res	
Green sturgeon, <i>Acipenser medirostris</i>	R	Anad	Few recent records
Sacramento sucker, <i>Catostomus occidentalis</i>	C	Res	
Eulachon, <i>Thaleichthys pacificus</i>	R	Anad	Probably extinct from Eel River
Southern Oregon Northern California coho salmon, <i>Oncorhynchus kisutch</i>	T	Anad	Distinct Population Segment (DPS)
California coast Chinook salmon, <i>O. tshawytscha</i>	T	Anad	Evolutionarily Significant Unit
Pink salmon, <i>O. gorbuscha</i>	R	Anad	Probably extinct from Eel River
Chum salmon, <i>O. keta</i>	R	Anad	
Resident rainbow trout, <i>O. mykiss</i>	C?	Res	Interbreeds with steelhead
North California coast winter steelhead, <i>O. mykiss</i>	T	Anad	DPS
North California coast summer steelhead, <i>O. mykiss</i>	T	Anad	DPS
Coastal cutthroat trout, <i>O. clarki clarki</i>	D	Anad	
Prickly sculpin, <i>Cottus asper</i>	C	Res	Young can rear in estuary
Coast range sculpin, <i>C. aleuticus</i>	C	Res	Young rear in estuary
Threespine stickleback, <i>Gasterosteus aculeatus</i>	C	Anad/Res	
Introduced (alien) species			
American shad, <i>Alosa sapidissima</i>	D	Anad	
Threadfin shad, <i>Dorosoma cepedianum</i>	A	Res	Pillsbury Reservoir
Golden shiner, <i>Notemigonus chryssoleucus</i>	C	Res	Pillsbury Reservoir
California roach, <i>Lavinia symmetricus</i>	A	Res	
Sacramento pikeminnow, <i>Ptychocheilus grandis</i>	A	Res	
Speckled dace, <i>Rhinichthys osculus</i>	C	Res	Van Duzen River
Brown bullhead, <i>Ameiurus nebulosis</i>	C	Res	Pillsbury Reservoir
Green sunfish, <i>Lepomis cyanellus</i>	C	Res	
Bluegill, <i>L. macrochirus</i>	A	Res	Pillsbury Reservoir
Largemouth bass, <i>Micropterus salmoides</i>	A	Res	Pillsbury Reservoir

IV. MAJOR SALMONIDS: DIVERSITY, DISTRIBUTION, ABUNDANCE

GENERAL SUMMARY

Diversity

All three major salmonids have populations recognized as distinct for the north coast region. The Chinook salmon are regarded today as part of the California Coast Evolutionary Significant Unit (ESU), while the coho salmon are part of the Southern-Oregon Northern California coho salmon ESU (Moyle et al. 2008). The steelhead are part of the North Coast Distinct Population Segment (DPS, Moyle et al. 2008¹). It is likely that an even greater number of seasonal runs or life-history variants within species existed in the Eel River system but there is no available documentation. Unfortunately, our knowledge of the population-level diversity of all these salmonid species in the Eel River system is highly incomplete because all salmonid stocks were heavily exploited long before any systematic assessments were attempted or even considered.

Distribution

We have only a general idea of the distribution of the major species, with poor records of upstream limits and historic use of tributaries. Chinook salmon were apparently widely distributed in the Eel River basin—occurring in the Van Duzen River and the South, Middle and North forks as well as far up the mainstem Eel River. Coho salmon occurred in at least the Van Duzen River and South Fork Eel River, as well as in the mainstem Eel River and Outlet Creek (Brown et al. 1994). Winter steelhead (including “fall” steelhead) historically occurred in all the major subbasins. Summer steelhead historically occupied at least the Middle Fork Eel, Van Duzen, North Fork Eel River rivers (Moyle et al. 1995, 2008).

Abundance

Although formerly numerous, the three principal anadromous salmonids—fall-run Chinook salmon, coho salmon, and steelhead (comprising several seasonal runs)—experienced dramatic population reductions during the past century. The recent-historical productivity of the Eel River system was generally described by Kubicek (1977: p.1):

“The Eel River has long been considered a good producer of steelhead-rainbow trout, *Salmo gairdneri* Richardson, coho salmon, *Oncorhynchus kisutch* Walbaum, and chinook salmon, *Oncorhynchus tshawytscha* Walbaum. The records of past runs of these fish over Benbow Dam and Cape Horn Dam fish ladders, as well as other evidence, support this view. During the 36-year period from 1938 to 1973, annual spawning escapements estimated for steelhead, coho salmon, and chinook salmon in the Eel River averaged 91,000, 24,000, and 60,000 respectively (Lee and Baker 1975). In California, the Eel River ranks second in steelhead and coho salmon production and third in chinook salmon production; its sport fishery is the second largest in northwestern California (California Department of Fish and Game 1965a and 1965b).”

“During the past decades, however, there apparently have been substantial declines in the sizes of the spawning runs of steelhead and salmon in the Eel River system. The apparent declines have been attributed to poor watershed management practices such as careless logging, extensive road building, and overgrazing by livestock (California Department of Fish and Game 1968). Natural occurrences, such as the extreme flooding that has occurred several times in the past three decades, may also have contributed to the problem.”

CDFG (1997: p.22-23) described the long-term declines and presently depressed population levels:

“At the turn of the century, the Eel River supported runs of salmon and steelhead that were estimated to exceed one-half million fish. Populations of salmon and steelhead have

¹ See Moyle et al. (2008) for an explanation of what is meant by an ESU and DPS and the subtle differences between them.

declined significantly from this early period due to human activities and habitat destruction. These adverse impacts resulted principally from land development and associated resource uses that included poor road design and construction, poor logging and grazing practices, excessive water diversions, and over-fishing. In 1964, [C]DFG estimated the annual spawning escapement in the entire Eel River system at approximately 82,000 steelhead, 23,000 coho salmon and 56,000 chinook salmon. [These numbers presumably reflect abundance between 1955 and 1964.] Major flood events in 1955 and 1964 occurred during a period of intensive land use, primarily related to timber harvest. These activities had destabilized most subbasins in the Eel River system. The floods caused watershed soils to move into streams and bury fish habitat in sediment. The most recent estimate of the average annual salmon and steelhead spawning populations in the Eel River system was made in the late 1980's and indicated that steelhead had declined to 20,000 fish, Chinook salmon to 10,000 fish and coho salmon to 1,000 fish. Although these estimates are based on limited scientific data, they are supported by anecdotal accounts, and reflect at least an 80 percent decline in salmon and steelhead populations from the early 1960's levels."

The multi-decadal declines of Chinook salmon and steelhead are exemplified by the trends in the upper mainstem Eel River. The combined data from fish ladder counts at Van Arsdale Dam (for the 1940s-1990s) and spawner surveys on Tomki Creek and the upper mainstem Eel River depicted the decline as do the Eel River escapement time-trends for Chinook salmon in the Eel River, especially compared with data on other Chinook salmon populations in northern California and southern Oregon by (SEC 1998). Those combined plots (spanning 1978/1979-1995/1996) generally showed similar patterns—i.e., low levels in the early 1980s, unusually high levels in the late-1980s, an historic low point in 1990/1991, and an apparent partial recovery of most populations between 1992/1993 and 1995/1996. Present populations have continued to be low, however.

A key report for the mid-20th century is the California Fish and Wildlife Plan, prepared by the California Department of Fish and Game (CDFG 1965c), that presented estimates of salmonid spawning escapements in California "coastal" streams—i.e., streams that flow directly into the ocean. The escapement numbers given in that report were generally not actual counts but were estimates with various degrees of accuracy.

CDFG's estimated spawning escapements of Chinook and coho salmon and steelhead for the entire Eel River system and the individual subbasins are presented in Table 2 (from CDFG 1965c) and data quality designations are given in parentheses. Those estimated spawning escapements were essentially educated guesses; data quality was designated as "C or C+" and defined as follows (from CDFG 1965):

"C = Estimates made by men who are familiar with the stream and who made comparisons with better-studied streams. C+ is used when the estimates had some data to assist them."

Table 2. Estimated salmonid spawning escapements for the Eel River System in the 1960s
(from CDFG 1965c).

	Chinook Salmon	Coho Salmon	Steelhead
Total Eel River System	55,500	14,000	82,000
Van Duzen River	2,500 (C+)	500 (C+)	10,000 (C+)
South Fork Eel River	27,000 (C+)	13,000 (C+)	34,000 (C+)
North Fork Eel River	0	0	5,000 (C)
Middle Fork Eel River	13,000 (C)	0	23,000 (C)
Mainstem Eel River	13,000 (C)	500 (C)	10,000 (C)

Taylor (1978: p.8), evidently drawing from CDFG (1965c), stated:

“Surveys of salmon spawning stocks have been conducted in the Eel River system, but they have usually covered relatively small portions of the drainage. The limited survey data available in the early 1960’s indicated that the Eel River system supported average annual runs of 56,000 king salmon and 14,000 silver salmon”

Various other reports giving population appraisals for Eel River salmonids have indicated serious declines from early historical population levels to the recent (20th century) and present numbers in at least the three major anadromous salmonids—viz., Chinook and coho salmon and steelhead—although some of those reports apparently relied on much of the same data from the earlier appraisals, especially CDFG (1965c). The total (historical) annual run-size for Chinook salmon was estimated to have been 103,000 fish, evidently for the entire Eel River basin (Berg Associates 2002, citing Humboldt County PEIR 1992).

The National Marine Fisheries Service (NMFS) Chinook Salmon Status Review (Myers et al. 1998) reported estimated spawning escapements for Eel River salmonids in the 1960s that were derived from the CFG Fish and Wildlife Plan (CDFG 1965c). The estimated escapement for the California portion of the Southern Oregon and California Coastal ESU was given as “about 88,000 fish, predominantly in the Eel River (55,500) with smaller populations in the Smith River (15,000), Redwood Creek, Mad River, Mattole River (5,000 each), Russian River (500), and several smaller streams in Del Norte and Humboldt counties” (Myers et al. 1998: p.201). Berg Associates (2002: p.107) presented almost the same information but excluded the Smith River escapement (i.e., 15,000 fish). Abundance indices based on fish counts at dams are available for certain portions of the Eel River watershed during some time periods—viz., counts of upstream migrants at Benbow Dam on the South Fork Eel River for 1938-1975 and counts at Cape Horn Dam on the upper mainstem Eel River for the 1940s up to “the present” (Myers et al. 1998: p.20). However, it was noted that the Chinook salmon data for the upper mainstem Eel River represented “a small, highly variable portion of the run” (Berg Associates 2002).

In the CDFG (1972) report to evaluate alternatives for water project development on the Middle Fork Eel River, spawning population sizes were estimated for the three major anadromous salmonids. Specifically, it was stated (CDFG 1972: p.36):

“The sizes of the anadromous fish runs in the Eel River were determined mathematically. Estimates of the runs were based on a tagging study (U.S. Fish and Wildlife Service, 1960) and on Department of Fish and Game counts of fish at Benbow Dam on the South Fork Eel River. These estimates assume that the trend for the entire river is proportional to that of the South Fork Eel. Admittedly, this may not be a valid assumption, but for purposes of advance planning for water project development and in the absence of adequate fish counting facilities, it must suffice.”

“The Eel River annually receives an average spawning run of 62,000 king [Chinook] salmon, 27,000 silver [coho] salmon, and 99,000 steelhead. These estimates do not include the river sport catch, but represent only the number of spawners.”

“The 99,000 steelhead includes about 2,000 summer-run fish which spawn in the upper Middle Fork Eel River and several hundred that spawn in the Van Duzen River. Summer-run steelhead are uncommon in California and, consequently, are considered quite valuable. In addition, they require special conditions during their adult residence in freshwater which makes them quite vulnerable to habitat alterations.”

For more recent abundance data, Myers et al. (1998: p.202) stated: “No total escapement estimates are available for the California portion of this ESU [i.e., Southern Oregon and California Coastal Chinook salmon Evolutionarily Significant Unit], although partial counts indicate that escapement in the Eel River exceeds 4,000.” Other recent population assessments of the anadromous salmonids reiterate the serious declines during the past decades. Berg Associates (2002:108, citing CDFG 1996) summarized the situation as follows.

“Salmon and steelhead resources have declined steadily in the mainstem since the early 1900’s, but have undergone drastic declines since 1988 in the upper reach (CDFG 1996). Fish counts conducted by CDFG and Pacific Gas and Electric biologists suggest that chinook salmon may be in danger of extirpation from the upper mainstem. Steelhead numbers were also alarmingly low. The drought of 1986-1992 and proliferation of non-native pikeminnow may have influenced the decline (CDFG 1996). Increased sediment yields into tributaries and mainstem reaches are a result of poor land-use practices, coupled with extreme floods of 1995 [sic] [i.e., this should be 1955] and 1964, have caused extensive damage to fish habitat and riparian vegetation (CDFG 1996). In some tributary watersheds, extensive land subdivision and associated road development continue to increase stream sedimentation, which fills pools, lowers dissolved oxygen in redds, and smothers food organisms (CDFG 1996).”

Information on summer steelhead, in relation to their holding areas in the lower Eel River, was summarized by Berg Associates (2002: p.108-109), based on recent monitoring efforts by local consultants.

“Summer steelhead have been observed consistently in the lower Eel River during surveys conducted under LOP 96-1 (Table 8). The primary holding area is the lateral scour pool along the Hansen Bar. This pool has the overhead cover, depth, and flow (at least at the head of the pool) steelhead prefer. It is possible the summer steelhead holding here are late-running Van Duzen River fish. They are unable to enter the Van Duzen due to the intermittent flow characteristics in the lower reach.”

“The first adult salmonids begin to enter the estuary in late August and September and the lower Eel River [gravel] extraction areas (Drake and lower Sandy Prairie) around mid-September (Jensen 2000; Halligan 1997, 1998). Prior to that salmon and steelhead hold in the Eel River estuary until the first rains of the season. Upon entering the extraction area, chinook and steelhead appear to hold primarily at the Sandy Prairie pool (upstream of the Boxcar Hole) while waiting for enough runoff to initiate further upstream migration. A secondary holding location is the lateral scour pool along the Hansen bar. Both of these locations have water depths ranging from 6-15 feet deep. However, entry to the Hansen pool appears to be dependent on the depth of water at the riffle at the upstream end of the Sandy Prairie bar. In some years this riffle is too shallow to allow passage except for perhaps half-pounder sized fish (Halligan, [personal communication]).”

“Migrating salmonids have also been observed holding underneath the Drake summer bridge (Halligan 1998). Three half-pounder steelhead were observed holding there even though loaded and empty trucks were crossing it every two or three minutes. Migrating salmonids have also been observed holding under summer bridges used to transport gravel over the Trinity River (Halligan pers. comm.).

Berg Associates (2002: p.109) also provided information on the year-to-year variation in the relative abundances of Chinook salmon and steelhead.

“Based on information contained in Halligan (1997, 1998) and Jensen (2000) adult migration timing appears to be slightly different from year to year, although this may be an artifact of survey intervals and runoff regimes. In 1996, very few fish entered the extraction areas until mid-October. By the end of October, 1996 over 1,500 chinook salmon and only a few steelhead were observed holding at the Boxcars. Very few fish were observed upstream of those locations. In 1997, nothing but steelhead were observed until the end of October when Chinook appeared. In 1999, Halligan observed approximately 40 times more steelhead than chinook during his fisheries surveys.”

Further information on combined abundance trends in Chinook salmon, coho salmon, and steelhead is presented in **Appendix A**. In the following sections we discuss the historic diversity, distribution and abundance of the species individually--Chinook salmon, coho salmon, and steelhead.

CHINOOK SALMON

Chinook salmon were once the most abundant and probably most genetically diverse anadromous salmonid in the Eel River basin, with large effects on the ecology of both the aquatic and riparian ecosystems.

Diversity

Chinook salmon were abundant and widely distributed in the Eel River and consequently were likely diverse genetically and ecologically as well. The National Marine Fisheries Service (NMFS 2005) suggested that there were as many as five independent populations of Chinook salmon in the Eel at one time: in the lower mainstem and upper mainstem Eel River, Middle Fork Eel River, South Fork Eel River, and Van Duzen River. It is theoretically plausible that there were even more than five independent Chinook salmon populations, as well as multiple runs, given the large area and variety of habitats in the Eel River basin because local adaptation is a common phenomenon in anadromous salmonids (Taylor 1991). This conjecture comports with recent theoretical assessments that seek to enumerate the historical salmonid population diversity in a given region. For example, Lindley et al. (2006) inferred the number of independent steelhead populations that possibly occurred in the California Central Valley based on certain environmental characteristics (mainly summer temperatures and topography of the streams), the physiological tolerances of steelhead, and some assumptions about the necessary spatial distances that defined discrete population units. They determined that as many as 81 demographically independent populations of steelhead may have simultaneously existed in the Central Valley region. Hence, it is plausible that a similar level of population differentiation existed among the Chinook and coho salmon and steelhead stocks in the Eel River system.

Although only fall-run Chinook exist in the Eel River today, it is likely that spring-run were once present as well (Myers et al. 1998: p.119-120), given the availability of summer holding habitat in the upper basin. However, there appears to be no substantive information to indicate the historical occurrence of spring-run Chinook salmon populations. Morford (1995: p.7) stated:

“Unlike other major California rivers, the Eel River did not support a population of spring run Chinook salmon. Nowhere in the records or from anecdotal information can one find reference to spring-run Chinook salmon. Visual surveys for adult summer steelhead trout in the Middle Fork Eel River have detected one or two individual salmon occasionally which might be spring-run Chinook salmon. However, they are thought to be fish that have strayed from their natal waters.”

The apparent historical uncommonness of spring-run Chinook salmon in the Eel River system is somewhat enigmatic because spring runs historically existed—and in some places presently still exist—in the Klamath River system to the north and throughout the California Central Valley system. Perhaps it was the combination of relatively limited snowmelt-driven flows in the spring and early summer (i.e., compared with the Klamath River and Central Valley systems) together with restricted access to holding and spawning habitats high in the watersheds, that accounted for their seeming absence from the Eel River.

The NMFS Status Review for Chinook salmon indicated the possible existence of spring-run Chinook in the Eel River system; i.e., (Myers et al. 1998: p.119-120):

“Chinook salmon in this ESU [Evolutionarily Significant Unit] exhibit an ocean-type life-history [i.e., similar to that of the fall run]; . . . Additionally, there was anecdotal or incomplete information on the existence of several spring-run populations, including the Chetco, Winchuck, Smith, Mad, and Eel Rivers. Allozyme data indicate that this ESU is genetically distinguishable from the Oregon Coast, Upper Klamath and Trinity River, and Central Valley ESUs.”

Interestingly, the predominant fall-run Chinook salmon of the Eel River system comprised two distinct forms—viz., the “regular” fall run that was the bulk of the populations and an unusual “late run.” Morford (1995: p.7) described the latter type as follows.

“. . . An important, yet less known, variant of the fall run chinook salmon is a group of chinook salmon which occur in the river beginning late December through February. They were especially abundant in the South Fork Eel River and may at one time have made up about 20% of the chinook salmon escapement in that system. They are larger than the fall run fish and seem to move up through the system rapidly, still retaining a bright sea-like condition far upstream. This contrasts to the more typical fall run chinook salmon which are locally known as the “black salmon” due to their relatively rapid aging process. However, like the fall run chinook salmon, the young of these late run fish do not appear to over-summer in the system. The Early European settlers called these late run fish “silversides” and they were especially prized for eating. This term was also used by Livingston Stone during the late 1800’s when he was located at the Gaston Fish Station on the Trinity River near Hoopa, California. It is believed by the author that the salmon variant Livingston Stone described as the “silverside” is not the same variant that occurs in the Eel River.”

In regard to the fall Chinook salmon as a whole, Morford (1995: p.4) noted: “Reports from the 1880’s indicate that the average weight of the Eel River salmon was 25 pounds. The author, in 1967, estimated the average weight of an adult salmon (as contrasted to a grilse or “jack” salmon) to be about 24 ½ pounds based on a sample of about 1300 fish. This consistency of weight indicates that mature Eel River Chinook salmon populations were composed predominantly of four and five year old fish. In order to reproduce successfully, habitat with sufficient depth, water velocity and suitable gravel must have been available for these fish.”

Abundance

The historical abundance of Chinook salmon in the entire Eel River system, as well as for its component subbasins, was estimated by the Steiner Environmental Consulting firm (SEC 1998). The SEC (1998) report summarized the historical cannery records using data originally compiled by Humboldt County Public Works² (1979). The cannery records of quantities of processed salmon were assumed to comprise mixtures of Chinook and coho salmon and were converted into whole-fish equivalents (SEC 1998). The resulting catch estimates averaged 93,000 fish per year for the 35 years of record (1857-1921) with a peak number of 585,000 fish processed in 1877. Those catch numbers were referred to as “escapements” by SEC (1998)—which technically would be correct if the fish were considered to have escaped only the coastal ocean fishery. This ignores the fact they were later caught, presumably largely in the estuary and lower river, and brought to the cannery. The actual total number of fish entering the river was somewhat higher, assuming at least 10-20% escaped the fishermen’s nets and were able to spawn.

² The SEC (1998) cites their source as Humboldt County Public Works (1991); however, this reference is likely an erroneous date citation.

Similarly, Berg Associates (2002:107, citing NMFS 2000) stated: “From 1853 to 1922, fish packing and cannery records documented from 15,000 to 600,000 salmonids were caught annually in commercial fisheries” on the Eel River. For the period 1877-1926, the peak output of the Eel River canneries was reported as 15,000 cases of canned salmon in 1883 (CDFG 1972, citing USDI 1960 [i.e., evidently USFWS 1960]; State of the Eel 1995, citing Brown and Haley 1974). Each case of canned Chinook salmon roughly equated to 66 pounds of whole fish (Collins 1892) or an average of four fish (Jordan and Gilbert 1887). Hence, the peak cannery production of reportedly 15,000 cases was roughly equivalent to 60,000 Chinook salmon—but that number is an order of magnitude lower than the peak number of salmon processed in 1877 (i.e., 585,000 fish) and lower than even the annual average of 93,000 fish for 1857-1921 noted above from the SEC (1998) report. Therefore, it seems that the number (15,000 cases) reported in the State of the Eel (1995) and CDFG (1972) is likely an under-estimate of the peak commercial catch. If we assume that 90% of the fish canned were Chinook salmon (favored because of size, abundance, and early entry into the rivers) and that the ocean and in-river fisheries captured 80% of the fish (probably a low estimate), then peak runs of 700,000-800,000 fish were likely, with average runs of 100,00-200,000 fish.

The U.S. Fish and Wildlife Service (USFWS) surveyed the spawning distribution of Chinook salmon during spawning seasons 1955/1956 to 1958/1959 (SEC 1998, citing COE 1980). For the entire Eel River basin, Chinook salmon escapements during those four years were estimated to have been 14,500 to 38,045 fish, averaging 24,361 fish. By extrapolating from the 1955-1959 subbasin distributions, USFWS determined that an average of 98,500 salmon (Chinook and coho salmon combined) annually spawned in the entire Eel River system during the broader period 1938-1962.

The CDFG (1997: p.23) reported:

“Populations of chinook salmon in the Eel River reflect coast-wide declines. In 1975, the last year of record, counts of chinook salmon, as well as coho salmon and steelhead, at Benbow Dam on the South Fork Eel River were approximately 20 percent of the counts from the early 1940’s (Figure 2). Counts at Cape Horn Dam on the upper Mainstem Eel River reflected drastic reductions during 1992-93 through 1994-95 spawning migrations, when less than five chinook each year were [*sic*] observed at Van Arsdale Fish Facility. More recent counts during the 1995-96 migration totaled 525 chinook, of which 55 were females. As recently as 1986-87, 1,754 chinook were counted there, and in 1987-88, 1,080 returned to the Van Arsdale Fish Facility (Grass, 1990). In contrast, the 1992-93 through 1994-95 runs observed on South Fork Eel and Van Duzen rivers and their tributaries indicated that population indices of chinook had increased slightly from recent years.”

Since the 1960s, the population sizes of Chinook salmon and other anadromous salmonids in the Eel River system are poorly known due to insufficient monitoring programs. According to the recent “Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead” (NMFS 2005), only cursory non-systematic stream surveys exist for the California Coastal Chinook salmon ESU in the Eel River basin—viz., on Sproul³ and Tomki creeks. Keeping mindful of the need for caution in interpreting such incomplete and variable data, the spawning survey data from Sproul and Tomki creeks appear to generally indicate very low numbers of fall-run Chinook salmon since 1989 until at least 2000 (NMFS 2005). Chinook salmon generally numbered at most about 100-200 fish in the Sproul Creek spawning surveys during 1995-2007, but in six of those years there were less than 100 fish (PFMC 2008). In the Tomki Creek spawning surveys there were usually fewer than 100 spawners estimated during 1995-2007, although estimates for three of the years ranged from 115 to 162 spawners (PFMC 2008).

³ Myers et al. (1998), NMFS (2005), PFMC (2008), refer to “Sprowl” Creek but the correct name is “Sproul” Creek, a tributary to the South Fork Eel River (e.g., CEMAR 2008).

Natural returns of Chinook salmon may be influenced by returns of hatchery fish. There are four hatcheries of limited scale that currently produce Chinook salmon in the Eel River basin. All those hatcheries have utilized broodstock derived either entirely from non-hatchery returning adults of local origin (Redwood Creek, Yager Creek and Hollow Tree Creek hatcheries) or from both hatchery and non-hatchery adults (Van Arsdale Fish Station) (NMFS 2005: p.143). It is uncertain to what degree hatcheries are contributing to the current population levels of naturally spawning Chinook salmon in the Eel River system due to the lack of quantitative data (NMFS 2005). If hatchery fish have strong interactions with wild fish (competition, predation), which is likely, there could be negative impacts.

The recent and current low abundance of Chinook salmon in the Eel River system reflects the generally depressed population levels of the California Coastal Chinook Salmon ESU (NMFS 2005). Although weir-counts of fall-run Chinook salmon at the Van Arsdale Fish Station (just below Cape Horn Dam) showed an increase during the late-1990s, those counts include both natural and hatchery-produced fish and the long-term influence of hatchery fish on the population's viability cannot be quantified (NMFS 2005). However, the counts of marked hatchery fish returning to Van Arsdale Fish Station since 1996 indicate that about 30% of the Chinook salmon adults have been of hatchery origin (NMFS 2005). It is also unclear whether the fish counted at Van Arsdale Fish Station are truly representative of the numbers of fall-run Chinook salmon in the entire mainstem Eel River or in other subbasins of the Eel River system.

These records indicate that historic runs of Chinook salmon probably ranged between 300,000 and 800,000 fish per year, declining to roughly 50,000-100,000 fish per year in the first half of the 20th century. After the big floods of 1955 and 1964, annual runs were generally considerably less than 10,000 fish. The listing of the Chinook salmon as a threatened species by NMFS indicates that the decline is continuing and the most recent numbers suggest that less than 1,000 wild adults have returned to the Eel River basin in recent years.

A caveat regarding the historical estimates of salmon abundance is that extensive hatchery plantings had been conducted in the early period of fisheries activities on the Eel River, starting with the Price Creek Hatchery (river mile 15) which was constructed in 1897 and operated until 1916 (see later section of this report). Other major hatchery facilities were the Fort Seward Hatchery (operating 1916-1942) and the Snow Mountain Egg Collecting Station (established 1907) that continues now as the Van Arsdale Fish Station (SEC 1998). Concomitantly, there were massive imports of Sacramento River Chinook salmon eggs into the Eel River system. The overall effects of heavy hatchery supplementation on the native Eel River salmon and steelhead populations cannot be fully determined. While returns of the hatchery fish could have been significant during the early decades (i.e., late-19th and early-20th centuries), genetic studies do not indicate introgression with Central Valley salmon, suggesting poor survival of the hatchery fish and little contribution to wild stocks (Moyle et al. 2008).

Further estimates of Chinook salmon abundance are presented in the regional (subbasin) distribution section (See Section V).

COHO SALMON

Coho salmon never approached the historical abundance of Chinook salmon in California, but coho populations had a significant presence in the larger rivers on the north coast, including the South Fork Eel River (Brown et al. 1994, CDFG 1997). They are generally associated with the cool permanent streams in the forested areas of the coastal fog belt. Information on their diversity and abundance in most northern California coastal streams essentially had not been collected until about a decade or so ago.

Diversity

The genetic diversity of coho populations, reflecting adaptations to local conditions, was not recognized until recently, by which time many of the local populations have disappeared or are likely to soon. A study by Bucklin et al. (2007, p 40) concluded:

“Our study implicates population fragmentation, genetic drift, and isolation by distance, owing to very low levels of migration, as the major evolutionary forces shaping genetic diversity within and among extant California coho populations. . . . [Our] resolution of smaller population units suggests that they are experiencing rapid genetic drift, inbreeding, and the associated deleterious effects of inbreeding depression. Accordingly management and rehabilitation of these populations is needed at much smaller scales than current ESU designations.”

Abundance

Regarding the general abundance of coho salmon in California streams, the California Fish Commission (CFG 1913: p.30) stated that:

“. . . they run abundantly in the Klamath and the Smith rivers, in Del Norte County; they are taken in considerable numbers in Eel River, in the fall; and they frequent many other of the coast streams, as far south as Monterey Bay.”

Information on northern California coho salmon was first consolidated by CDFG in connection with a petition to list northern California coho together with southern Oregon coho salmon as a threatened species. That information was represented by Weitkamp et al. (1995: p.109, citing CDFG 1994) as follows.

“Most information for the northern California region of this ESU was recently summarized by the California Department of Fish and Game (CDFG 1994). They concluded that ‘coho salmon in California, including hatchery stocks, could be less than 6 percent of their abundance during the 1940’s, and have experienced at least a 70 percent decline in numbers since the 1960’s’ (CDFG 1994, p. 5-6). They also reported that coho salmon populations have been virtually eliminated in many streams, and that adults are observed only every third year in some streams, suggesting that two of three brood cycles may already have been eliminated.”

Although coho salmon abundance in particular rivers and watersheds of northern California has been poorly recorded, the entire population constituting the northern California and southern Oregon ESU was estimated by Weitkamp et al. (1995: p.111) to have numbered “about 10,000 natural fish and 20,000 hatchery fish” during the 1980s and early-1990s. The numbers were based on regional estimates of spawner abundance given by Weitkamp et al. (1995) and Brown et al. (1994). Brown et al. (1994, their Table 4) estimated that 2,040 “native and naturalized” coho salmon occurred in the entire Eel River watershed, compared to 11,060 native and naturalized coho salmon in all other California streams north of San Francisco Bay. “Naturalized” fish are defined as the progeny of naturally spawning parents but they possess some degree of hatchery-derived ancestry. However, a study by Bucklin et al. (2007) indicates that California coho have been highly resistant to inbreeding with hatchery coho salmon of out-of-basin origin, so most local populations have maintained their genetic integrity.

It is evident that coho salmon historically numbered in the tens of thousands of adult fish in the Eel River system, judging from the annual counts conducted by the CDFG during 1933-1949 at Benbow Dam (South Fork Eel River)—e.g., counts ranging from 7,370 to 25,289 coho salmon (Murphy and Shapovalov 1951, Brown and Moyle 1994).

Brown et al. (1994: p.245) summarized the Eel River coho salmon populations as follows.

“The Eel River (Humboldt County) probably supports the largest remaining native populations in California. One estimate places the Eel River run at 40,000 annually (U.S. Heritage Conservation and Recreation Services 1980, App.); however this figure exceeds a more recent statewide estimate of 33,500 spawners (Sheehan 1991). Presently, coho salmon are known to spawn mainly in the tributaries of the South Fork Eel River. In the main-stem Eel River, coho salmon are known to have spawned in several small

tributaries of Outlet Creek as recently as the 1988-1989 season (G. Flosi, App.; W. Jones, App.). Nielsen et al. (1991, App.) conducted surveys on 69 km of Outlet Creek and on 12 of its tributaries during the 1989-1990 season but were unable to find any coho salmon. All but four tributaries had supported coho salmon in the past (Brown and Moyle 1991a, App.). The lower main-stem Eel River apparently is not used as spawning or rearing habitat to any significant degree (Murphy and DeWitt 1951, App.). In the Van Duzen River, juveniles have been captured recently in small numbers from the main river and two small tributaries, Grizzly and Cummings Creeks (Brown and Moyle 1991b, App.).”

“Tributaries of the South Fork Eel River have been recently surveyed by Nielsen et al. (1991, App.). In the 1989-1990 spawning season, less than 300 adult coho salmon were counted in the system, which probably supports, at best, 1,320 spawners . . . Very few juveniles have been present in areas of the South Fork Eel River drainage where there is adequate habitat to support large numbers. Early reports document samples of thousands of juveniles from some streams—4,844 in the Bull Creek system in 1939 (Shapovalov 1940) and 3,000 in 1951 (Hallock et al. 1952); 3,475 in Ten Mile Creek in 1951 and 4,369 in 1952 (Kimsey 1952, 1953); and 1,250 in Dean Creek in 1939 (Shapovalov 1940).”

“Coho salmon were formerly more widespread in the Eel River drainage. California Department of Fish and Game (CDFG) files contain reports of coho salmon in Indian Creek (main-stem tributary above Outlet Creek) and several tributaries to Tomki Creek. During the 1946-1947 season, 47 coho salmon passed through the Van Arsdale fish facility on the upper main-stem Eel, 315 km from the sea, but they have not been recorded there since (Grass 1990a). The Tomki Creek drainage has been intensively studied since 1986, but no coho salmon have been captured or observed (Steiner Environmental Consultants 1990, App.). There are no recent records of coho salmon in tributaries to the North Fork Eel and Middle Fork Eel Rivers (W. Jones, App.; L. Brown, personal observation), although they were formerly present there.”

Despite the incomplete record of coho population trends, the currently depleted state of the coho salmon run(s) in the Eel River system is illustrated by the available data; i.e., (CDFG 1997: p.23):

“The South Fork Eel River has a significant, although remnant, population of coho salmon. Presently, an estimated 500 to 1,000 coho adults spawn in the South Fork Eel River subbasin. Moyle and Morford (1991) estimated 1,000 coho spawners in the South Fork Eel River system. The last count made at Benbow Dam Fishway, in 1975, consisted of only 509 total coho. These fish are what remain of coho runs of approximately 17,000 adult coho counted in 1945-46 at Benbow Dam (Figure 2). Coho salmon adult run-size estimates are not available for other Eel River subbasins.”

For more recent years, there are no reliable time-series data available on the abundance of adult coho salmon (NMFS 2005). The general indication from very limited information on the overall abundance of coho salmon in the Eel River system is that substantial declines in population levels have occurred over the decades—viz., estimated coho salmon numbers were 14,000 fish in the mid-1960s (CDFG 1965c), 4,400 fish in the mid-1980s (NMFS 2005, citing Wahle and Pearson 1987) and about 2,000 fish by the early-1990s (Brown et al. 1994).

The CDFG (2002) Status Review on coho salmon also cited the Benbow Dam (South Fork Eel River) counts as the most recent time-series data. Based on the Benbow Dam counts conducted during 1938-1975, an average of 15,000 coho salmon were counted during the 1940s (maximum, 25,000 coho in 1947) (CDFG 2002: p.46), which declined to an average of “about 1,800 coho salmon adults annually between 1966 and 1975, the last 10 years of counts” (CDFG

2002: p.69). More detailed data on the Benbow Dam counts were presented by Taylor (1976, his Table 2) and are given in our Table 3. Coho salmon have been recently observed in some tributaries of South Fork Eel River, Van Duzen River, and Outlet Creek. However, coho salmon are believed to have been extirpated from the North Fork and Middle Fork of the Eel River (CDFG 2002).

Table 3. Counts of up-migrating salmon and steelhead at the Benbow Dam fish-ladder, South Fork Eel River. Modified from Taylor (1978, his Table 2).

Year ¹	South Fork Eel River, Benbow Dam		
	Chinook salmon	Coho Salmon	Steelhead
1938	6,051	7,370	12,995
1939	3,424	8,629	14,476
1940	14,691	11,073	18,308
1941	21,011	13,694	17,356
1942	10,612	15,037	25,032
1943	7,264	13,030	23,445
1944	13,966	18,309	20,172
1945	12,488	16,731	13,626
1946	16,024	14,109	19,005
1947	13,160	25,289	18,225
1948	16,312	12,872	13,963
1949	3,803	7,495	13,715
1950	14,357	12,050	15,138
1951	12,476	11,441	13,774
1952	7,256	3,711	19,488
1953	7,948	3,052	15,405
1954	5,367	5,952	13,609
1955	3,974	5,977	10,065
1956	1,530	5,717	12,333
1957	3,050	5,433	7,910
1958	1,472	3,344	11,984
1959	473	2,119	8,367
1960	2,665	3,184	6,370
1961	2,046	8,479	14,374
1962	3,688	10,031	8,303
1963	2,918	14,316	14,255 ^H
1964 ²	8,315	4,468	2,358
1965	2,455	3,804	9,283
1966	8,649 ^J	1,480 ^J	3,296 ^{H,J}
1967	3,006	2,461	3,292
1968	2,278	1,289	2,443
1969	3,200 ^H	3,170 ^H	2,788 ^H
1970	9,367 ^H	2,070	3,328 ^H
1971	5,026	1,509	2,082 ^H
1972	2,640	750	3,320 ^H
1973	5,006	3,993	6,941 ^H
1974	3,865	1,224	2,613
1975	4,101	509	1,847

¹ Each designated year refers to the up-migration and spawning season spanning that year and the following year (referred to as “counting-year”). For example, “1925 refers to counting years 1925-1926, etc.” (Taylor 1978, his Table 2, footnote 1).

² All 1964 data are preliminary; Benbow Dam counts are “incomplete because of floods” (Taylor 1978, his Table 2, footnote 2).

^H “This figure is an estimate—station was closed before the end of the run” (Taylor 1978, his Table 2, footnote H).

^J “Includes 369 chinooks, 210 coho salmon and 133 steelhead counted with electric counter” (Taylor 1978, his Table 2, footnote J).

Recent surveys of Eel River juvenile coho salmon have been conducted over various time periods (i.e., 8 to 18 years) by private timber companies for selected streams (NMFS 2005). Those surveys included five index sites on five streams in the South Fork Eel River subbasin and two sites on one stream in the Middle Fork Eel River subbasin (NMFS 2005). The survey results indicated that juvenile coho salmon densities at the index sites showed apparent positive trends over time (i.e., positive slopes in the linear regression lines) but those trends (slopes) were not statistically significantly different from zero, given the limited number of samples.

Aside from the limited data from spawning surveys on selected streams and the older fish-ladder counts at dams, another rough indication of coho population levels over the entire Eel River basin is the percentage of suitable streams that are occupied by coho salmon. Updated analyses by CDFG (for the period spanning the coho brood-years 1986-2000) and NMFS (for coho brood-years 1987-2001) generally corroborated the earlier findings by Brown and Moyle (1991a) in regard to the percentage of historical coho-bearing streams in northern California that have continued to be utilized by coho salmon until recent years (NMFS 2005).

However, the Eel River was the most notable exception to the generally constant rate of stream occupancy by coho salmon—i.e., by showing stream occupancy rates declining from the range 48%-58% (for brood-years 1987-1995) to 30%-31% in the subsequent two brood cycles (i.e., for brood-years 1996-2001) (NMFS 2005).

Overall, given the habitat likely available, historic numbers of spawning adult coho salmon were probably in the 50,000-100,000 fish per year range. There may still have been runs of 20,000-40,000 fish in first half of the 20th century, based on angler reports. By the 1960s, the number of spawners was likely less than 15,000 fish, with numbers dropping by about 5-10% of spawners per year in subsequent years. Coho salmon thus appeared headed for extirpation from the Eel River basin by 2025 if not sooner.

STEELHEAD

Diversity

Steelhead apparently still have diverse local populations in the Eel River basin. Two seasonal runs of steelhead—viz., the predominant “winter-run” and also “spring-run” (summer steelhead—were known to occur in the Eel River system as early as the 1930s. Shapovalov (1939: p.17) stated:

“Unknown to most Eel River anglers is the fact that large, sea-run, not spent, steelhead may be caught in certain portions of the watershed throughout the summer months. These fish apparently constitute a true spring run, entering the river probably mostly in May and migrating upstream. . . . Like the winter-run steelhead they do not feed in fresh water, with possible rare exceptions, but remain in good condition throughout the summer.”

CDFG (1997) described the steelhead populations of the Eel River system as comprising *three* seasonal runs—i.e., fall, winter and spring-summer runs, with the winter run being the most numerous run. The distinction between the fall and winter runs is not clear, however.

Molecular genetic analysis has demonstrated the evolutionary differentiation of the summer and winter steelhead runs in the Middle Fork Eel River and there is no question that they compose somewhat different gene pools. Summer and winter steelhead lineages apparently began to diverge from each other approximately 16,000 to 28,000 years ago (Nielsen and Fountain 1999). Within the Middle Fork Eel River subbasin, juvenile trout samples from various tributaries “showed significant genetic differences indicating [the existence of] isolated, small, resident population.” Furthermore, there were “significant genetic differences between winter steelhead from the Middle Fork Eel River and those from the South Fork Eel River, Lawrence Creek (Van Duzen tributary), and Willits Creek (upper Eel River tributary)” (Moyle et al. 2008: p.43; citing Clemento 2006).

Abundance

The overall historical and recent abundance of steelhead in the Eel River system is poorly known, but the river was famous for its sport fisheries for abundant and large fish in the 1920s and 1930s. The estimated numbers of steelhead spawners for the entire Eel River system was reported to be 82,000 fish in the mid-1960s (Busby et al. 1996, citing CDFG 1965c) and steelhead abundance data over several decades are available for certain parts of the system (Busby et al. 1996, McEwan and Jackson 1996). It is evident that steelhead populations in the Eel River “declined significantly” as summarized by McEwan and Jackson (1996: p.35):

“... Annual counts of adults at Cape Horn Dam in the upper watershed of the main stem Eel River declined from an average of 4,400 during the 1930’s to about 1,000 during the 1980’s Annual counts made at Benbow Dam on the S[outh] F[ork] Eel River also show a decline from historical numbers, from an average of 18,784 during the 1940’s to 3,355 during the 1970’s (counts were discontinued after 1975). Recent indications are that steelhead populations also appear to have declined significantly in the S.F. Eel River, which may be due in part to predation or other adverse effects from introduced Sacramento squawfish (*Ptychocheilus grandis*), which are now widespread throughout the system. There are no historical or present basin-wide estimates of steelhead abundance in this system.”

McEwan and Jackson (1996) presented population-size indices--i.e., counts averaged for certain decades (1930s-1970s) as well as single-year counts. We reproduce those data here in Table 4. Recent abundance estimates of the winter run are not available for the individual subbasins but the CDFG’s most recent (late-1980s) basin-wide population estimate for the Eel River system was 20,000 adult steelhead (CDFG 1997).

Historically, large numbers of winter-run steelhead utilized the South Fork Eel River. The CDFG (1997: p.23) stated:

“On the South Fork Eel River at Benbow Dam, over 20,000 winter-run steelhead were counted each year between 1941 and 1944. The last count in 1975 tallied less than 2,000 fish. Decline was steady throughout the period (Figure 2). Adult winter-run steelhead counts at the Van Arsdale Fish Facility reflect similar declines since the early 1940’s (Figure 3).”

Spring run/summer steelhead occur primarily in the Middle Fork of the Eel River system. As noted by CDFG (1997: p.23),

“... The Middle Fork Eel River has one of the most significant populations of spring/summer-run steelhead in California. However, recent counts of these fish are about 10 to 20 percent of counts made in the 1930’s and 40’s. Earlier counts of returning adult spring/summer-run steelhead to the Middle Fork Eel River were commonly in the thousands and as high as 6,000. Counts since 1966 have ranged from 198 to 1,601.”

McEwan and Jackson (1996: p.38) similarly noted:
“Since the early 1970’s, systematic surveys have been undertaken on summer steelhead holding habitat to census adult summer steelhead. The most abundant population is in the M[iddle] F[ork] Eel River (CDFG unpublished data). This population has not fully recovered from the devastating 1964 flood which aggraded the river bed, filled-in holding pools, and smothered spawning gravels (Eric Gerstung, DFG Associate Fishery Biologist, pers. comm.). Adult population numbers have declined since 1987 (Table 4). The present estimated annual statewide abundance of adult summer steelhead is about 2,000 adults.”

Although time-series on adult steelhead numbers had been collected at the fish-ladders at Cape Horn Dam (upper mainstem Eel River) and Benbow Dam (South Fork Eel River) during previous decades (Table 4), only the Cape Horn Dam counts extend into the 1990s. Fish counts were also regularly conducted at the Cape Horn Dam fish ladder after 1922-1923. High

steelhead escapements were recorded during the 1930s that often exceeded 3,000 fish but a precipitous decline occurred since the 1950s through the 1990s (SEC 1998). Those earlier (pre-1950) fish-ladder counts may have been affected (i.e., bolstered) by hatchery releases, but it is not known to what extent the hatchery releases affected the steelhead numbers. In any event, SEC (1998) noted that the decline in steelhead since the late 1980s was similar to the pattern observed for Chinook salmon.

To compare with the upper mainstem Eel River, the Benbow Dam fish-ladder counts on the South Fork Eel River had an annual average of ~19,000 steelhead adults during the 1940s and ~3,350 steelhead adults during the 1970s (Busby et al. 1996, citing Shapovalov and Taft 1954 and McEwan and Jackson 1996). Hence, the downward trend of steelhead in the South Fork Eel River roughly parallels the inter-decadal decline also observed for steelhead in the upper mainstem Eel River (SEC 1998, their Figure 5.2-1). As SEC (1998) noted, hatchery supplementation of unknown magnitude had been conducted throughout the Eel River basin during the decades coinciding with the Van Arsdale fish-ladder counts and may have confounded the underlying population trends of the wild steelhead populations. However, the adoption of more careful monitoring procedures since 1980/1981 reportedly now allows better determination of hatchery versus natural (equivalently, “wild”) fish. Hence, relatively recent data on naturally produced spawners appear to be reliable indicators of recent trends. The trends for wild steelhead roughly match the pattern shown by Chinook salmon in the upper mainstem Eel River—i.e., substantial numbers during the 1980s followed by a collapse to near-zero population levels (SEC 1998).

Summer steelhead survey counts have been collected for summer steelhead in the Middle Fork Eel River. For the period 1966-2002, summer steelhead numbers ranged around 200-1,600 fish, with a maximum 5-year average of 1,246 fish (Table 4 and NMFS 2005).

Table 4. Total Steelhead Population Indices (from McEwan and Jackson 1996, Tables 3 and 4; and NMFS 2005, Table 51). Data for the upper mainstem Eel River and South Fork Eel River are average annual counts (over the specified decade) or annual run size of all seasonal runs combined, and with wild and hatchery fish combined unless otherwise stated. Blank entries mean that no data were collected or available. Summer steelhead data are from dive surveys of adult summer holding areas.

	Eel River upper mainstem, at Cape Horn Dam (all steelhead)	South Fork Eel River, at Benbow Dam (all steelhead)	Middle Fork Eel River (summer steelhead only) ¹	Van Duzen River (summer steelhead only) ¹
Decades				
1930s ³	4,394 (4,390)	(13,736)		
1940s ³	3,560 (4,320)	18,800 (18,285)		
1950s ³	3,601 (3,597)	12,800 (12,802)		
1960s ³	890 (917)	6,700 (6,676)		
1970s ³	731 (721)	3,400 (3,355)		
1980s ³	(1,287)			
Individual Years				
1977			654	
1978			377	
1979	87		1,298	31 ²
1980	1,966		1,052	25 ²
1981	646		1,601	6
1982	369		1,054	8
1983	1,534		666	13
1984	1,980		1,524	58
1985	1,199		1,490	
1986 ⁴	1,952 [1,114]		1,000	
1987 ⁴	2,168 [666]		1,550	52
1988 ⁴	331 [138]		711	42 ²
1989 ⁴	691 [107]		726	4 ²
1990 ⁴	31 [19]		449	
1991 ⁴	60 [26]		691	31 ²
1992 ⁴	823 [52]		516	0 ²
1993			622	

¹ “Estimated from dive surveys of 70 to 100% of the adult summer holding areas, unless otherwise noted.” (McEwan and Jackson 1996, their Table 4, footnote 1)

² “Estimated from dive surveys of 50 to 69% of the adult summer holding areas.” (McEwan and Jackson 1996, their Table 4, footnote 2)

³ First numbers in each cell are from McEwan and Jackson (1996, their Table 3). Numbers in parentheses are from NMFS (2005, their Table 51).

⁴ First numbers in each cell are combined wild and hatchery fish counts. Numbers in square brackets are wild fish counts.

Return rates for wild adult steelhead were calculated for the population segment that spawned above Cape Horn Dam during the period 1979/1980 to 1993/1994 (SEC 1998). Return rates for steelhead were computed differently from the return rates for salmon because of the greater uncertainty associated with abundance estimates of down-migrating juvenile steelhead during the seasonal high-flow period. Specifically, steelhead return rates were based on the number of steelhead juveniles estimated from summer surveys during the year preceding the year of emigration, which were adjusted by an estimated over-winter survival rate of 75 percent. Those juvenile steelhead abundance estimates were then divided by the number of adult steelhead that passed up the Van Arsdale fish ladder two and three years later on the assumption that adults had spent two or three years at sea. This result is an index of percent returning fish (survival rates).

The steelhead return rates to the uppermost mainstem Eel River during the recent 1987-1994 period were generally low (i.e., values of 2% or lower) during the years 1987 to 1992—thus matching the correspondingly low rates for Chinook salmon during the late-1980s in that area (SEC 1998). There was an exceptionally low return rate of wild Eel River steelhead for the 1989 emigration year (i.e., for juveniles that migrated to sea in 1989)—viz., a value of 0.10 percent, which was similar to the return rate of 0.18 percent for hatchery steelhead returning to the Warm Springs Hatchery on the Russian River (SEC 1998). However, the steelhead return rates showed an increase during the last years of that period (to values within 2%-5%) that is suggestive of some degree of recovery.

Overall, however, both winter and summer steelhead have undergone severe declines in the basin. Based on habitat availability and the few population estimates that exist, historic numbers were likely to have been 100,000-150,000 adults per year (both runs combined), declining to 10-15,000 by the 1960s. Present numbers are probably considerably less than 1,000 fish in both runs, with summer steelhead in danger of extinction in the near future if the numbers of spawners declines further.

FACTORS AFFECTING SALMONID ABUNDANCE

The decline of salmonids and their fisheries in the Eel River is due to a number of interacting factors. However, the biggest problem in recent decades has been damage to the watershed by logging and other human activities, greatly reducing its capacity to support cold-water fish year around. Here we discuss (1) hatcheries, (2) fisheries, (3) logging and other land use, (4) Dams and diversions, and (5) invasive alien species.

HATCHERIES

Among the earliest fishery-related activities by federal and state agencies in California was the establishment of egg-collecting stations and hatcheries for salmon, especially in the northern Sacramento River basin of the Central Valley and the northern California coast. The U.S. Fish Commission's first salmon egg-taking station and hatchery on the Pacific Coast was established in 1872 on the McCloud River (a tributary of the Sacramento River) and the California Fish Commission's first fully functional hatchery opened in 1888 on the Upper (Little) Sacramento River (Stone 1897, CFC 1890).

The first government fishery facility on the northern California coast was the federal egg-collecting station established in 1889 on the Trinity River at Fort Gaston, Hoopa Indian Reservation (Humboldt County) (Brice 1895). That station was soon followed by an egg-collection "substation" on Redwood Creek in 1891 which supplied salmon eggs to the main Fort Gaston Hatchery and by the Korbel Hatchery on the Mad River in 1893. However, all three of those stations were abandoned in 1898 due to their remote locations and inaccessibility (Leitritz 1970).

The initial hatchery activities on the Eel River during the late-1890s were directed toward salmon but efforts to increase the steelhead runs soon followed. The California Fish Commission stated in its Seventeenth Biennial Report for 1901-1902 (CFC 1902: p.32):

"At the last session of the Legislature there was appropriated the sum of \$2,000 to be expended in the work of steelhead propagation. This was made available after January 1, 1902. After placing a dam, with proper racks and traps, on Price Creek, the work of collecting steelhead for propagation was undertaken by the Commission for the first time, commencing March 5, 1902, and continuing to May 17, 1902. Unusual freshets in the spring interfered materially with our take. A total of 342,000 steelhead eggs were collected. . . . Four fifths of the eggs collected were taken on Price Creek. We have since prepared the necessary apparatus to capture the parent fish in traps on Howe Creek, which is about half a mile distant from our hatchery. We will be able to operate these two egg-collecting stations—Price Creek and Howe Creek—with one crew. . . ."

"The steelhead is the parent of all our coast stream trout, and is one of our valuable food fishes. It is becoming more and more popular in our markets, therefore we feel that steelhead propagation should become one of the features of our work. . . ."

The apparent benefits of the early hatchery operations were attested by the California Fish Commission by comparison of the salmon and steelhead population abundances during that period (CFC 1907: p.26-27):

"Another striking example of the efficiency of our methods is shown on Eel River, in Humboldt County. In 1898 a salmon hatchery was established on Price Creek near its junction with Eel River. According to the figures furnished by Mr. M. A. Wilcox, Federal Statistician at Washington, D. C., who has collected these data for nearly twenty years, the average number of pounds of salmon shipped from Eureka was less than 500,000. To be exact, the figures in 1899 were 470,806 pounds net. Taking his figures in 1904, or five years later, which was six years after the artificial propagation of salmon was undertaken by this Commission in that portion of our State, they show that the shipments from that port reach a grand total of 1,877,000 pounds. These figures are still

better appreciated when a comparison is made between the increase of salmon propagated artificially and the steelhead allowed to propagate naturally (in the same streams and during the same period of time), bearing in mind that there was no change whatever in the law as to season, or method of capturing the fish. While the salmon under artificial propagation showed an increase of about one hundred and fifty per cent, the steelhead under natural propagation had decreased fifty-one per cent. Further comment seems unnecessary.”

The apparent success of the salmon hatchery operations on the Eel River was repeatedly lauded in the California Fish Commission’s biennial reports. In the 23rd Biennial Report, the Commission stated (CFGF 1914: p.69):

“ . . . We are pleased to note that the salmon are yet plentiful in Eel River, and do not show any signs of a decrease, although the fishing has been as heavy as in past years. This hatchery was established in 1898 at a time when the average number of salmon shipped did not exceed 500,000 pounds. Five years after the artificial propagation of the salmon the number had increased to over 1,500,000 pounds annually. The salmon eggs that restored the run of salmon in Eel River were the surplus eggs shipped from the Sacramento River stations”

The repeated large-scale plantings of non-native salmon stock from the upper Sacramento River basin is especially noteworthy—in some years accounting for far more young salmon than were produced by native Eel River broodstock. Some examples from the reports of W.O. Fassett, Superintendent of the “Eel River Hatchery” are as follows.

“Gentlemen: The following is my report of the salmon hatch at this station for the season commencing December 7, 1908, and ending March 6, 1909. The eggs arrived in four shipments, as follows: December 7th, 1,000,000; December 27th, 1,500,000; January 5, 1909, 1,500,000 from Mill Creek, and December 21st, 1,440,000 from Battle Creek, making a total of 5,440,000 salmon eggs received. The hatch was successful, and I planted in Eel River and Price Creek 5,374,200 good healthy fry.” (CFGF 1910: p.99-100)

“Gentlemen: The following is my report of the salmon hatch at this station for the season commencing December 5, 1909, and ending March 23, 1910. The total number of eggs received was 6,000,000, and were received in four shipments, as follows: December 5th, 1,471,000; December 26th, 1,438,500; December 31, 1909, 1,541,000, and January 10, 1910, 1,549,500. The eggs were all shipped from Mill Creek and were as near perfect as possible, the loss being practically nothing. The hatch was most successful, and the fry were distributed in Price Creek and Eel River.” (CFGF 1910: p.100)

Similarly, for the year 1913, the California Fish Commission reported (CFGF 1914 p.69):

“ . . . Before the freshet caused the [Eel] river to rise a number of mature fish were taken and 472,250 eggs were collected; these, with 3,611,000 eggs shipped from Mill Creek station [Sacramento River basin], were successfully hatched and the fry liberated in Mad River, Elk River, Jacoby Creek, Freshwater Creek and Eel River and Price Creek, . . . ”

In later decades, extensive hatchery operations in the Eel River basin and elsewhere in California were conducted by the successor agencies of the U.S. Fish Commission and California Fish Commission—viz., the U.S. Fish and Wildlife Service and California Department of Fish and Game—and by various public and private organizations. The history of plantings of hatchery-produced salmonids has been summarized in National Marine Fisheries Service reports (e.g., Myers et al. 1998).

Steiner Environmental Consulting (SEC 1998) presented a general historical overview of hatchery plantings of Chinook salmon into the Eel River system in relation to the Potter Valley Project monitoring program. The greater proportion of Chinook salmon plantings involved out-of-basin stocks, particularly from the Sacramento and Trinity river systems. The great majority of steelhead plantings into the Eel River system appear to have been of native Eel River stock(s), with a small fraction coming from the Mad River Hatchery.

The effects of plantings of hatchery Chinook salmon and steelhead were regarded as generally positive in terms of bolstering population levels—as indexed by returning adult numbers at the Van Arsdale Fish Station—but the lack of detailed data preclude any definitive conclusion as to whether or not this was really the case. Indeed, hatchery managers really had no idea about how well the fish released were actually surviving; large returns could also have the result of highly favorable natural conditions, especially in the ocean. In addition, planting practices may have had adverse effects on native stocks, such as competition between hatchery and natural juvenile salmonids or by facilitating predation on small naturally produced juveniles by larger hatchery steelhead smolts. Also, previous hatchery operations may have exerted negative genetic and disease effects on wild salmonid population(s) (SEC 1998: p.5.12-5, and references therein).

Further details of the plantings of hatchery fish and their effects on Eel River Chinook salmon and steelhead stocks were described by SEC (1998: p.xxii-xxiii) as follows.

“Data on hatchery plants of salmon and steelhead in the Eel River were compiled from published and unpublished documents. Reporting varied in methods and detail level. From these sources, information regarding the numbers, size, stock origin, and date of the plants were summarized.”

“More than 39 million chinook salmon have been planted in the Eel River since 1900. The vast majority of these were eggs and fry of Sacramento River origin planted in the lower mainstem prior to 1920. Between 1921 and 1960, the number of chinook planted to the Eel River is unknown due to lack of detail in planting records. From 1971 to 1980, most chinook planting occurred at Van Arsdale Fisheries Station [upper mainstem Eel River] or in the South Fork Eel River. The vast majority of these fish originated from Iron Gate Hatchery [Trinity River]. The South Fork Eel River and Outlet Creek were the sites of most planting between 1981 and 1990. Chinook stocking between 1991 and 1995 took place at the South Fork Eel River and Van Duzen River. All chinook planted after 1981 were of Eel River origin.”

“Since 1900, more than 9 million steelhead have been planted in the Eel River, mostly to the mainstem and South Fork Eel River. Prior to 1920, steelhead eggs and fry of Eel River stock were planted in tributary streams of the mainstem Eel River. Due to poor documentation, the number of steelhead planted in the Eel River between 1921 and 1960 is unknown. Many steelhead were rescued in the upper mainstem between 1939 and 1970. Between 1956 and 1965, most steelhead were planted in the South Fork Eel River, which continued to receive large numbers of steelhead plants through 1995. Most planting between 1965 and 1995 occurred at Van Arsdale Fisheries Station. Most Van Arsdale plants were of Van Arsdale stock, although some Mad River Hatchery stock was used in 1974 and 1978. Mean size of steelhead planted at Van Arsdale Fisheries Station increased between 1970 and 1985.”

“Effects of hatchery chinook plants upon adult returns to Van Arsdale Fisheries Station are considered to be negligible. Hatchery chinook might have contributed to returns in the late 1970’s and 1980’s, but lack of hatchery markings and/or recovery data precluded identification of adults. In 1984, chinook were hatched and reared at Van Arsdale Fisheries Station and released below the South Fork Eel River. Some of these

fish may have contributed to elevated returns in the late 1980's, but at most one or two marked fish from this group were recovered during spawning surveys in the study area.”

“Hatchery supplementation may have helped sustain steelhead run size in the upper mainstem prior to 1981. However, the lack of hatchery markings precluded quantification of hatchery returns during those years. Since 1981, approximately 50 percent of adult steelhead returns to Van Arsdale Fisheries Station have been confirmed to be of hatchery origin. Additionally, plants of adult steelhead in Lake Pillsbury between 1940/41 and 1958/59 may have helped to sustain anadromous populations in the study area, although data to support this hypothesis are limited.”

Overall, the magnitude of the early plantings of hatchery salmonids into the Eel River system was very large, but even so, the plantings did not maintain salmonid population levels to a significant degree.

As summarized by SEC (1998):

- More than 39 million Chinook salmon had been planted into the Eel River since 1900, the “vast majority” of which were “eggs and fry of Sacramento River origin planted in the lower mainstem prior to 1920.”
- During the period 1971-1980, most Chinook salmon plantings were done at Van Arsdale Fisheries Station (upper mainstem Eel River) or in the South Fork Eel River. The “vast majority” of the planted fish were from the Iron Gate Hatchery on the Klamath River.
- More than 9 million steelhead had been planted in the Eel River since 1900, and all of the fish planted before 1920 were of Eel River origin.
- The degree to which the plantings of hatchery Chinook salmon and hatchery steelhead have helped bolster the populations is not clearly understood, but for Chinook salmon the benefits to the upper mainstem Eel River population is considered to have been negligible.

It could be surmised from limited data that the apparent effects of plantings of hatchery Chinook salmon and steelhead were initially positive in terms of bolstering population levels—as indexed by returning adult numbers at the Van Arsdale Fish Station (upper mainstem Eel River)—but the lack of good comparative data precludes any definitive conclusions. There is evidence that hatchery fish originating from outside the Eel River basin may not have persisted or contributed much to populations in the long run (e.g., Bucklin et al. 2007). On the other hand, past planting practices may have had adverse effects such as increasing competition between hatchery and natural juvenile salmonids or facilitating predation on small naturally produced juveniles by the releases of larger hatchery steelhead smolts.

FISHERIES

The commercial fishery for salmon in the Eel River system started relatively early, in the mid-19th century, and operated at roughly the same period as the heyday of the salmon fishery in San Francisco Bay and the Sacramento-San Joaquin River Delta. However, the Eel River fishery had a much shorter duration, effectively ending in the first part of the 20th century. The Eel River fishery was dominated by the salmon canning industry, as had occurred in other salmon fisheries in California and elsewhere on the Pacific coast.

The great productivity of the early commercial fishery prior to its decline and eventual demise due to overfishing (and probably other factors) was highlighted by a CDFG report (CDFG 1972: p.42-43):

“The Eel River has supported both sport and commercial fisheries for well over a century. Commercial salmon fishing in the river began as a serious industry about 1854. In 1857, about 2,000 barrels of cured salmon and 50,000 pounds of smoked salmon were prepared from Eel River catches (Wainwright, 1965). In that same year, the catch from the Eel River was greater than that from the Sacramento River. Salmon runs fluctuated widely in the Eel River, with huge runs in some years and small runs in others. As early as 1876, concern was expressed over the wanton destruction of salmon by the commercial interests. Cannery records from 1877 to 1926 show a peak of 15,000 cases of salmon canned in 1883 (USDI, 1960 [i.e., USFWS 1960]). The commercial fishery on the river was abolished by law in 1926 when it shifted to the Pacific Ocean, where it exists today.”

The commercial fishery evidently caused substantial reductions of the salmon run(s) during the early-fall season, even in years of normal rainfall. As noted by Shebley (1922: p.80): “. . . The salmon; upon entering the mouth of the river, are compelled to remain in the large pond below Loleta until the river rises in the fall, as there is not water during the seasons of normal rainfall to allow the fish to pass over the wide, shallow riffles connecting the large pools from South Fork to the large pool at the mouth of the river.”

“As a rule the river rises to a considerable extent, but not before the majority of the salmon are caught by the commercial fishermen at the mouth of the river in the large pool.”

Furthermore, the highly detrimental impact of commercial fishing activities on the steelhead run(s) of the Eel River was pointedly noted by the California Fish Commission (1907: p.47-48):

“At the last session of the Legislature the trout law was so amended that the taking of steelhead with nets at any time was prohibited. This law has created some antagonism among the small element in Humboldt County who follow the vocation of fishing, and we believe they will make a determined effort at the forthcoming session of the Legislature to have it changed so as to again permit the catching of steelhead with nets. When it is shown that the total value of the steelhead that were caught and shipped to market by the fishermen from all parts of the State did not, in the year 1904, exceed \$1,600, and this small amount was distributed among eighty or ninety fishermen, net fishing would seem of insufficient importance compared to the far greater value the steelhead will have in being allowed to ascend all the coastwise streams to their headwaters for the purpose of spawning.”

“The collection of steelhead eggs at our Eel River station has not been nearly so large as we could wish and easily handle, due entirely to the drain by net fishing, and consequent reduced run of spawn fish. So long as the net fishermen could lawfully operate in tide water, they were stopping absolutely the passage of the fish on their way to spawning grounds and hatching stations. The few that managed to ascend had to encounter other dangers and when they did reach spawning beds the very small percentage of fish hatched under natural conditions was not sufficient to offset the drain caused by the nets; besides cutting off our supply of spawn fish at the hatcheries. For the three years we have operated in Humboldt County the largest take in one season, operating simultaneously at three or four different points, had not been over 350,000 eggs, until during the spring of 1906, after the restriction prohibiting netting became effective, when, operating but one small trap on Price Creek (which was at different times flooded), we were able to take the largest number of steelhead eggs ever taken in that county. We therefore urgently recommend that no change be made in the existing law.”

The legal commercial fishery was not the sole cause of the salmonid population declines. Illegal fishing by non-commercial poachers as well as by the commercial fishermen was undoubtedly a significant factor at times. For example, the California Fish Commission (1907: p.11-12) noted the extent of illegal harvests apprehended in California during the two years 1905-1906:

“Our regular deputies have seized thousands of pounds of fish and game in transit; fish that were underweight, or that had been taken in violation of the law; . . .”

“More than 60,000 pounds of dried shrimp and shrimp shells were taken; 19,000 pounds of striped bass; 2,600 pounds of salmon; more than 8,000 pounds of steelhead . . .”

While those numbers above were state-wide totals, they nonetheless reflect similar activities that presumably occurred within the Eel River system and in other watersheds.

In the 20th century in-river commercial fisheries were banned, but ocean fisheries for salmon continued, with unknown effects on Eel River stocks. Likewise, thousands of salmon and steelhead were removed each year by sport anglers, given that releasing a fish once caught was unthinkable. In recent years, ocean fisheries have been mostly shut down or reduced and most angling is catch-and-release, mainly reflecting the low abundance of the fish.

FLOODS, LOGGING, AND LAND USE

It is very evident that the Eel River system has undergone profound changes in its physical and biological features since the initial Euro-American settlement in the region 150 years ago. Some of those changes, such as the great floods of 1955 and 1964, interacted strongly with anthropogenic factors such as intensified timber harvesting after World War II. Thus, intense localized logging can magnify the destructive effects of high rainfall, and vice versa. As noted by Morford (1995: p.5):

“From an ecological perspective, significant alterations have occurred in the frequency and magnitude of precipitation and streamflows as a result of land use activities such as timber harvest and/or deforestation. Road building and similar watershed disturbances also resulted in increased watershed sediment production. This in turn caused in-stream sediment transport to increase, upsetting the geomorphological balance that had favored indigenous flora and fauna.”

It is virtually certain that both human and natural factors had negative effects on Eel River salmonids to varying degrees and it is very likely that most factors had synergistic (i.e., compounded) interactions. A number of the most notable events and factors are mentioned repeatedly among the studies included in our literature review. Specifically, the catastrophic effects of the massive floods of 1955 and 1964 included massive erosion, sedimentation and channel reconfiguration. Morford (1995: p.2) noted that “the 1964 flood of record resulted in basic geomorphic changes in the Eel River basin” and that “subsequent flood events have not restored geomorphic conditions in the mainstem river to that which were present prior to the 1964 event.” Additionally, the early logging practices inflicted severe damage to stream channels and riparian vegetation as well as the obvious reduction of forest tracts on streamside slopes. Furthermore, the effects of the Benbow, Cape Horn, and Scott dams in the Eel River system were forcefully noted by the CDFG biologists working on the northern California coast during the early 20th century, particularly in reference to Scott Dam on the upper mainstem Eel River.

The multiple profound changes in the Eel River ecosystem and their repercussions on the anadromous salmonids—primarily Chinook salmon—was summarized by Morford (1995: p.5-6):

“By the 1950’s, a large volume of unnaturally produced sediments became available for transport downslope to waterways and hence to the ocean. Major hydrological events, such as the floods of December 1955 and December 1964, mobilized much of this sediment and moved it in or adjacent to the river system. However, much of the sediment was not carried to the ocean and removed from the system. Along the way, a large volume of the newly generated sediments became stored in stream banks and stream channels awaiting further flow events. These future events will have to generate sufficient energy to cause a positive net removal of sediment from the system. The length of time it will take for a single particle of sediment to make this journey may be measured in hundreds, thousands, if not tens of thousands of years depending upon the frequency and magnitude of future flows. Unfortunately, the Eel River system has not had the conditions or flow events that will provide for this positive net removal of sediments from the system which will be required to restore previous geomorphic conditions.”

“From an immediate perspective, Chinook salmon must reproduce the species in order to survive. This requires that they have sufficient water in the river to navigate upstream to favorable spawning habitats and have sufficient flow and habitat for the young to migrate successfully to the sea. Changes which have occurred in the watershed have reduced the importance of mainstem spawning and increased the importance of tributaries for reproduction of the fall run Chinook salmon. These changes make the continued existence of this variant [*sic*] more dependent on the availability of sufficient streamflows in the months of October and November to cause increased tributary flow in those few tributary streams still important for successful reproduction.”

“Reductions in spring runoff and increased sediment storage in the mainstem river have caused a reduction [of] the space available for the progeny of the returning salmon. This results in conditions less favorable for smolt survival. These factors, especially in light of the several consecutive years of low spring flows in the 1980’s, have apparently also caused fundamental ecological changes to occur in the river. These apparent changes have resulted in the population explosion of exotic predator fish populations which have taken advantage of newly established ecological niches. This predator population further lessens the potential for species survival.”

High-Flow Events and Geomorphological Changes

The great flood of 1964 and, to lesser degrees, the floods of 1955, 1986, and 1997 engendered massive changes in the physical structure and ecological processes of the Eel River system—a large part of which was the result of previous disruptive human activities such as clearcut logging, extensive road-building, grazing and other practices that facilitated land erosion (Keter 1995). Those flood events and their effects on the Eel River ecosystem were described by Morford (1995: p.9-10):

“The most striking event that has led up to these changes was the great flood of December, 1964. During that event, flows at Scotia reached a level of about 650,000 cfs and the 10 day volume of water amounted to about 4,590,000 acre feet. This, in a river, where a 10 day flow event seldom exceeds 2,000,000 acre feet.”

“The ‘work potential’ of the 1964 event was several magnitudes greater than comparable events such as the flood of December 1955 and the flood of February 1986. The ‘work potential’ is a term that may be used to describe the amount of ‘Energy’ generated by a volume or ‘Mass’ of water traveling downslope at a certain ‘Velocity.’”

“The upshot of the 1964 event was that a large amount of sediment moved into the river from upslope areas. This sediment filled in pools which had been historically deep. Sediment also was temporarily stored in the active river channel in large volumes awaiting future mobilization. As a result the geomorphology of the system was catastrophically altered.”

“Streamflows which have occurred since the 1964 flood have been moderate. These include those of the drought period in the late 1970’s and those of the late 1980’s and early 90’s when even average flood events failed to materialize.”

Significantly, the physical changes wrought by the 1964 flood will not be reversed anytime soon either by human design (i.e., restoration projects) or natural events (e.g., future floods). As Morford (1995: p.12) demonstrated with past data on peak flows:

“Comparison of the average annual 10 day peak flow volumes for the 1970/93 [i.e., 1970-1993] period with those from 1940/59 reveal that the average volume of the peak flow events did not vary greatly over the 43 year period of record that was reviewed. What this implies is that the geomorphological effects of the 1964 event will still be felt far into the future even if sources of sediment recruitment were reduced to levels approaching those of pre-European times.”

The study of Sloan et al (2001, p 129) confirms Morford’s observations: “Channel widening from extensive bank erosion was the dominant geomorphic change along the lower Eel River during major floods. As a result of the 1964 flood, the largest amount of widening was 195 m and represented an 80% change in channel width. Channel narrowing characterized the periods after the 1955 and 1964 floods. More than 30 years after the 1964 flood, however, the river had not returned to pre-flood width, which suggests that channel recovery required decades to complete. A long recovery time is unusual given that the Eel River . . . has an exceptionally high sediment yield. This long recovery time may reflect highly seasonal precipitation and runoff, which are concentrated in 3–5 months each winter”

While the 1964 flood was a natural event of unprecedented magnitude in the short time Euro-Americans had been in the watershed, its effects were clearly exacerbated by the human-caused changes to the landscape, especially logging. Summerfield et al. (2002) indicate that the recent flood events reflect a climatic shift that increases their frequency. They suggest that on an annual basis about one-third of the sediment being deposited in the ocean off the mouth of the Eel River is of anthropogenic origin, the result of past mass-wasting events that deposited sediment in the river channel. Montgomery et al. (2001) show how logging and associated practices can create the large movements of sediment into coastal rivers.

Timber Harvest Operations

The damaging effects of early logging (timber harvest) operations were recognized by early CDFG biologists working on northern California coastal streams. For example, Shapovalov and Vestal (1938: p.3) noted:

“In addition, considerable lumbering has been carried on and has created additional problems. In practically every stream whose drainage basins have been logged off, log jams that partially or completely block the stream have been found. The lumbering operations have also often created abnormal erosion, causing pools to fill in, spoiling spawning grounds, and tending to hasten the closing of the stream mouths at low water. From the viewpoint of fish life, then, the most important improvement that could be effected in the streams would be the general restoration of natural conditions, by clearing out log jams and accumulations of debris and by uniting the flows at the stream mouths

and keeping the mouths open at low water. It is felt that many more young fish would be produced and would reach the ocean through such measures.”

The increasingly pervasive effects of timber harvest operations were further noted by a U.S. Forest Service and U.S. Bureau of Land Management Report on the North Fork Eel River watershed (USFS-USBLM 1996: p.106), which was the branch of the Eel least affected by logging (Keter 1995):

“Timber harvesting has occurred to an increasing extent in the North Fork Eel River watershed since World War II. Most of the harvesting has been done by clearcutting on private lands. This has probably increased rates of sediment production in some parts of the watershed. Patch cuts that have been made on National Forest lands do not appear to have caused any large mass wasting features, but they may have caused some small debris slides along lower-order streams that have had localized affects [*sic*] on slope stability and erosion processes. There also probably has been increased surface runoff from clearcuts that may have increased sedimentation.”

While this somewhat sanguine point of view on logging may be true for parts of the North Fork watershed, the unrestricted logging--with clear-cutting and hundreds of miles of temporary roads--that took place starting in the late 1940s set up much of the watershed for the huge erosion and mass-wasting events (landslides) that occurred during the periods of heavy rain and high flows (e.g., Montgomery 2001). Improvement in timber harvest regulations in recent decades presumably has reduced the immediate and cumulative impacts of timber harvest in the Eel River and especially on anadromous salmonids. However, present-day logging operations along primary salmonid streams (i.e., the streams which salmonids actually occupy) are probably still consequential as indicated by the inability of most salmonid populations to recover in these streams.

DAMS AND DIVERSIONS

The negative effects of the larger dams in the Eel River system were clearly described by Leo Shapovalov and other CDFG biologists during the 1930s-1940s, who based their assessments on limited quantitative data coupled with extensive field experience throughout the Eel River basin and in other northern California coastal streams. Compared to many other California watersheds, the Eel River system has been subjected to relatively little damming and water diversion but the effects of even a few diversions can have significant impacts—at least from time to time—on certain segments of the anadromous salmonid populations in the system. The lack of large water-supply dams on the Eel River is not from lack of trying. A proposal to build Dos Rios Dam on the Middle Fork Eel River, in order to send the water into the Central Valley, was defeated in 1971 (Simons 1994, Hundley 2001). This action helped to motivate California to create a state Wild and Scenic Rivers act in 1972, which more or less made the Eel River off-limits for such development in the future.

The three largest dams in the Eel River system that were in place (all by the 1930s) and their general impacts were described by Shapovalov (1939: p.18):

“Unlike the Klamath and Sacramento systems, the Eel River watershed as a whole contains no mining and little agricultural development. As a result, there are very few diversions and dams for diversions. Three dams have been erected for purposes of power development: Benbow Dam on the South Fork near Garberville, Cape Horn Dam forming the Van Arsdale Reservoir on the main Eel near Potter Valley, and Scott Dam forming Lake Pillsbury on the main Eel in Lake County. The first two have fishways over them, but Scott Dam has no fishway over it and has cut off some of the best spawning grounds in the entire watershed (Gravelly Valley).”

“The fishways at Benbow Dam and Cape Horn Dam have not functioned in entirely satisfactory fashion in the past. In October of 1938 the Division of Fish and Game made changes to the north fishway at Benbow Dam which has improved matters there to some extent. No King Salmon pass through the fishway at Cape Horn Dam, perhaps partly because the entrance to the fishway does not function satisfactorily at low water. At very high water so much water comes over this dam that many fish are battered on the rocks below, striving to ascend false channels in the rocks. The entrance to this fishway was repaired in December of 1938 by the Division of Fish and Game.”

“A great deal of the natural flow of the Eel River is diverted from Van Arsdale Reservoir to the East Branch of the Russian River. During low water of the dry season this diversion creates very unfavorable conditions for fish in the portions of the river from Cape Horn Dam to the entrance of the Middle Fork at Dos Rios. At this time (usually in September) the effects are also of consequence all the way to the mouth of the Eel.”

“It must be realized that dams simply are not compatible with the maintenance of spawning runs of steelhead and salmon and will prove a greater or less hindrance even when the best possible fishways are constructed over them.”

For the remainder of this section, we focus on the Potter Valley project because it contains two dams that are most likely to affect salmon and steelhead populations (see also Appendix C).

Potter Valley Project

The Potter Valley Project, consisting of Cape Horn Dam, Scott Dam (and Pillsbury Reservoir) and the tunnel connecting the diversion at Van Arsdale to the Russian River, was built in the early 20th century and is currently operated by the Pacific Gas and Electric Company (VTN 1982, SEC 1998). It is the only major water diversion and hydroelectric project on the Eel River. Its potential effects on salmon and steelhead are (1) blockage of access to spawning and rearing areas upstream of Scott Dam, (2) increase in summer flows in the reach between Scott Dam and Cape Horn Dam, where the water is diverted, and (3) decreases in flow in the mainstem river below the diversion.

Assessments of the Project's effects suggest that the direct population impacts on salmonids are not especially strong relative to total salmonid production in the Eel River system (VTN 1982, SEC 1998). The problem, of course is, that dam-related effects are masked in part by the massive legacy effects of past logging and flood events, with little chance of recovery as long as the dams stay in place.

The effects of the Potter Valley Project, located on the upper mainstem Eel River, on Chinook salmon and steelhead utilization of habitats upstream of Scott Dam and Lake Pillsbury were evaluated in a “mitigation study” conducted by VTN Oregon, Inc. (VTN 1982). The study ascertained the amount of habitat that became inaccessible to salmon and steelhead due to the construction of Scott Dam. It estimated that approximately 35 miles of “major channels” were lost to both Chinook salmon and steelhead and another 23 miles of “minor channels” were lost to steelhead and an unknown but small amount were lost to Chinook salmon.

Specifically, VTN (1982: p.291) stated:

“Aerial and ground surveys of current habitat conditions in the Eel River system upstream of Scott Dam, conducted in the last five years, indicate that chinook salmon and steelhead trout are blocked from spawning and rearing in approximately 25 miles of major channels above Lake Pillsbury and 10.5 miles of channels inundated by Lake Pillsbury (Table 3.10-1 and Figure 3.10-1). Steelhead trout have been blocked from an additional 23 miles of minor channels that may have been used above Lake Pillsbury (Table 3.10-2). Major channels include 8 miles of the mainstem Eel River, 11 miles of the Rice Fork, and 6 miles in Salmon and Smokehouse Creeks. Minor channels include

tributaries to the Eel River, Rice Fork, and Salmon Creek. It is possible that chinook salmon could migrate into some of the tributaries included as minor channels, but the length of accessible stream cannot be determined with available data.”

The amount of spawning area upstream of Scott Dam appears to have been limited even before the construction of the dam. Revealing descriptions of potential habitats in the mainstem and tributary reaches of the upper Eel River above Lake Pillsbury were provided by VTN (1982: p.291 and 298).

“The mainstem Eel River upstream of Lake Pillsbury contains mainly rubble, boulder, and gravel substrates (Table 3.10-1). Gravels suitable for spawning occur as isolated pockets (5-20% of streambed area) among the dominant rubble and boulders. Extensive gravel bars, characteristic of the Eel River downstream of Scott Dam, are absent except immediately upstream of Lake Pillsbury. During the 1981 ground surveys, a major barrier falls was observed in the mainstem Eel River, approximately 0.1 mile downstream of Cold Creek. It consists of an old landslide of large boulders, forming a series of falls and multiple channels. Two consecutive, vertical drops of approximately 8 feet form an impassable barrier for all fish migrating upstream. Other barriers may exist in the mainstem, although none were observed during the aerial survey.”

“The Rice Fork contains extensive gravel bars (60% of streambed area) of apparently good quality for spawning in the lower and middle sections (6-8 miles). The channel is constricted in the upper section, and boulder substrates are more prevalent. The upper limit of accessibility is estimated to be Salt Creek, although no barriers were observed during the 1981 surveys.”

“Salmon and Smokehouse Creeks are tributaries to the north side of Lake Pillsbury. The lower reaches of these streams spread out in braided channels over an extensive gravel and rubble flood plain and contain good quality spawning gravel. Upstream areas were not examined; however, judging from topographic maps, each stream is probably accessible to migrating salmonids for several miles upstream of Lake Pillsbury. The greatest potential for a migration barrier is the low gradient multi-channel gravel flood plain that may disperse the streamflow to the extent that there is not adequate water depth for fish to pass.”

Summertime rearing conditions, especially streamflows and temperatures, in the upper Eel River drainage above Scott Dam appear to be suitable for steelhead/rainbow trout as reflected by the following excerpts (VTN 1982: p.298-299), as well as by Kubicek's (1977) earlier observations.

“Summer rearing conditions for steelhead trout appear to be fair in the mainstem Eel River. Streamflows were estimated to be 2-3 cfs. Midday water temperatures in August 1981 were 21.5°C near Trout Creek, 24.0°C below Corbin Creek, and 26.0°C above Cold Creek. Cold Creek entered the Eel River at 19.0°C, lowering the Eel River temperature to 22.5°C; however, the river temperature rose to 26.5°C less than ½ mile downstream. Resident rainbow trout (2-10 inches) were present in most pools, but rarely exceeded more than 5-10 fish in any single pool. The fish observed did not appear stressed by the relatively high water temperatures. Streamside shading by vegetation or large boulders was sparse (<10% of streambed area).”

“Rearing conditions in the Rice Fork appear to be slightly better than in the mainstem Eel River. Estimated streamflows ranged from <1 cfs near Salt Creek to about 2 cfs near Bear Creek. Water temperature was 23.0°C at both locations. Riffle and run areas were more abundant (60-90% of streambed area) than in the Eel River (40-80%), as was

streamside shading by riparian vegetation (10-60%). Rainbow trout were more abundant and larger (up to 12 inches).”

“Cold Creek, Anderson Creek, and Corbin Creek, the three principle [*sic*] tributaries to the mainstem Eel River upstream of Lake Pillsbury, have generally good summer habitat conditions with water temperatures from 15 to 26°C, moderate to dense shading, and rainbow trout common. These tributaries are not accessible, however, due to the barrier falls downstream of Cold Creek. Tributaries downstream of the barrier falls have not been surveyed recently, but due to steep gradients and barriers near the Eel River, they are considered to be unimportant as summer rearing habitat for steelhead trout. Summer habitat conditions in most of the tributaries accessible to steelhead in the Rice Fork appear fair to good with temperatures from 15 to 26°C, sparse to dense shading, and rainbow trout common.”

Judging from very limited information, it appears that the quality of habitat conditions in at least several of the tributaries in the Rice Fork upstream of Lake Pillsbury deteriorated between the time of the CDFG stream surveys in 1938 and subsequent stream surveys conducted during the years 1977-1979 and 1981. Specifically, VTN (1982: p.299) reported:

“Stream surveys conducted in 1938 by CDF&G in the Rice Fork tributaries; Bear, Rice, and Deer Creeks; indicated fair to good conditions with flows of 2-6 cfs, water temperatures of 16 to 20°C, and rainbow trout present. Recent surveys indicate poor to good conditions with less flow (<1 cfs), higher water temperatures (18-25°C), and rainbow trout less abundant. Habitat quality and fish abundance in these streams is evidently lower now than in 1938. If this is typical of general habitat conditions throughout the drainage above Lake Pillsbury, the total carrying capacity has probably declined since the 1930s and since construction of Scott Dam. The magnitude or degree of change cannot be determined, however, due to the lack of adequate historical data.”

However, the overall effect of the Potter Valley Project on salmon and steelhead numbers is difficult to judge. The variety of natural habitat characteristics in the project area resulted in differential impacts both upstream and downstream of the Scott Dam site. As described by VTN (1982: p.300):

“Aquatic habitat conditions in the major channels of the Eel River drainage upstream of Scott Dam vary widely from a narrow, steep, largely rubble and boulder channel in the mainstem Eel River to a broad, low gradient, extensively gravel channel in the Rice Fork. The mainstem Eel River upstream of Scott Dam has no comparable counterpart downstream of Scott Dam. Reach Type 6 of the Eel River (Figure 2.8-1) may have been very comparable under natural flow conditions; however, this reach now receives high sustained flow releases from Scott Dam. The Rice Fork is most comparable to Tomki Creek from Cave Creek to Wheelbarrow Creek. Each has a broad, low gradient channel, and extensive gravel deposits; the major difference is the lack of sustained summer streamflow and slightly less riparian vegetation in Tomki Creek. Salmon Creek, the other major channel area upstream of Scott Dam, is probably most comparable to Soda Creek, just downstream from Scott Dam. The broad, open gravel flood plain in the downstream section of each typically dries up during summer.”

Conditions for salmonids in the upper half of the reach between Cape Horn Dam and Scott Dam improved due to summer flow releases that provide cool water that previously had not occurred, thus benefiting steelhead but not helping Chinook salmon much. However, the loss of access to habitats above Scott Dam had obvious negative effects by eliminating usage of those areas. Rice Fork and Salmon Creek (both upstream of Scott Dam) appear to have been significant producers of Chinook salmon and especially of steelhead, during most years, when adequate stream flows were naturally sustained during summertime.

A brief investigation by a CDFG warden, J Mullin, indicated that the indirect effects from flow regulation and flow reduction on the upper mainstem Eel River upon the migratory behavior and spawning distribution of salmon (and perhaps steelhead) may be more serious than has been generally acknowledged (CDFG memoranda by Warden J. Mullin, dated August 25 and September 12, 1995). Indeed, the multiple effects of altered streamflows in the upper mainstem Eel River were discussed by biologist Morford (1995). Some of Morford's inferences—or “speculation,” as he described it—include the following (Morford 1995: p.2-3):

--“operation of the Potter Valley Project has altered the geomorphology of the upper Eel River by impeding the free flow of sediment through and downstream of Van Arsdale Dam and reservoir.”

--“pre-spawning mortality potential from predation, poaching and delayed migration is significant and is directly affected by hydrological conditions.”

--“in the recent past, Chinook salmon have been unable to successfully reproduce in the mainstem river when streamflow conditions have prevented entry into tributary streams.”

--“annual Chinook salmon access to remaining tributary spawning areas was historically uncertain. This access remains uncertain today.”

--“variants of the fall run Chinook salmon population which used mainstem spawning areas, including the Middle Fork Eel River, have been much reduced in numbers or have been eliminated from the population because of geomorphic changes and other factors.”

--“it is likely that successful Chinook salmon spawning did not occur in the Eel River system for a period of 7 out of 8 consecutive years beginning in 1985 because of delayed navigational flows.”

--“the incidence of reduced flows during Chinook salmon outmigration has increased from 1 year in 4 (25%) during the 1940's and 1950's to about 3 years in 5 (57%) during the 1970's and 1980's.”

--“it is likely that successful Chinook salmon out migration did not occur in the Eel River system for a period of 8 out of 9 consecutive years beginning in 1984.”

--“mammal predation has generally increased in the recent past with perhaps 35-40% of escapement showing marks indicating encounters with river otter, bear and other mammals. In the upper Eel River, mammal predator population increases are especially notable. Observations of mammal predation suggest that predation success increases during low flow periods.”

--“recent geomorphic and hydrological changes in the upper Eel River have favored the establishment and proliferation of a robust introduced fish predator population e.g., the Sacramento River squawfish [pikeminnow].”

--“that minor changes in the operation of the Potter Valley Project during periods important for upstream and downstream [C]hinook salmon migration could mitigate effects of natural streamflow variation.”

Furthermore, the loss of salmonid habitat upstream of Scott Dam means that there are fewer areas to serve as refuges for salmon and steelhead and to contribute to population production during environmentally unfavorable periods such as extended droughts.

Prior to the Potter Valley Project (i.e., before 1922), Chinook salmon spawner numbers (“escapements”) in the upper mainstem Eel River upstream of the mouth of Outlet Creek--i.e., the Potter Valley Project and upstream areas--were estimated to have been almost 10,000 fish (SEC 1998). That number was inferred by using historical cannery records for the total Eel River commercial harvest and dividing up the total catch for different portions of the Eel River watershed based on the spatial distributions of spawners among subbasins that were observed in later spawning surveys. The 10,000 fish estimated for the upper Eel River is probably lower than the historical maximum spawner numbers because the historical cannery records represented numbers for exploited populations—i.e., populations under harvest that already were reduced from their former levels.

Overall, while the dams on the upper mainstem Eel River have had undeniable negative effects on streamflows and salmonid populations, the exact degree and significance of the population impacts requires more careful, independent evaluation. In particular, a thorough, independent evaluation is needed to determine if the enhanced summer flows between the two dams cause an increase in salmon and steelhead survival that compensates for the loss of habitat upstream of Scott Dam.

INVASIVE FISHES

The Eel River has been invaded by at least 10 alien fish species (Table 1). Two of the species, from neighboring watersheds, are abundant and widespread--viz., the California roach and Sacramento pikeminnow (Brown and Moyle 1997). However, only the introduction of the pikeminnow has caused concern. The Sacramento pikeminnow is a large piscivorous minnow native to the California Central Valley that was illegally introduced into the Eel River sometime in 1979 or 1980. Their subsequently rapid invasion of much of the Eel River system has posed perhaps the most profound ecological challenge (aside from humans) to the native anadromous salmonids within the past century or more. The pikeminnow become increasingly piscivorous as they grow larger and can consume substantial numbers of juvenile salmonids and other fishes (Brown and Moyle 1997, Moyle 2002).

As noted by SEC (1998: p.5.11-2),

“The recent colonization of the Eel River by *P. grandis*, accompanied by their rapid population growth, basin-wide range expansion, and a simultaneous decline in salmonid populations, has resulted in a considerable interest on the part of resource agencies, decision makers, and special interest groups. The sense of urgency echoed by this response assumes that the presence of this predatory species will further impact salmonid fisheries which have already experienced significant declines during the past 50 years.”

The SEC (1998) report concluded, however, that more extensive time-series data are needed on salmonid population abundance (and, presumably, on pikeminnow abundance) and environmental factors including ocean conditions in order to correctly evaluate the interactions of all those variables. Nonetheless, there is little reason to doubt that pikeminnow have a major negative effect on the distribution and abundance of steelhead, Chinook salmon, and other fishes in the Eel River (Brown and Moyle 1991, Brown and Brasher 1995, Moyle 2002). Their effect occurs both through predation and through competition (White and Harvey 2001, Reese and Harvey 2002). Their effect may be especially strong when salmonid populations are low, making it difficult for the salmonids to recover.

V. DISTRIBUTION OF ANADROMOUS SALMONIDS THE EEL RIVER SYSTEM

The distribution of salmon and steelhead in the Eel River basin has not changed as much as their abundance, although many populations are now missing. In this section we discuss the occurrence of the three major anadromous salmonids in the mainstem Eel River and subbasins in more detail. This section is based largely on the reviews and data in CDFG's Restoration Action Plan (CDFG 1997), the Berg Associates' (2002) Biological Assessment of the effects of gravel mining operations on salmonids, and the NMFS Status Review of Chinook salmon (Myers et al. 1998). The CDFG Restoration Action Plan, in particular, identified the runs (stocks) of anadromous salmonids and their spatial distributions within each of the Eel River subbasins. The Restoration Action Plan also summarized the habitat-related problems facing the various runs—e.g., flood-related sedimentation of pools and riffles and consequent changes in water temperatures, dissolved oxygen levels and supply of food organisms; grazing and timber harvest practices that lead to deterioration of fish and riparian habitats. In this section, we discuss the general distribution patterns of Chinook salmon, coho salmon and steelhead, then their patterns of use by major regions and sub-basins: (1) the delta and estuary, (2) lower mainstem, (3) upper mainstem, (4) North Fork, (5) Middle Fork, (6) Van Duzen, and (7) South Fork. We conclude with a summary of the findings of Becker and Reining (2009) on the historic and present distribution of steelhead in the basin.

General Distribution

Fall-run Chinook salmon historically occurred in all the principal subbasins of the Eel River system. Based on information obtained from interviews with local residents, it appears that spring-run Chinook salmon occurred at least in the North Fork Eel River (Keter 1995, USFS-USBLM 1996: p.104). There is little, if any, information on the occurrence of spring-run Chinook salmon in other Eel River subbasins but it is likely that they historically entered the South Fork Eel River and perhaps also the Middle Fork Eel River.

Coho salmon utilized mainly the South Fork Eel River and Van Duzen River (Brown and Moyle 1991a, 1991b, Brown et al. 1994), although they also occurred in the upper part of the mainstem Eel River as far as Ryan Creek (NMFS 2001) and they were recorded at the Van Arsdale Fish Station (Berg Associates 2002) at least in occasional years. There also are past reports of coho salmon utilizing the lower mainstem and tributaries of the Middle Fork Eel River (CDFG 1997).

Winter steelhead were originally distributed throughout the Eel River system and summer steelhead had viable populations in the Middle Fork Eel River and Van Duzen River. They have been reported as using "large areas" of the Eel River drainage for spawning and rearing (Nielsen and Fountain 1999). Summer steelhead in the Middle Fork Eel River have constituted one of the most significant (i.e., viable) summer steelhead populations in California (CDFG 1997). Summer steelhead reportedly also occurred in the North Fork Eel River (Moyle et al. 1995), but apparently they have been extirpated from there in recent years.

Little is known of the sea-run cutthroat trout although apparently they have always been mainly confined to the Eel River estuary, with a permanent population in the tributary, Salt Creek (Moyle 2002). Berg Associates (2002) indicated that limited numbers of sea-run cutthroat trout entered the Van Duzen River but if so, they probably utilized only the lowermost portion of the watershed.

CDFG (1972) provided the following descriptions and distributional information for the three primary anadromous salmonid species as of 1972.

"King [Chinook] Salmon. Eel River king salmon are fall-run fish. Adults begin to enter the river in late August and the run reaches a peak in October and early November. Low streamflow prevents early run fish from migrating upstream much beyond tidewater. These fish lie in the pools and estuary below Fernbridge until the first large storm raises the river sufficiently to permit upstream migration. This pattern may be repeated several times during the season with waves of fish moving upstream following each storm."

“Salmon reach the upper portions of the Eel River in October or November, depending on the rainfall pattern. The run reaches a peak in the Dos Rios area in November or December and continues on into January.”

“King salmon spawn in the main river as well as in the major tributaries. Many of the minor tributaries are also used for spawning; however, during dry years, low streamflow may prevent salmon from ascending these smaller streams.” (CDFG 1972: p. 38)

“Silver [coho] Salmon. In the Eel River the silver salmon spawning migration is of short duration. The run starts in mid-October, reaches a peak in November, and tapers off in December. Spawning is predominantly confined to the South Fork and lower tributaries of the main Eel and Van Duzen Rivers. Silvers are not known to migrate in the main Eel to above the confluence of the North Fork.” (CDFG 1972: p.39)

“Steelhead. Steelhead spawn in the main river and in most of the smaller streams and tributaries throughout the Eel River drainage.”

“Steelhead exhibit variable life cycles with fish of many life history categories making up the spawning run. First spawners usually compose from 55 to 95 percent of the spawning run in California streams (Shapovalov, 1967). These first-spawners are usually 3 or 4 years old and have spent from 2 to 3 years in freshwater and from 1 to 2 years in the ocean.”

“Steelhead enter the Eel River in varying numbers throughout the year. Most are winter steelhead which enter the river from November through April. These fish spawn within the same season, generally during February, March, and April.”

“A small run of summer steelhead usually enters the river from March to the end of June. These fish migrate to the upper reaches of the Middle Fork and Van Duzen rivers where they remain until the following spring when they spawn. The Eel River also receives a significant run of “half-pounders”, which are young steelhead that have been to sea for a brief period and have returned to fresh water. These fish are from 9 to 11 inches long and usually are sexually immature (Murphy and DeWitt, 1951; Kesner and Barnhart, 1972).” (CDFG 1972: p.40-41)

Eel River Delta and Estuary

The Eel River delta and estuary provides habitat, or at least a migratory conduit, for Chinook and coho salmon, sea-run forms of rainbow trout and coastal cutthroat trout, green sturgeon, non-native American shad, and Pacific lamprey (Monroe et al. 1974: p.52-55). The Eel River delta, which merges with the estuary, extends from Grizzly Bluffs and the confluence of the Van Duzen and Eel rivers in the east, north of the Wildcat Ridges and south of Table Bluff. Historically, the delta included about 50 square miles of depositional habitat through which the main river meandered or flooded (CDFG 1997). The Eel River Estuary is the fourth largest estuary in California and supports (or supported) a diversity of habitats: tidal marshes, eelgrass meadows, tidal flats, large open areas with sand, mud and gravel bottoms, and mud, sand and rock beaches. It is usually divided into three ecologically distinct areas: Eel River mainstem, North Bay and Salt River which are regarded as part of the adjacent Humboldt Bay system (<http://groups.ucanr.org/HumboldtHabitatGoals/>). The three areas include sloughs and side channels in the lower 6.8 miles of the Eel River below the small town of Fernbridge (which frequently floods). Estuarine habitat today covers somewhat less than 4 square miles, an area that reflects about a 60% reduction in habitat due to diking and draining for agriculture, as well as from increased sedimentation from the river (SCS 1989). Historically, the delta and estuary were undoubtedly of major importance for the rearing of juvenile salmon and steelhead, as are other Pacific coast estuaries. This function appears to have been largely lost, although it is also poorly studied.

Lower Mainstem Eel River

Chinook and coho salmon and steelhead at least transiently occupy the mainstem Eel River and associated tributaries, using the area primarily as migration corridors. However, it is possible that Chinook salmon and steelhead more substantively occupy the middle mainstem Eel River area during seasons when water temperatures are low. Berg Associates (2002: p.109) stated:

“Chinook salmon and steelhead are known to be seasonally distributed throughout the assessment area (middle mainstem Eel River) and connecting tributaries. Coho are known to use the assessment area as a migratory corridor and therefore may also be seasonally present. Coho usage of the mainstem Eel River and tributaries entering the assessment area is currently unknown but thought to be limited based on CDFG tributary sampling for coho that was conducted in 2000. The Van Arsdale Dam operations [i.e., Cape Horn Dam] reported coho adults during the 2001/2002 winter. These fish had to have passed through the assessment area in order to reach Van Arsdale. If these fish produce offspring, they will need to pass through the assessment area during their downstream migration to the ocean. High summer water temperatures most likely exclude coho, chinook, and all but the hardiest steelhead from the mainstem Eel River during the summer and fall months (June through September). Salmonids are known to over-summer in the cooler waters of the tributaries.”

The CDFG’s Fish and Wildlife Plan (1965c) presented the following spawning escapement estimates (educated guesses) for the mainstem Eel River: 13,000 Chinook salmon, 500 coho salmon and 10,000 steelhead (seasonal runs of steelhead were not specified). In the Status Review Update for coho salmon, NMFS (2001: p.12) stated:

“A final tributary to the main fork of the Eel River, Ryan Creek has been surveyed by the California Department of Fish and Game since 1986. Coho salmon were found in modest numbers in 1988 and 1989, and lower numbers in 1992. However, no fish have been captured at this site [i]n the last eight years [up to 2001] (Scott Harris, CDFG, unpubl. data)”.

It is likely that prior to the heavy sediment-depositing flood events of the past 50 years, the mainstem and its lower tributaries supported some year around rearing of juvenile salmon and steelhead, especially if there were extensive areas of groundwater upwelling and shady riparian areas. Today, its main importance seems to be as a highway to move fish up and down from the estuary and ocean.

Upper Mainstem Eel River

There is no sharp boundary between the upper and lower mainstem Eel River, but historically, the upper mainstem had more spawning and rearing habitat, including deep bedrock pools that thermally stratified or received inflow of cool sub-surface water. But access to suitable upstream areas seems to have become a major limiting factor for salmon.

According to Morford (1995: p.8), “For several years running, chinook salmon have been unable to navigate Tomki and Outlet Creeks, streams once important for spawning. Estimates of recent spawning populations (1960’s and 70’s) in these creeks range up to 2,000 and 3,000 fish respectively.”

Data from counts of up-migrating adult Chinook salmon at the Van Arsdale Fish Station (Cape Horn Dam) are limited but they provide a rough sketch of the numbers of fish reaching that point during some years of the 1940s-1960s period (Table 4, Taylor 1978, his Table 2).

Regarding the mainstem reach between Scott Dam and Van Arsdale Reservoir, Kubicek (1977:116) noted:

“Shapovalov (1945) stated that Eel River between Scott Dam and Van Arsdale Reservoir was one of the most productive stream sections in California. He reported that

this section was heavily populated by juvenile steelhead and resident rainbow trout of large size. A fish ladder exists at Cape Horn Dam, allowing anadromous species to utilize this stream section. Fish counts at Cape Horn Dam indicate that steelhead spawn in this area in all years, chinook salmon in some years, and coho salmon not at all. In fact, coho salmon are not known to utilize the Eel River above the Middle Fork (California Department of Fish and Game 1965a).”

Kubicek (1977:117-118) also remarked upon the flows below Cape Horn Dam (Van Arsdale Reservoir):

“Almost the entire streamflow entering Van Arsdale Reservoir is diverted to Potter Valley and the Russian River system during summer; flows at Potter Valley parallel those at Scott Dam (USGS 1961-1963 and 1964b, 1972b). Therefore, flows in the Eel River below Cape Horn Dam are limited.”

“Although this stream section is classified as marginal, thermally stratified pools with satisfactory bottom temperatures do exist. DWR [Department of Water Resources] monitored surface and bottom temperatures in two 10-foot deep pools above Tomki Creek from July 18 to August 8, 1973. Although surface temperatures were marginal on 7 days, bottom temperatures indicated a satisfactory habitat (21.0-24.5[°C]) during normal summer flows. To determine the effects of streamflow on the vertical stratification of temperature, flows of 5.6 (normal summer flow), 22, 40, and 83 cfs were released from Cape Horn Dam during this period. As flows increased, thermal stratification broke down, and bottom temperatures increased. Bottom temperatures became the same as warm surface temperatures at 22 cfs in one pool and 40 cfs in the other. Under present conditions, normal low summer flows prevent the mixing of warm surface and cool bottom waters in deep pools during warm afternoons and, thus, are important in maintaining areas of satisfactory habitat for salmonids between Cape Horn Dam and Tomki Creek. A few springs were noted entering this stream section which may indicate that cool bottom water in some pools is supplied by spring flow.”

Hence, the low seasonal flows and warmer temperatures generally afforded limited suitable habitat for salmonids below Cape Horn Dam during the summer. Kubicek (1977:120) reported:

“Juvenile steelhead up to 7 inches in length were abundant in the pool immediately below Cape Horn Dam during all three sampling periods; this pool was particularly well shaded and offered a suitable habitat. However, few steelhead were observed in the rest of this stream section. Local residents reported observing some juvenile steelhead in a few of the deeper pools.”

Coho salmon reportedly have occurred in the upper mainstem Eel River, references to which were given by Mullin (memo., August 25, 1995: p.2):

“Arrival of Coho salmon in the upper reaches of the Eel River peaks in November-December. According to Brown and Moyle (1991a), Coho salmon occurred historically in the upper mainstem Eel River drainage as far up as Indian Creek and Tomki Creek and several of its tributary streams. Grass (1990) states that during the 1946-47 season, (47) Coho salmon were recorded passing through the Van Arsdale Fish Facility located 2.7 miles upstream of the mouth of Tomki Creek, but have not been recorded since. Coho salmon presently occur in the upper mainstem Eel drainage as far up as Outlet Creek drainage. These stocks represent the longest run of Coho salmon in California. (W. Jones, Dec.) (DFG ‘Petition to the Board of Forestry to List Coho Salmon’ 1994).”

Annual counts at Cape Horn Dam provide data on adult winter steelhead over a time period from the 1930s to early-1990s (Tables 4 and 5, Taylor 1978, his Table 2, McEwan and Jackson 1996, their Table 3). Those data showed a general decline of the upper mainstem steelhead populations from about 4,400 during the 1930s to about 1,000 during the 1980s (McEwan and Jackson 1996).

North Fork Eel River

There are indications that at least one run of Chinook salmon, two steelhead runs (spring and winter runs) and a Pacific lamprey run historically occurred in the North Fork Eel River. Information on historical fish stocks was compiled by Keter (1995) from interviews with knowledgeable local people. That information is summarized as follows (from USFS-USBLM 1996, based on Keter 1995).

(USFS-USBLM 1996: p.103-104):

“Coho (*Oncorhynchus kisutch*) - There is no evidence that coho existed in the North Fork of the Eel River.”

“Chinook (*O. tshawytscha*) – A spring and fall run of chinook may have been present in the North Fork. Spring chinook, but not fall, were observed prior to 1964. There is no evidence chinook were ever present above Split Rock.”

“Steelhead (*O. mykiss*) – Two runs of steelhead may have been present, a winter and spring run. Based on interviews, the spring run was dominant. It is estimated that the number of steelhead, prior to 1860, was approximately 6,930 fish (based on 150 fish/mile). Numbers may have been higher historically due to better habitat conditions.”

“Resident rainbow trout (*O. mykiss*) – This species is present throughout the watershed, averaging six-to-ten inches, with an average adult length of six inches.”

(USFS-USBLM 1996: p.107):

“Chinook – No chinook have been observed above Split Rock in recent surveys. However, a jaw was found at the mouth of Cox Creek in 1980. Asbill Roughs and Split Rock may be a barrier to migrating adult chinook salmon.”

“Steelhead – The winter steelhead run is the most dominant anadromous fish run in the North Fork Eel River, but data are not available to estimate current population size. Isolated sightings of summer steelhead occurred as late as 1990 (USDA Forest Service 1967-1992), but overall the run is in danger of extinction (Higgins et al., 1992). Red Mountain Creek and West Fork of the North Fork of the Eel River contained the highest average densities of one and two-year old steelhead per pool of all tributaries surveyed in 1995 (Thornburgh, 1995).”

“Pacific Lamprey – Lamprey have decreased in number along with salmonids. Spawning sites noted in surveys conducted from 1967 to 1992 indicate the presence of lamprey in the watershed.”

“Resident rainbow trout and Sacramento sucker – Current population size and distribution of these species within the watershed is unknown.”

Hence, there is evidence for the historical occurrence of at least spring-run Chinook salmon, “spring-run” (i.e., summer) steelhead and almost certainly winter steelhead, given that winter steelhead recently have been the “most dominant” anadromous fish present in the North Fork Eel River. Other sources indicate the predominance of winter steelhead (sometimes called

“fall-run” steelhead) during most of the past (20th) century in the mainstem Eel River and Middle Fork Eel River (McEwan and Jackson 1996).

Given the fact that fall-run Chinook salmon are—or were, until recently—broadly distributed in the Eel River system, they probably historically occurred in the North Fork Eel River, although coho salmon were absent (USFWS 1996).

Kubicek (1977: p.149) observed:

“Salmon are blocked near the mouth of the North Fork by a natural barrier (California Department of Fish and Game 1965a); therefore, steelhead and/or resident rainbow trout are the only salmonids found in all but the lower few miles of the North Fork. During the summer of 1973, trout were only observed in areas of cool spring upwelling or cool tributary inflow.”

Morford (1995: p.8) stated:

“Besides the mainstem Eel River, Chinook salmon spawning occurred in the lower mile to mile and one half reach of the North Fork, Eel River. They have never been reported, as far as can be determined, upstream from that location.”

CDFG (1965c) estimated the number of spawners using the North Fork during 1960-64 to be as follows: zero Chinook salmon, zero coho salmon and 5,000 steelhead (no seasonal runs of steelhead were specified). Curiously, in 1997, CDFG (1997: p.32) stated that ,steelhead -- as well as resident native rainbow trout—utilized the length of the North Fork Eel River from its confluence with the mainstem “to the headwaters near Kettenpom, Zema, and the Hettenshaw Valley [river mile 35].” The report noted that Chinook salmon were restricted to the North Fork below Split Rock (rm 5), which apparently presented a migration barrier . However, Chinook salmon and spring-summer steelhead likely surmounted that barrier in the past according to ”historic reports” (CDFG 1997). Overall, Chinook salmon population levels in the 1990s were considered to be “severely depressed” in the North Fork Eel River subbasin, and steelhead numbers also were “well below historical levels” (CDFG 1997: p.33).

Middle Fork Eel River

The Middle Fork Eel, with its accessible headwaters high in the Coast Range, has always been important for salmon and steelhead. Today it is the main refuge for the endangered summer steelhead, which may be down to just a few hundred fish (Moyle et al. 2008).

Morford (1995: p.8) stated:

“... Chinook salmon were historically abundant in the Middle Fork Eel River. Their numbers were reported to be about 10,000 fish in the late 1950’s by the U.S. Fish and Wildlife Service. By the mid 1980’s, those numbers had declined to about 100 fish and were still fished for by the local Native American community. Members of the Covelo Indian Community recently have reported that chinook salmon have not been observed in the Middle Fork Eel River, Williams Creek and/or Round Valley streams since about 1988.”

The CDFG’s Fish and Wildlife Plan presented the following spawning escapement estimates for the Middle Fork Eel River during the early- to mid-1960s (CDFG1965c, their Table S3): 13,000 Chinook salmon, zero coho salmon and 23,000 steelhead (seasonal runs of steelhead were not specified). The summer steelhead run in the Middle Fork Eel River has been documented by CDFG fish counts (McEwan and Jackson 1996). The available counts for the years 1977-1993 range from lows of 377 fish (for 1977-1978; presumably over-summering fish in 1977 that spawned during 1978) and 449 fish (for 1990-1991) to highs of 1,550 fish (1987-1988) and 1,601 fish (1981-1982)).

Kubicek (1977: p.129) reported that during a stream survey in the summer 1973, “24 adult summer steelhead were observed in the 2-mile stretch from Osborn Station to Hellhole

Canyon” and that “During the July sampling period, juvenile steelhead and/or resident rainbow trout up to 10 inches in length were abundant in the Osborn Station area.” Furthermore, Kubicek (1977: p.129) stated:

“... Smith and Elwell (1961) reported that summer steelhead and the greatest abundance of juvenile steelhead in the Middle Fork were concentrated above Osborn Station in 1959. Steelhead ascend at least the lower two-thirds of this stream section; chinook salmon ascend the Middle Fork up to a point near the lower boundary of this section; and coho salmon are not known to utilize the Middle Fork drainage (California Department of Fish and Game 1965a). A resident rainbow trout population is distributed throughout most of the Middle Fork, but the precise distribution and size of this population is unknown (Smith and Elwell (1961).”

The CDFG (1997: p.34) stated that anadromous salmonids—specifically spring-summer steelhead and winter steelhead--as well as native rainbow trout utilized the Middle Fork Eel River between its confluence with the mainstem Eel River up to the headwaters in the Yolla Bolly mountains (rm 70). Chinook salmon and winter steelhead evidently are restricted to the reaches below the Black Butte River confluence (rm 32). Coho salmon were reported to have occurred in the past in the lower reach and in tributaries of the Middle Fork (CDFG 1997). A relatively large stock of summer steelhead occurs in the Middle Fork Eel River and, during the summer low-flow period, those fish become concentrated in the upper, cooler reaches of the subbasin (CDFG 1997). Recent fish counts indicated that summer steelhead numbers have been at “depressed levels” (CDFG 1997). Similar to other Eel River subbasins, fish count data indicate “severely depressed” population levels of Chinook and coho salmon and winter steelhead numbers are “well below historical levels” (CDFG 1997: p.34).

Van Duzen River

The CDFG presented the following spawning escapement estimates for the Van Duzen River subbasin during the early- to mid-1960s (1965c, their Table S3): 2,500 Chinook salmon, 500 coho salmon and 10,000 steelhead (seasonal runs of steelhead were not specified). The CDFG (1997) stated that the most serious declines in salmon and steelhead stocks in the Van Duzen River subbasin occurred in the aftermath of the record 1955 and 1964 floods. CDFG fish counts for the 1990s “suggest that chinook and coho salmon populations are severely depressed in some Van Duzen tributaries” and “Steelhead numbers are also well below historic levels” (CDFG 1997: p.29).

In a Biological Assessment of the effects of gravel mining operations on anadromous Pacific salmonids, Berg Associates (2002) indicated that the Van Duzen River at that time was utilized by fall-run Chinook salmon, winter-run and summer-run steelhead, and limited numbers of coho salmon and sea-run cutthroat trout, although record of cutthroat trout may be an error. Berg Associates (2002: p.92) stated that steelhead were the most abundant anadromous salmonids, with the winter run being “the most numerous and widespread” of the two steelhead runs. The summer-run steelhead mostly over-summered in deep pools in the mainstem Van Duzen River between Bridgeville (rm 31) and the confluence of the South Fork Van Duzen River (rm 45), with spawning and rearing occurring primarily in the South Fork Van Duzen River (Berg Associates 2002, citing Hadley 2001).

The anadromous salmonids were limited to the lower one-third of the Van Duzen River watershed with the uppermost migration barrier being Eaton Rough Falls at river mile 46 (CDFG 1997). Berg Associates (2002: p.92) cited CDFG surveys that documented Chinook salmon spawning in many of the larger tributaries of the lower watershed, including Hely, Cummings, Root, and Grizzly creeks with a combined annual run numbering 2,500 fish after the floods of 1955 and 1964. However, the stated number (2,500) of Chinook salmon spawners very likely underestimates the earlier historical abundance of salmon due to the destructive effects of those great floods.

The Berg Associates' (2002) assessment comports with an earlier synopsis by the CDFG in regard to the spatial distribution of salmon and steelhead in the Van Duzen River (Horton and Rogers 1969: p.4):

“Salmon are unable to reach the upper river drainage because of a natural barrier 37 miles above the mouth. This is also a partial barrier to steelhead, and in some years may be a complete block, depending upon the water discharge when the fish arrive. Eaton Rough Falls, 46 miles above the mouth, is a complete barrier to all anadromous fish except the Pacific lamprey.”

“Summer-run steelhead are especially restricted since they arrive later in the spring when high flows are descending. These fish rest in deep pools during the summer months between Bridgeville and the confluence with the South Fork Van Duzen [River]. They may use the South Fork, since a few were observed in 1967 and 1968 in the main stem just below the confluence. They were reported in the South Fork prior to the formation of the lower barrier on the main River.”

“We observed winter-run steelhead in Yager, Cummings, Hely, Root, Grizzly, Fish, Hoagland, Brown, and Little Larabee creeks and the South Fork Van Duzen located 5, 7, 14.4, 18.7, 22.0, 26.5, 29.7, 30.6, 31.7, and 45.0 miles, respectively above the mouth.”

“King salmon were observed in the main river, Root and Grizzly creeks, while silver salmon utilized Cummings and Yager creeks.”

“Resident trout occupy the headwaters above the confluence of the South Fork Van Duzen and above barriers located on a few of the smaller tributaries.”

“The average annual abundance of spawners in the Van Duzen River system is estimated at 2,500 king salmon, 500 silver salmon, and 10,000 steelhead (Calif. Fish and Game, 1965). We estimate there are 100 to 300 summer-run steelhead annually.”

South Fork Eel River

Anadromous salmonids that historically utilized and continue to occur in the South Fork Eel River subbasin include Chinook salmon, coho salmon and steelhead. The South Fork has the advantage of being in the coastal fog belt, which keeps it cool in summer and helps to make many of the small tributaries permanent cold-water streams. The CDFG's Fish and Wildlife Plan presented the following spawning escapement estimates for the South Fork Eel River during the early- to mid-1960s (CDFG 1965c, their Table S3): 27,000 Chinook salmon, 13,000 coho salmon and 34,000 steelhead (seasonal runs of steelhead were not specified).

Counts of salmon and steelhead passing up the Benbow Dam fish ladder had been conducted starting in 1938. As stated by Taylor (1978: p.8):

“... Though counts at Benbow Dam represent a small proportion of the total populations spawning in the Eel River system (about 5% of the king [Chinook] salmon and 25% of the silver [coho] salmon) they constitute the best long-term information available on Eel River runs.”

Annual counts of adult steelhead at Benbow Dam documented the presence of winter steelhead and their declining population trend in the South Fork Eel River (Taylor 1978, McEwan and Jackson 1996). Average counts over almost four decades showed a constant decline: i.e., 18,800 fish (for the 1940s), 12,800 (1950s), 6,700 (1960s) and 3,400 (1970-1975) (McEwan and Jackson 1996).

Taylor (1978: p.8-9) further noted:

“The numbers of salmon passing Benbow Dam have declined dramatically since counting was begun. Average counts during the first 10 years of operation (1938-1947) were 11,869 king salmon and 14,327 silver salmon. During the last 10 years (1966-1975) average annual counts were 4,714 king salmon and 1,846 silver salmon. The most recent of these counts indicate that king salmon runs are relatively stable but silver salmon runs are continuing to decline. In 1975 only 509 silver salmon were counted past the dam.”

The salmon and steelhead stocks in the South Fork Eel River experienced their most serious population declines following the 1955 and 1964 floods (CDFG 1997). Even several decades later, however, it was reported that fish counts were suggestive of severe population depression of Chinook and coho salmon in some South Fork tributaries and that steelhead numbers “are also well below historic levels” (CDFG 1997: p.31).

Although historical salmonid population records are provided by counts of adult fish at Benbow Dam on the South Fork Eel River from the late-1930s to 1970s, there are no comparable data for the most recent decades. As further summarized by NMFS (2001: p.12):

“Numbers of adult coho salmon at Benbow Dam showed a long and general decline from an average of more than 13,000 fish in the 1930s and 1940s (range 7,327 to 25,289) to about 5,700 fish in the 1950s and 1960s (range 1,289 to 14,316), to fewer than 1700 fish in the 1970s (range 509 to 3,993) before the dam and counting facility were removed”.

There was a dramatic coho population increase in the South Fork Eel River indicated by the counts in 1962 and 1963, as was similarly observed for coho salmon counts conducted at Sweasy Dam on the Mad River (NMFS 2001). More current population data for coho salmon in the South Fork Eel River are represented by summer survey counts of juvenile coho. Specifically, NMFS (2001: p.12) reported:

“Summer surveys of coho salmon juveniles have been conducted in a number of index reaches in the South Fork Eel River drainage by both private landowners and California Department of Fish and Game. Data from these surveys indicate no obvious trends in abundance (Figure 26). The 1996 and 1997 year classes were relatively strong, as was the 1999 year class. The 1995, 1998, and 2000 year classes were comparatively weak.”

“A longer-term data set from two sites in Hollow Tree Creek, a tributary to the South Fork Eel River, indicates a somewhat different pattern. As was seen in Mendocino County, a general decline in abundance has been observed since the late 1980s (Figure 27), and numbers in 1998 through 2000 are lower than for the rest of the 1990s. There is some suggestion in the data that the 1995/1998 brood lineage is the weakest in the South Fork Eel and its tributaries.”

During the summer 1973, Kubicek (1977: p.161) observed “six trout over 20 inches in length” in two pools located two miles below Elder Creek which he considered “could possibly have been summer steelhead.” Kubicek (1977: p.161-162) also noted:

“... Elwell (1965) stated that some of the best nursery areas for juvenile salmonids in the South Fork are found in this stream section. He reported that young steelhead were far more abundant in this stream section (excluding approximately the lower 2 miles) than in any other portion of the South Fork which he surveyed.”

Presently, the South Fork Eel River contains salmonid habitats with varying degrees of suitability (i.e., for spawning, rearing and adult holding) depending on location and seasonal factors. For example, low streamflows in the lower mainstem Eel River during the summer and fall can prevent salmonids from ascending to more favorable upriver areas, including the South Fork (Berg Associates 2002).

“Overall, the salmonid populations in the South Fork Eel River declined steadily during the 20th century. The population declines have been attributed to land management activities, drought, ocean conditions, and proliferation [o]f non-native fish species, aside from the devastating effects of the 1955 and 1964 floods (Berg Associates 2002: p.118). The invasion of Sacramento pikeminnow into the South Fork Eel River has been noted as a potentially significant mortality factor contributing to the population decreases of the native salmonids (Berg Associates 2002, citing CDFG 1996) and perhaps also of other native fishes such as sculpins (Berg Associates 2002, citing White and Harvey 2001).”

Steelhead: the CEMAR study.

A comprehensive evaluation of the historical and current distributions of steelhead-rainbow trout in the Eel River system was recently completed by the Center for Ecosystem Management and Restoration (CEMAR). Their literature survey comprised determinations of the known, probable or possible, and unknown distributions—both historical and current—of steelhead-rainbow trout for individual streams in each of the major subbasins of the Eel River watershed (Becker and Reining 2009; the report is available at the CEMAR website, www.cemar.org). The detailed review of steelhead and rainbow trout distributions and extensive archive of source documents in the CEMAR report corroborate and augment the coarser-scale picture for steelhead that we provide in our present report. Future CEMAR studies may provide similar distributional information on salmon species in the Eel River.

The CEMAR survey found that some information on steelhead was available for 558 tributary streams in the Eel River basin (Becker and Reining 2009). Of that number, there was definite evidence that 463 streams (designated as DF streams) historically supported steelhead runs or populations, 17 other streams (PB streams) probably historically contained steelhead, and another three streams (PS streams) possibly had steelhead runs or populations. Additionally, there were 37 streams in which steelhead historically were possibly absent (PA streams) and 39 streams (UN streams) for which there was insufficient information to draw conclusions on historical occupancy.

For the current distribution status (i.e., within the past 15 years) of steelhead-rainbow trout, the CEMAR survey found 332 streams that definitely support runs or populations (i.e., there are presently 332 DF streams, or 72% of the historical DF streams), 17 streams (PB streams) that probably support runs or populations, and six streams (PS streams) that possibly contain them. Nineteen study streams (PA streams) have no evidence of current steelhead-rainbow trout populations, and 186 streams (UN streams) are of uncertain or unknown status. The CEMAR report also stated that there was sufficient evidence to conclude that 163 (or 35%) of the 463 historical DF streams are currently capable of supporting steelhead. Becker and Reining (2009: p.334) conclude:

“... It is possible, then, that more than half of the known historical steelhead streams (i.e., streams with historical DF status) in the Eel River watershed no longer support steelhead reproduction, although an unknown number of stream-based *O. mykiss* populations may continue to produce smolts. However, the paucity of recent monitoring data suggests against over-interpretation of the finding regarding anadromy.”

There was limited reliable information on population levels for individual streams. The available evidence indicated that in 123 streams (22% of the total study streams) there had been population declines of steelhead-rainbow trout, although this probably underestimates the true situation due to the lack of data for many streams (Becker and Reining 2009).

To illustrate some of the information from the CEMAR survey, we present several notable examples pertaining to summer steelhead below.

South Fork Eel River

[Becker and Reining (2009: p. 77)]:

“Staff from DFG surveyed several areas of the South Fork Eel River from 1938 through 1941. “Good” spawning areas and “excellent” pools and shelter were noted in several areas during these surveys and juvenile steelhead were present (DFG 1938b, DFG 1938c). A 1938 DFG survey report notes logging impacts on the South Fork, “Large sections of the stream banks are caved in with gravel bars over-grown with willows forming large, silt covered still pools more favorable to catfish and sunfish than to trout and salmon. Formerly large redwoods (as judged by stumps) came right to rivers edge and held the banks firm. Now, there are greater floods, higher temperatures, poorer oxygen, and lower water in summer” (DFG 1938d).”

[Becker and Reining (2009: p. 78)]:

“In a 1992 report on the distribution of summer steelhead, Weldon Jones described observations of summer steelhead that took place in the South Fork Eel River from the 1930s until the 1960s. These fish were thought to spend the summer in deep pools between the Wilderness Lodge and Rattlesnake Creek; however, Jones noted that “The run was reported as never being large” (DFG 1992a, p. 4). He also stated that anecdotal reports of summer steelhead in the South Fork Eel River were still heard occasionally around the time the report was published, in 1992.”

North Fork Eel River

[Becker and Reining (2009: p.202-203)]:

“Several reports indicate that while winter-run steelhead continue to use the North Fork Eel River, summer steelhead may now be extirpated from the drainage. In a 1975 report entitled “The status of spring-run steelhead (*Salmo gairdneri*) in the Eel River system, the author, Larry Puckett, wrote, “Spring-run steelhead have been observed in the past in the North Fork Eel River. . . however, they have not been observed there in recent years” (DFG 1975, p. 6). In 1992 the Humboldt Chapter of the American Fisheries Society published a report identifying the risk of extinction in 49 salmon and steelhead stocks. In this report, summer steelhead in the North Fork Eel River were designated as “high risk of extinction.” High risk stocks were defined by populations that “showed continuing spawner declines with fewer than 200 adults” (Higgins 1992). The 1996 North Fork Eel River Watershed Analysis cites USFS data as indicating that, “Isolated sightings of summer steelhead occurred as late as 1990 . . . but overall the run is in danger of extinction” (USFS 1996, p. 107).” In 1995 testimony regarding timber harvest plans in the Yager Creek watershed, fisheries biologist Patrick Higgins stated, “Elsewhere in the Eel River drainage, Black Butte River and North Fork Eel River summer steelhead have gone extinct” (Higgins 1995, p. 2).”

Middle Fork Eel River

[Becker and Reining (2009: p.222)]:

“In a 1992 report on the distribution of summer steelhead, Weldon Jones described observations of summer steelhead that took place in the Middle Fork Eel River beginning in the 1930s (DFG 1992). Fishing for summer steelhead became popular on the Middle Fork in the early 1950s. However, anglers noticed a decrease in the number of fish in 1955 and a severe flood that year caused damage to summer steelhead habitat. Following the floods in 1964, during which “summer holding areas were almost entirely obliterated” (DFG 1992, p. 7), DFG closed the Middle Fork Eel River to summer steelhead fishing.”

VI. CONCLUSIONS

Coho salmon, Chinook salmon, and steelhead are all on a trajectory towards extinction in the Eel River basin, with only winter steelhead being widely enough distributed and abundant enough to persist beyond the next 50 years. Historically, it is likely that in wet periods with good ocean conditions, the Eel River supported runs of well over a million salmon and steelhead (800,000 Chinook, 100,000 coho, and 150,000 steelhead), with about half that number being present in less favorable years. At present, the numbers seem to be, on average, about 3,500 fish total (+/-1,000) per year (1,000 Chinook, 500 coho and 2,000 steelhead). Although these numbers are very approximate, they are the best that can be supported by our skimpy information and, regardless, they represent greater than 99% decline in numbers. The Eel River watershed not only once supported large numbers of salmon and steelhead, but it once supported a diverse fauna of anadromous fishes, including multiple runs of Chinook salmon, steelhead, lamprey and other fishes. These fishes in turn had strong biological interactions with the surrounding terrestrial communities, linking them with the flow of ocean nutrients to the land, and terrestrial nutrients to the fish.

Considering the historic importance of the Eel River in supporting both commercial and sport fisheries for salmon and steelhead, it is astonishing both that we know so little about what is going on in the watershed or why salmon and steelhead are headed towards extinction. The Eel River system has been largely ignored by management agencies during recent decades; there have really been no significant fisheries management activities since the 1940s. This lack of attention for the Eel River appears to have been largely due to its relatively isolated location, the lack of any urban centers in the basin, and the completeness and rapidity of loss of salmonid resources. Once the salmon could no longer support fisheries, the commercial fishing community largely lost interest and once the steelhead and salmon declined to low levels, the sport fishing community largely lost interest. This poor state of affairs is entirely due to human actions.

All of the Eel River subbasins have been affected to varying degrees by the general factors that degrade physical habitats, reduce instream flows or degrade water quality, disrupt ecosystem integrity and biotic functions, and impose biological stresses on the native fish fauna including anadromous salmonids. At the watershed scale major factors include intensive forest removal near streams and on steep hillsides and stream channel and bank alterations, which destabilized naturally unstable landscapes. The legacy effects of logging peaked in the 19th century and then again in 1940s-1960s. The destabilizing conditions, created largely by logging, allowed the massive rains and floods of 1955 and 1964--harmful even under the best of circumstances--to devastate the entire watershed, eroding channels and depositing massive amounts sediment in the riverbed. Also creating major problems were the construction of dams and diversions and the introductions of non-native fishes. The Potter Valley Project, while affecting a relatively small part of the total watershed, blocks access to upstream areas and reduces flows in the mainstem Eel River due to water diversion to the Russian River, although rearing conditions for steelhead may have improved in the reach between Scott and Cape Horn dams. Predation and competition by the recently introduced Sacramento pikeminnow continues to be a major factor that reduces recovery potential of natural populations of salmon and steelhead in the Eel River. Together, all of these factors continue to pose challenges to recovery of anadromous salmonids. Accomplishing even a partial recovery will be extraordinarily difficult and require the focused energy of many people and organizations, as well as a genuine commitment of governmental agencies to a major restoration program.

VII. RESTORATION RECOMMENDATIONS

Bringing salmon and steelhead back to Eel River will first require emergency care, then a long-term program of restoring the populations back to health, defined as self-sustaining populations that can support at least limited harvest. Given that the Eel River basin is the least developed large river basin in California, there always exists the potential for self sustaining

salmon and steelhead populations that approach historic numbers. Here are a few of the actions that are needed to make restoration of salmon and steelhead a reality:

1. Establish a well-funded Eel River Restoration Program. The program would have a professional full time administrator and staff assigned to it from both state and federal agencies. It would be advised by a broad-based (beyond the watershed) stakeholder group that would help to set priorities for research and management. Many of the recommendations that follow would fall under this organization's purview. A first step would be to establish goals and objectives for a long-term restoration program.

2. Establish the Eel River Science Program, or perhaps a North Coast Science Program because the results could be applied to other rivers as well. There are some very good scientists who already work in the Eel River basin (or who could work in the basin) and could focus more of their efforts on finding ways to improve conditions for salmonids if funds were provided. Ideally, the program would involve establishing small field research facilities (such as exist on the South Fork Eel) in several key places in the basin. The science program should probably be based out of Humboldt State University, as the closest academic institution.

3. Develop a GIS based analysis to help determine both where problem areas are in the Eel River basin and where the areas/streams are that could benefit from immediate restoration efforts.

4. Develop a process that would involve the private landowners of the basin to help ensure their cooperation with restoration efforts.

5. Conduct an independent evaluation of the Potter Valley Project that looks at its costs and benefits, including benefits to Russian River salmon and steelhead.

6. Establish and fund a major monitoring program for all salmonids in the basin. Conduct annual surveys of spawners and juveniles for at least 10 years, and then evaluate the information to determine if less frequent monitoring would be possible. This program should have separate surveys or counting stations for all salmonids.

7. Develop a special program to find ways to control or reduce populations of pikeminnow. Salmon recovery especially is not likely to happen without reduced pikeminnow predation.

8. Continue to work on reducing human impacts on the Eel River estuary in order to maximize rearing habitat for juvenile salmonids. There is considerable interest in this right now and it should be continued.

9. Provide special protection for summer steelhead (e.g., to prevent poaching) while they are holding over the summer, as well as determining what it will require to maintain holding pools.

10. Expand wilderness protection to the headwater of all the major forks, including the Van Duzen. Protection of the uppermost tributaries is an important step to managing erosion and other problems.

11. Establish a statewide information program to improve interest and appreciation for the Eel River watershed.

12. Give the entire South Fork Eel Watershed a special protected area status (e.g., South Fork National Park), with a focus on creating conditions that will favor coho salmon.

13. Implement strict timber harvest and grazing management rules for the basin that provide maximum protection for all streams, including first-order streams.

14. Establish permanent sources of revenue for the above activities using creative means, such as surcharges on economic-generating activities in the watershed (logging, power, tourism). Consider creating an Economic Development Commission for the basin, treating it like a third-world country, but promoting ecologically friendly development (e.g., ecotourism, no-impact timber harvest, angling opportunities).

VIII. LITERATURE CITED

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APPENDIX A. GENERAL TRENDS FOR EEL RIVER SALMONIDS IN THE UPPER MAINSTEM EEL RIVER

Prior to the Potter Valley Project (i.e., before 1922), Chinook salmon spawner numbers (“escapements”) in the upper mainstem Eel River --i.e., the Potter Valley Project and upstream areas--were estimated to have been almost 10,000 fish. That number was inferred by using historical cannery records dating back to the 1850s for the total Eel River commercial harvest and dividing up the total catch for different portions of the Eel River watershed based on the spatial distributions of fish among subbasins observed in later spawning surveys by the U.S. Fish and Wildlife Service (USFWS). The 10,000 fish estimated for the upper Eel River is probably lower than the historical maximum spawner numbers because the historical cannery records were numbers for exploited populations—i.e., populations under harvest and already reduced from their former levels.

Based on the USFWS surveys for the entire Eel River basin during the 1955/1956-1958/1959 spawning seasons, the proportionate distribution of spawners into different subbasins could be inferred and extrapolated to earlier and broader time periods (SEC 1998). For that four-year period (1955-1959), the portion of the Chinook salmon escapements corresponding to the Willits Ridge subbasin (i.e., essentially the Potter Valley Project area below Scott Dam and Pillsbury Reservoir) was estimated to be 2,800 spawners or ~12% of the total basin escapement (24,361 spawners) (SEC 1998).

For the longer period 1938-1962, when an average of 98,500 Chinook and coho salmon (combined) spawned annually in the Eel River system, about 8,000 Chinook salmon (i.e., 8.1% of the basin total for both species) were attributed to the Willits Ridge subbasin encompassing the upper mainstem Eel River (from Dos Rios up to Pillsbury Reservoir, excluding Outlet Creek and its tributaries) (SEC 1998, citing U.S. Army COE 1980). Additionally, about 2,499 spawners were estimated to have used the river area above Scott Dam prior to its construction (VTN 1982). Hence, by combining the 8,000 and 2,499 fish estimates (totaling 10,499 fish), it was estimated that the average number of Chinook spawners that historically used the upper Eel River (above the confluence of Outlet Creek) was 10.4% of the system-wide total escapement of Chinook plus coho salmon (SEC 1998).

The preceding computation that yielded the value of 10.4% strictly pertains to the 1938-1962 period but might be further applied to a broader and earlier time period as an inferential exercise that probably is somewhat valid. If the Potter Valley Project area and areas further upstream produced about 10.4% of the salmon in the entire Eel River basin, that percentage would correspond to an annual average of 9,700 Chinook (plus coho) salmon out of a total Eel River basin average of 93,000 salmon for the period 1857-1921. SEC (1998: p.5.1-1) noted that the peak historical production in occasional years may have been six times greater than those averages, judging from the “peak annual cannery figures.”

The multi-decadal population trends of Chinook salmon and steelhead were examined by Steiner Environmental Consulting (SEC 1998) using spawning escapement data and adult return rates. The adult return rates were defined as the number of adults (3- and 4-year olds combined) returning to spawn divided by the number of downstream-migrating juveniles in the cohort that gave rise to those adults. Data on the recent-historical salmon escapements for the upper mainstem Eel River are derived from several sources (SEC 1998: p.5.1-2):

- The most complete counts of Chinook salmon are from the Van Arsdale Fisheries Station comprising fish-ladder counts taken at Cape Horn Dam starting in 1946/1947; however, no data were recorded in six of the years during the late-1940s to early-1950s.
- Spawning surveys in Tomki Creek (a major tributary 4 miles below Cape Horn Dam) during certain years within the period 1964/1965 to 1978/1979 (i.e., 5 years of data) and then annually for 1979/1980 to 1995/1996.
- Spawning surveys on the mainstem Eel River between Outlet Creek and Cape Horn Dam, conducted during the periods 1979/1980 to 1981/1982 and 1985/1986 to 1995/1996.

The combined data from those three sources were presented in graphs of time trends in Chinook salmon escapements and return rates of adult salmon (and steelhead) (SEC 1998, their Figures 5.1-1, 5.1-2 and 5.1-4). As stated by SEC (1998), the time-series for the historical cannery data and recent-historical surveys and fish-ladder counts (1940s-1990s) depicted the generally acknowledged significant decline of West Coast Chinook salmon populations over the past century, with most of the decline having occurred prior to the 1950s.

Although the three data sources—i.e., the fish counts for Van Arsdale Fish Station and spawner surveys for Tomki Creek and the upper mainstem Eel River—are among the best available long-running data sets, they all have significant limitations. As noted in the updated status review for west coast salmon and steelhead by NMFS (2005: p.139), “These data are not especially suited to rigorous analysis of population status for a number of reasons, and [therefore] sophisticated analyses were not pursued.”

In regard to the Van Arsdale Fish Station counts, NMFS (2005: p.139) explained the data limitations:

“Two characteristics of the data weaken inferences regarding population status drawn from the time series of counts of adult Chinook salmon reaching Van Arsdale Fish Station (VAFS). First, adult salmon reaching VAFS include both natural- and hatchery-spawned fish, yet the long-term contribution of hatchery production to the spawner population is unknown and may be quite variable due to sporadic operation of the egg take-and-release programs since the mid-1970s. Second, and perhaps more important, it is not clear what VAFS natural spawner counts indicate about the population or populations of Chinook salmon in the Eel River. As a weir count, measurement error is expected to be small for these counts. However, very little spawning habitat exists above VAFS, which sits just below the Cape Horn Dam. This dearth of habitat suggests that counts made at VAFS represent the upper edge of the spawners’ distribution in the upper Eel River. Spawner access to VAFS and other headwater habitats in the Eel River basin is likely to depend strongly on the timing and persistence of suitable river flow, which suggests that a substantial component of the process error in these counts is not due to population dynamics. For these reasons, no statistical analysis of these data was pursued.”

Furthermore, concerning the spawner survey data for Tomki and Sprowl creeks (and other stream reaches), NMFS (2005: p.139, 142) advised that:

“Caution in interpreting these results is warranted, particularly given the quasi-systematic collection of these data, and the likelihood that these data include unquantified variability due to flow-related changes in spawners’ use of mainstem and tributary habitats. In particular, inferences regarding population status based on extrapolations from these data to basinwide estimates of abundance are expected to be weak and perhaps not warranted.”

Notwithstanding the data limitations, the fish counts at the Van Arsdale Fish Station provide useful data on trends (Table 5).

Table 5. Counts of up-migrating salmon and steelhead at the Van Arsdale Fish Station fish-ladder (Cape Horn Dam), upper mainstem Eel River. Modified from Taylor (1978, his Table 2). Blank cells indicate no data were available.

Year ¹	Upper Mainstem Eel River	
	Chinook salmon	Steelhead
1933		3,247
1934		2,255
1935		6,310
1936		6,861
1937		3,413
1938		4,786
1939		3,889
1940		2,225
1941		
1942		
1943		
1944		9,528
1945		5,054
1946	917	4,409
1947	994	178
1948		2,433
1949		
1950	55	1,091
1951		5,444
1952		2,197
1953		2,590
1954		6,131
1955	5	3,719
1956		4,109
1957	2	5,151
1958		3,335
1959		2,206
1960		1,130
1961		1,693
1962	9	2,030
1963	3	846 ^H
1964	63	921 ^I
1965	94	423
1966	148	534
1967		531
1968		340
1969	15	719
1970	34	1,863
1971		696
1972		586
1973		947
1974		996
1975		712
1976		2
1977		585

¹ Each designated year refers to the up-migration and spawning season spanning that year and the following year (referred to as “counting-year”). For example, “1925 refers to counting years 1925-1926, etc.” (Taylor 1978, his Table 2, footnote 1).

² “All 1964 data are preliminary” (Taylor 1978, his Table 2, footnote 2).

^H “This figure is an estimate—station was closed before the end of the run” (Taylor 1978, his Table 2, footnote H).

^I “Ladder out of operation Dec. 25 to Feb.1 ” (Taylor 1978, his Table 2, footnote I).

Another important set of historical data is represented by the Benbow Dam fish ladder counts (South Fork Eel River) for the period 1938-1975 (Taylor 1978, his Table 2). We present the Benbow Dam fish counts in Table 3. Those counts provide a direct indicator of actual salmon and steelhead abundances in the South Fork. For Chinook salmon, the annual counts at Benbow Dam ranged between 473 and 21,011 fish, with an average of 6,998 fish (SEC 1998). Those Benbow Dam counts can be used as surrogate data, in a sense, to infer the abundance trends of salmon in the upper mainstem Eel River during the same period (i.e., 1938-1975). Specifically, it was determined from the USFWS (1955-1959) surveys that the relative abundances of Chinook salmon in the Willits Ridge “subbasin” (i.e., essentially the upper mainstem Eel River) and Benbow Dam (South Fork Eel River) subbasin were 8,000 and 10,000 fish, respectively—i.e., an 8-to-10 ratio (SEC 1998, citing U.S. Army COE 1980). Hence, multiplying the time-series of Benbow Dam counts (for 1938-1975) by a conversion factor of 80 percent provided indirect estimates for the upper mainstem Eel River area over the same period. The resulting computed time-series of Chinook salmon escapements for the upper mainstem Eel River portray an early period of high escapements (~8,800-10,000 fish) during the 1930s-1940s followed by a period of much lower escapements (~1,700-4,000 fish) in the 1950s-1970s (SEC 1998, their Figure 5.1-1). The SEC (1998: p.5.1-1) report noted that, “The most conspicuous part of the chinook trend was revealed by the plummet during the 1950’s.”

SEC (1998) further suggested that the assumption of at least a “rough correlation between the South Fork and upper mainstem [C]hinook populations” was corroborated to some degree by similar “rough parallels” between the steelhead counts taken at Benbow Dam and Van Arsdale Dam (upper mainstem Eel River) during the same period.

However, Chinook salmon runs into Tomki Creek (tributary to upper mainstem Eel River) as recently as the 1980s exceeded 1,000 spawners in three out of seven years so the population had not yet completely collapsed. Chinook salmon escapements for the entire Potter Valley Project area in 1985-1988 were still fairly high, ranging between 4,400 and 8,600 spawners (with peak numbers in 1986-1987 and 1987-1988), although the 17-year average (1978-1995) was only 2,000 spawners. The upper Eel River Chinook population collapsed to near zero in 1989/1990 and remained at those low levels for six years, but it showed a slight increase in 1995/1996 (SEC 1998).

Additionally, the escapement time-trends for Chinook salmon in the Eel River were compared with data for other Chinook salmon populations in northern California and southern Oregon (SEC 1998, their Figure 5.1-3). Those combined plots (spanning 1978/1979-1995/1996) generally showed similar patterns—i.e., somewhat low levels in the early 1980s, unusually high levels in the late-1980s, an historic low point in 1990/1991, and an apparent partial recovery by most populations between 1992/1993 and 1995/1996 (SEC 1998: p.5.1-3 and their Figure 5.1-3). It was noted that, “In general, similarities between trends for several river systems suggested that certain factors were simultaneously affecting anadromous life histories” (SEC 1998: p.5.1-3).

More explicitly, SEC (1998) surmised:

“... Several Northern California and Southern Oregon salmonid populations have experienced similar trends in escapements and return rates (sections 5.1 and 5.2), pointing to the ocean environment as a major common influence on survival.” (SEC 1998: p.5.10-1)

“Multiple-drainage trends and the cyclical nature of ocean productivity provide strong empirical evidence that ocean conditions must be taken into account when interpreting year-by-year changes in salmonid population levels. High ocean productivity can mask problems associated with habitat loss or degradation, management practices, or other factors. The apparent success of the 1983/84 chinook brood may reflect this scenario; abundant returns in the 1980s simply may have been an artifact of unusually high ocean productivity, masking chronically low historical escapements. Conversely, if Eel River

salmonid populations were generally chronically depressed well below historical levels, a sudden downturn in ocean productivity could drive returns to unsustainable low levels, thereby increasing vulnerability to other negative influences that ordinarily would be accommodated. The recent collapse of chinook and wild steelhead populations in the study area during the early 1990's may fit this pattern.” (SEC 1998: p.5.10-5 and 5.10-6)

The return rates for wild Chinook salmon spawners in Tomki Creek were determined from survey data on downstream-migrating juveniles and smolts and on returning adults (SEC 1998). Tomki Creek was considered as representative of other streams along the upper mainstem Eel River because it contained substantial salmonid habitat; also, importantly, high quality data had been collected from that stream. The trends in return rates of Chinook salmon complemented the trends observed in the spawning escapement data (SEC 1998, their Figure 5.1-4)—i.e., showing a pronounced drop in return rates from 1986 onwards that corresponded with the dramatic decline in Chinook escapements after the 1987/1988 spawning year-class (SEC 1998, their Figure 5.1-4). Furthermore, SEC (1998: p.5.1-3 and 5.1-4) inferred that:

“... Because return rate calculations compensate for variations in juvenile production, it was clear that low returns in many years (especially the early 1990's) were due to factors associated with later phases of chinook life histories more than with problems associated with production or survival of chinook fry within the study area.”

APPENDIX B. HATCHERY-RELATED ACTIVITIES IN THE EEL RIVER SYSTEM

There has been a long history of hatchery-related activities at various points within the Eel River basin and other northern California stream systems dating back to the late-19th century. The Eel River basin and nearby streams were especially important in the earliest hatchery operations in California and were initiated in response to heavy commercial harvests of the Eel River salmon stocks. A brief synopsis was given in the “State of the Eel 1995” document that was produced after a public meeting (March 25, 1995) on Eel River issues (State of the Eel 1995: p.8):

“Interestingly, this early commercial fishery led to the introduction of a hatchery program in the river system. Hatcheries were constructed at Price Creek in 1897, and in other locations throughout the basin; in many cases, their purpose was to augment declining cannery production (Burns, 1974 [i.e., Brown and Haley 1974]). However, Price Creek hatchery could not develop a reliable local brood source of ripe chinook females. After the hatchery’s trapping efforts failed, attempts were made to have the Eel River commercial fishermen provide ripe females, but the fishermen would not cooperate. Lacking adequate local egg sources, the facility obtained chinook eggs from the Sacramento, Noyo, and Russian River systems. Consequently, the Eel River was routinely stocked with millions of fry grown from eggs from these other river systems, resulting in less genetically fit fish in the Eel Basin. The facility was move[d] to Steelhead Creek near Alderpoint in 1916, and was finally closed in 1942. Egg taking stations at Snow Mountain (1914) and Branscomb (1921) are distant relatives of today’s rearing ponds and egg taking stations (e.g. on Redwood Creek and Hollow Tree Creek). Adult steelhead were helicoptered from Benbow Dam to the Mad River hatchery in the early 1970s. An experimental hatchery established in the 1950s on Cedar Creek (South Fork) conducted several chinook life history investigations during the hatchery’s short lifetime.”

Another overview with further details of early hatchery activities in the Eel River basin through mid-20th century was given by Brown and Haley (1974: p.22-23):

“The history of hatchery operations in the Eel River Basin is typical of river basins all along the coast. The first Eel River hatchery was constructed on Price Creek near Fortuna in 1897. The first salmon eggs hatched in this operation were imported from Battle Creek hatchery in the Sacramento River Basin. The first planting of steelhead fry in California was made with fish produced at Price Creek in 1902. In that same year an egg collecting station was established on nearby Howe Creek. In 1907 the Snow Mountain Egg Collecting Station was established to take eggs from salmon and steelhead at the newly constructed Van Arsdale Dam on the upper Eel River. The Price Creek operation suffered from siltation and low summer flows from the beginning so, when the Northwestern Pacific Railroad opened up the canyon of the main Eel in 1916, Price Creek Hatchery was abandoned in favor of a new installation near Alderpoint. Fort Seward Hatchery, as it was called, was situated on Steelhead Creek which was little better than Price Creek as a water supply. In 1942, war-induced labor problems made it necessary to abandon Fort Seward Hatchery. The Branscomb (Eel River), Bull Creek, and Bryan’s Rest egg collecting stations, all shortlived, were established as satellites to Fort Seward Hatchery. The Department of Fish and Game began testing the adequacy of Cedar Creek, tributary to the South Fork at Leggett, in 1949 and subsequently constructed Cedar Creek Hatchery in 1955. Partially inundated by the flood of December 1955, and totally inundated in December 1964, Cedar Creek Hatchery has been abandoned. Silver salmon have been planted in selected tributaries of the South Fork Eel since 1964, but these fish have been raised in Sacramento Basin hatcheries.”

Although juvenile “silver” (coho) salmon were reared in Sacramento River basin hatcheries, Brown and Haley (1974) noted that those fish were originally from eggs collected in either the Eel River system or other coastal streams. Hence, those plantings of young coho salmon were largely or wholly of native strains from the Eel River or nearby northern coastal California streams.

However, the overall effectiveness of those earliest hatchery activities evidently was limited due to the procedural policies of that time. Nonetheless, the hatchery operations in the Eel River and other river systems gradually began to yield demonstrable benefits. Brown and Haley (1974: p.23) noted:

“Price Creek and Fort Seward hatcheries planted fish that were too young to contribute significant numbers of salmon and steelhead to the basin. Fort Seward Hatchery had great social appeal, however, and residents of outlying areas bemoaned that their favorite creeks are no longer stocked with “trout”. Cedar Creek Hatchery, although not designed or intended to be a major enhancement facility, demonstrated clearly that silver salmon and steelhead spawning escapements could be significantly increased by a modern hatchery in the basin. During nine years of operation, five experimental lots of yearling fish were planted in the South Fork. Returns from these plants contributed 62% of the silver salmon run over Benbow Dam in 1961, 11% of the steelhead in 1958, 10% of the steelhead in 1959, and 6% of the steelhead in 1960.”

In an early review of hatchery operations in California, Shebley (1922: p.76-77) briefly described the history of the Price Creek Hatchery—the first hatchery in the Eel River system--on the lower Eel River.

“In its endeavor to increase the salmon supply in California the [California Fish] commission investigated conditions on Eel River, and in 1897 a hatchery was erected on Price Creek, one of the tributaries of Eel River, about twelve miles from its mouth.”

“The first [Chinook salmon] eggs were shipped from Battle Creek [Sacramento River basin] to the new station in December of that year. This station proved to be a great success. Eel River, like the headwaters of the Sacramento, has no predatory fish except the trout to devour the salmon fry. The water of the river from the mouth of Price Creek to the ocean flows through deep pools, with very little current. The salmon fry find perfect conditions in this stretch of water, and enter the ocean with very little loss and in fine condition. This station has also been used for collecting and hatching steelhead eggs for distribution in the streams in Humboldt County. The increase in salmon in Eel River, following the establishment of this station, is another example of the benefit derived from artificial propagation. At the time the first salmon fry from the hatchery were liberated in Eel River during the spring of 1898, the average annual shipment of salmon from Eureka was about 500,000 pounds. After the establishment of the hatchery there was a steady increase, and in 1904 the shipment was over 1,500,000 pounds.”

“In 1902 this hatchery made the first plant in the state of steelhead trout fry. After the spring of 1906, when the restriction prohibiting netting became effective, there was a marked increase apparent. In operating one small trap on Price Cree (which was at different times flooded) the largest number of steelhead eggs ever taken in Humboldt County was secured. In 1916 the hatchery was moved to a point on Eel River near Fort Seward.”

As had occurred in other California river systems, the hatchery activities on the Eel River had been initiated and expanded in response to overexploitation and reductions of the salmonid stocks. Accordingly, the California Fish Commission surmised (Shebley 1921: p.52; 1922: p.79):

“The commercial fishing at the mouth of the Eel River and the spearing of the breeding salmon on the riffles on the upper reaches of the river necessitated the propagation of salmon in larger numbers on Eel River.”

However, experimental attempts to conduct egg-collecting operations near the mouth of the mainstem Eel River and on Bull Creek, a tributary of the South Fork Eel River, demonstrated the impracticality of such operations in the lower regions of the Eel River system. Specifically, Shebley (1921: p.53; 1922: p.80) explained:

“Any attempt to place racks across the main Eel River or the South Fork, anywhere near its mouth, is almost impossible, as the loose nature of the formation is not solid enough to hold the racks and, even if this were overcome, the tremendous amount of water that comes down Eel River during flood periods, carrying logs and debris of all kinds, would make it impossible to retain any kind of a rack in the river. Furthermore, if a rack could be built that would stand the flood water of the river, when the salmon were running, the number of fish that would be entering the river would be all fresh run from the ocean and would have to be held too long in order to allow them to mature.”

“An egg-collecting station on Eel River or its tributaries must be situated far up the stream, away from the tremendous floods and the floatage matter in the river, and must be in the upper reaches near the spawning grounds, where the fish have spent the necessary time in fresh water for the breeders to mature.”

The early hatchery activities were also summarized by Myers et al. (1998: p.154):

“California coastal hatcheries and egg collecting stations began operating on several coastal streams in the early 1890s, but the first permanent facility was not established until 1910, with the construction of the Snow Mountain Station (currently known as Van Arsdale Fisheries Station) on the Eel River (Shebley 1922). Facilities on the Eel and Mad Rivers were constructed to rehabilitate depressed north coast populations (Kelly et al. 1990). A total of 95 million chinook salmon fry were released into California coastal rivers from 1875 to 1919, the majority (84 million) into the Eel River (Cobb 1930). Hatchery releases of fall-run chinook salmon since the 1970s have been relatively small, especially when compared to the large programs in the adjacent Sacramento River Basin. . . For example, the Smith River has received about 133,000 fall-run chinook salmon per year (NRC 1996), a fraction of the number of fish released into Sacramento River tributaries of similar size. The majority of the current coastal California fall-run chinook hatchery programs tend to use stock developed within basin, although these stocks may not be wholly native due to the long history of interbasin transfers that were common in earlier decades (CDNR 1931) [i.e., CFGC 1931].”

Finally, Berg Associates (2002) presented a brief overview of hatchery plantings of anadromous salmonids in the Eel River system, based on information drawn from previous literature compilations by the CDFG and other sources (e.g., timber company records). Most of the planting information generally pertained to the entire Eel River watershed because detailed records on the numbers of fish planted and their locations and dates were usually not kept, although there are cases where such information was recorded such as for the Van Duzen River. Hence, the historical record of hatchery plantings in the Eel River system is highly incomplete but still sufficient to clearly show that salmon and steelhead from various sources (including the upper Sacramento River basin) were extensively planted into the Eel River system.

To further illustrate the nature and scope of hatchery plantings of salmon and steelhead in the Eel River watershed, we present following excerpts (in re-arranged order) from Berg Associates (2002: p.92-93).

“Prior to 1977, the actual number of hatchery reared fish released into the Van Duzen River is vague and complete records could not be located. Documentation that has been

collected (see below) spans from the period between 1898 and 1914 when a hatchery was established at Price Creek in response to public and commercial interest concerns over depleted stocks. A review of historical newspaper references, compiled by Susie Van Kirk, dating from 1854 to 1995, documents the release of 61,036,107 chinook salmon and 17,720,000 steelhead into the Eel River and its tributaries. These hatchery stocks originated predominantly from the Battle Creek and McCloud hatcheries (initially). These figures are based on newspaper articles referencing releases between 1898 and 1914. Millions of eggs and fish are referenced for other years where hatchery release numbers are not given. The majority of these newspaper articles refer to the release of fish within the Eel [R]iver system, but others provided more detail, specifically naming the Van Duzen River among other tributaries within the system that were planted.”

“After 1914, the Price Creek hatchery was closed due to geologic instabilities that continually compromised the water impoundment necessary for hatchery operations. A new hatchery site was chosen at Fort Seward, at which point historical records become even more obscure relative to numbers and locations of hatchery releases. While no concise historical record of hatchery releases exist for the Van Duzen River the newspaper articles indicate that the river had introduced stock as early as 1898 (when the Price Creek hatchery was established).”

“The Yager Creek hatchery has been operated since its construction in 1977 and has historically planted steelhead, coho salmon, and chinook salmon. The steelhead stock have [been] documented in three Humboldt Beacon articles as originating from the Mad River and Iron Gate hatcheries. The historical data for the hatchery releases from 1977 to 1990 have not been reviewed and summarized to date and the newspaper articles discuss the arrival of 50,000 to 100,000 fish arriving at the hatchery for rearing while failing to document released numbers later. However, the PALCO records dating back to 1990 can be summarized by the total number of steelhead, chinook salmon, and coho salmon released from the Yager Creek hatchery from the time between 1990 and 2002 as follows: steelhead trout 90,257, chinook salmon 306,927, and coho salmon 6,500.”

“CDFG stocking records indicated that 3,000 steelhead of Little Lost Man Creek origin were released in Stevens Creek in 1985.”

APPENDIX C. EFFECTS OF THE POTTER VALLEY PROJECT

Extensive changes in both land-use and water-use in river basins throughout California over the past one and a half centuries have significantly impacted salmon and steelhead populations, and the Eel River is no exception. Although significant habitat changes in the Eel River basin span a shorter time period, they have been pronounced in certain parts of the system with correspondingly profound effects on the salmon and steelhead runs. Among the more significant alterations of the Eel River system was the construction of the Potter Valley Project by the Pacific Gas and Electric Company (PG&E) on the upper mainstem Eel River in the early 20th century and its continuing operations up to the present. The Potter Valley Project comprises primarily Scott Dam and Pillsbury Reservoir and, a short distance down-river, Cape Horn Dam and Van Arsdale Reservoir along with the Potter Valley Powerhouse and the associated water diversion system leading to the East Fork Russian River (SEC 1998).

The primary issue in regard to the Potter Valley Project is the degree to which Chinook salmon and steelhead populations have been diminished as a result of that project. It has been estimated that up to approximately 2,500 Chinook salmon adults potentially would be supported in the river above Scott Dam if that habitat were available (VTN 1982). A fairly substantial amount of habitat above Scott Dam is now inaccessible to steelhead as well. However, it is not clear how many steelhead spawners would have been supported in the upper reaches but it is almost certainly more than the number of Chinook salmon spawners. We infer a greater expected number of steelhead than Chinook salmon because of the smaller average size of steelhead and their requirement for smaller-sized spawning gravels and their ability to use sparser and smaller gravel deposits.

In the following segments we present summaries of several key studies and evaluations that address the controversial issue of the Potter Valley Project's impacts on anadromous salmonid populations. We summarize the studies separately resulting in some redundancy. However, the repetition serves to reinforce and refine our knowledge of this portion of the Eel River system. Although the studies focused primarily on the upper mainstem Eel River, the Potter Valley Project's influence ramifies to various degrees through other parts of the system.

VTN Oregon, Inc. Potter Valley Project (FERC No. 77) Fisheries Study Final Report. Volume I. 1982. Prepared for Pacific Gas and Electric Company, Department of Engineering Research. 3400 Crow Canyon Road, San Ramon, California 94583. December 1982. VTN Oregon, Inc. 25115 S.W. Parkway, Wilsonville, Oregon 97070.

An initial fisheries-related assessment of the Potter Valley Project was conducted by the consulting firm VTN Oregon, Inc. during the three-year period 1979/1980 to 1981/1982. The purpose of the study was “to determine adequate streamflow releases from the Potter Valley Project for maintenance of chinook salmon and steelhead populations in the upper Eel River drainage” (VTN 1982: p.xx).

Some of the major findings of the VTN (1982) study are summarized in the following discussion as a partial overview of the relationship between the Potter Valley Project and the Chinook salmon and steelhead runs in the upper mainstem Eel River. The general findings are presented by topics.

Spawning Population Size

Spawner abundance was estimated by salmon carcass surveys and aerial redd surveys in the mainstem Eel River and Tomki Creek. The upper mainstem Eel River between the Tomki Creek and Outlet Creek confluences supported the bulk of spawning activity—at least as roughly estimated by the aerial survey conducted during 1979—but Tomki Creek also was an important production area. VTN (1982: p. 306) stated:

“During the 1979/1980 season, 2,410 salmon were estimated to have spawned in the Tomki Creek drainage, compared to 3,500 in the Eel River between Tomki Creek and Outlet Creek and 84 in the Eel River between Scott and Cape Horn Dams. Excellent spawning habitat is found throughout most of the Tomki Creek drainage.”

A particularly productive area of the upper mainstem Eel River was the reach downstream of Hearst Riffle (~7 miles downstream from the mouth of Tomki Creek). VTN (1982: p.306) reported that “An estimated 766 salmon spawned in 4 miles of stream below Hearst Riffle; approximately 80% of these fish spawned in the upper 1.2-mile section.”

In contrast to Chinook salmon, steelhead ascended the upper Eel River past Cape Horn Dam in substantial numbers to spawn. VTN (1982: p.307) stated:

“A majority of steelhead trout that ascend Cape Horn Dam spawn in the mainstem Eel River rather than in tributary streams. During the 1980/81 season, a total of 1,530 steelhead ascended Cape Horn Dam by the second week of February; during that week, only 75 steelhead and 41 redds were observed in tributaries above Cape Horn Dam, and approximately one month later, even fewer fish and redds were observed.”

Cape Horn Dam Fish Counts (Van Arsdale Fish Station)

The upper Eel River watershed area above Cape Horn Dam appears to have been relatively insignificant in terms of Chinook salmon spawning and production—at least at the time of the initial Potter Valley Project study. VTN (1982: p.305) concluded:

“Chinook salmon spawning escapement to the Eel River above Cape Horn Dam is a minor component of the total spawning population within the study area. During four years of comparable data, salmon ascending Cape Horn Dam comprised 0 to 4% of the estimated populations in Tomki Creek. Also, during the 1979/80 season, 3,500 salmon were estimated to have spawned in the Eel River between Tomki Creek and Outlet Creek, while only 84 salmon passed over Cape Horn Dam. During the last 27 seasons of record, salmon counts at Cape Horn Dam have ranged from 0 to 175; in ten of those seasons, no salmon ascended the dam. Chinook salmon, as a self-sustaining population, may have

been eliminated from the Eel River above Cape Horn Dam; the salmon ascending Cape Horn Dam being strays from downstream areas.”

However, steelhead---in contrast to Chinook salmon---utilized the area upstream of Cape Horn Dam to a considerable extent. The importance of that area was specifically noted by the VTN (1982: p.305) study:

“Steelhead trout spawning escapement to the Eel River above Cape Horn Dam appears to be a major component of the total spawning population within the study area. The river between Scott and Cape Horn Dams is the primary steelhead rearing habitat area within the study area during the summer. During the 45 seasons of record, steelhead counts at Cape Horn Dam have ranged from 39 to 9,528; mean annual counts of steelhead for each decade of record show a decline from 4,394 in the 1930’s to 721 in the 1970’s. The high quality permanent summer rearing habitat that exists between Scott Dam and Cape Horn Dam is one of the primary factors contributing to the maintenance of this run.”

Chinook salmon and steelhead population losses

VTN (1982) attempted to quantify the population reductions of Chinook salmon and steelhead resulting from the loss of access to habitats upstream of Scott Dam. By utilizing information from previous studies and their own data to compare habitats both downstream and upstream of Scott Dam, VTN (1982) inferred the probable former fish densities in the upstream reaches. By combining those estimated fish densities with the estimated amounts of formerly available habitats, VTN (1982) calculated the probable numbers of Chinook salmon and steelhead that formerly used the areas upstream of Scott Dam.

VTN (1982: p.300) surmised, for example, that:

“The Rice Fork is most comparable to Tomki Creek from Cave Creek to Wheelbarrow Creek. Each has a broad, low gradient channel and extensive gravel deposits; the major difference is the lack of sustained summer streamflow and slightly less riparian vegetation in Tomki Creek.”

Hence, abundance estimates of Chinook salmon obtained for Tomki Creek (downstream of Scott Dam) could be justifiably used as surrogates of former salmon abundance in some reaches located upstream of Scott Dam such as the Rice Fork. Specifically, VTN (1982: p.300) stated:

“The four-year average for chinook salmon escapement into Tomki Creek is probably the best indicator of current salmon abundance (35 fish/mile). Given the apparent degradation of habitat since construction of Scott Dam, the highest recorded chinook escapement into Tomki Creek (2,410 in 1979) may be a better indicator of previous abundance (70 fish/mile).”

In contrast, the level of salmon production in the mainstem Eel River just below Cape Horn Dam probably was not comparable to that in the reaches above Scott Dam; i.e., (VTN 1982: p.300):

“Estimates of Chinook salmon abundance in the mainstem Eel River downstream of Cape Horn Dam are probably poor indicators of previous abundance above Scott Dam due to the difference in habitat characteristics between the two areas.”

Obtaining abundance estimates for steelhead that formerly utilized the upper drainage above Scott Dam is even more problematic than for salmon because of the paucity of relevant data. VTN (1982) attempted to roughly estimate the former numbers of adult steelhead above Scott Dam by applying fish density values from one of the upper tributaries (i.e., Soda Creek) as a surrogate in their calculation. Specifically, VTN (1982): p.303) reasoned:

“Tributaries to the Eel River between Scott and Cape Horn Dams are not regulated, and adult steelhead abundance in Soda Creek (42 steelhead/mile in 1981) may be a

reasonable indicator of potential steelhead abundance upstream of Scott Dam. Return of steelhead trout to the Eel River between the two dams in 1980/81 (1,966) was 44.7% of the average return during the 1930 decade (4,394). If a similar decline has occurred in returns to Soda Creek, the 1981 density of 42 steelhead per mile can be multiplied by 2.23 to represent the average return during the 1930 decade: 94 steelhead per mile.”

To summarize, VTN (1982: p.304) drew the following conclusions regarding the amounts of lost stream habitats—i.e., streams with access denied to anadromous salmonids—after the construction of Scott Dam and the consequent reductions in Chinook salmon and steelhead numbers.

“Habitat survey results suggest that chinook salmon and steelhead trout could currently spawn in 25.2 miles of the Eel River and tributaries upstream of Lake Pillsbury. Addition of approximately 10.5 miles inundated by Lake Pillsbury brings the total loss of available spawning area due to construction of Scott Dam to 35.7 miles. Steelhead trout might have access to an additional 22.7 miles of minor channels in the tributaries.”

“Estimates of historical run size and the length of stream available prior to construction of Scott Dam are: 70 chinook/mile, 94 steelhead/mile, and 35.7 miles of stream. Estimates of the number of fish lost are: 2,499 chinook salmon and 3,356 steelhead. The estimate derived here for chinook salmon lost due to construction of Scott Dam compares favorably with the estimate made by CDF&G of 2,300, the estimate for steelhead trout is one and one-third times higher than the CDF&G estimate of 2,500 (CDF&G 1979, unpublished).”

Numbers of juvenile salmonids diverted from the upper Eel River by the water project operations

The numbers of juvenile Chinook salmon and steelhead that were diverted during their downstream migration out of the upper Eel River via the Potter Valley Project Powerhouse were estimated by VTN (1982). For the years 1980-1982, the estimated numbers of diverted juveniles were: (in 1980) 854 Chinook and 1,568 steelhead; (1981) zero Chinook and 13,139 steelhead; (1982) 350 Chinook and 5,145 steelhead. These numbers are substantially lower than the number of steelhead diverted during the year 1961/1962, which was estimated to have been 24,766 steelhead (Day 1964). The observed decrease in numbers of diverted fish evidently resulted from the installation of a fish screen after 1961/1962.

Temperatures, juvenile growth and emigration

Chinook salmon

The effects of cooler water temperatures above Cape Horn Dam on the growth rates and emigration timing of juvenile Chinook salmon were discussed by VTN (1982). The cooler water conditions evidently were more favorable for higher growth rates of juvenile Chinook salmon compared to downstream areas. However, when suitable temperatures (17°-20°C) for peak emigration occurred later in the reach above Cape Horn Dam and thereby delayed the timing of emigration, the juveniles consequently appeared to experience low survival as they moved downstream through the warmer areas. VTN (1982: p.229-230) provided further details.

“For all three years of trapping, the downstream migration patterns of juvenile chinook salmon were similar and seemed to depend primarily on water temperature. The major peaks of emigration occurred when water temperature reached 17 to 20°C at PVP/DFS [Potter Valley Powerhouse/Diversion Fish Screen] in 1980 and 1982, at Tomki Creek in 1982, and at the Eel River site in 1980, 1981, and 1982 (Figures 3.7-1 through 3.7-6). When water temperatures exceeded 22°C, major emigration tended to decline. In 1980 and 1982, the catch rate at the Eel River site dropped sharply to near zero when water temperatures approached 24°C and then increased substantially when water temperatures

dropped to below 22°C. At the Eel River site in 1981, very few fish were captured when water temperatures rose above 22°C. Other studies have also indicated the importance of temperature to downstream migration of chinook salmon. McPherson and Cramer (1981) stated that water temperatures approaching 19°C stimulated chinook salmon emigration in the Rogue River. Additionally, Thomas (1975) found that a sudden increase of stream temperature caused an increase of chinook salmon emigration in Washington.”

“Emigration of chinook salmon reared above Cape Horn Dam occurs later than elsewhere in the study area apparently due to cool water releases from the bottom of Lake Pillsbury during spring. Temperatures necessary to stimulate migration (17-20°C) did not occur above Cape Horn Dam until late May to mid-July during the three years of study; in contrast, temperatures in Tomki Creek and the Eel River above Outlet Creek reached the 17-20°C level by mid-April to early May. The delay in migration for chinook reared above Cape Horn Dam can expose them to lethal temperature conditions downstream and reduce or eliminate the likelihood of successful passage to the ocean. For example, the major peak of emigration above Cape Horn Dam in late June 1980 did not appear at the Eel River site; in fact, no juvenile chinook salmon were caught at the Eel River site after June 12 during the 1980 migration season. This may be explained by the differences in water temperatures at the two locations. At the time peak emigration occurred above Cape Horn Dam in 1980 (late June), water temperatures in the Eel River downstream from Cape Horn Dam were approaching or exceeding lethal levels (24°C) as defined experimentally by Brett (1952).”

“Results from 1982 contrasted with the 1981 results. In 1982, the major period of emigration from above Cape Horn Dam occurred in late May and juvenile chinook salmon were present in the catch at the Eel River site until mid-July. The presence of chinook salmon in the Eel River above Outlet Creek during mid-summer was probably a direct result of cooler water temperatures downstream of Cape Horn Dam in 1982. The earlier emigration of chinook salmon from above Cape Horn Dam in 1982 may have been due to the experimental release of water from the surface of Lake Pillsbury. Surface releases were made from May 14 to June 15 to determine the effect of release level on temperature and on downstream migrating salmonids in the river between Scott and Cape Horn Dams. River temperatures were increased about 5 to 7°C as a result of the surface releases and reached the 17 to 20°C level much earlier than under normal operating conditions (Section 3.6, Instream Flow Study and Appendix H). It appears that manipulation of water release from Scott Dam can affect the timing of emigration of chinook salmon from the Eel River above Cape Horn Dam, and is an effective tool for improving the timely emigration of salmon from the study area.”

The effects of temperatures on salmon growth rates was further explained by VTN (1982: p.231-232),

“Temperature differences within the study area may also affect growth rates of juvenile chinook salmon. The apparent growth rates of juvenile chinook salmon, as indicated by mean length per two-week interval (Appendix I), differ between the PVPH/DFS, Tomki Creek and the Eel River trapping sites and between years. Cooler water temperatures upstream of Cape Horn Dam may be more conducive to growth as compared to the warmer water temperatures downstream of Cape Horn Dam. In 1980, juvenile chinook salmon appeared to grow faster above Cape Horn Dam than at the Eel River site. Mean lengths of juvenile salmon above Cape Horn Dam increased from 47 to 83 mm from mid April through late June, a growth rate of approximately 4.5 mm per week. At the Eel River site above Outlet Creek, mean lengths increased from 47 to 66 mm during the same time period, a growth rate of approximately 2.4 mm per week. Water temperatures above Cape Horn Dam varied from 10 to 17°C between mid April and late June, roughly

averaging 14°C. Water temperatures at the Eel River site varied from 14 to 30°C during the same time period, roughly averaging 21°C.”

“In 1982, mean lengths of emigrating salmon from above Cape Horn Dam increased from 49 to 107 mm from mid-May through early July, a growth rate of approximately 8.3 mm per week. Tomki Creek fish showed an apparent growth rate of 2.0 mm during the same time period, indicating that these fish were probably emigrating soon after hatching. The catch from the Eel River site showed an increase in mean length from 42 to 73 mm during the same time period, a growth rate of 4.4 mm per week. Water temperatures above Cape Horn Dam from mid-May through early July varied between 13 and 19°C, roughly averaging 16°C. Tomki Creek water temperatures varied between 15 and 24°C, averaging 19°C. Eel River water temperatures near Outlet Creek varied between 13 and 27°C, roughly averaging 20°C.”

“Satterthwaite (1981) reported that Rogue River chinook salmon grew faster when water temperatures were 16 to 17°C as compared to 18 to 19°C. Additionally, McPherson and Cramer (1981) found that the body condition of juvenile salmon decreased when water temperature exceeded 21.6°C. During the present study, the greatest growth rate was observed above Cape Horn Dam in 1982. According to Satterthwaite’s criteria, the fish from above Cape Horn Dam were reared in optimum temperatures in 1982; water temperatures above Cape Horn Dam were lower than optimum in 1980, thus producing the slower growth rate. Growth rates at Tomki Creek and the Eel River site were much slower, apparently due to the higher than optimum water temperatures.”

Steelhead

The downstream emigration of young-of-year steelhead was strongly related to environmental conditions. VTN (1982: p. 247) reported:

“The major emigration of age 0+ fish from above Cape Horn Dam was associated with changes in stream temperatures, decreasing streamflows and near maximum photoperiod. Emigration began when streamflow decreased from high spring levels and rising stream temperatures approached 12 to 14°C; emigration ended when temperatures were at their summer maximum of 20 to 22°C (Figures 3.7-7 through 3.7-9). Substantially larger numbers of fish migrated on certain days. These “peaks” were commonly associated with one or more of the following: 1) rapid changes in water temperature relative to surrounding days, 2) sudden drops in streamflow during spring and summer, 3) sudden increases in streamflow during fall, and 4) a new moon.”

In contrast, the emigration of older juveniles was less tied to environmental conditions (VTN 1982: p.248):

“Age 1+ and older fish began their migration from above Cape Horn Dam when temperatures were at their minimum (7°C), flows were high and unstable, and photoperiod was short. However, numbers of migrating fish remained fairly low until April when temperatures were above 10°C and rising quickly and flows had dropped and stabilized considerably (Figures 3.7-7 through 3.7-9). Peaks in migration of older fish were less extreme than those of the 0+ fish and did not appear to be associated with specific environmental factors.”

The VTN (1982: p.248) study found that “rising stream temperatures in April appeared to be a primary factor initiating the major migration period [of juvenile steelhead] from above Cape Horn Dam.” That finding is consistent with the earlier observation by Shapovalov and Taft (1954) who “found rising temperature to be important in triggering the beginning of major emigration” (VTN 1982: p.248). However, another important point is that juvenile steelhead

require sufficiently cool water temperature to undergo the smoltification process. Specifically, VTN (1982: p.248) noted:

“Adams et al. (1975) and Zaugg (1981) observed a reduction of smolt transformation at temperatures over 15°C. This may partially explain the cessation of emigration of age 1+ and older fish in mid-June of 1981 and 1982 at Cape Horn Dam, while age 0+ fish continued to migrate.”

“Kerstetter and Keeler (1976) also found that declining water temperatures brought an extension of steelhead emigration. This was observed during the present study in mid-June 1982, when a sudden drop in water temperature associated with the change from surface to bottom water release from Lake Pillsbury apparently brought about a large peak in age 0+ emigration. These large numbers of age 0+ steelhead may have been readied for this emigration by the experimental release of warmer surface water from Lake Pillsbury earlier in the spring; increases in temperature may increase the percentage of fish that smolt at age 1 by shortening the incubation period and increasing growth (McPherson and Cramer 1981).”

However, excessive water temperatures also may curtail the downstream emigration of age 0+ steelhead even though they are not undergoing smoltification. As noted by VTN (1982: p.248),

“Kerstetter and Keeler (1976) found that water temperatures over 17°C caused a major decline in emigration. This may explain the cessation of emigration of the age 0+ fish in late July 1982, when water temperatures had risen to 17 or 18°C.”

With regard to changes in streamflow and their effects on juvenile steelhead emigration, VTN (1982: p.249) summarized:

“Past studies have also indicated importance of streamflow changes on the downstream migration of juvenile steelhead. Shapovalov and Taft (1954) found that earlier migrations occurred in low flow years; they felt that the rate of change in flow may have been an important factor. During the present study, the first major seasonal peaks in emigration usually occurred following large and rather rapid decreases in flow from high spring levels. Additionally, a sudden flow reduction at Scott Dam in mid-July 1981 triggered a sudden migration of age 0+ steelhead downstream past Cape Horn Dam. Unfortunately, because of the limited rearing habitat below Cape Horn Dam due primarily to high water temperatures, most of these fish probably did not survive through the summer (Section 3.8, Summer Fish Inventory). Sudden increases in flow may also affect downstream migration. Shapovalov and Taft (1954) and McPherson and Cramer (1981) observed that peaks in the fall migration of age 0+ fish were associated with freshets; this pattern was observed in 1981 and 1982 between Scott and Cape Horn Dams when a peak in migration occurred during the first fall storm in October.”

Hence, it was concluded by VTN (1982: p.249) that changes in streamflows below Scott Dam can have variable effects on juvenile steelhead but offer potential benefits to the steelhead population if the streamflows are properly managed:

“The response of the age 0+ steelhead to sudden changes in flow and temperature below Scott Dam indicates that the manner in which flow releases are made can have a major impact on the timing of the juvenile steelhead migration and ultimately on the successful passage of these fish to the ocean. Depending on the time of year, and therefore the quality of the rearing habitat below Cape Horn Dam, stimulation of migration could be either beneficial or deleterious to juvenile steelhead. Through proper manipulation of the magnitude and temperature of releases at Scott Dam, steelhead populations above Cape Horn Dam could be greatly benefited.”

Summertime sampling

VTN (1982) conducted extensive summertime sampling during 1980-1982 in the upper mainstem Eel River and tributaries, both above and below Cape Horn Dam. Four major fish species that were consistently captured in the mainstem Eel River from Cape Horn Dam downstream to Outlet Creek were Pacific lamprey, steelhead trout, California roach and Sacramento sucker. The distribution and relative abundance of juvenile steelhead in particular varied between years (i.e., 1981 versus 1982), evidently in response to differences in summer streamflows and associated water temperatures. Specifically, the total population estimates of steelhead in the mainstem Eel River between Cape Horn Dam and Outlet Creek was 3,949 fish during August 25-September 2 of 1981, compared to 11,496 fish estimated during August 24-September 30 of 1982 in only a subsection (i.e., "Reach Type 1") composing roughly 50% of that river reach.

A major inference from those summer survey data was that water temperature was an important determinant of juvenile steelhead survival and abundance through the summer months. As stated by VTN (1982: p. 268),

"The population estimate for Reach Type 1 alone in August 1982 exceeds the stream total estimates (between Cape Horn Dam and Outlet Creek) for the previous two years. and is a reflection of the potential production of the Upper Eel River if temperatures were not limiting."

Furthermore, the importance of the mainstem reach between Cape Horn Dam and Scott Dam for steelhead rearing was reiterated (VTN 1982: p. 268-269):

"Results of the quantitative sampling at three sites between Scott Dam and Cape Horn Dam in 1982 indicated a much larger population density of steelhead than downstream (Tables 3.8-4, 3.8-5 and 3.8-9). The population estimate for riffle areas in the 6 miles of Reach Type 5 was 9,359 (1,560/mile), compared to 11,496 in 14 miles of Reach Type 1 (821/mile) and 1,468 in 4 miles of Reach Type 4 (367/mile) (Table 3.8-9). Even greater differences in density would be expected during years of more normal temperature conditions. As discussed elsewhere in this section of the report, high water temperatures severely limit steelhead populations below Cape Horn Dam in normal years; however, in 1982, unusually cool temperatures allowed much greater survival of steelhead. In contrast, temperatures above Cape Horn Dam are highly suitable for steelhead in both normal and cooler than normal years; thus, population levels above Cape Horn Dam are expected to fluctuate little from year to year, based solely on summer water temperatures. In comparison to the mainstem below Cape Horn Dam, the river upstream is normally inhabited by much larger numbers of juvenile steelhead during the summer (July/August)."

The tributaries to the Eel River between Scott Dam and Outlet Creek were important summer habitats for primarily steelhead trout and California roach, while Pacific lamprey and Sacramento sucker were rarely captured there (VTN 1982: p. 275-278). Steelhead population estimates at the tributary sampling sites through the summer and between years reflected the effects of summer streamflows and water temperatures. VTN (1982: p.279) stated:

"... Winter and spring streamflows were generally higher in 1982 than in 1981, possibly facilitating more successful migration, spawning and incubation in 1982; however, based on juvenile steelhead abundance in June 1981, spawning and incubation were quite successful that year. Higher summer streamflows and lower summer water temperatures in 1982 probably provided more suitable rearing habit[at] than in 1981, carrying a larger percentage of available steelhead through the summer and resulting in larger populations in nearly all tributaries sampled (Table 3.8-17)."

Hence, the summer surveys demonstrated the importance of both the mainstem Eel River reach between Cape Horn and Scott dams and the tributaries (VTN 1982: p.279):

“Mainstem population estimates downstream of Cape Horn Dam were generally low compared to the mainstem above Cape Horn Dam and to tributaries (Table 3.8-18). Direct comparison of all areas and years is not possible; however, it is clear that the mainstem Eel River between Cape Horn Dam and Outlet Creek usually supports far fewer steelhead through summer than either the mainstem Eel River between Scott Dam and Cape Horn Dam or all tributaries combined from Scott Dam to Outlet Creek. The mainstem Eel River between the two dams appears to be an important summer rearing habitat for juvenile steelhead trout, as are tributaries in the study area.”

Additionally, VTN (1982: p.279-282) noted:

“Although the age of most juvenile steelhead trout collected during electrofishing surveys appeared to be young-of-the-year (age 0+) at all sites, considerably larger numbers of steelhead over 100 mm (probably age 1+ and older) were collected in the mainstem between Scott and Cape Horn Dams in 1982 (Table 3.8-19). Steelhead over 100 mm comprised 9% or less of the total steelhead collected from mainstem sites below Cape Horn Dam and from tributaries; this contrasts sharply with 33 to 71% steelhead over 100 mm collected at mainstem sites above Cape Horn Dam in 1982 using similar quantitative sampling techniques. Large young-of-the-year populations in 1981 may have contributed a more-than-usual number of yearling steelhead to the 1982 populations. Nonetheless, these 1982 data further indicate the importance of the Eel River between Scott and Cape Horn Dams as the prime steelhead rearing habitat in the study area.”

“... Larger numbers of steelhead over 100 mm collected in tributary streams as compared to the mainstem below Cape Horn Dam (Table 3.8-19) further indicates the importance of tributaries within the study area (primarily Garcia, Thomas and Bucknell Creeks) as permanent summer rearing habitat for steelhead trout.”

The habitability of different river sections for juvenile steelhead was evaluated in relation to previous temperature assessments (VTN 1982: p.283):

“Juvenile steelhead trout abundance and water temperatures recorded in the mainstem Eel River and tributaries during 1980 and 1981 correspond well with the classification of Kubicek (1977). He classified the Eel River between Scott Dam and Cape Horn Dam as ‘satisfactory’ with respect to temperature conditions for steelhead trout during summer, between Cape Horn Dam and Tomki Creek as ‘marginal’, and between Tomki Creek and Outlet Creek as ‘lethal.’ A maximum daily temperature of 28.0°C or greater for at least 100 continuous minutes was considered lethal to steelhead trout; temperatures from 26.5°C up to, but not including, 28.0°C were considered marginal; and temperatures less than 26.5°C were considered satisfactory.”

The general importance of temperature effects on steelhead abundance was summarized as follows (VTN 1982: p.284-285).

“Temperature appears to be the major factor controlling the abundance and distribution of juvenile steelhead in the Eel River during the summer. The largest numbers of steelhead were caught in the Eel River above Cape Horn Dam where temperatures remain satisfactory. In late summer of both 1980 and 1981, steelhead numbers decreased with distance downstream from Cape Horn Dam, coincident with an increase in temperatures to marginal levels between Cape Horn Dam and Tomki Creek and lethal levels below Tomki Creek. The Cape Horn site, which had the lowest temperatures of the mainstem sites below Cape Horn Dam, generally maintained the largest population of steelhead below the dam during summer (July/August). Lethal temperatures below Tomki Creek were coincident with very low numbers of juvenile steelhead. The lack of complete

mortality at temperatures considered lethal may be due to the presence of cool water in stratified pools, to cool water inflow from tributaries and springs, or to thermal adaptation of Eel River steelhead stocks.”

“In late summer of 1982, steelhead were more abundant below Cape Horn Dam and their distribution was more uniform than in previous summers, reflecting the more suitable temperature conditions in 1982. The greater abundance of steelhead downstream of Tomki Creek in 1982 also corresponds well with the criteria for ‘marginal’ and ‘lethal’ temperature conditions and indicates that habitat conditions in the Eel River are strongly dependent on water temperature.”

The use of flow releases to moderate inhospitable water temperatures downstream of reservoirs generally is a logical tactic but would have less effectiveness as air temperatures increase (i.e., in spring and summer) and with increasing distance downstream of the release point. As VTN (1982: p.285) noted in that regard:

“A comparison of summer water temperatures and streamflows below Cape Horn Dam during the 1980 Instream Flow Study and during studies by DWR in 1973 (DWR 1973, unpublished data), shows a decline in water temperatures with increasing flows (Figure 3.6-6); however, the decline is small with moderate flow increases, and temperatures still increase with distance below Cape Horn Dam. Variation from the regression lines shown in Figure 3.6-6 may occur due to the effects of changing air temperature and temperature of water being released at Cape Horn Dam. Temperature variability is greatest at low flows.”

“... Increased summer flow releases from Cape Horn Dam would apparently extend the area of satisfactory or marginal water temperatures for steelhead rearing further downstream, but the distance extended would depend on: a) magnitude of flow being released; b) temperature of water being released at Cape Horn Dam; and c) weather conditions. The expected increase in area of suitable habitat would be very small with moderate increases in flow (20-30 cfs). Even at flows above 30 cfs, high summer water temperatures would remain the major limiting factor to steelhead survival in the mainstem below Cape Horn Dam.”

Steiner Environmental Consulting. 1998. Potter Valley Project Monitoring Program. Effects of operations on upper Eel River anadromous salmonids. Final Report. March 1998. Steiner Environmental Consulting. P.O. Box 250. Potter Valley, CA 95469.

Following the initial investigation by VTN (1982) on the Potter Valley Project area, Steiner Environmental Consulting (SEC) embarked on a longer-term comprehensive evaluation of the environmental conditions and the potential and actual impacts of the project (summarized in SEC 1998). Those inferred impacts are summarized here from the SEC (1998) Final Report under the following topical categories.

Alteration of river thermal regime due to the Potter Valley Project water releases

As a result of project operations, the extended period of cold-water releases in the upper mainstem Eel River between Cape Horn Dam and (upstream) Scott Dam/Pillsbury Reservoir delays the development and onset of out-migration of juvenile Chinook salmon rearing in that reach. The developmental and migration delay was an average of 19 days relative to the timing of juvenile out-migration from Tomki Creek. This delay caused the later-migrating juveniles in the mainstem to encounter warming conditions in the downstream reaches and potentially experience lower survival rates, especially during early May. During essentially the first half of the out-migration periods from the study locations—i.e., the time period between which 5% and 50% of the entire out-migration occurred in the respective study locations—the out-migrating juveniles or smolts from above Cape Horn Dam were generally larger (i.e., by ~4 mm) than out-migrating fish from Tomki Creek. Hence, the results “implied that fish reared in a cooler environment need to attain a larger size to achieve the necessary N^+K^+ ATPase levels for smoltification and the migratory response” (SEC 1998: p.5.7-3).

Management options have been explored to use controlled Pillsbury Reservoir releases to adaptively manipulate river temperatures below the reservoir. However, there are both positive and negative consequences of such flow and temperature manipulations for Chinook salmon and steelhead. For example, conditions that trigger Chinook emigration from above Scott Dam (positive impact) may inadvertently stimulate the movement of smaller age 1+ steelhead that would subsequently experience lower survival rates (negative impact).

Effects of flow releases below Cape Horn Dam (Van Arsdale Reservoir) on juvenile salmon migration

A study of marked juvenile Chinook salmon showed a positive correlation between out-migration rates and mainstem discharges in the migration route from Tomki Creek to Outlet Creek (at flows 97-169 cfs).

Faster transit rates likely facilitate higher survival due to lessened exposure to stressful thermal conditions, but the study with marked juveniles did not demonstrate a direct relationship between flow level (or flow fluctuations) and juvenile survival rates (SEC 1998).

Entrainment of salmon and steelhead juveniles

Entrainment of salmon and steelhead juveniles appears to have been of low magnitude during the study period. Entrainment of juveniles “was estimated to have little or no impact on adult salmon and steelhead returns [i.e., on spawning escapements]” (SEC 1998: p.xx). The extent of mortality of entrained steelhead juveniles was determined to be usually equivalent to zero to eight adults lost per year but it was singularly high during 1984-1985 when juvenile steelhead losses were equivalent to approximately 65 adult steelhead that otherwise would have returned to spawn. Furthermore, the results for Chinook salmon seemed less definite and were probably influenced by the low levels of adult spawning and juvenile production above Cape

Horn Dam in many years during the period 1970-1997 (SEC 1998, their Table 4.3-5). SEC (1998: p.5.9-2) concluded: "The available data suggest that entrainment was not a significant factor affecting chinook returns for any year monitored." A new fish screen that was installed in December 1995 was expected to eliminate further entrainment losses of juvenile salmonids.

Improved mainstem habitat conditions for steelhead juveniles

Project flow releases in the reach between Scott Dam and Cape Horn Dam have improved summer flows and temperatures since 1922 (when Scott Dam was completed). These favorable conditions benefited juvenile steelhead which experience faster growth in the mainstem Eel River reach compared to juvenile growth rates in the tributaries. It was demonstrated from scale analyses that steelhead that had reared in that mainstem reach frequently attained a size sufficient for ocean entry (i.e., 190-280 mm) during a single year of growth compared to at least three years of rearing needed to attain the same growth in the tributaries (SEC 1998). Chinook salmon juveniles did not benefit as much as steelhead from the improved flows and rearing conditions in the mainstem reach between Cape Horn and Scott dams. There is less spawning by Chinook salmon in the mainstem above Cape Horn Dam compared to the mainstem below Cape Horn Dam or to Tomki Creek, a major tributary below Cape Horn Dam.

Potential effects on adult Chinook salmon migration to upstream areas

SEC (1998) reported that the earliest arriving Chinook salmon in the Potter Valley Project study area occurred between mid-October and early December during the study years, depending on the prevailing flow levels and incidence of drought in those years. Limited fall pulse-flow releases from Cape Horn Dam noticeably affected the migration of adult Chinook salmon into the study area as reported by SEC (1998: p.xiv):

"The Potter Valley Project has provided the majority of water for migration in 7 years between 1985/86 and 1995/96. The project demonstrated the ability to pulse flows in a manner that promoted chinook migration. Salmon have been documented entering the study area on average pulse flows of 98 cfs at the Eel River above Outlet Creek gage (range 32 to 188 cfs). The average duration of all flow pulses was approximately 3 days. Non-project pulse flows, including CDFG blockwater releases, were able to promote fish movement from below Outlet Creek to the mainstem above Cape Horn Dam. Project-related pulse flows (averaging 59 cfs at E-11) promoted fish movement below and into the study area in 4 years of the study. These releases and the corresponding fish movements indicate that a relatively small amount of water can significantly affect chinook movement as far downstream as Ft. Seward (KP 101). Pulse releases from the project attracted fish past Tomki Creek in 1986/87 and 1995/96. Chinook have entered Tomki Creek on approximately 15 cfs, the lowest observed flow for chinook movement."

The importance of sufficient flows to facilitate the upstream migration of adult Chinook salmon was also emphasized by Morford (1995).

Cape Horn Dam fish ladder

The fish ladder evidently prevented or delayed the passage of Chinook salmon over Cape Horn Dam during some years before structural modifications were made to the fish ladder in 1987. Before the modifications, Chinook salmon arriving below the dam required 12.8 hours on average to enter the ladder but after the modifications the average time to enter was 0.6 hours. The effects of the fish ladder on steelhead passage could not be determined, but the study results did not indicate "any gross deficiencies in ladder performance" (SEC 1998: p.xvii). However,

flows in the fish ladder that are less than 9.8 cfs or greater than 10.5 cfs can pose passage problems for up-migrating fish.

Facilitation of introduced Sacramento pikeminnow

As in many other river systems in California and elsewhere, the alteration of the natural hydrologic regime by water impoundments and diversions on the Eel River significantly changed environmental conditions—e.g., flow levels, flow timing and spatial patterns, and stream temperatures—at least during certain times of the year. Such instream changes often favor introduced fish species such as Sacramento pikeminnow and largemouth bass to the detriment of the native salmonids.

The relatively recent introduction into the Eel River system of the predatory Sacramento pikeminnow (*Ptychocheilus grandis*)—also formerly called Sacramento squawfish, Sacramento pike, chappaul, white salmon and other names-- has created substantial problems for the native anadromous salmonids and resident species. As noted by SEC (1998: p. 5.11-2), the entry of Sacramento pikeminnow followed by “their rapid population growth, basin-wide range expansion, and a simultaneous decline in salmonid populations” has been of concern to fisheries managers and other Eel River stakeholders.

The general characteristics and occurrence of pikeminnow in the Eel River system were concisely described by SEC (1998: p.5.11-1):

“They were introduced into the Eel River sometime during the late 1970’s (Brown et al. 1987), presumably as a bait bucket release into Lake Pillsbury. Larger *P. grandis* prefer large pools in low velocity riverine habitat; they will also inhabit reservoirs. Smaller (presumably immature) *P. grandis* are found in a wide range of habitats from reservoirs to pools and riffles. Relatively high *P. grandis* populations (mostly small fish) have been documented in the mainstem Eel River summer survey sections between Scott and Cape Horn dams (Section 4.7). These survey sections are primarily riffle habitat[.] Preferred temperatures are between 16° and 22°C, but they can survive to 33°C (Cech et al. 1990). *P. grandis* have high reproductive potential, laying many thousands of eggs (Burns 1966), but growth is relatively slow with sexual maturity not being reached until the third or fourth year. *P. grandis* may live for 9 years or more (Taft and Murphy 1950). When young, they feed primarily on insects and plants, shifting their diets to fish and larger invertebrates as they mature.”

The following detailed commentary on the relationship between the Sacramento pikeminnow and Eel River salmonids is taken directly from SEC (1998: p.5.11-1 to 5.11-2).

“In their native rivers, *P. grandis* co-exist with salmonids (Moyle 1976; Vondracek et al. 1989). *P. grandis* will prey upon juvenile salmonids, but the species tend to segregate much of the year based on physical characteristics (Dettman 1976; Brown and Moyle 1981). *P. grandis* favor larger pools in warmer water while the salmonids generally rear in the higher-gradient, cooler tributary habitat during the summer. When the distribution of both groups overlap, *P. grandis* tend to dominate at temperatures exceeding 15°C. The mechanisms for the dominance can be behavioral displacement (competition for food resources being implicit) or direct predation. Salmonid behavior in these rivers suggests an evolutionary response to the threat of predation. When river systems are altered by flow management, structures, or other disturbances, the balance of species may shift dramatically . . .”

“The first *P. grandis* juveniles were captured at the Potter Valley Powerhouse in 1980 (VTN 1982). Distribution throughout the drainage appears to have been accelerated by the flood of February 1986 (SEC 1991). The species is currently present in the larger reaches of all Eel River sub-basins (Brown and Moyle 1991b; Brown and Moyle 1992). Eel River *P. grandis* populations increased dramatically during the early 1980’s, making

them the dominant species in the larger main channel reaches during summer months (SEC 1995; CDFG unpublished data).”

“*P. grandis* may pose a significant risk to the salmon and steelhead resources of the Eel River (Brown and Moyle, in press) [i.e., Brown and Moyle 1997]. This threat manifests itself in the form of direct predation and habitat displacement. Predation impacts vary seasonally and may be localized (Brown 1982). Displacement can result directly from behavioral exclusion (Brown and Moyle 1991a; Brown and Brasher 1995) or increased competition for limited trophic resources. The effects of both predation and displacement can be exacerbated by alterations to the river system.”

“Conditions in many main channel reaches of the Eel River drainage appear to favor *P. grandis* over salmonids during certain periods of the year (SEC 1995; CDFG unpublished data). The rapid establishment of *P. grandis* is believed responsible for a significant decline in steelhead rearing densities in the mainstem Eel River between Cape Horn (Section 5.8) and Scott dams, a condition which likely effects [sic] adult escapements (Section 5.19). The structures associated with Cape Horn Dam and the Van Arsdale diversion provide habitat for *P. grandis* (A. Grass, CDFG, personal communication; L. Week, CDFG, personal communication), hence they may encourage predation. Warm summer water temperatures and low flows below Cape Horn Dam historically provided marginal steelhead rearing habitat (Kubicek 1977). Once distributed below Cape Horn Dam, *P. grandis* rapidly dominated, eliminating the limited steelhead rearing which historically existed (Section 5.8). While *P. grandis* dominate the warmer mainstem reaches, the tributaries continue to support significant populations of rearing steelhead. Juvenile salmonids emigrate from spawning and rearing areas during spring when higher flows and cooler water temperatures somewhat limit the predatory activity of *P. grandis*. *P. grandis* in the Eel River demonstrate strong seasonal migration patterns (B. Smith, USFS, personal communication). During spring, they tend to congregate in the main channel at confluences with tributaries, presumably feeding on outmigrating juvenile salmonids. Predation is likely to pose the greatest risk to the salmonids during years with lower spring flows, warmer water temperatures, and low adult salmonid escapements. As the season progresses, *P. grandis* appear to move to upstream locations including the lower reaches of some smaller tributaries for spawning. By summer, the fish older than two or three years of age tend to congregate in large and somewhat barren main channel pools during the day, migrating at night to more favorable foraging areas in nearby riffles (B. Harvey, USFS, personal communication). At the Potter Valley Project, both Lake Pillsbury and the Eel River between Scott and Cape Horn dams provide favorable habitat for *P. grandis*. Prior to the introduction of *P. grandis*, these locations both provided important salmonid habitat. Now, both areas have demonstrated significant salmonid declines coincidental with *P. grandis* increases.”

However, SEC (1998) noted that their perceived impacts of Sacramento pikeminnow on salmonids in the Eel River must be analyzed in the broader environmental context that subsumes other potential factors affecting salmonid populations. Specifically, they stated (SEC 1998: p.5.11-2):

“It is important, though, that any assessment of the impact of *P. grandis* be done with the understanding that the precipitous decline of Eel River salmonids during the late 1980’s paralleled a coastwide trend of similar population collapses in most river systems (sections 5.1 and 5.2). The true impact of squawfish [pikeminnow] in the Eel River will not become clear until both the Eel River and coastwide salmonid trends can be evaluated over a period of several ocean productivity cycles.”

Nevertheless, it is obvious that the dramatic population increase and distributional expansion of pikeminnow through much of the Eel River basin poses a substantial, and perhaps insurmountable, challenge to the anadromous salmonids in at least some of the larger reaches. Hence, considerable effort has been put into studies and management actions to control the pikeminnow populations in the Eel River (SEC 1998). As noted by SEC (1998), additional innovative strategies to control pikeminnow impacts on salmonids may be worthwhile or even necessary to consider—including increased protection and restoration of habitats in the tributaries. An intriguing approach would be the use of strategic flow releases to aid juvenile salmonid movements. Specifically, SEC (1998: p.5.11-3) suggested:

“Management of cold water releases from Scott Dam during late spring might minimize predation by *P. grandis* on newly-emerged steelhead who are actively dispersing into rearing habitat between the dams. Refinement of spring flow releases below Cape Horn Dam may enhance the timely emigration of salmonid smolts from the upper mainstem.”

Yet, even substantial management efforts may have limited success in controlling Sacramento pikeminnow populations in the Eel River, as recognized by SEC (1998: p.5.11-3):

“A ‘no action’ policy in the river may lead to stabilization of the *P. grandis* population and age structure, reducing the impact from the initial rapid expansion experienced during the early colonization period. Even with the implementation of various management options, it is questionable whether salmon and steelhead living sympatrically with *P. grandis* in the Eel River would be capable of attaining the level of reproductive success present before the introduction of *P. grandis*.”

California Department of Fish and Game. Warden John Mullin to CDFG Associate Biologist Rick Macedo, memoranda (dated August 25 and September 12, 1995) Regarding the adequacy of fall-winter and spring-summer flows for adult and juvenile salmonids in the Eel River.

The perceived impacts on anadromous salmonids due to the Potter Valley Project's alteration of the natural flow regime below Scott Dam (Pillsbury Reservoir) and especially below Cape Horn Dam (Van Arsdale Reservoir) were further discussed in a pair of CDFG memoranda-communications (from CDFG Warden John Mullin to Associate Fishery Biologist Rick Macedo; henceforth, "Mullin memo" September 12 and August 25, 1995). The two memoranda addressed the impacts of the altered flow regimes during the spring-summer and fall-winter seasons, respectively.

Spring-summer flows

Drawing from studies reported in VTN (1982) and Steiner Environmental Consulting (SEC 1987-1994, The Potter Valley Project Annual Progress Reports), Mullin directly quoted passages from those reports to show that annual spring-summer instream flows were substantially reduced by the water project operations at least until July 1 in most years. Some of the most telling passages are as follows (Mullin memo, September 12, 1995: p.3-5, quoting VTN 1982).

"An evaluation of summer rearing habitat for steelhead trout, modified for temperature suitability, indicates that the most important rearing area exists between Scott and Cape Horn Dams. Summer rearing habitat available in this section is greatest (>8-% of optimum) at flow release of 68 to 265 cfs. Summer rearing habitat in the Eel River below Cape Horn Dam (and particularly below Tomki Creek) is limited by high water temperature. Moderate summer flow releases of 20-30 cfs from Cape Horn Dam would have minimal effects on reducing stream temperatures to suitable levels; releases ranging from 76 to 166 cfs would be required to achieve suitable temperature conditions between Tomki Creek and Outlet Creek."

"Relatively cool temperatures in the Eel River between Scott and Cape Horn Dams, due to the usual release of water from the bottom of Lake Pillsbury, apparently cause a delay in emigration from this stream section. This has a profound adverse effect on salmon emigrating from above Cape Horn Dam; by the time water temperatures above Cape Horn Dam approach emigration-stimulating levels (around 17°C), temperatures downstream approach lethal levels (over 24°C), probably resulting in the loss of these emigrating fish." [The Mullin memo added, "A review of temperature data in Steiner (1987-94) has indicated that temperature mixing, when possible, has not significantly alleviated this situation."]

"In most years, steelhead emigrating as late as June are apparently lost to the fishery. Water temperature data and summer fish inventories indicated that there is little habitat available to juvenile steelhead during the summer months below Cape Horn Dam."

"The Eel River between Scott and Cape Horn Dams provides the most important summer rearing habitat for juvenile steelhead trout in the study area; higher densities occur in this section than in other portions of the study area. Tributary streams between Scott Dam and Outlet Creek provide fair to good quality rearing habitat and are important components of the total available rearing habitat within the study area. The Eel River between Cape Horn Dam and Tomki Creek provides some additional rearing habitat, but of lower quality than in the Eel River upstream of Cape Horn Dam and in most tributaries. The Eel River between Tomki Creek and Outlet Creek provides little or no

rearing habitat that can be considered suitable during most summers due to high temperatures.”

“Temperatures in the Eel River between Cape Horn Dam and Outlet Creek are influenced greatly by the reduction in flow that occurs at Cape Horn Dam. Temperatures typically increase to peak levels in mid-June through August.”

An important analysis of instream flows in the upper mainstem Eel River was conducted by Sheldon C. Bachus that demonstrated the large extent to which the flow regime had been changed by the Potter Valley Project flow releases (Mullin memo, September 12, 1995: p.5-6):

“A recent study, *The Eel River Unimpaired Flow Study*,” by Sheldon C. Bachus, covers a 15-year period (water years 1977/78-1991/92). This study shows the differences between the expected natural behavior of the river and its actual flows as a result of artificial diversion and reservoir management. The 15-year period is important because it contains a wide range of hydrologic extremes from the El Nino years of the early 1980’s to the intense drought experienced at the end of the decade into the 1990’s. The study showed that on July 1 actual flows below Cape Horn Dam averaged 16 percent of expected (natural) flows. Expected flows on July 1 exceeded 76 cfs (suitable rearing habitat between Cape Horn Dam and Outlet Creek) for five of the 15 years profiled. The other 10 years (mostly drought years) ranged from 21 to 69 cfs (43 cfs average). During the mild summer of 1982, the actual flow on July 1 was 13 cfs and the expected flow (below Cape Horn Dam) was 87 cfs. (The actual flows below Cape Horn Dam on July 1, 1980 and 1981 were 10.0 and 8.3 cfs respectively.) The actual flow in the Eel River above Outlet Creek was 48 cfs on July 1, 1982. Actual flows on July 1, 1980 and 1981 above Outlet Creek were 28 and 29 cfs. (Expected flows above Outlet Creek for July 1, 1980, 1981, and 1982 were 87, 59.7, and 116 cfs respectively.) Expected flows above Outlet Creek were over 48 cfs on July 1 for 13 of the 15 years covered by the Bachus study. [Note: The minimum spring/summer streamflow releases for the interim study period (1979-1982) were essentially reduced by 50 percent at re-licensing in 1983.]

Mullin asserted that the reduction of spring-summer flows below Cape Horn Dam “explains why the downstream migration of both salmon and steelhead smolts is, according to Steiner [SEC] (1987-94), ‘A phenomenon which occurs predominantly before June 1.’” (Mullin memo, September 12, 1995: p.6)

Mullin concluded that the Potter Valley Project operations have had significant adverse impacts on the juvenile salmonids that attempt to down-migrate or rear below Cape Horn Dam (Mullin memo, September 12, 1995: p.6-7).

“A review of the VTN, Steiner, and Bachus studies shows that the current spring/summer flow regime is extremely detrimental to juvenile salmonid emigration and rearing below Cape Horn Dam. The VTN and Steiner studies show that, due to the low flows/higher water temperatures, the lengthy stretch of the Eel River between Cape Horn Dam and Outlet Creek has been rendered threatening during the late spring and lethal during the summer for juvenile salmonids. The low flows have also made it more difficult for juvenile salmonids to escape certain predators that thrive in the warmer water. The Bachus study showed that during most normal rainfall or mild summer years, natural flows would have produced suitable salmonid habitat between Cape Horn Dam and Outlet Creek throughout the summer. Conditions for steelhead rearing during all years would have at least been suitable between Cape Horn Dam and Tomki Creek. In all cases, survival conditions for salmonid emigration would have been enhanced by the higher flows and lower temperatures provided by the natural behavior of the river.”

“After 15 years of study, it appears that project operations have managed to enhance squawfish populations at the expense of chinook salmon and steelhead. Coho salmon

have probably also been affected. A flow schedule based on the expected natural behavior of the river system would provide the habitat necessary to reverse this trend.”

However, the primary issue is whether or not the reduced flow schedule actually exerted a negative impact on the juvenile salmonid population (mainly steelhead-rainbow trout) that otherwise would not have occurred with a fully natural flow regime through the entire summer and early-fall periods. In other words, would the river reaches in question have become too warm and unsuitable as salmonid habitat even under the natural (pre-project) flows, but later in the summer or early fall instead of by July 1 (as occurs under the water project operations)? It would seem that the relatively low elevation of the mainstem Eel River headwaters and limited snowpack would preclude summer-long cold flows even in normal years. Hence, additional hydrological analysis for the upper mainstem Eel River probably would provide further clarification of the former natural condition and useful insights on realistic water management options.

Fall-winter flows

The fall-winter instream flow regime set by the Potter Valley Project FERC license also has posed distinct challenges during dry years to Chinook salmon (and, in the past, probably coho salmon) that attempt to migrate to the upper mainstem Eel River. The fall flow period is problematic because it follows the summer period of limited flow releases and nonexistent rainfall. The Federal Energy Regulatory Commission (FERC) summarized the situation (in 1983) of the salmon and steelhead in the upper mainstem Eel River (quoted by Mullin memo, August 25, 1995: p.4):

“The decline in numbers of steelhead trout and Chinook salmon utilizing the upper reaches of the Eel River for spawning and rearing of young has been attributed to the quantity and timing of releases from the existing Cape Horn and Scott Dams.”
“Although spills occur at Cape Horn Dam during fall and winter, the duration is often insufficient to allow upstream migrating adult salmonids to reach the fish ladder at Cape Horn Dam.”

The challenges encountered by salmon due to low fall flows were summarized by Mullin (memo, August 25, 1995: p.5):

“During the drought of the late 1980’s and early 1990’s, the fish counts again experienced a precipitous decline. Review of Lake Pillsbury inflow data, the ‘Eel River Unimpaired Flow Study [i.e., Bachus 1995],’ and SEC [Steiner Environmental Consulting] Chinook salmon counts during this period indicate that water was withheld in large quantities at critical times. The fall migrations of 1988 and 1989 demonstrate how a migration stimulated by runoff can be stalled and subject to unfavorable spawning and survival conditions. When there is enough water for fish to reach tributaries like Outlet Creek and Tomki Creek, these creeks often have more flow than the mainstem Eel River. These conditions can encourage fish to ascend lower tributaries rather than continue upstream in the Eel River. The fish remaining in the Eel River face abrupt and unnatural flow reductions. VTN (1982b) concludes their study by comparing salmon escapement into Tomki Creek with fish ladder counts. ‘During four years of comparable data, salmon ascending Cape Horn Dam comprised 0 to 4% of the estimated populations in Tomki Creek.’ The gradual loss of Coho salmon upstream of Outlet Creek follows a similar trend. The 1989 flow data shows that the impoundment/diversion can significantly affect flows as far downstream as Fortuna near the mouth of the Eel River. It appears that the current flow regime can negatively impact every stage of adult salmon migration.”

A significant point noted by Mullin (memo, August 25, 1995: p.5) was that the new flow schedules and block-water releases during the fall seasons of 1985-1992 did not, in practice,

result in actual benefits to the up-migrating salmon because of mistiming and inadequate volumes of the flows.

“Review of all SEC progress reports revealed some interesting facts. Apparently, during the critical months of October and November (1985-1992), the new flow release schedule had not differed significantly in application from the pre-1979 schedule. There was essentially no change in the October schedule other than base flow requirements. The November schedule changed significantly in theory only. During December, trigger events with flow regulation or block water releases are often ineffective at best. December flow regulation has usually been too late and lacks the quantity, pulses, and peaks shown to facilitate upstream salmonid migration. Block water releases not coincident with tributary runoff lack a positive effect at best.”

Mullin (memo, August 25, 1995) provided a detailed example of how low-flow conditions may alter the migration timing and distribution of spawners despite the occurrence of storm events and the consequent management release of “block water”—i.e., a volume of stored water (2,000-2,500 acre feet) in Lake Pillsbury that is allocated for discretionary release by CDFG to assist the fall salmonid migration. The release of block water was contingent upon a triggering event defined in the FERC License Article 38 as “the occurrence between November and December 31 of any year of an accretion flow between Scott Dam and Cape Horn Dam of 75 cubic feet per second (cfs) mean daily flow” (Mullin, citing Steiner 1991). Furthermore, no triggering event could be considered as such if it occurred within seven days of a previous triggering event (Mullin, citing FERC License Article 38). The example from Mullin (memo, August 25, 1995: p.4) follows.

“After a November triggering event, the summer minimum flow (maximum 10 cfs required) continues unless there is enough cumulative inflow (Article 38). November of 1988 provides an example of how this can work. Between November 22 and 24, 1988, Lake Pillsbury gained over 16,000 acre/feet from storm runoff. This equates at least 2,500 cfs per day. On November 22, 625 cfs spilled over Cape Horn Dam (all accretion). There was a triggering event, but no change in minimum release requirements due to lack of cumulative flow. The next day, November 23, 891 cfs spilled over Cape Horn Dam. (Remember, no trigger event may follow another trigger event by seven days or less.) The flow was back to 70 cfs by November 26 and averaged 30 cfs for the remainder of the month. Inflow into Lake Pillsbury was still about 250 cfs on November 30. Steiner (1990) describes the 1988 Chinook migration: ‘Chinook migratory activity was associated with periods of elevated discharge. Significant runoff from a major storm on November 22 resulted in increasing discharge at E-11 (Van Arsdale/Cape Horn) from 26 to 625 cfs. A total of 204 Chinook (62 percent of the yearly total) reached the ladder trap by the time the discharge returned to pre-event levels on November 27.’ (27 cfs) ‘A block water release was initiated by CDFG between December 2 and December 10. During this period discharge ranged from 69-193 cfs (stabilized for 7 days around 190 cfs).’ ‘Ladder counts indicated a much smaller pulse of migratory fish responded to the block water release.’ (Steiner 1990) Tomki Creek went from 153 cfs on November 26, 93 cfs on the 27th, 64 cfs on the 28th, down to 35 cfs on the 30th. Perhaps the Chinook run escaped up Tomki Creek. ‘The peak migration was observed in Tomki Creek and at Van Arsdale (KP252.2) from November 24 to 26.’ (Steiner 1990). During these three days, Tomki Creek averaged 234 cfs, and the Eel River below Cape Horn Dam averaged 135 cfs. On the 27th, Chinook salmon migration in the Eel River was virtually blocked at 27 cfs. Outlet Creek flow between November 27 and 30 exceeded the flow in the mainstem Eel River. In fact, flows in Outlet Creek roughly equaled or exceeded actual flows in the mainstem throughout this event.”

A second example, represented by events during the fall 1989, further highlighted the substantial differences between the natural unimpaired flows and the actual project-release flows Mullin (memo, August 25, 1995: p.2-3).

“The minimum flow requirement in October is summer flow (maximum 10 cfs). Until a November triggering event, all runoff over 10 cfs may be diverted into the Russian (Article 38) [of the FERC License]. October and November 1989 provide good examples of how this system works. In October 1989, a storm added about 7,500 acre/feet to Lake Pillsbury between October 22 and 27. This averages 625 cfs per day. The actual flow below Cape Horn Dam was 7.5 cfs on October 22, 98 cfs on the 23rd, 27 cfs on the 24th, and back to 7.7 on October 25. Another smaller storm in November did not cause a trigger event (less than 75 cfs accretion). The flow below Cape Horn Dam went up to 37 cfs on November 25, 96 cfs on the 26th, 25 cfs on the 27th, and 14 cfs on the 28th. There were no actual flows during October and November 1989 exceeding 100 cfs. A recent study (Bachus 1995) showed that under natural conditions (no impoundments or diversions) there would have been 15 days of flows exceeding 100 cfs below Cape Horn Dam during these two October and November runoff events. Ten of the 15 days would have exceeded 200 cfs. The first runoff event in October was predicted to peak on October 23 at 1,306 cfs (Fortuna peaked at 6,900 cfs on October 24). The second event in November was predicted to peak on November 26 at 580 cfs. The predicted flows between these two events never dropped below 42 cfs. The actual flows dropped to 6.4 cfs. ‘This disparity points to vast differences between the expected natural flow of a river system and its actual flow as a result of artificial diversion and reservoir management.’ [citing Bachus 1995, The ‘Eel River Unimpaired Flow Study’]”

“Predicted (natural) flows above Outlet Creek peaked at 1,576 cfs on October 23 and exceeded 100 cfs for 11 days. During the last week of November, predicted flows above Outlet Creek peaked at 834 cfs on November 26 and exceeded 100 cfs for 14 days. (Bachus 1995)”

“The actual flow in Outlet Creek peaked at 332 cfs on October 23 and 145 cfs on November 26. No fish were found by Department surveys in the Outlet Creek drainage that season. (Jones 1989)”

California Department of Fish and Game. Warden John Mullen to Mr. Ralph Carpenter, CDFG Inland Fisheries Division, Letter (dated May 8, 1996). Comments regarding the draft Eel River action plan.

In a subsequent CDFG internal communication by Warden John Mullen, the amounts of suitable summertime habitat available to juvenile steelhead were compared for the 30-mile reach below Cape Horn Dam (i.e., Cape Horn Dam to Outlet Creek) and the 12-mile reach between Cape Horn Dam and Scott Dam during four years of favorable streamflow and temperature conditions. One intent of Mullen’s analysis was to determine the available habitat areas (AHA) for those four favorable years to augment and counterbalance the available habitat assessments previously presented by VTN (1982) for year 1982 as well as two other years that were highly unfavorable—i.e., the “two very hot summers (1973 and 1980) when tributary inflow was less than 3 cfs” (Mullen Letter, May 8, 1996: p.2).

Aside from the environmentally favorable year of 1982 (i.e., higher streamflows and lower water temperatures), there were three subsequent years (1989, 1990, 1993) when summer water temperatures did not exceed 28°C and increased tributary inflows occurred. Mullen estimated the amounts of suitable habitat—termed “re-modified available habitat area” or RAHA)—that would have been available to juvenile steelhead based on “actual peak summer

water temperatures and predicted natural flows on July 1” for those four favorable years. Those re-modified estimates were presented along with estimates of available habitat area (AHA) that were based on the original limiting criteria from the VTN (1982) Instream Flow Study; i.e., 30°C and maximum 13 cfs flow below Cape Horn Dam. The resultant values are given in the following Table 6 (modified from Mullen Letter of May 8, 1996, his Table 1).

Table 6. Available Habitat Area (square feet) for Juvenile Steelhead in the Upper Mainstem Eel River. Values in rows indicated by “VTN” were from VTN (1982); rows indicated by “RAHA” were “re-modified” by Mullen (Letter, May 8, 1996).

	1982	1989	1990	1993
Scott Dam to Cape Horn Dam (VTN)	748,218	748,218	765,356	562,545
Cape Horn Dam to Outlet Creek (VTN)	25,272	25,272	15,825	15,825
Cape Horn Dam to Outlet Creek (RAHA)	1,591,446	442,794	1,230,171	3,002,884
Cape Horn Dam to Outlet Creek (RAHA with 13 cfs actual flow)	124,815			

The results indicate that substantially greater amounts of suitable habitat could be available for juvenile steelhead with greater (i.e., natural) flows below Cape Horn Dam to Outlet Creek than actually occurred under the prevailing flow releases. Interestingly, the estimated available habitat (i.e., 124,815 square feet) under the actual flow (13 cfs) and actual peak temperature below Cape Horn Dam in the summer of 1982 was substantially greater than the amount based on the original VTN study’s criteria (i.e., 25,272 square feet).

There are potentially significant insights that can be gained from further examination of the streamflow and temperature data from the VTN (1982) and SEC (1998) studies, together with additional information on salmon and steelhead biological requirements. As aptly stated by Mullen (Letter May 8, 1996: p.3),

“The conclusions of the VTN study were apparently based on technological rather than scientific parameters. The fixed flow releases of the Potter Valley Project bear little resemblance to natural phenomena. VTN’s ‘worst case scenario’ approach was apparently predicated on the perspective that, during some years, increased flows would not benefit the fishery and water would be ‘wasted’. Variations in atmospheric and geologic conditions were apparently not considered. They also seem to ignore evolutionary concepts like genetic and behavioral diversity, or the opportunistic nature of a species. VTN did however collect a great deal of data in a scientific manner. The cost of repeating such a task would be prohibitive. A re-analysis of the data is necessary if scientific conclusions are desired.”

APPENDIX D. MICHAEL MORFORD: EEL RIVER HYDROLOGY AND CHINOOK SALMON.

Michael Morford spent much of his professional life working on the Eel River, as a biologist for USFWS and as a consultant. Few people ever got to know the river and its fishes better. In 1995, he wrote a report to summarize some of what he knew. This appendix is a summary of his report:

Morford Consultants (Morford). 1995. Eel River hydrology and Chinook salmon. An analysis of USGS streamflow data collected at Scotia, Humboldt County, California with emphasis on fisheries. Periods of analysis 1940 through 1960, 1970 through 1993. Draft Report, August 1995. Morford Consultants, 23211 East Side Road, Willits, California 95490.

The importance of adequate streamflows during appropriate times for the life-stages of Chinook salmon was emphasized in this analysis which examined the record of streamflows in the Eel River and the apparent effects on the salmon populations. The general effects of timely streamflows on up-migrating fall-run Chinook salmon were stated by Morford (1995: p.4) as follows:

“The Eel River Chinook salmon enter the estuary beginning in August and continue into January. Their life expectancy upon entering fresh water is about 2 to 2½ months. They typically reside in the estuary for some period awaiting increased streamflows. However some fish do not await the rains to migrate. They move as far upstream as Eel Rock even during low flow periods. Eel Rock is located on the mainstem Eel River about 15 miles upstream from the confluence with the South Fork Eel River. These fish wait in the mainstem river for major streamflow increases before migrating further upstream. If major streamflow increases do not materialize, the maturing fish are either forced to spawn where they are or die.”

“Historical accounts and personal observations by the author and others, suggest that these larger fish occupied spawning habitat in the mainstem river and streamflow conditions permitting, the larger tributary streams. A characteristic which has been observed repeatedly is that mature salmon will travel upstream as far as flow conditions permit prior to occupying spawning habitat during their window of spawning opportunity. This characteristic likely had important evolutionary significance in that the early populations of salmon (October/November spawners) would typically occupy spawning habitat in the mainstem river while later runs of fish (the “Black Salmon” or “Thanksgiving fish” and the “silverside”) may either have moved further upstream in the system to habitat previously unoccupied or migrated into tributary streams.”

Morford (1995) noted that the usual pattern during the wet season consisted of several widespread minor rainfall events followed by major storm events. By comparing streamflow measurements taken at various points in the watershed (from U.S. Geological Survey gages), Morford surmised that precipitation and, hence, streamflows increased roughly uniformly over the entire Eel River drainage.

Furthermore, Morford inferred from the streamflow records that the proportionate amounts of streamflows at various points in the system were relatively constant from year to year. Specifically, Morford (1995: p.13-14) stated:

“The importance of this comparison is that it illustrates that generally streamflows in Outlet Creek and elsewhere in the drainage are more or less a constant fraction of those occurring at Scotia. In the case of Outlet Creek it amounts to about 5% of the Scotia streamflow. Beginning at the upstream portion of the drainage, the volume equal to about 3% of that flow which occurs at Scotia is diverted through the Potter Valley Diversion. A volume equal to about 6% of the flow at Scotia flows past Van Arsdale Dam. A volume equal to less than 1% of the Scotia flow originates from Tomki Creek.

The flow at Dos Rios is generally about 11% of the volume of Scotia flow while the streamflow at Fort Seward is about 55% of that at Scotia.”

“Based on these comparisons, it is possible to infer the expected reproductive success of chinook salmon over the period of analysis based on adult transportation needs.”

Effects of Fall Streamflows on Spawning Success

Morford (1995) compiled the streamflow data for the two periods 1940-1959 (i.e., pre-1964 flood) and 1970-1992 (post-1964 flood) and determined the extent to which the annual fall streamflows (i.e., during October 15-December 10) were adequate to ensure spawning success. Morford posited that if the timing and magnitude of the fall flows did not provide sufficient streamflow increases by December 1, then spawning success of that year’s Chinook salmon run would be very adversely affected.

Morford’s tabulation of fall streamflow volumes and his assessments of expected Chinook salmon spawning success for the corresponding years is represented in our Table 7 (which is derived from Morford’s Table 1). Morford (1995: p.14) described his Table 1 as follows:

“Table 1 provides the author’s summarized estimate of Chinook salmon spawning success based on streamflow conditions for the 20 year period of analysis prior to the 1964 flood event. It summarizes conditions for a 23 year period after the 1964 event. This analysis was based on the timing and magnitude of the increase in fall/winter streamflows in the system. It is the judgment of the author that if these increases did not occur prior to December 1 of each year, the prognosis for spawning success was much reduced.”

These data show that wide variations in fall streamflow volumes occurred within both time periods and were accompanied by variable expectations of spawning success. However, there has been a progressive overall decline in Chinook salmon abundance in the Eel River over the past half-century—as has been recognized by many fisheries workers. That general decline, while caused by multiple factors, was significantly propelled by the great 1964 flood event.

Table 7. Qualitative Assessments of Chinook Salmon Spawning Success in the Eel River System in Relation to Fall Runoff (October 15 to December 10) at Scotia (modified from Morford 1995, his Table 1).

Year	Fall Runoff ¹ (acre feet)	Percent of Average Fall Runoff	Estimated Spawning Success
1940	96,700	18	Poor, some mainstem potential
1941	508,000	93	Poor, main flows after November 27
1942	505,900	92	Good, main flows after mid-November
1943	102,300	19	Marginal mainstem; poor in tributaries
1944	759,300	138	Good
1945	1,439,500	263	Good
1946	376,400	69	Good
1947	282,100	51	Good early; poor after November 15
1948	288,700	53	Poor
1949	44,900	08	Poor
1950	1,878,100	343	Good
1951	1,242,000	227	Good
1952	707,800	129	Poor, late flow increase
1953	619,700	113	Good
1954	629,600	115	Good
1955	568,500	104	Good
1956	149,000	27	Poor, early November peak
1957	693,900	127	Good
1958	54,500	10	Poor
1959	18,400	03	Poor
1970	2,414,300	301	Good
1971	272,000	34	Moderate to Good
1972	386,500	48	Moderate to Good
1973	3,194,700	398	Good
1974	136,000	17	Poor
1975	498,500	62	Moderate to Good
1976	22,600	03	Poor
1977	328,600	41	Moderate to Good
1978	28,000	03	Poor
1979	933,000	116	Good
1980	344,600	43	Poor
1981	1,885,200	235	Good
1982	1,116,900	139	Good
1983	2,161,700	269	Good
1984	1,934,500	241	Good
1985	418,400	52	Poor
1986	110,300	14	Poor
1987	871,800	109	Poor
1988	660,600	82	Good
1989	158,500	20	Poor
1990	52,100	06	Poor
1991	93,400	12	Poor
1992	633,500	79	Poor

¹ Fall runoff values are for the designated calendar year--e.g., fall 1940 runoff is for the calendar year 1940.

Morford further elaborated upon the effects of the 1964 flood and other streamflow factors (Morford 1995: p.16-17):

“There are two significant factors that have affected recent Chinook salmon populations in the Eel River. First is the effect of the 1964 flood event which changed the geomorphology of the system. Prior to the 1964 event, reproductive success of Eel River chinook salmon was dependent upon substantial mainstem spawning to maintain population levels. This was especially important in those years when access to tributary streams was not available. Since 1964, known locations of mainstem spawning have supported fewer and fewer fish, suggesting that this variant of the population has declined significantly. The most likely reason for this decline is that this population was unable to reproduce successfully because of the fluid nature of the streambed and the large amount of fine sediments moving through the system.”

“The second factor that has affected recent chinook salmon populations is the two back to back 4 year periods when transportation flows for the fall run chinook salmon failed to materialize. Review of streamflow data for the period 1984 through 1992 suggest that in only one year out of nine did transportation/spawning flows materialize in time to accommodate the fall run chinook salmon population. Essentially, the genetic material associated with at least two generations of chinook salmon was lost.”

Table 8. Qualitative Assessments of Smolt Down-migration Success for Chinook Salmon in the Eel River System in Relation to Spring Runoff (May 1 to June 25) at Scotia (modified from Morford 1995, his Table 2).

Year	Spring Runoff ¹ (acre feet)	Percent of Average Spring Runoff ²	Estimated Smolt Down-migration Success
1941	461,281	155	Good
1942	668,050	224	Good
1943	288,764	96	Moderate
1944	214,098	71	Moderate
1945	310,978	104	Moderate
1946	127,037	42	Poor
1947	120,400	40	Poor
1948	633,973	211	Good
1949	175,177	59	Poor
1950	253,512	84	Moderate
1951	196,931	66	Moderate
1952	368,991	118	Good
1953	804,843	258	Good
1954	184,594	62	Poor
1955	390,916	131	Good
1956	306,199	102	Moderate
1957	713,987	240	Good
1958	389,700	131	Good
1959	96,478	32	Poor
1960	505,451	170	Good
1971	258,109	93	Moderate
1972	164,080	60	Poor
1973	168,021	61	Poor
1974	227,626	83	Moderate
1975	441,354	160	Good
1976	123,954	45	Poor
1977	51,544	19	Poor
1978	295,558	107	Good
1979	442,696	161	Good
1980	190,983	69	Poor
1981	126,294	42	Poor
1982	331,726	111	Good
1983	766,945	257	Good
1984	228,434	77	Moderate
1985	92,592	31	Poor
1986	175,944	59	Poor
1987	95,649	32	Poor
1988	145,900	49	Poor
1989	154,795	52	Poor
1990	693,106	232	Good
1991	162,027	54	Poor
1992	110,915	37	Poor
1993	879,598	293	Good

¹ Spring runoff values in this table are for the designated calendar year--e.g., spring 1941 runoff is for the calendar year 1941.

² Several values for the percent of average spring runoff differ somewhat from the corresponding values for the same “runoff year” given in Table 9—e.g., values for 1943 in Table 8 (96%) versus 1942 in Table 9 (106%). Such deviations occurred in the original tabulated values in Morford (1995, his Tables 2 and 3) which are reproduced here.

Effects of spring streamflows on smolt down-migration success

Morford compared spring flows (i.e., during May 1-June 25) and his subjective assessment of downstream migration conditions (i.e., down-migrating “success”) between the two time periods 1941-1960 and 1971-1993. The main elements of his tabulation (Morford 1995, his Table 2) are given in our Table 8. As was observed with the fall flows, both good-moderate and poor spring-flow years commonly occurred during the two time periods.

The intervening 1964 flood between the time periods had inescapable effects on salmonid juveniles and smolts; viz. (Morford 1995: p.17):

“The aftermath of the 1964 flood left many of the formerly deeper holes in the river filled, reducing the volume of living space available for juvenile salmonids in what had been an ecosystem relatively free from competitors and predators.”

Yet, there were other important changes in spring streamflows and the consequences for the salmonid populations over recent decades. Morford (1995: p.17-19) commented:

“The most striking aspect of this summary is the magnitude of changes that have occurred in the estimate of success from the period 1941 through 1960 and 1971 through 1993. The frequency of good or moderately good years changed from 3 out of 4 to less than 1 out of 2 years (75% versus 43%). This is reflected in the reduction of flows as of May 1 from about 9,000 cfs to a level of about 3,000 cfs or less.”

“The changes in streamflow appears to have naturally occurred either from alteration in rainfall or from a reduction in snow accumulation in the Middle Fork Eel and North Fork Eel River drainage or both.”

“Reduction in spring runoff has likely caused other ecological changes to occur. These changes could include the subtle warming to the reduced volume of Eel River waters during the spring and summer. This would provide advantage to such exotic species as the Sacramento River squawfish [pikeminnow] which tend to prefer warm water.”

Combined effects of fall and spring streamflows

The combined results of Morford’s comparison of fall and spring flows with expected spawning and smolt out-migration success, respectively, were presented in his Table 3 and are reproduced in our Table 9.

The most cogent points to be taken from this tabulation are that (1) the frequencies of poor streamflow conditions during the fall for migration and spawning increased somewhat between the two time periods (from 40% in 1940-1959 to 47% in 1970-1992) and (2) the frequencies of poor streamflow conditions during the spring for smolt down-migration increased substantially (from 25% in 1940-1959 to 57% in 1970-1992). Furthermore, the necessity of having adequate streamflows during both the fall and subsequent spring season further reduced the chances of producing viable cohorts.

Table 9. Qualitative Assessments of Annual Spawning and Smolt Downstream Migration Success of Chinook Salmon in the Eel River System (modified from Morford 1995, his Table 3).

Year	Percent of Average Fall Runoff ¹	Estimated Spawning Success	Estimated Down-migration Success	Percent of Average Spring Runoff ^{1,2}
1940	18	Poor	Good	155
1941	93	Poor	Good	224
1942	92	Good	Moderate	106
1943	19	Marginal	Moderate	97
1944	138	Good	Moderate	104
1945	263	Good	Poor	42
1946	69	Good	Poor	40
1947	51	Good	Good	211
1948	53	Poor	Poor	59
1949	08	Poor	Moderate	84
1950	343	Good	Moderate	66
1951	227	Good	Good	118
1952	129	Poor	Good	268
1953	113	Good	Poor	62
1954	115	Good	Good	131
1955	104	Good	Moderate	102
1956	27	Poor	Good	240
1957	127	Good	Good	131
1958	10	Poor	Poor	32
1959	03	Poor	Good	170
Frequency of poor conditions		40%	25%	
1970	301	Good	Moderate	93
1971	34	Moderate to Good	Poor	60
1972	48	Moderate to Good	Poor	61
1973	398	Good	Moderate	83
1974	17	Poor	Good	160
1975	62	Moderate to Good	Poor	45
1976	03	Poor	Poor	19
1977	41	Moderate to Good	Good	107
1978	03	Poor	Good	161
1979	116	Good	Poor	69
1980	43	Poor	Poor	42
1981	235	Good	Good	111
1982	139	Good	Good	257
1983	270	Good	Moderate	77
1984	241	Good	Poor	31
1985	52	Poor	Poor	59
1986	14	Poor	Poor	32
1987	109	Poor	Poor	49
1988	82	Good	Poor	52
1989	20	Poor	Good	232
1990	06	Poor	Poor	54
1991	12	Poor	Poor	37
1992	79	Poor	Good	293
Frequency of poor conditions		47%	57%	

¹ Fall runoff is for the fall of the designated year (e.g., fall of 1940); spring runoff is for the calendar year following the designated year (e.g., spring of 1941, for listed year 1940).

² Note that the spring runoff for each designated year in this table actually occurs in the following calendar year—i.e., following the fall runoff of the designated year. For example, the fall runoff for the 1940 spawning season is paired with the spring runoff period in 1941 when the resultant juveniles migrate downstream.

The Potter Valley Project

Morford (1995) particularly discussed the Potter Valley Project in regard to its effects on streamflow conditions and impedance of salmonid movements through the river. Morford (1995: p.22-23) described the project and its ramifications for salmonids as follows.

“The Potter Valley Project is located on the upper Eel River at about River [*sic*]. It regulates about 330 square miles of drainage or about 10% of the drainage located upstream from Scotia. The Project consists of Snow Mountain Dam and reservoir, e.g. [*sic*] Lake Pillsbury. The Dam and reservoir impounds and reregulates Eel River water[.] A portion of that storage is diverted through a Potter Valley power generating facility into the Russian River watershed. That diversion is located just upstream of Van Arsdale Dam. Lake Pillsbury has a limited storage capability. Uncontrolled spills from the reservoir are common during the winter and spring periods.”

“Snow Mountain Dam [now called Scotts Dam] is a total barrier to fish migration and has eliminated fish from many miles of formerly important habitat. Van Arsdale Dam, while also a barrier, is fitted with a fish ladder allowing adult fish upstream passage. The Potter Valley diversion is being fitted with a fish screen to divert young fish around the Van Arsdale Dam and Potter Valley Diversion. This screen replaces one constructed in the early 1970’s which never proved to be effective.”

“Operation of the Potter Valley Project has always had an adverse effect on the upper Eel River. For many years it was operated in such a fashion that these effects were acceptable and a viable fishery was maintained. It is an accepted fact that the old Van Arsdale fish ladder was ineffective at certain flow conditions and was seldom attractive to Chinook salmon. Steelhead trout were more successful in navigating the ladder and a number of them were passed upstream of the Van Arsdale facility.”

“During this period of time, the California Department of Fish and Game conducted an informal program of releasing adult steelhead trout into Lake Pillsbury to take advantage of spawning and rearing habitat upstream of that facility. Progeny of those fish would occupy habitat in Lake Pillsbury and a number of them would migrate downstream during periods of reservoir spills. For whatever reason, both Lake Pillsbury and the reach of the Eel River between the Dams was very productive of ‘trout’. These ‘trout’ were likely age 2 and 3 steelhead trout which ultimately would return to the ocean. The practice of transferring adult steelhead upstream of Lake Pillsbury stopped in the 1960’s around the time the steelhead trout population upstream of Van Arsdale began to decline. The amount of Chinook salmon and steelhead trout spawning and rearing habitat in the main river system appears to have remained rather constant but the quality of tributary streams for that purpose appears to have been substantially reduced.”

“In the early 1970’s, an important event occurred at Van Arsdale Dam [Cape Horn Dam] with the failure of the mechanism which would open the low level outlet at that facility.

This event is significant from 2 or 3 fishery perspectives. First, failure to open the low level outlet has prevented gravel from passing around and through the structure. This has prevented significant recruitment of gravel to abut an 8 mile reach of the Eel River reducing the habitat value of that river reach. Gravel in that reach has been washed downstream leaving significant river reaches without sufficient gravel for spawning, insect production and other purposes.”

“The 2nd effect of this failure is that Van Arsdale Reservoir has been filled with material. Due to the natural gravel sorting process, it is believe[d] that material next to the Dam is primarily fines [i.e., fine sediment], the size of the gravels increasing progressively upstream from the site. In the 1950’s and 1960’s, water depths in Van Arsdale Reservoir approached 25 feet in depth. This depth provided over-summer habitat for juvenile steelhead and likely provided a pathway for migratory fish moving through the reservoir into the fish ladder. During this period, a gravel bar was established in front of the diversion so that only the upper layer of the reservoir water column was entrained through the diversion. Entrainment of surface water may have avoided a significant fish entrainment problem at the diversion since that portion of the water column is usually not frequented by fish. It has been observed that fish occupying the upper portion of the water column are often eliminated from the population because of predation and other natural selection processes.”

It is, therefore, obvious that aside from severely impeding (at Cape Horn Dam) or completely blocking (at Scotts Dam) the anadromous salmonid migrations, the dams have disrupted a fundamental ecosystem process in the upper mainstem Eel River—viz., downstream gravel transport and replenishment of salmonid habitats below Cape Horn Dam. Interestingly, as noted by Morford, the gravel accretion within Van Arsdale Reservoir has reduced the available habitat there for at least juvenile steelhead but, coincidentally, it probably helped reduce entrainment of the juveniles into the water diversion pathway that supplies the Russian River system.

However, it is the streamflow impacts of the Potter Valley Project that present issues of concern. Several of those issues were briefly considered (Morford 1995: p.24-25)—viz., summer streamflows below Cape Horn Dam, insufficient springtime flows during drier years, and infrequent winter flows for Chinook salmon upstream migration.

“The Potter Valley Project diverts about 1/3 of the average annual flow in the upper Eel which would have been destined to pass Van Arsdale. This amounts to about 3% of the annual flow at Scotia or about 6% of the average annual flow at Fort Seward. Although these amounts may not appear to be significant to some, the impairment of natural flows may be critical for fish.”

“The concern that summer streamflows are not sufficient to maintain a year-round fishery in the Eel River downstream from Van Arsdale has been raised as a[n] issue. It is the opinion of the author that this is a non-issue. The mainstem reach of the Eel River has not been important for salmonid rearing for many years based on the interest this river has shown to anglers since the 1940’s and beyond. Unimpaired summer flows at Van Arsdale did not commonly exceed 20 cfs, the maximum flow which will allow thermal stratification to persist downstream to Outlet Creek. Many of the deeper pools which did thermally stratify prior to the 1964 flood event still have not regained the depth needed to provide areas of thermal refuge either on a temporary or seasonal basis. Project related flow release of 7 cfs appears to be a reasonable flow from a fisheries perspective.”

“The upper Eel River, like the Middle Fork Eel River, like the Middle Fork Eel River, has been heavily logged. This has affected the ability of the watershed to hold moisture in the form of snowpack. Even without the Dam and Diversion, it is unlikely that the

system could provide sustainable conditions [similar] to unregulated historic spring and summer flows. As suggested by the review of recent spring migratory flows, there is a need to address spring streamflow releases with the intent of augmenting those releases during years of poor to moderate flow conditions. The author suggests that revised spring flow release procedures be developed to augment the natural system based on an April 1 forecast of May 1 flows at Fort Seward. May 1 flows can be predicted based on a method of hind casting. It is suggested that when Fort Seward flows are predicted not to exceed 3,000 cfs, the project be required to release a flow of 300 cfs as of May 1 which would be incrementally reduced downward to the project approved summer flow by June 15 of that year. This method of flow release would mimic the natural system and could be applied to the project in all years except those dry or critically [*sic*] years when releases in this magnitude would threaten the project purpose.”

“A more difficult issue revolves around the need to increase upstream migratory flows for adult Chinook salmon. There is a need to pass unimpaired winter flows (Oct.-Dec.) through the system. This would mimic the natural events which trigger upstream Chinook salmon migration. The project has limited capability since the maximum flow release from Lake Pillsbury is regulated by a constricted needle valve. This issue needs to be reviewed to determine its feasibility and practicality concurrently with dam safety requirements.”

Notably, Morford recognized that the ecosystem-wide changes (e.g., heavy deforestation in places) in the Eel River drainage had altered its present functionality—particularly in regard to sustaining historical-level spring and summer flows. Nonetheless, his work suggests that streamflow improvements could be quite beneficial especially for the spring down-migration of smolts during the moderately drier years.