FACTORS IN NORTHERN CALIFORNIA THREATENING STOCKS WITH EXTINCTION

By Patrick Higgins, Soyka Dobush and David Fuller

Humboldt Chapter of the American **Fisheries Society**
P.O. Box 210
Arcata, California 95521
June 1992

The national Endangered Species Committee of the American Fisheries Society (AFS) recently published a report on the threat of extinction facing populations of anadromous salmonids throughout the Pacific Northwest (Nehlsen et al. 1991). The Humboldt Chapter of AFS began research in October 1991 for this report detailing the status of stocks of coho salmon *(Oncorhynchus kisutch),* chinook salmon (0. *tshawytscha),* steelhead *(0. mykiss)* and sea run coastal cutthroat trout (0. *clarki)* that might be at some risk of extinction in the chapter area. The Humboldt AFS territory covers coastal drainages in California from the Russian River north to the Oregon border, including the Klamath and Trinity Rivers.

The purpose of this Humboldt AFS report is to examine assertions made by Nehlsen et al. (1991) with respect to the actual health of the stocks classified in northwestern California and to describe the factors that have lead to stock declines. It **is** hoped that the report will be a catalyst for cooperation in preserving and restoring those runs that may be headed for extinction. Natural and human induced factors have contributed to the decline of salmon, steelhead and coastal cutthroat trout populations in northwestern California. These factors include drought, forest fires, floods, poor ocean productivity, major dams, impacts-of logging and related sedimentation of stream beds, mineral and gravel mining, overgrazing, diversions, exotic species introductions, over-fishing, and hatchery practices.

STOCK STRUCTURE OF ANADROMOUS SALMONIDS

The homing tendency of salmon leads to the evolution of races or "stocks" which develop specific adaptations to their native environments (Ricker 1972). The "stock concept", which recognizes these distinct sub-populations, is widely accepted in fisheries science (Berst and Simon 1981). Survival strategies of native salmonid juveniles, such as timing of out-migration, are flexible and-respond to environmental cues but also have heritable components that are genetically based. Genetic comparisons can be used to distinguish between stocks but such tests are not always conclusive (Utter 198 1). Resistance to disease, early life-history strategies, special morphological traits such as body size or shape, number **and** size of eggs, ocean migration patterns, spawn timing, or date of the return to their home stream are also criteria that may be used to define stocks (Nicholas and Hankin 1988a). Nehlsen et al. (1991) point out that "it is at the stock level that conservation and rehabilitation of salmon, if it is to be successful, will take place."

TABLE OF CONTENTS

STOCKS AT RISK

It is now recognized that stocks of anadromous salmonids, **such as** the winter run chinook salmon on the Sacramento River, may be defined as species in terms of the federal Endangered Species Act (National Marine Fisheries Service 1980). The term "species" is defined in Section 3 of the ESA to include "any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." The term '*endangered species" means any species which is in danger of extinction-throughout all or a significant portion of its range as per the Endangered Species Act of 1973. An endangered population is one that shows a persistent decline in its spawning population (Bjomn and Homer 1980). When a stock declines to fewer than 500 individuals, it may face a risk of loss of genetic diversity which could hinder its ability to cope with future environmental changes (Nelson and Soule 1986). A random event such as a drought or variation in sex ratios may lead to extinction if a stock is at an extremely low level (Gilpin and Soule 1990). The National Marine Fisheries **Service (NMFS), (1987)** acknowledged that, while 200 adults might be sufficient to maintain genetic diversity in a hatchery population, the actual number of Sacramento River winter run chinook needed to maintain genetic diversity in the wild would be 400-l 100.

Nehlsen et al. (1991) used three categories of risk to describe stocks. Stocks at "high risk of extinction" or category A populations showed continuing spawner declines with fewer than 200 adults. Category B stocks were those "at moderate risk of extinction" that might have currently stable populations above 200 spawners but that have declined substantially **from** historical levels. "Stocks of concern" (C) are low and unstable but specific information may be lacking on true population numbers, or may have higher spawner escapements but some specific threat is known that could cause severe population decline or loss.

METHODS

Humboldt AFS sent questionnaires to its members and other fisheries professionals throughout northwestern California requesting specific responses to Nehlsen et al. (1991) and additional information on other stocks at risk. Information was gathered from file records and reports from the California Department of Fish and Game (CDFG), U.S. Fish and Wildlife Service (USFWS), and the U.S. Forest Service. Restoration groups conducting spawning surveys in various watersheds were also consulted. **A** current study for NMFS (Brown and Moyle in press) on the status of coho salmon provided additional information. A final draft was circulated to 24 members of the Cal-Neva chapter of AFS in February 1992 for further review. Humboldt chapter members received a final draft for peer review in March 1992.

FINDINGS

This report identifies 49 naturally spawning Pacific salmon and anadromous trout stocks at varying degrees of risk, in the north coast region of California from Russian River north to the Oregon border. Of these 20 are at high risk of extinction, three are at moderate risk of extinction, and 26 are of special concern (Table 1, Figure 1).

Northern California fisheries scientists generally agreed with the findings of Nehlsen et al. (1991). However, local scientists provided current information pertaining to: population levels of stocks delineated in Nehlsen et al. (1991); and additional stocks which were unrecognized in the Nehlsen et al. (199 1) document. In contrast to Nehlsen et al. (199 1) coastal cutthroat trout have been reclassified at a lower risk (from B to C). Nehlsen et al. (1991) classified the Eel and Klamath River summer steelhead stocks at -B- risk level. More detailed assessment from local professionals has subdivided and reclassified summer steelhead as follows: Middle Fork Eel River -C- (lower risk); North Fork Eel River and Van Duzen River **-A-** (higher risk); Middle Klamath tributaries, Salmon River, South Fork Trinity River and Upper Trinity River -A- (higher risk); while the North Fork Trinity River, New River, Mad River and Redwood Creek have similar risk **classifications** Winter steelhead were not mentioned in our north coast area due to insufficient information for risk assessment. Coho salmon were divided from small streams north of San Francisco (Nehlsen et al. (199 1) into individual basins as more detailed information was available to classify 13 coho stocks at -C- or -A- risk levels. Changes in the fall chinook classifications include deletion **of Smith and** Russian Rivers from the Nehlsen (1991) list and addition of Little River, Bear River and South Fork Trinity River all at level -C- Redwood Creek, Mad River and Eel river **fall chinook stocks were** reassessed to stocks of concern rather than the Nehlsen et al. (1991) moderate risk assessme nt. Two spring chinook stocks were added to the Nehlsen et al. (1991) list, South **Fork Trinity and Trinity** rivers.

Russian River pink salmon (0. *gorbuscha)* were reported by Nehlsen et al. **(1991) as** a stock at high risk of extinction but were left off the Humboldt AFS list. Contributors **felt that pink salmon** and chum salmon (0. keta in California should not be classified with other anadromous **salmonid** stocks at risk. While the past occurrence of pink and chum salmon is of historic interest **and adds a** long term perspective on habitat decline, they probably do not represent retrievable gene resources, because their appearance is presently incidental. These species are still sporadically encountered in numerous northern California streams **(Peter** Moyle personal **communication).** A **small spawning** population of chum salmon exists on Mill Creek, in the Smith River basin (Jim Waldvogel personal communication).

The lack of information often prevented finer distinctions of sub-populations in larger watersheds. This report does not necessarily imply that all stocks listed are synonymous with distinct populations as defined under the Endangered Species Act of 1973.

Table 1. Northwestern California stocks of Pacific anadromous salmonids at risk of extinction. A= high risk of extinction, B= moderate risk of extinction, C= stock of concern.

CHINOOK SALMON

Spring Race

Klamath River (Salmon River) (A)*
South Fork Trinity River (A)
Trinity River (C)
Smith River (A)*

Fall Race

Lower Klamath (below Weitchpec) (B)*
South Fork Trinity (C
Scott **River (C)***
Shasta River (A)*
Humboldt **Bay** Tributaries (A)*
Bear River (C)
Redwood Creek (C)
Littfe River (C)
Mad River (C)
Eel River (C)
Mattole River (A)*

COHO SALMON

Lower Klamath (below Weitchpec) (C)*
Trinity River(C)*
Scott River **(A)**
Humboldt Bay Tributaries **(C)**
Eel River (C)
Pudding Creek **(A)**
Big River (C)
Navarro River (C)
Garcia River (A)
Russian River **(A)**
Redwood Creek (C)
Wilson Creek (C)
Little River (C)
Mad **River (A)**
Mattole River (A)
Noyo River (C)
Ten Mile River (C)
Albion River (C)
Gualala **River** (A)
Bear River (C)

STEELHEAD TROUT

Summer Race

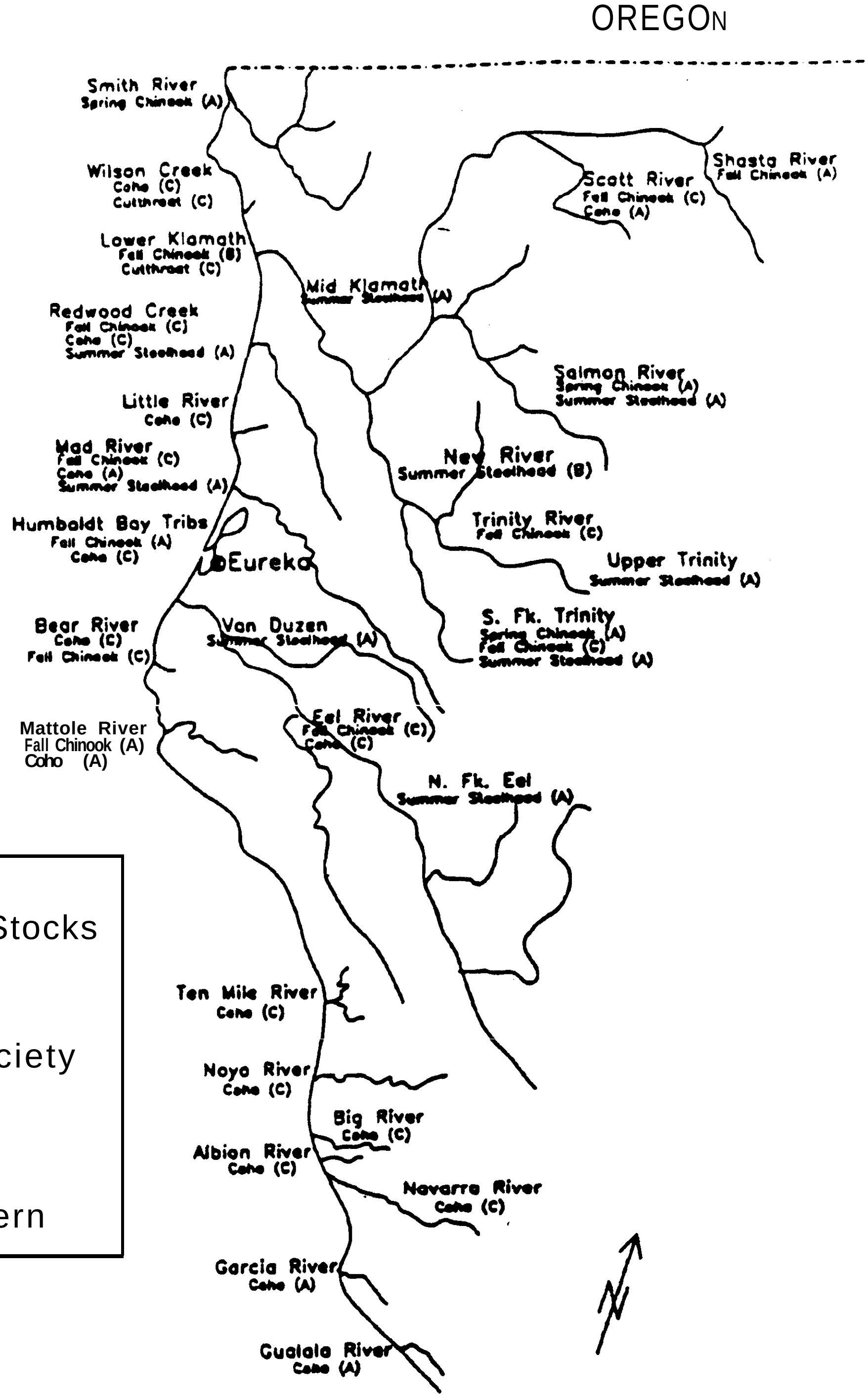
Middle Fork Eel River (C)
North Fork Eel River (A)
Middle Klamath Tributaries **(A)****
South Fork Trinity River (A)
North Fork Trinity River (B)
Upper Trinity River **(A)**
Mad River **(A)***
Redwood Creek **(A)***
Van Duzen River (A)
Salmon River (A)
New River (B)

COASTAL CUTTHROAT TROUT

Lower Eel River (C)
Lower Klamath River (C)'
Mad River (C)
Wilson Creek (C)

• Same designation as list in Nehlsen et al. (1991)
**** Dillon, Elk, Indian, Clear, Red Cap and Bluff Creeks**

For More Information Contact:
Humboldt Chapter American Fisheries Society
PO Box 210
Arcata, CA 95521



MAP
Anadromous Salmonid Stocks
At Risk of Extinction

Humboldt Chapter
American Fisheries Society

A- = High Risk
B = Moderate Risk
C = Stock of Concern

Figure 1. Map of Humboldt Chapter AFS area showing Pacific anadromous salmonids at risk of extinction.

CAUSES FOR DECLINE

Nehlsen et al. (1991) stated that the "decline of salmon, steelhead, and sea-run cutthroat trout populations has resulted from habitat loss and damage; inadequate passage and flows caused by hydropower; agriculture, logging and other developments; over-fishing, primarily of weaker stocks in mixed stock fisheries; and negative interactions with other fishes, including non-native hatchery salmon and steelhead." All of these factors, plus natural events, have contributed to the decline of anadromous salmonid stocks in northwestern California. While there is consensus on the relative risk of loss of populations, fish scientists have not reached a mutual agreement on causes and relative weight.

Habitat loss: Northwestern California has some of the most erodible terrain in the world (Judsen and Ritter 1964, California Department of Water Resources 1982a). Continental plate collisions off the coast cause buckling of the earth's crust, forming major faults on land that almost all rivers in the region follow (Carver and Burke 1987). Marine sediments form the majority of the parent material in the Coast Range. Because these weakly consolidated materials are uplifted, over-steepened, and sheared by faults (Carver et al. 1983), then pelted by intense rainfall, they are very prone to landslides (California Department of Water Resources 1982a).

With the high inherent erosion risk and intensive timber management on the north coast, flood events can cause major soil loss (Janda et al. 1975, Earth Science Associates 1981). Sedimentation of stream beds is implicated as a principal cause of declining Salmonid populations in the region. Mass wasting of steep, erodible hillslopes where timber harvest has occurred, and failure of roads on unstable slopes has caused catastrophic erosion (MacCleery 1974, Janda et al. 1975, Wahrhaftig 1976, LaVen and Lehre 1977, Kelsey 1980, Earth Science Associates 1981, Hagans et al. 1986). A complete list of streams impaired by non-point source pollution, primarily sediment from timber harvest, has been identified for the Environmental Protection Agency (EPA) and the State Water Resources Control Board (SWRCB) water quality data bases, and is included as Appendix A (Humboldt AFS 1987b, 1989).

Severe erosion risk also exists on decomposed granitic soils which occure in the Klamath Mountains in a band'that extends from Mt. Ashland south to Grass Valley Creek near Weaverville. Streams impaired by decomposed granite sands include Grass Valley Creek, the Upper Trinity River, and Cottonwood Creek and Beaver Creek in the Middle Klamath Basin. Despite construction of a $20 million sediment retention structure, Grass Valley Creek annually pours tons of sediment into the Trinity River severely degrading spawning and rearing habitat for salmon and steelhead. Timber harvests have recently been approved by the California Department of Forestry (CDF) in areas below Buckhom Dam despite high erosion risk. The Scott River has also experienced considerable degradation of fish habitat as a result of decomposed granite sands derived from logged areas, road surfaces, and road cuts (Sommerstrom et al. 1990). Scott River tributaries with problems related to decomposed granite include French, Sugar, Crystal, Patteson, and Kidder Creeks.

Many low gradient tributaries throughout the region were formerly optimal salmon spawning and rearing streams. Large logs that lodged in the flatter stream reaches caused scouring and deep hole formation which provided optimal rearing habitat for coastal cutthroat trout and coho salmon (Sedell et al. 1988). Additionally, channels in these reaches were often braided, creating side channels with lower water velocities that are preferred by young-of-the-year fish (Nawa et al. 1990). Unfortunately, these low gradient areas are also where problems persist if large quantities of sediment enter the stream system (Lisle 1981). Large logs that were washed out or buried in past floods are not being replaced naturally due to logging in stream side areas (Sedell et al. 1988).

Loss of pools from sedimentation has reduced rearing habitat, but evidence is emerging that stability of spawning gravel may be the critical limiting factor for salmon. In studies of aggraded stream beds in southwest Oregon, Nawa et al. (1990) found that scour and fill during minor storms (two year events) was sufficient to cause mortality of salmonid eggs and alevin. Spawning populations of chinook salmon in Euchre Creek decreased from 2000 to fewer than 200 and coho populations are now extinct (Nawa et al. 1990). Work by Payne and Associates (1989) indicates that gravels are extremely unstable in lower Klamath tributaries and that mortality of eggs similar to that noted by Nawa et al. (1990) could be occurring there.

Numerous north coast streams are so aggraded that surface flows are lost during summer months. Plugs of sediment where aggraded tributaries join main rivers often block migration routes for adult and juvenile salmonids (Payne and Associates 1989). Many tributaries that were spared during past floods have recently suffered from over-cutting of timber and may experience substantial habitat deterioration in the event of a future flood (Coats and Miller 1981).

When large amounts of sediment fill valley bottoms, riparian vegetation shows major damage. Stream side conifers are partially buried by past floods and have died. Lisle (1981) noted that recruitment of conifer into stream side areas altered by debris flows, may take more than a century. Even willows and alders have difficulty colonizing stream side zones in highly aggraded streams because of gravel instability (Lisle 1981). High stream temperatures become a chronic problem because of lack of shade. Temperature increases can shift ecological relationships allowing fish species, such as suckers, dace or shiners, to become dominant over salmonids (Reeves 1985). Removal of riparian vegetation can make streams in interior areas more subject to freezing and anchor ice formation (Jack West personal communication).

Races of salmon spawned along the entire length of most north coast rivers as recently as the 1950's (USFWS 1960). The Eel River mainstem had a capacity for over 100,000 salmon redds (USFWS 1960). Success of main river spawners seems to have greatly decreased after the 1955 or 1964 floods (Scott Downey and Mike Morford personal communication). Main river channels have become increasingly unsuitable for all salmonids during summer months due to high stream temperatures (Kubicek 1977, Rogers and Wood 1991, USFWS 1991). Over 25% of the pools in the main forks of the Eel River reach temperatures of over 80 degrees F during summer (Kubicek 1977). Decreasing stability of spawning gravels due to aggradation was asserted to be the major cause of declines of salmon runs on the South Fork of the Trinity River (CDWR 1982b) and may have also played a role in loss of mainstem spawning salmon in other rivers in the region.

Additional problems for salmonids and other fishes have resulted as a result of sediments filling main river channels. Holding pools for summer steelhead and spring chinook on the South Fork of the Trinity were filled (CDWR 1982b) and the channel has yet to recover significantly (Haskins and Irrizary 1988). Green sturgeon (Acipenser *medirostris) were* no longer observed in the South Fork Trinity after the 1964 flood and their occurrence in the Eel may have also greatly decreased (Pat Foley, personal communication). The candlefish or eulachon (Thaleicthys pacificus) is a smelt that spawns in the lowest seven miles of the Klamath River. It has been an important food resource for the Yurok Indians, who have noted in recent years that the fish has experienced a dramatic decline (USFWS 199 1).

Fine sediment has also filled estuaries of north coast rivers, greatly diminishing carrying capacity of these areas of vital importance to juvenile chinook **salmon** and coastal cutthroat trout (Puckett 1977, Hofstra 1983, Busby 1991). Species diversity declined dramatically in the Eel River estuary, and the estuary decreased considerably in size between 1950 and 1977 (Higgins 1991). The ocean survival for chinook salmon juveniles is greatly increased if fish are able to attain a larger size by rearing for an extended period in the estuary (Simenstad et al. 1982, Healy 1982). Lack of habitat area in the estuary due to sediment&ion may be forcing juvenile chinook salmon into the ocean at a less than optimal size thus reducing their ocean survival (Nicholas and Hankin 1988b).

Dams on the Trinity and Klamath Rivers now block hundreds of miles of spawning habitat. The spring race of chinook and coho salmon adapted to the Upper Klamath basin, and Upper Trinity steelhead, chinook and coho salmon were lost as a result of dam construction. Main river habitat on the Klamath and Trinity Rivers below the dams has been impacted by flow diversion. Since potions of these rivers below the dams rarely experience floods, the complex natural river channel has not been maintained. Approximately 80% of flows from the Trinity watershed above Lewiston have been diverted to the Central Valley since 1965. Decreased habitat area, lack of recruitment of spawning gravels, unnatural channel restriction by vegetation, and loss of flushing flow events all contribute to diminished carrying capacity for salmonids in rivers below dams. Nutrient loading associated with grazing, combined with increased insolation of reservoirs, create algal blooms in the reservoir above Iron Gate Dam on the Klamath, which contribute to water quality problems in the river below.

Agricultural diversion of stream flows, removal of riparian vegetation from overgrazing, and water quality problems related to agricultural runoff have adversely affected salmon and steel-head runs in the Scott and Shasta Rivers of the Klamath Basin. Water temperatures over 90 degrees F have been measured on the Shasta River in recent years (Rogers and Wood 1991).

The Russian River has special problems because of the growing population in its watershed. Suburban and urban development in the river corridor often seriously degrades tributaries. Sewage treatment facilities for the city of Santa Rosa are sometimes overwhelmed during storms, and dump raw sewage into the river. Gravel extraction has depleted some tributaries of spawning substrate, while gravel minning in main rivers has caused complete destruction of old river terraces and associ-ated riparian communities. Warm Springs Dam has blocked spawning gravel recruitment and blocked access to natural spawning areas. Increasing diversions to supply **a** growing wine industry have dewatered some tributaries that formerly supported fish. The County of Sonoma has been mandated by the State Attorney General to build more adequate fish passage at the Heal&burg Dam. The dam has restricted passage to adult salmonids in years of low flow.

Hatchery Practices: Problems related to hatchery practices have also played a role in the decline of some stocks, especially coho salmon, in northwestern California. The Humboldt Chapter of AFS has been seeking cessation of stock transfers of non-native anadromous salmonids by the California Department of Fish and Game for some time (Humboldt AFS 1975). The Chapter mem-bership supported a resolution to that effect in 1987 (Humboldt AFS 1987). Non-native salmon or steelhead stocks have been introduced as broodstock in hatcheries and widely transplanted (Brown and Moyle in press, USFWS 1991). Studies have shown that anadromous salmonids transferred to other watersheds rarely persist for more than two generations without assistance from artificial culture, due to lack of appropriate adaptations to their new environment (Altukhov and Salmenkova 1986). Withler (1982), in an extensive literature review, found no successful case anywhere on the West Coast of establishing a new run of anadromous salmonids by transplanting stocks.

When non-native hatchery strays spawn in the wild, young fish with non-native genes result (Altukhov and Salmenkova 1986). Studies in the Pacific Northwest have shown that juvenile salmonids spawned by stray hatchery fish and hatchery wild hybrids have lower survival rates (Riesenbichler and McIntyre 1977, Smith et al. 1985, Chilcote et al. 1986). Juvenile fish that are hybrids or of hatchery origin may lack resistance to disease, or other traits critical for survival (Kapuscinski 1984). The impacts of stock transfers increase dramatically if non-native anadromous salmonids are planted on top of wild populations for several generations (Riggs 1990). If this occurs, "genetic swamping" or loss of local adaptations may lead to population extinction (Altukhov and Salmenkova 1986).

Non-native anadromous salmonids have been transferred routinely by the California Department of Fish and Game to almost all north coast basins. The Iron Gate Hatchery coho broodstock was founded with eggs from the Columbia River Basin and has since been transplanted to several Klamath River tributaries, Prairie Creek Hatchery, Mad River Hatchery, Smith River, Freshwater Creek and other locations (Marshall 1970, Hiser 1978-89). Coho from Washington state were also used to start a rearing program on Freshwater Creek (Will 1976-78). Trinity River Hatchery's coho salmon broodstock was formed from numerous non- native. stocks, and subsequently planted in the South Fork of the Trinity River and Mad River Hatchery (Beddell 1974-89). Coho salmon stocks from the Quilcene (Washington) and Klaskanine Rivers (Oregon) were widely transplanted throughout northwestern California in the 1950's and 1960's (Richard Ridenhour, personal communication).

The Noyo fish culture station for coho salmon, operated by the California Department of Fish and Game, supplemented its broodstock in years of low escapement in the 1970'9 with eggs from the Alsea River in Oregon and the Washougal River in Washington (as documented in CDFG transfer permits). Noyo coho have been transplanted to almost all Mendocino county coastal streams, Mad River Hatchery, and Prairie Creek Hatchery, and are the origin of the broodstock at Warm Springs Hatchery on the Russian River (Will 1976-78, Snyder and Sanders 1979, Estey 198 1). Studies of coho salmon in Mendocino County streams show that native alleles are very rare, probably as a result of gradual hybridization following stock transfers (Jennifer Nielsen, personal communication). Brown and Moyle (in press) report that nineteen stock introductions of non-native coho salmon to the Mad River have. occurred during eighteen years of Mad River Hatchery operation. Stock transfers of steelhead have also occurred in northwestern California Washougal River summer steelhead were introduced into the Mad River Hatchery, Prairie Creek Hatchery, and Trinity River Hatchery (Will 1976-78). The Trinity River Hatchery winter steelhead broodstock was formed from numerous non-native components (Bedell 1974-89). The winter steelhead run at the Mad River Hatchery was originally founded on Eel River stocks from Benbow Dam. The steelhead from Mad River Hatchery were widely transplanted during the mid-1970s in a "Coastal Steelhead Planting and Release Program" (Will 1976-78). Streams planted included Smith River, Eel River, Garcia River, Gualala River, Trinity River, Klamath River and Van Duzen River. Behnke (1982) cited a low return rate for Mad River Hatchery steelhead smolts planted in the Gualala River in 1977, a much smaller size fish than the native strain on return, and only a 4% success ratio for repeat spawning as compared to a 38% rate for wild Gualala River steelhead. Stock transfers of anadromous salmonids from the egg taking station at Van Arsdale Dam to watersheds other than the Eel River were also common (Richard Ridenhour, personal communication).

The California Department of Fish and Game (CDFG) has used hatchery coho from many sources to enhance runs and re-establish populations in California coastal streams. The Oregon Department of Fish and Wildlife (ODFW) embarked on a similar coho salmon enhancement program in the 1970's using one broodstock to supplement runs in streams along the entire Oregon coast. Evaluation of the Oregon program showed that introduced coho juveniles experienced lower survival rates than native coho juveniles, while native smolt production was decreased by competition (Nickleson 1986). Adult returns to the stream were about equal in stocked and unstocked streams but subsequent smolt production was decreased in stocked streams (Smith et al. 1985). The Solazzi et al. (1983) evaluation concluded that widespread transplantation of fingerling coho salmon in Oregon lacked sustained biological benefit. Nickelson (1986) reported that coho salmon stocks in Oregon shifted from a balance of 50% hatchery and 50% wild fish to 85% hatchery and 15% wild fish.

Stock transfers within large watersheds may also compromise genetic diversity of runs adapted to various sub-basins. Iron Gate Hatchery fall chinook salmon have been used to supplement runs in numerous tributaries downstream as far as Pecwan Creek below the convergence of the Trinity River (Hiser 1978-89). Run timing in these transplanted stocks may be inappropriate because of different rainfall and runoff patterns in the various areas of the Klamath Basin and may decrease genetic diversity (USFWS 1991). Winter steelhead from Rowdy Creek Hatchery are transplanted to many tributaries throughout the Smith River watershed.

Stock transfers may introduce diseases to which native populations do not have resistance (Pacific Northwest Fish Health Protection Committee 1989). Noyo River hatchery coho salmon stocks are known to harbor bacterial kidney disease (BKD). BKD is problematic because juvenile fish may appear healthy but causes their inability to adjust to salt water which may cause mortality during smoltification (PNFHPC 1989). The disease can be passed from fish to fish in the wild, so transplanting Noyo coho salmon could be introducing this disease to wild populations of salmon and steelhead.

Recent epidemics of infectious hematopoietic necrosis (IHN) at Trinity River Hatchery (Foote 1990) are implicated in very low returns of fall chinook salmon to the facility in 1990 and 199 1. Chen (1984) discovered that several strains of IHN exist and that salmonid juveniles are often not resistant to strains of IHN not endemic to their watershed. Introduction of non-native salmon and steelhead eggs to the Trinity River Hatchery (Bedell 197689) may have carried with them a non-endemic strain of this disease leading to the recent epidemic.

All steelhead, rainbow trout, and chinook salmon native to the main Klamath River have evolved resistance to a virulent pathogen, ***Ceratomyxa Shasta,*** which seems to have its origin in marshes in the Upper Klamath Basin (Carelton 1989, Buchanan in press). Outplanting of Trinity River Hatchery steelhead substantially increased straying rates of this largely exotic stock (USFWS 199 1). Subsequent interbreeding with wild steelhead may have had *a* negative impact on their resistance to C. shasta similar to decreasing resistance to C. ***shata that*** resulted from stock introductions of coho salmon in the **Nehalem River** in Oregon (Kapuscinski 1984).

Hatchery broodstocks can also lose genetic diversity due to brood handling practices, insufficient founding population size, low returns, or other factors (Simon et al. 1986, Simon 1988). Fertility of Iron Gate Hatchery coho has dropped to 38% due to inbreeding depression resulting from very low returns during the 1970's. Hedrick et al. (1987) noted that chinook and coho salmon hybrids were occurring in the Trinity **River Hatchery**. Current research is being conducted to discover the extent of chinook/coho crossing at the hatchery (Tom Hassler personal communication). Spring chinook salmon at Trinity River Hatchery may overlap in their time of return with early run fall chinook. It is possible that unless a systematic approach is taken to marking or segregation of these runs that spring run timing could be lost.

Care must be taken to prevent mixing of hatchery stocks with the few remaining wild spring chinook populations such as those in the Salmon River basin (CDFG 1990). In addition, stock segregation between fall and spring chinook stocks must be preserved by preventing within basin stock transfer of fall-run progeny to traditional spring-run habitat. This action may contribute to hybridization between these stock groups.

Competition between hatchery juveniles and wild fish has been documented as a cause for decrease in wild stocks in other areas (Smith et al. 1985, Steward and Bjomn 1990). Stempel(1988) believed that such competition might be occurring in the main stem of the Klamath and Trinity Rivers, resulting in low survival of both hatchery and wild juvenile salmonids. Trinity River and Iron Gate Hatcheries greatly increased production of chinook salmon juveniles from about five million annually before 1985 to about 18.5 million as adult returns to the hatchery increased (USFWS 1991). Combined production of juveniles from the hatcheries since 1985 has often exceeded the CDFG production goal of 11.3 million juvenile chinook salmon by 50% or more. These years of high hatchery output have been followed by two consecutive years of record low escapement of chinook salmon to the Klamath Basin in 1990 and 1991. The pattern of increased hatchery output and decreased adult escapement would be consistent with density-dependent rearing mortality in the river and/or estuary , limiting survival of both hatchery and wild salmonid juveniles. There is emerging evidence that **competition** for food in the ocean might also limit survival of hatchery coho of Columbia River origin in years of poor upwelling (McGie 1984, Riesenbichler and Emlen 1988, Brodeur 1990).

Introduction of Exotic Species: Non-native fishes have been introduced into rivers throughout northwestern California for over a century but transplanted stocks did not usually survive. Recent introduction of the Sacramento squawfish (Ptychocheilus grandis) into the Eel River drainage, however, is causing a serious problem (Brown and Moyle 1990). Squawfish attain large size and eat smaller fish as they mature. The species has spread to most areas of the Eel River basin in a little over a decade and is better adapted to warm water conditions in the main Eel River during summer than are native salmonids. Smallmouth bass (Micropterus ***dolomieu)*** are widespread on the Russian River. If the increasing temperature trend in main rivers is not reversed, shifts toward dominance of warm water adapted species can be expected to increase (Reeves 1985).

Harvest: Over-fishing in the early days of European settlement led to the depletion of some stocks even before habitat degradation. Stocks of chinook salmon on the Eel River dropped to low levels due to over-harvest as early as 1878 (Higgins 1991). Commercial fisheries on the Klamath River were banned in the early 1930's due to dramatic drops in escapement (McEvoy 1986). A commercial fishery for spring chinook also existed on the Smith River until 1932 (Wendy Cole, personal communication). Fisheries in recent time have been much more closely regulated, but problems of over-harvesting salmon off northern California have been documented as recently as the late 1970's (Hankin 1985, Hankin 1990).

Populations reaching extremely low levels are vulnerable to exploitation and may be driven to extinction. Problems arise in "mixed stock" fisheries such as ocean salmon fisheries, where hatchery salmon, which can sustain harvest rates up to 90% are harvested together with wild salmon, which can stand a maximum harvest rate of 65% (Ricker 1980, Fraidenberg and Lincoln 1985). When wild stock population estimates decline their risk of extinction increases. Exploitation rates for wild stocks should be adjusted to the stock population levels. Conservation problems can arise from in-river fisheries in the Klamath Basin if high fishing effort is exerted while stocks at risk are passing through the lower river (USFWS 1990b). The ability to target hatchery stocks in harvest strategies would relieve pressure on the wild stocks.

Current harvest management strategies do not deal with the issue of protecting specific depressed wild stock populations. The Genetic Stock Identification Report (Gall et al. 1989) found that the model used by the Pacific Fisheries Management Council (PFMC) may have substantially under-estimated the ocean catch of chinook salmon from the Klamath River in the 1987 and 1988 season. The Klamath Ocean Harvest Model (KOHM) was developed using the catch data of Trinity River Hatchery and Iron Gate Hatchery salmon that have been coded wire tagged. Results of Gall et al. (1989) suggest that wild salmon from the Klamath Basin may not exhibit the same migratory patterns as hatchery fish and, therefore, may not be adequately protected by the KOHM. The Klamath Management Zone (KMZ) closures may intensify fishing efforts in areas north and south of the zone. Wild fish with migration patterns to the north or south of the KMZ would, therefore, experience elevated fishing pressure as a result of many years of current management (USFWS 1991). Late season fisheries off the mouth of the Mad, Eel, and Mattole Rivers allowed by the PFMC (1990) in recent years target some runs described at risk of extinction in Table 1. Klamath National Forest spawning surveys have found a chronic problem with under escapement of fall chinook salmon in many streams that have good habitat quality. Runs in these streams may also be experiencing adverse impacts due to ocean harvest.

Despite extensive and prolonged habitat depletion and degradation, northern California continues to possess significant quantities of productive salmonid habitat. Disturbingly, much of this habitat receives little utilization due to depressed natural spawner escapements. For example, a natural spawner escapement goal of 115,000 for fall chinook in the Klamath River basin was established by CDFG and adopted by PFMC (CH2MHill 1985). This goal was in part based on the capacity of available habitat. Realization of this goal has occurred in only three of 14 years between 19784991 (PFMC 1992), despite extensive habitat restoration efforts. Further, in-river returns of natural spawners for 1990 and 1991 fell below the minimum escapement floor of 35,000 adults, and is expected to again in 1992 (PFMC 1992). Overescapement has occurred in very limited and localized instances (eg. Bogus Creek) and is considered primarily a result of hatchery straying.

The Klamath Fisheries Management Council, which advises the PFMC on the harvest of Klamath Basin stocks, has expressed concern over the incidental catch of Klamath River chinook salmon in the whiting fishery off the northern California coast. This fishery has had an allowable incidental catch of 10,000 chinook salmon in recent years. The effects on the ocean food web of removing millions of pounds of whiting and potential food resource depletion for adult chinook salmon has never been evaluated.

High seas drift net fishing has been implicated as a cause for decline of large winter steelhead from coastal streams in California (Light et al. 1988) although little documented evidence has been available to substantiate this. Observations of steelhead returning to Rowdy Creek Hatchery (Smith River) in 1992 showed healed gillnet scars on 30 adults out of the 155 returning (Jim Waldvogel, personal communication). Japan, with the largest north Pacific drift net fleet, has agreed to cease such activities in May 1992. The United Nations continues efforts to halt drift net fishing by South Korea and Taiwan.

Illegal harvest or poaching can be a serious problem for salmon and steelhead on their spawning beds. Spring salmon and summer steelhead races have greater vulnerability because they hold in very clear streams throughout summer. Decline of summer steelhead and spring chinook populations on the Salmon River and on the South Fork of the Trinity River are at least partially as a result of poaching. Roelofs (1983) also cited poaching of summer steelhead as a serious problem on the New River. The Middle Fork of the Eel River summer steelhead are considered **a** "stock of concern" because of concerns about poaching: Runs of summer steelhead on the North Fork of the Eel may have been driven to near extinction by poaching (Mike Morford, personal communication).

Natural Contributions to Declines: Extensive wildland fires burned large areas of California in 1987, causing destabilization of many watersheds. Salvage logging after the burns may have significantly elevated erosion and mass wasting potential. Numerous middle Klamath River tributaries were affected including important anadromous fish producing streams such as Grider Creek, Elk Creek, Indian Creek and Clear Creek. The Salmon River was profoundly affected, particularly those areas that were burned previously in the 1977 Hog Fire. Erosion risk in the Salmon River is highest in drainages with decomposed granitic terrain such as Crapo Creek, Olsen Creek, Kanaka Creek and the North Fork of the Salmon River., **A** large area of the South Fork of the Trinity River watershed was burned in 1987 and another major fire burned the upper watershed in 1988.

Climatic cycles have played a major role in reducing many runs of anadromous salmonids regionally. Frissell and Hrai (1988) described a change in rainfall patterns for southern Oregon. From 1900 to 1950 storm peaks occurred from November to January, but after 1950 storms have typically arrived later, from late December through February. The combined effects of unstable stream beds and later storm cycles has selected for late runs of chinook salmon (Frissell and Hrai 1988).

Records of northern California precipitation from 1988 to 1992 show very low rainfall from October through December. These months are the critical spawning time for chinook and coho salmon runs. The drought has restricted access to many tributary spawning salmon stocks for almost a full life cycle (Scott Downey, personal communication). These fish have been forced to spawn in main river habitat where the risk of mortality of eggs and alevins is very high, because of stream bed movement and poor gravel quality. Drought conditions are further exacerbated by aggraded conditions of streambeds. Payne and Associates (1989) found that access to lower Klamath River tributary mouths was blocked by large deltas that had been deposited since 1964. Several of these tributaries lack surface flow into November in drought years as a result of aggradation.

Loss of large deep pools in lower mainstem rivers has reduced holding habitat for emigrating adult fish. These fish, while awaiting winter rains, must hold in the estuary or off the mouth of rivers, possibly increasing their vulnerability to predation by marine mammals and to ocean fisheries.

Ocean conditions off northern California and their relationship to survival of anadromous salmonids are poorly studied except for recognition that El Nino currents decrease growth and survival of both chinook and coho salmon. Brodeur (1990), in studies off Oregon and Washington, found that the diet of juvenile coho salmon in the ocean shifted in years with varying degrees of upwelling. He concluded that lack of food resources and intensive planting of coho smolts were leading to density-dependent mortality in the ocean in some years.

RECOMMENDATIONS

* Managers must protect all existing suitable habitat from degradation through reform of land and water regulations, management and enforcement. Populations listed in this report cannot sur-***vive*** without maintaining existing quality habitat, and will not rebound without large and small scale efforts in the following areas.

* Private timber land managers must fully commit to erosion control and prevention on their lands. Major soil loss and attendant loss of silvicultural productivity can be expected if this effort is not initiated (Coats and Miller 1981). Part of the solution to habitat problems is a substantial reform of California Forest Practice Rules (Humboldt AFS 1992). Activities on unstable soil types should be limited in order to ***decrease*** erosion risks and to protect against future flood damage (CDWR 1982a). Existing roads in poor condition or design must be up graded or put to bed (Fumiss et al. 1990). Review of timber harvest plans must include limits on allowable watershed disturbance to prevent over-cutting and subsequent fisheries habitat degradation (Coats and Miller 198 1). Continuing timber harvest in basins currently impaired might require off site erosion control to mitigate for any increase in sediment expected from logging activities. Large conifers must be left in stream side zones, not just for shade but for the important habitat elements they provide (Sedell et al. 1988). Riparian restoration in all previously harvested streamside locations would accelerate compliance with desired future conditions and should be a primary objective for land managers.

* In interior basins, water conservation and riparian restoration could reverse habitat declines and help restore fisheries while maintaining agricultural productivity. Enforced screening and maintenance of agricultural diversions could save hundreds of thousands of juvinle salmonids each year. Increasing efficiency of water use in the Central Valley would reduce demands on Trinity River water and allow further water allotments for aquatic habitat needs. Increased flow in the Trinity River recently awarded to the Hoopa Indian Tribe, in recognition of their reserve rights, is a positive advance towards restoring the productivity of the system. Sufficient flows to maintain channel integrity below all dams must be developed for long term fish habitat maintenance. Channel maintenance flows need to be developed for all dam impacted river systems. Marsh restoration in areas surrounding Upper Klamath Lake could significantly improve water quality in the lake and in all of the Klamath River below it.

* The only apparent solution to protecting salmon stocks at risk from mixed stock harvest is to selectively harvest hatchery salmon and release wild salmon in all fisheries where feasible. If all hatchery salmon were marked, this strategy could be implemented. Klamath River Indian tribes should develop harvest stratagies that shift fishing efforts towards hatchery stocks and away from stocks at risk of extinction. Catch-and-release fisheries for wild steelhead may be necessary as well.

* Stock transfers of all anadromous salmonids in California should cease (Humboldt AFS 1987a). Salmon and steelhead hatcheries should be fully integrated into restoration efforts and optimal levels of smolt production determined by scientific methods. Emphasis on yearling pro-

grams for chinook salmon, especially at iron Gate Hatchery, may provide greater cost efficiency and exert lower competition impacts on wild stocks. A complete re-evaluation of hatchery operations in California, similar to that recently completed in the Columbia River Basin (Riggs 1990), is needed in light of the current status of anadromous salmonids in the state.

- Small-scale hatcheries used to rebuild native fish populations need to prevent inbreeding. Each project should be continuously evaluated to monitor competition with native fishes. When fish populations reach carrying capacity, enhancement should cease.

- Spawning ground surveys have indicated potential conflicts between instream mining operations and larval development of steelhead in Klamath River tributaries. Impacts of mining activities may be reduced by changing local operating seasons. The Mining Act of 1872 should be reformed to increase protection of stream and riparian habitat.

* Stocks at risk of extinction should be allowed to maintain minimum viable populations in order to avoid federal intervention and species listing. Extreme caution should be applied in management decisions when stocks are at critically low levels. Current wild stock population trends must be reversed. Minumum wild stock escapement goals should be determined and evaluated for every watershed basin in California. The current "natural" escapement floor for the Klamath system does not address individual stock population; which could become extinct if not monitored. Underutilization of existing habitat is apparent at present escapement levels in some Klamath subbasins. Evaluate the current minimum escapement floor for the Klamath system and mandate a no harvest policy when the floor is approached.

CONCLUSION

The findings of the Humboldt Chapter of AFS concur with those of Nehlsen et al. (1991) and Brown and Moyle (in press): numerous stocks of salmon and steelhead in northern California are threatened with extinction. These fish are important to the economy and culture of northwest-em California, and maintaining wild stocks offers the best hope of restoring self sustaining runs. Loss of these locally adapted anadromous salmonids may be irreversible without preserving and expanding available refugia. Nehlsen et al. (199 1) state that in order for anadromous salmonid stocks to survive and prosper into the next century that "a new paradigm" must emerge "that advances ecosystem function and habitat restoration rather than hatchery production." Successful recovery of fisheries populations depends on efforts from both fisheries and land (habitat and watershed) managers. While the primary focus of land managers should be habitat protection, fisheries managers must sustain the existence of individual stocks through retention of viable spawning population escapement. Success will require a long-term commitment to developing and implementing a recovery strategy capable of restoring interlinked terrestrial and aquatic systems in an ecosystem approach.

Ultimately, the best solutions for protecting and restoring fisheries habitat will come from local communities and land owners as well as from fisheries professionals. Farmers and ranchers may be most capable of arriving at the best solutions for improving efficiency of water USC if their cooperation can be won. Similarly, interdisciplinary professionals could help formulate the best solutions to controlling erosion while continuing to maintain a viable forest products industry in northwestern California. Problems like controlling poaching and introduction of exotic fishes also require local community support. Erosion control and prevention could become a major source of jobs for displaced timber workers. Long term economic benefits to rural communities from increased tourism as fishing improves could be considerable as well. Volunteer opportunities should develop into internships and job placement in areas of monitoring, contracting and implementing viable restoration activities.

It is the hope of the Humboldt Chapter of AFS that by clearly portraying the magnitude of the problems facing anadromous salmonids in northwestern California, all parties will recognize the need to join efforts to prevent further losses. If we fail to take immediate action, further loss of stocks will occur. If cooperation is not forthcoming, protection of many of the stocks at risk could be sought under the Endangered Species Act. Humboldt AFS would rather help build cooperation for a community based restoration program that takes a long-term approach to ecosystem recovery.

ACKNOWLEDGEMENTS

Thanks to the following people who attended meetings, shared information or provided comments on our report.

Bruce Amato	David Anderson
Randy Bailey	Jerry Barnes
Dr. Roger Barnhardt	Paul Brouha
Greg Bryant	Ken Byrne
Mike Callaghan	Vicki Campbell
Wendy Cole	Barry Collins
Scott Downey	Todd Flannigan
Rod Fortier	Bryan Furman
Ken Gallagher	Colinda Guiterres
Karen Kenfield	Tom Kisanuki
Wendy Jones	Aldaron Laird
Jim Lintz	Mike Maahs
Mike McCain	Dave McLeod
David Menem	Mike Morford
Dr. Peter Moyle	Jennifer Nielsen
Alan Olson	Joe Polos
Larry Preston	Dr. Terry Roelofs
Dr. Richard Ridenhour	Park Steiner
Jim Waldvogel	Tom Wtsaloh
Brian White	Dave Will

REFERENCES

Altukhov, Y.P. and EA. Salmenova 1986. Stock transfer relative to natural organization, management, and conservation of fish populations. In: N. Ryman and F. Utter (eds.) Population Genetics and Fisheries Management University of Washington Press. Seattle, WA.

Bedell, G.W. 1974-89. Annual Report for Trinity River Salmon and Steelhead Hatchery. California Dept. of Fish and Game. Inland Fisheries Div. Sacramento, **CA.**

Behnke, RJ. 1982. Wild trout sport fisheries and hatchery programs for the future. Proceedings from symposium: The role of hatcheries in the management of wild salmonids Cal Trout, San Francisco, CA.

Berst, A.H. and RC. Simon (eds.). 1981. Proceedings of the Stock Technical Report of Fisheries and Aquatic Sciences Concept Symposium. Canadian Jour. of Fisheries and Aquatic Sciences. 38 (12).

Bjornn, T.C. and N. Homer. 1980. Biological criteria for classification of Pacific salmon and steelhead as threatened or endangered under the Endangered Species Act. Report to National Marine Fisheries Service, Seattle, WA.

Brodeur, G. 1990. Are juvenile salmon food resources limited in the coastal environment? In: Proceedings from Estuary and Ocean Productivity Workshop, United States Fish and Wildlife Service, Klamath Field Office, Yreka, CA. pp 29-60

Brown, L.R. and P.B. Moyle. 1990. Eel River Survey.: Final Report. Department of Fish and Wildlife, University of California, Davis. Contract F-46-R-2 for the California Department of Fish and Game.

Brown, L.R. and P.B. Moyle. In Press. Draft report on the status of coho salmon in California. National Marine Fisheries Service, Terminal Island, CA.

Buchanan, D. In press. Klamath Basin Trout. From Oregon Department Fish and Wildlife studies on: Diversity Within and Between Rainbow Trout in Oregon River Basins. Oregon Department of Fish and Wildlife, Research Station, Corvallis, OR.

Busby, M. 1991. *The abundance* of epibenthic and planktonic macrofauna and feeding **habits** of fall chinook salmon (Oncorhynchus tshawytscha) in the Mattole River estuary/lagoon. M.S. Thesis, Humboldt State University 130 p.

Calif. Dept. of Fish and Game. 1990. Status and management of spring chinook salmon. Inland fisheries division, Sacramento, CA 12pp.

California Department of Water Resources. 1982a. Watershed management for unstable and erodible areas in north western California Prepared for U.S. Environmental Protection Agency and the California State Water Resources Control Board. 68 pp.

Calif. Dept. of Water Resources. 1982b. South Fork of the Trinity River salmonid enhancement study. CDWR, Northern District, Red Bluff, **CA.** 175pp.

Carleton, A. 1989. *Ceratomyxa shasta geographic ad seasonal* distribution in northern California and comparative salmon strain susceptibility. M.S. Thesis. Humboldt State University, Arcata, CA.

Carver, G.A., T.A. Stephens, and J.C. Young. 1983. Quaternary thrust and reverse faulting on th Mad River fault zone, coastal northern California Geo. Soc. of Amer. Abstracts. Vol. 15(5).

Carver, G.A., and RM. Burke. 1987. Late Pleistocene and Holocene paleoseismicity of Little Salmon and Mad River thrust fault systems, Northwest California Implications to the seismic potential of the Cascadia Subduction Zone. Geo. Soc. of Amer. Abstracts. Vol. 9(7).

CH2M Hill. 1985. Klamath Basin Fisheries Resource Plan. United States Department of Interior Contract no. R17644.AD. 11 270 pp.

Chen, M.F. 1984. **Comparative** susceptibility of salmond fishes and salmonid fish cells to five isolates of infectious hemotopoietic necrosis and biological properties of two plaque variants. PHD **Dissertation,** Oregon State University, Corvallis, OR

Chilcote, M.W., S.A. Leider, J.J. Loch. 1986. Differential reproductive success of hatchery and wild summer steelhead under natural conditions. Trans. Amer. Fish. Soc. 115: 726 -735.

Coats, RN. and T.O. Miller. 198 1. Cumulative silvicultural impacts on watersheds: a hydrologic and regulatory dilemma Environmental Management. 5(2): 147- 160.

, Earth Science Associates. 198 1. Lower Klamath Basin Investigation. For the United States Department of Interior, Bureau of Indian Affairs, Palo Alto, CA. 141 p.

Estey, D.F. 1981. Annual Report Warm Springs Salmon and Steelhead Hatchery, 1981-82. Region 3, California Department **of** Fish and Game, Inland Fisheries Div., Sacramento, CA.

Foote, J.S. 1990. Disease survey proposal for salmonid populations in the Trinity **River. United** States **Fish and** Wildlife Service memo. Coleman Fish Hatchery, Anderson, **CA.**

Fraidenberg, M.E. and RH. Lincoln. 1985. Wild chinook salmon management: an international conservation challenge. N. Am. J. Fish Mgmt. 5:3 11-329.

Frissell, C.A. and T. Hrai. 1988. Life history patterns, habitat change, and productivity **of fall chinook stocks of** southwest Oregon. In: B.Shepard (ed) Proceedings of 1988 Northeast Pacific Chinook and **Coho Workshop.** Amer. Fish. Soc.

Fumiss, M.J.,. T.D. Roelofs, and C.S. Yee. 199 1. Road Construction and Maintenance. In: W. Meehan, (ed) Influences of Forest and Rangeland Management on Salmonid Fishes and Their **Habitats.. Amer. Fish. Soc. special** publication. 19:297-323.

Gall, G.A., B. Bentley, C. Panattoni, E.Childs, C. Qi, S. Fox, M. Mangel, J. Brodziak and R.Gomulkiewicz. 1989. Chinook Mixed Stock Fishery Project. University of California. Davis, CA.

Gilpin, M.E. and **M.E. Soule.** 1990. Minimum **Viable Populations: Processes of Species Extinction.** In: **M. Soule (ed) Conservation Biology: The Science of Scarcity and Diversity University of Michigan Press. pp** 19-36.

Hagans, D.K., **W.E. Weaver, and M.A. Madej.** 1986. **Long term on site and off site effects of logging and erosion in the Redwood** Creek Basin in northern California. Nat. Council on Air and Streams, Tech. Bull. 460.260 Madison **Av., New York, NY.**

Hankin, D.G. 1985. Analyses of recovery data from fall chinook salmon released from IronGate Hatchery and Trinity River Hatchery, and implications for management of wild and hatchery chinook salmon stocks in the Klamath River system. Contract with **USDI, Bureau of Indian Affairs, Northern California,Hoopa, CA 117 pp.**

Hankin, D.G. 1990. Effects of monthly releases of hatchery-reared chinook salmon and size at age **of maturity and** fishery contribution rate. Oregon Department **of Fish and Wildlife, 90-4 Portland,** OR 37pp.

Haskins, D.M. and RA. Irrizarry. 1988. A holistic appraisal of cumulative watershed effects on watershed conditions and fisheries, South Fork of the Trinity River, Northwestern **California. USDA Forest Service Shasta**

Trinity National Forest, Redding, CA 41 pp.

Healy, M.C. 1982. Juvenile Pacific salmon in estuaries; the life support system. In: V. Kennedy (ed.), Estuarine Comparisons. Academic Press. New York ,NY pp 3 15-341.

Hedrick, R.P., S.E. LaPatra, J.L. Fryer, T. McDowell, and W.H. Wingfield. 1987. Susceptibility of coho (Oncorhychus *kisutch)* and chinook salmon *(Oncorhynchus tshawytscha)* hybrids to experimental infections with infectious hematopoietic necrosis virus (IHNV). Bull. of the European Assoc. of Fisheries Pathology. 7(4):97.

Higgins, P.T. 1991. Habitat Types of the Eel River Estuary and Their Associated Fishes and Invertebrates. In: C. Roberts (ed.) Report on Fish and Wildlife Species of the Eel Delta. Funded by Eel River RCD, USDA Soil Conservation Service, Eureka, CA.

Hiser, C.A. 1978-89. Annual Report from Iron Gate Salmon and Steelhead Hatchery. California Department of Fish and Game. Inland Fisheries Div. Sacramento, CA.

Hofstra, T.D. 1983. Management alternatives for Redwood Creek Estuary. Redwood National Park, Arcata, CA.

Humboldt Chapter American Fisheries Society. 1975. Letter to Region I CDFG by President Han K Pennington regarding stock transfers. Humboldt Chapter AFS files, Arcata, CA.

Humboldt Chapter American Fisheries Society. 1987a. Stock Transfer Policy Resolution to California Salmon and Steelhead Advisory Committee. Ratified by Membership a! 1987 annual meeting. Humboldt Chapter AFS files, Arcata, CA.

Humboldt Chapter American Fisheries Society. 1987b. Chapter position on State Water Resources Control Board Data Base on Impaired Water Bodies. Letter to Don Maughn, Chair State Water Resources Control bard. April 26, 1987. Humboldt Chapter AFS files, Arcata, CA.

Humboldt Chapter American Fisheries Society. 1989. Chapter input into EPA water pollution data base. Letter to Tuck Vath, NCRWB, Dec. 12, 1989. Humboldt Chapter AFS files, Arcata, CA.

Humboldt Chapter American Fisheries. Society. 1992. Comments to Board of Forestry on Revision of Forest Practice Rules. Letter to Dean Cromwell, Executive Secretary Board of Forestry, February 23, 1992. Humboldt Chapter AFS files, Arcata, CA.

Janda, R.J., KM. Nolan, D.R Harden and S.M. Coleman. 1975. Watershed conditions in the drainage basin of Redwood Creek, Humboldt County, California U.S. Geologic Survey, Menlo Park, CA. Open File Report 75-568. 266 p.

Judson, S. and D.F. Ritter. 1964. Rates of regional denudation in the United States. Jour. of Geophys. Research. Vol. 69(11):3395-340 1.

Kapuscinski, A.R 1984. Genetics concerns in salmon and steelhead conservation and enhancement Genetics workshop for Enhancement Planning Team. Oregon State University. Newport, OR

Kelsey, H.M. 1980. A sediment budget and an analysis of geomorphic processes in the VAn Duzen River basin, north coastal California, 1941-1975: Summary. Geol. Soc. Am. Bull., Part I, 91:190-195.

Kubicek, P.F. 1977. Summer water temperature conditions in the Eel River system with reference to trout and salmon. M.S. Thesis, Humboldt State University, Arcata, CA. 198 p.

Lannan, J. E., and A. R Kapuscinski. 1984 Genetic guidelines for evaluation and selection of enhancement projects under the Salmon and Steelhead Conservation and Enhancement Act. Report to Enhancement Planning Team, Pacific Marine Fisheries Commission, Newport, OR

LaVen, R and A. Lehre. 1977. The effects of timber harvest and roads on sediment yield and channel morphology in the Fox Planning Unit, Six Rivers National Forest, Eureka, CA.

Lichatowich, J.A. and J.D. McIntyre. 1987. Use of hatcheries in the management of Pacific anadromous salmonids. Amer. Fish. Soc. Symposium. 1: 131-136.

Light, J.T., S. Fowler, and M. Dahlberg. 1988. High seas distribution of North American steelhead as evidenced by recoveries of marked or tagged fish. Fisheries Research Institute, University of Washington, Seattle, WA. FRI-UW-8816.

Lisle, T.E. 198 1. The recovery of stream channels in north coastal California from recent large floods. In: K. Hashagen (ed.) Habitat Disturbance and Recovery Proceedings. Cal Trout, San Francisco, CA. pp 3 1-41

MacCleery, D.W. 1974. Logging on South Fork Mountain, a look at past activities and implications for future management of the area USDA Forest Service, Shasta-Trinity National Forest, Redding, CA.

Marshall, L. 1970. Annual Iron Gate Salmon and Steelhead Hatchery Report, Fifth Year of Operation, 1969-70. CDFG Inland Fisheries Division, Region 1, Redding, Sacramento, CA.

McEvoy, A.F. 1986. The fishermen's problem: ecology and law in California fisheries, 1850- 1980. Cambridge University Press, NY. 368 pp.

McGie A.M. 1984. Evidence for densitydependence among coho salmon stocks in the Oregon Production Index Area pp.37-49. In W.G. Percy (ed.): The influence of ocean conditions on the production of salmonids in the north Pacific. Oregon State University, Sea Grant Publication.

National Marine Fisheries Service (NMFS). 1980. Policy position papers for the consideration of Columbia River salmon under the Endangered Species Act. Paper #2: Biological thresholds of endangerment. NMFS, Seattle, WA.

National Marine Fisheries Service. 1987. Endangered and threatened species, winter run chinook salmon. Federal Register 52: 604 I-6048.

Nawa, R.K., C.A. Frissell, and W.J. Liss. 1990. Life history and persistence of anadromous salmonid stocks in relation to stream habitats and watershed classification. Oak Creek Labs, Oregon State University. Corvalis, OR · Performed under contract for Oregon Department of Fii and Wildlife.

Nelson, K. and M. Soule. 1987. Genetical Conservation of Exploited Fishes. In: N. Ryman and F.Utter (eds). Popula tion Genetics and Fisheries Management University of Washington Press. Seattle, WA.

Nehlesn, W., J.E. Williams, J.A. Lichatowich. 199 1. Pacific Salmon at the Crossroads West Coast Stocks of Salmon, Steelhead, and Sea-run Cutthroat Trout at Risk. Fisheries Vol. 16, No. 2.

Nicholas, J.W. and D.G. Hankin. 1988a. Chinook salmon populations in Oregon coastal river basins. Descriptions of life histories and assessment of recent trends in run strengths. Funded by Oregon Department Fish and Wildlife. Oregon State University Extension Service. Corvallis, OR

Nicholas, J.W. and D.G. Hankin. 1988b. Variations in distribution of juvenile chinook salmon in Oregon coastal river basins: implications to future stock transfer practices. In: B. Shepard (ed). Proceedings of 1988 Northeast Pacific Chinook and Coho Workshop. American Fisheries Society.

Nickelson, T.E. 1986. Influence of upwelling, ocean temperature, and smolt abundance on marine survival of coho salmon in the Oregon production area Can. Jour. of Fish. and Aquat. Sci. 43: 527-535.

Pacific Fisheries Management Council. 1990. Pre-season Report I: Stock abundance analysis for 1990 ocean salmon fisheries. Portland, OR

Pacific Fisheries Management Council. 1992. Stock abundance analysis for 1992 ocean salmon fisheries preseason report I. Portland, OR

PNFHPC (Pacific Northwest Fish Health Protection Committee) 1989. Model Comprehensive Fish Health **Protection Program.** 1002 N.E Holladay Street, Portland, **OR**

Payne, T.R. and Associates. 1989. Lower Klamath **River tributary delta study.** US Department of Interior, Bureau **of Indian** Affairs, Redding, CA.

Puckett, L.K. 1977. The Eel River Estuary - Observations on morphometry, fishes, water quality, and invertebrates. **California** Department of Fish and Game under contract with California Departmentof Water Resources. 26 pp.

Reeves, G.H. 1985. Competition between redside shiners and steelhead trout in the Umpqua River, Oregon. Doctoral thesis, Oregon State University, Corvallis, OR

Ricker, W.W. 1972. Heredity and environmental factors effecting certain salmonid populations Pages 19-160 In: Stock Concept of Pacific Salmonids. University of British Colombia, Vancouver.

Ricker, W.E. 1980. Causes of decrease in age and size of chinook salmon *(Oncorhynchus tshawytscha). Canadian* Tech. Report 944. Department of Fisheries and Oceans, Ottawa, **Canada**

Riesenbichler, R.R. and J.D. McIntyre. 1977. Genetic differences in growth and survival of juvenile hatchery and wild steelhead trout. J. Fisheries Res. Board of Can 34: 123-l 28.

Riesenbichler, R.R and J.M. Emlen. 1988. A re-evaluation of models predicting density-dependent survival at sea for coho salmon. In: B.G. Shepard (ed.): Proceedings of 1988 Northeast Pacific Chinook and Coho Salmon Work shop. Western Division AFS. Pacific NW Chapter, Penticton, British Colombia, Canada.

Riggs, L. 1986 Genetic considerations in salmon and steelhead planning. Northwest Power Planning Council, Portland, OR

Riggs, L. 1990. Principles for genetic conservation and production quality. Northwest Power Planning Council contract no. C90- 005. Portland, OR

Roelofs, T.D. 1983. Current status of summer steelhead stocks and habitat, and recommendations for their management. U.S. Forest Service, Region 5. San Francisco, CA.

Rogers, D. and R. Wood. 1991. Shasta River Fisheries Water Quality Project, 1990-91. Funded by Klamath River Task Force, US Fish and Wildlife Service. Klamath Field Office, Yreka, CA. 39 pp.

Sedell, J.R., P.A. Bisson, F.J. Swanson, and S.V. Gregory. 1988. What we know about large trees that fall into streams and rivers. In: From the Forest to the Sea: A Story of Fallen Trees. USDA Forest Service and USDI, Buearu of Land Management. General Technical Report PNW-GTR-229. Portland, OR

Simenstad, C.A., K.L. Fresh, and E.O. Salo. 1982. The role of Puget Sound and Washington coastal esturies in the life history of Pacific salmon: an unappreciated function. In: V. Kennedy (ed) Estuarine Comparisons. Academic Press. New York, NY. 709 pp.

Simon, RC. 1988. Seven Avenues for Redress of Fish Hatchery Problems Involving Restricted Genetic Variability. Proceedings of the American Fisheries Society Bioenhancement Seminar. Portland, OR

Simon, RC., J.D. McIntyre, H. Hemmingson. 1986. Family size and effective population size in a hatchery coho salmon population. Can. Jour. of Fish. and Aqua Sci. 43: 2434-2442.

Smith, E.A., B.A. Miller, J.D. Rogers, M.A. Buckman. 1985. Outplanting Anadromous Salmonids - A Literature Survey. Oregon Department of Fish and Wildlife for Bonneville Power Administration. Project No. 85-68.

Snyder, RU. and S.W. Sanders. 1979. Summary of Operations Noyo River Egg Collecting Station 1964 through 1978.

Region 3, California Department of Fish and Game, Inland Fisheries Division, CA.

Solazzi, M.F., S.L. Johnson, T.E. Nickelsen. 1983. The effectiveness of stocking hatchery coho pre-smolts to increase rearing densities of juvenile coho in Oregon coastal streams. 14pp. Oregon Department of Fish and Wildlife. Portland, OR

Sommerstrom, S., E.M. Kellogg, and J.L. Kellogg. 1990. Scott River Basin Granitic Sediment Study. Coop agreement 14-16-00 l-89506 Siskiyou RCD, and Klamath River Task Force, US Fish and Wildlife Service, Yreka, CA.

Stempel, M. 1988. Possible implications of integrating hatchery and natural production of salmon and steelhead in the Trinity River Basin. US Fish and Wildlife Service, Weaverviille, CA.

Steward, C.R and T.C. Bjomn. 1990. Supplementation of salmon and steelhead stocks with hatchery fish: a synthesis of published literature. Idaho Cooperative Fisheries and Wildlife Research Unit, University Of Idaho, Moscow, ID. Tech. Report 90- 1.

U.S. Fish and Wildlife Service. 1960. Survey of chinook salmon spawning habitat in northwestern California Natural Resources of Northern California US Fish and Wildlife Service, Pacific Southwest Field Committee.

U.S. Fish and Wildlife Service. 1990. Klamath-Trinity River Basin spring chinook salmon stock evaluation and run-size forecast. USFWS Fisheries Assistance Office, Arcata, CA. 3 1 pp.

U.S. Fish and Wildlife Service. 1991. Long Range Plan for the Klamath River Basin Conservation Area Fishery Restoration Program. Klamath Field Office, Yreka, CA. 320 pp.

Utter, F.M. 198 1. Biological criteria for definition of species and distinct intraspecific populations of anadromous salmonids under the U.S. Endangered Species Act of 1973 Can. Jour. of Fii and Aqua Sci. 38:1626-1635.

Wahrhaftig, C. 1976. Statement of erosion problems in Redwood Creek. Memo to the Board of Forestry. January 15, 1976. From California Department of Fish and Game files, Eureka, CA.

Will, RD. 1976-78. Annual Report Mad River Salmon and Steelhead Hatchery. California Department of Fish and Game, Region 1, Inland Fisheries Division. CA.

Withler, F.C. 1982. Transplanting Pacific Salmon. Canadian Technical Report of Fisheries and Aquatic Sciences 1079. 27 p.

Personal Communications

Cole, Wendy: U.S. Forest Service Fishery Biologist, Gasquet Ranger District, Six Rivers National Forest.

Downey, Scott: California Fish and Game Restoration Coordinator, Eel and Mattole Rivers.

Foley, Patrick: Graduate student at Humboldt State University studying green sturgeon.

Hassier, Tom: Professor of Fisheries, US Fish and Wildlife Service Coop. Unit Humboldt State University.

Laird, Alderon Trinity Fisheries Restoration Associates.

Mot-ford, Mike: Member of Klamath River Management Council Technical Team.

Moyle, Peter: Professor of Fisheries, University of California, Davis.

Nielsen, Jennifer: Doctoral Candidate in Fisheries, University of California Berkeley.

Ridenhour, Richard: Professor of Fisheries, Humboldt State University, Arcata.

West, Jack: U.S. Forest Service Resource Officer, Klamath National Forest, Yreka.

Waldvogel, Jim: University of California Marine Advisor, Crescent City.

APPENDIX A

Impaired Waterbodies Entered by Humboldt AFS into Clean Water Data Base for California State Water Resources Control Board and U.S. Environmental Protection **Agency.**

Ah Pah Creek
Black Butte **River**
Browns Creek
Dean Creek
Eel River
Eel River
Eel River Estuary
Etna Creek
French Creek
Garcia River
Gualala River
Hayfork Creek
Kidder Creek
Klamath River
Klamath River Estuary
Mad River
Mattole River
Mattole River Estuary
McGarvey Creek
Moffett Creek
Omagar Creek
Pelletreau Creek
Post Creek
Redwood Creek
Redwood Creek Estuary
Salt River
Scott River
South Fork of the Trinity River
Van Duzen River