Promotes the Conservation, Development and Wise Utilization of the Fisheries

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American Fisheries Society

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March 29, 1992

To: All Humboldt AFS Members
From: Soyka Dobush, Dave Fuller, Pat Higgins
Re: "Stocks at Risk" in Chapter Area

Hello Fellow Fisheries Scientists,

The Humboldt AFS report on salmon, steelhead, and coastal cutthroat trout at risk of extinction in northwestern California is attached to the correspondence. This report is supplemental to Nehlsen et al (1991). Our report offers greater detail for our area, both in terms of potential stock loss and the mechanisms operating to cause decline. This product is a true consensus of our collective expertise and has been peer reviewed beyond the chapter area. Approximately 50 copies of the final draft were circulated for review. Over the past six months more information has been added and stock status refined.

A quote from Nehlsen et al applies applies equally to this supplement; " The list is incomplete and provides only an imperfect snapshot of the status of these fishes. Our investigations were often met with incomplete data, a lack of sufficient information for most systems, and the lack of a comprehensive picture." This report does provide evidence that there are stock declines trending toward extinctions, particularly of salmon stocks. This paper has the approval of the Policy and Resolutions Committee and it is time for the Chapter to endorse the findings so we may share it with the public.

Please take time to read the enclosed report and attend our Annual Conference this Saturday, April 4. If you can't attend, but have comments on the report, please contact Pat Higgins at 822-9428. Final discussion and , hopefully, ratification will take place at the business meeting at 5:00 P.M. after the Conference at the Bayside Grange. Glenn Phillips, President Elect of the Western Division AFS will be giving us a regional update as well.

Another aspect of the "Stocks at Risk" project embarked on by the Policy and Resolutions Committee was to share the information as widely as possible, after report completion. Toward that end, Pat Higgins will be representing the Chapter before the Humboldt County Board of Supervisors at 9:05 A.M. April 7, in the Supervisors Chambers of the Humboldt County Courthouse. **We are encouraging every fisheries scientist to attend this meeting to convey to the Board and the community that there is unilateral agreement that this problem is real and action must be taken.**

Our conference on preserving biodiversity will be a good first step in public education. Comments were received from Paul Brouha, AFS Executive Director and he thinks that the report is suitable for [illegible] magazine providing focus of attention.

STOCKS OF SALMON, STEELHEAD AND CUTTHROAT TROUT OF NORTHERN CALIFORNIA AT RISK OF EXTINCTION

By Patrick Higgins, David Fuller and Soyka Dobush

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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 (*Oncorhynchus tshawytscha*), steelhead (*Oncorhynchus mykiss*) and sea run coastal cutthroat trout (*Oncorhynchus clarkii*) that might be at some risk of extinction in the chapter area. The territory of Humboldt AFS covers coastal drainages in California from the Russian River north to the Oregon boarder, 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 listed in northwestern California and to make sure that stock designations used are logical. 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, over-grazing, flow depletion related to agriculture, introduction of exotic species, over-fishing, and hatchery practices.

STOCK STRUCTURE OF ANADROMOUS SALMONIDS

The tendency of salmon to return to the stream of their birth leads to the evolution of races or "stocks" which develop specific adaptations to their native environment (Ricker 1972). The "stock concept", which recognizes these distinct sub-populations, is widely accepted in fisheries science (Berst and Simon 1981). Strategies for survival of native salmonid juveniles, such as timing of out-migration, are flexible and respond to environmental cues but have a heritable component that may be genetically based. Genetic comparisons can be used to distinguish between stocks but such tests are not always conclusive (Utter 1981). 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 other 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."

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 listed as species under the federal Endangered Species Act (NMFS 1980). An endangered population is one that shows a persistent decline in its spawning population (Bjornn and Horner 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 any future environmental change (Nelson and Soule 1986). In addition, a random event such as a drought or variation in sex ratios may lead to extinction if a stock is at such an extremely low level (Gilpin and Soule 1990). The National Marine Fisheries Service (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 400-1100.

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 exact population numbers. Some "C" stocks might also have higher spawner escapements but some specific threat is known that could cause severe population decline or loss.

METHODS

Humboldt AFS members and other fisheries professionals throughout northwestern California were sent questionnaires that asked for specific responses to Nehlsen et al. (1991) and if they had knowledge of other stocks at risk. Members were notified of several committee meetings where information for the report was reviewed. A final draft was circulated to many members of the Cal-Neva Chapter of AFS in February of 1992. Data was also gathered from file information or reports from the California Department of Fish and Game, U.S. Fish and Wildlife Service, and the U.S. Forest Service. Restoration groups that conduct spawning surveys in various watersheds were also consulted. A current study for the National Marine Fisheries Service (Brown and Moyle in press) on the status of coho salmon provided additional information. Copies of the meeting minutes and drafts of the white paper were circulated to the chapter membership.

FINDINGS

Fisheries scientists in northern California were in general agreement with the findings of Nehlsen et al (1991) but had some constructive suggestions for refinement of the report. Many stocks listed have been retained by the Humboldt AFS report (Table 1), but additional stocks have also been added to the list. While coastal cutthroat trout may be faring substantially better than Nehlsen et

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Table 1. Stocks of Pacific anadromous salmonids in northwestern California 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)
Smith River (A)*
Trinity River (C)

Fall Race

Lower Klamath (tribs below Weitchpec) (B)*
Scott River (C)*
Little River (C)
Humboldt Bay Tributaries (A)*
Bear River (C)
South Fork Trinity (C)

Shasta River (A)*
Redwood Creek (C)
Mad River (C)
Eel River (C)
Mattole River (A)*

COHO SALMON

Trinity River (C)
Wilson Creek (C)
Lower Klamath (tribs below Weitchpec) (C)
Little River (C)
Humboldt Bay Tributaries (C)
Bear River (C)
Pudding Creek (A)
Big River (C)
Navarro River (C)
Garcia River (A)

Scott River (A)
Redwood Creek (C)
Mad River (A)
Eel River (C)
Mattole River (A)
Noyo River (C)
Ten Mile River (C)
Albion River (C)
Gualala River (A)

STEELHEAD TROUT

Summer Race

Middle Fork Eel River (C)
North Fork Eel River (A)
Van Duzen River (A)
South Fork Trinity River (A)
North Fork Trinity River (B)

Mad River (A)*
Redwood Creek (A)*
Salmon River (A)
Clear Creek (A)
New River (B)

COASTAL CUTTHROAT TROUT

Lower Eel River (C)
Lower Klamath (C)

Mad River (C)
Wilson Creek (C)

* Same designation as list in Nehlsen et al. (1991)

al. (1991) indicated, salmon stocks in northwestern California have virtually collapsed. Native coho salmon populations are almost all at low and unstable levels. Numerous fall chinook stocks and wild spring chinook in the Klamath Basin are at high risk of extinction. Insufficient information on winter steelhead was available to categorize risks to this stocks of this species but most stocks of summer steelhead have been identified as at risk.

Russian River pink salmon (Oncorhynchus 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 in California should not be classified with other anadromous salmonid stocks at risk. While the past occurrence of pink and chum salmon (Oncorhynchus keta) 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 now only incidental. Including them in our report might also confuse the public as this issue emerges. These species are still regularly collected in numerous northern California streams, however (Peter Moyle personal communication). A small spawning population of chum salmon exists on Mill Creek, in the Smith River basin (Jim Waldvogel personal communication).

Causes for Declines

Nehlsen et al (1991) stated that the "decline of salmon, steelhead, and sea-run cutthroat trout populations has resulted from habitat loss and damage, and 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 played into the decline of anadromous salmonid stocks in northwestern California.

Habitat loss: Northwestern California has some of the most erodible terrain in the world (Judsen and Ritter 1964, CDWR 1982b). Continental plate collisions off the coast cause buckling of the Earth's crust forming major earthquake faults on land that almost all rivers in the region follow (Carver and Burke 1987). Marine sediments, pushed up by compression, form the parent material of 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 (CDWR 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 Assoc. 1981). Sedimentation of stream beds is implicated as a principal underlying cause of decline of many salmonid populations in the region. Mass wasting of steep, erodible hillslopes that have been clear cut and failure of roads on unstable soils has caused catastrophic erosion during past floods (MacCleery 1974, Janda et al 1975, Wahrhaftig 1976, LaVen and Lehre 1977, Kelsey 1980, ESA 1981, Hagans et al 1986). Watersheds where severe erosion and loss of fish habitat has been documented include

Jones Creek and South Fork of the Smith River, Wilson Creek, Klamath River, Redwood Creek, South Fork of the Trinity River, Mad River, Van Duzen River, Eel River, Mattole River, Bear River and Mendocino coastal streams. A complete list of streams impaired by non-point source pollution, primarily sediment from timber harvest, which AFS has identified for the EPA and the State Water Resources Control Board water quality data bases is included as Appendix A (Humboldt AFS 1987, 1989).

Severe erosion risk also exists on decomposed granitic soils which occur 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. The Scott River has also experienced considerable degradation of fish habitat as a result of decomposed granitic sands coming off of logged areas, road surfaces, and road cuts (Sommerstrom et al 1990). Tributaries with problems related to decomposed granite in the Scott Basin include French Creek, Sugar Creek, Crystal Creek, and Kidder Creek.

Many tributaries throughout the region that have low gradients, were formerly optimal salmon spawning and rearing streams. Large logs lodged in the flatter stream reaches and deep holes were scoured around them that were optimal rearing habitat for coastal cutthroat trout and coho salmon (Seddell et al 1988). The channel in these reaches was often braided and side channels developed which had slow water velocities best suited for young-of-the-year fish (Nawa et al 1990). Spawning gravels also washed into these sections from steeper tributaries that were inaccessible to salmon. Unfortunately, these flat areas are also where problems persist if large quantities of sediment enter the stream system (Lisle 1981). Furthermore, large logs are no longer available to replace old logs that were washed out or buried due to logging in stream side areas (Seddell et al 1988).

Many north coast streams show signs of having harbored past debris flows and remain shallow, wide, warm, and unstable for decades after floods (Lisle 1981, Appendix A). Continuing sediment contributions are prolonging recovery of some of these streams. Loss of pools due to sedimentation has greatly reduced rearing habitat, but evidence is emerging that stability of spawning gravels may be the critical limiting factor for salmon. Nawa et al. (1991) found that scour and fill during minor storms (two year events) of aggraded stream beds in southwest Oregon was sufficient to cause mortality of salmonid eggs and alevin. Runs of chinook salmon in Euchre Creek decreased from 2000 to less than 200 and coho populations are now extinct (Nawa et al 1991). Work by Payne and Associates (1989) indicates that gravels are extremely unstable in lower Klamath tributaries, so mortality of eggs similar to that noted by Nawa et al (1990) is likely to be occurring there.

Cedarholm (1983) found that similar changes in stream beds, resulting from logging, altered run timing of steelhead stocks in western Washington as well. Late runs of steelhead, that laid their eggs during receding flows from the last storm events of the winter, became dominant because eggs laid before that time were washed out or buried so deep they did not survive. Changes to later spawn timing have been noted by some fisheries workers in northwestern California but no formal studies have been conducted.

Major damage to riparian zones results when large amounts of sediment fill valley bottoms. Large stream side conifers died when they were partially buried by past floods and were subsequently salvage logged. Lisle (1981) noted that recruitment of conifers into stream side areas altered by debris flows may take more than a century. Even willows and alders have a difficult time colonizing stream side zones in highly agraded streams because of gravel instability (Lisle 1981). High stream temperatures become a chronic problem due to lack of shade. Temperature increases can shift ecological relationships allowing fish species, such as suckers, dace or shiners, to become dominant over salmonids (eg. Reeves 1985). Removal of riparian also make streams in interior areas more subject to freezing and anchor ice formation (Jack West personal communication).

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

Main river channels have become increasingly unsuitable for all salmonids during summer months due to high stream temperatures (Kubicek 1977, Rogers and Wood 1990, 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). Races of salmon spawned along the entire length of most north coast rivers as recently as the 1950's (USFWS 1960), but success of main river spawners seems to have greatly decreased after the 1955 or 1964 floods (Scott Downey and Mike Morford personal communication). Aerial photos from before and after the 1955 flood on the Mad River show a major sediment build up following the flood (Alderon Laird personal communication) which would be consistent with loss of spawners.

Clean gravel beds, that allowed water circulation through redds bringing eggs oxygen and carrying away wastes, were replaced by tons of fine sediment in lower rivers. Decreasing stability of spawning gravels due to agradation 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. Despite construction of a $25 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 Buckhorn Dam despite high erosion risk.

Additional problems for salmonids and other fishes have resulted as a result of filling of main river channels. Holding pools for summer steelhead and spring chinook on the South Fork of the Trinity were filled in (CDWR 1982b) and the channel has yet to recover significantly (Haskins and Irrazary 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 been in a dramatic decline (USFWS 1991). The dwindling numbers of the candlefish may be as a result of decreased spawning success due to changes in stream bed conditions.

Pulses of sediment have also filled estuaries of north coast rivers, greatly diminishing carrying capacity of this area that is of vital importance to juvenile chinook salmon and coastal cutthroat trout (Puckett 1977, Hofstra 1983, Busby 1990). Species diversity in the Eel River estuary dropped dramatically and the estuary shrunk considerably in size between 1950 and 1977 (Higgins 1991). The survival of chinook salmon juveniles in the ocean is greatly increases if they are able to attain larger size by rearing for an extended period in the estuary (Simenstad 1982, Healy 1982). Lack of habitat area in the estuary due to sedimentation may be forcing juvenile chinook salmon into the ocean at a less than optimal size thus limiting their survival (Higgins 1991). Continuing disturbance of lower river areas due to gravel extraction is also a continuing and significant habitat problem on the Eel and Mad Rivers.

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 coho salmon were lost as a result of dam construction. Main river habitat on the Klamath and Trinity River below the dams has been impacted by flow depletion. Since these rivers no longer experience floods, the complex natural river channel has not been maintained. About 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, un-natural channel restriction by vegetation, and lack of flows to flush fine sediments all contribute to diminished carrying capacity for salmonids in rivers below dams. Algae blooms in the reservoir above Iron Gate Dam on the Klamath also contribute to water quality problems in the river below.

Agricultural diversion of stream flows, removal of riparian vegetation due to over-grazing, and water quality problems related to agricultural runoff have adversely effected salmon and steelhead runs in the Scott and Shasta River in the Klamath Basin. Water temperatures over 90 degrees F have been measured on the Shasta 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 degrade 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 and main river gravel mining has included complete destruction of old river terraces and associated riparian communities. Increasing diversions to supply a growing wine industry have also de-watered 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 Hieldsburg Dam. The dam has served as a barrier to adult salmonids on their spawning journey 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 reform of stock transfers of non-native anadromous salmonids by the California Department of Fish and Game for some time (Humboldt AFS 1975). The Chapter membership supported as 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 review of the literature, found no successful case of establishing a new run of anadromous salmonids by transplanting stocks anywhere on the West Coast.

When non-native hatchery strays spawn in the wild, young fish with some non-native genes may result (Altukhov and Salmenkova 1986). Studies in other areas 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, appropriate behavior, or other traits critical for survival (Kapucinski 1984). The impact of stock transfers increases 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 1975). Trinity River Hatchery's coho salmon broodstock was formed from numerous non-native stocks and subsequently planted in the South Fork of the Trinity and Mad River Hatchery (Beddell 1974-89).

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's with eggs from the Alsea River in Oregon and the Washougal River in Washington (CDFG transfer permits). Noyo coho have been transplanted to almost all Mendocino coastal streams, Mad River Hatchery, Prairie Creek Hatchery, and are the origin of the broodstock at Warm Springs Hatchery on the Russian River (Snyder and Sanders 1979, Will 1982, Estey 1984). Studies of coho salmon in Mendocino County streams show that native alleles are very rare, probably as a result of gradual hybridization as a result 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 winter steelhead broodstock was formed from numerous non-native components (Bedell 1974-80). 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-1970's in a "Coastal Steelhead Planting and Release Program" (Will 1976-78). Streams planted included Smith River, the Eel River, Garcia River, Gualala River, Trinity River, Klamath River and the 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 than the native strain on return, and only a 4% success ratio for repeat spawning as compared to a 38% rate for wild Gualala steelhead.

The California Department of Fish and Game has used hatchery coho from many sources to try to increase runs and re-establish populations in California coastal streams. The Oregon Department of Fish and Wildlife embarked on a similar but more organized 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 showed lower survival than native coho juveniles but that native smolt output was decreased by competition (Nickleson 1986). Adult returns to the stream were about equal in stocked and unstocked streams but subsequent smolt output was decreased in stocked streams (Smith et al. 1985). The conclusion of the evaluation was that widespread transplantation of fingerling coho salmon lacked sustained biological benefit (Solazzi et al 1983). Another significant finding of the report was that coho salmon stocks in Oregon shifted from a balance of 50% hatchery and 50% wild fish to 85% hatchery and 15% wild fish (Nickelson 1986).

Stock transfers within large watersheds may also compromise genetic diversity of runs adapted 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 due to different rain fall 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 their inability to change salt regulation due impaired kidney function may cause mortality during smoltification (PNFHPC 1989).** The disease can be "horizontally transmitted" or 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 1991. 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 Hatchery (Bedell 1974-85) 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 (Carlton 1989, Buchanan in press). Outplanting of Trinity River Hatchery steelhead substantially increased straying rates of this largely exotic stock (USFWS 1991). Subsequent interbreeding with wild steelhead may have had a negative impact on their resistance to C. shasta similar to decreasing resistance to C. shasta that resulted from stock introductions of coho salmon in the Nehalem River in Oregon (Kapucinski 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 other wise segregating these runs that spring run timing could be lost.

Competition between hatchery juveniles and wild fish has been documented as a cause for a decrease in wild stocks in other areas (Smith et al. 1985, Steward and Bjornn 1990). Stempel (1988) felt 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 now 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*) is widespread on the Russian River. If trends toward warming of main rivers is not reversed, shifts toward dominance of warm water adapted species can be expected to increase.

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-harvest of salmon off northern California have still occurred as recently as the late 1970's (Hankin 1980, Hankin 1986).

While over-fishing may not be the principal cause of decline of salmon stocks, as some populations reach extremely low levels, harvest may contribute to their extinction. Problems arise in "mixed stock" fisheries such as the ocean commercial and sport fisheries, where hatchery salmon, which can sustain harvest rates of up to 90%, are harvested together with wild salmon, which can stand a maximum harvest rate of 65% (Ricker 1980, Fraidenberg and Lincoln 1985). If habitat conditions are poor for wild salmon, as they are in many north coast river basins, they may be even less able to sustain harvest. Conservation problems also stem from Indian net fisheries in the Klamath Basin if high fishing effort is exerted while stocks at risk are passing through the lower river (USFWS 1990).

Current harvest management strategies do not deal with the issue of protecting specific depressed wild stocks. In recent years, the Pacific Fisheries Management Council (PFMC) has implemented extensive ocean closures of both commercial and sport fishing in the Klamath Management Zone (KMZ) between Shelter Cove and Humbug Mountain south of Port Orford, Oregon (PFMC 1989). The Genetic Stock Identification Report (Gall et al 1989) found that the model used by the 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. Effort shift due to closures in the KMZ may intensify fishing efforts in areas north and south of the zone. **Wild fish having migration patterns to the north or south of the KMZ would, therefore, experience elevated fishing pressure as a result of current management in many years (USFWS 1991).**

Extremely low returns of fall chinook salmon in the Smith River in 1990 were not linked to any known habitat problems or a natural event such as a flood. Because the Smith has very good habitat conditions, it may be a good control stream to show problems with ocean harvest or other factors in the ocean limiting escapement. **Late season fisheries off the mouth of the Mad, Eel, and Mattole Rivers allowed by the PFMC (1990) in recent years are targeted at some runs listed in this report as at some "risk of extinction".**

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 chain 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. However, 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). Asian nations engaged in this form of harvest agreed to cease such activities in May 1992.

Illegal harvest or poaching can be a serious problem for salmon and steelhead on their spawning beds. **Spring or summer races of salmon and steelhead have even more vulnerability because they hold in very clear streams throughout summer.** Decline of summer steelhead and spring chinook 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 listed as a "stock of concern" due to 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 effected including important anadromous fish producing streams such as Grider Creek, Elk Creek, Indian Creek and Clear Creek. **The Salmon River was profoundly effected; 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 Salmon River. A large area of the South Fork of the Trinity River watershed was also 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).

From the winter of 1988 to 1992 there has been very low rainfall in northern California from October through December, the critical spawning time for chinook and coho salmon runs. **The drought has restricted access of many tributary spawning stocks of salmon 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, due to stream bed movement and poor gravel quality. Drought conditions are further exacerbated by agraded conditions of stream beds. Payne and Associates (1989) found that access to lower Klamath River tributaries was blocked by large deltas that had been deposited since 1964 at the mouths of these streams. Several of these tributaries lack surface flow into November in drought years as a result of agradation.

Pools in the lower Eel River near Fern Bridge had sufficient pool depth, with cold water strata on the bottom, to hold juvenile chinook salmon and summer steelhead in 1950 (Murphy and DeWitt 1952). Fall run fish could enter the river and hold even in low water years, while awaiting winter rains. Sedimentation has filled pools reducing volume and cover and possibly eliminating cold water strata that would have formerly have provided refuge during droughts. Fish now 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 is poorly studied except for recognition that El Nino currents decrease both 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.

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 northwestern California and maintaining stocks offers the best hope of restoring self sustaining runs. Loss of these locally adapted anadromous salmonids may be irreversible. Nehlsen et al (1991) 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." Such a model in northwestern California will require full scale cooperation from fishermen, management agencies, private land holders, and a broad segment of the public. Success will require a long-term committment, on the order of 50-100 years, taking an ecosystem restoration approach.

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 (Furniss 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 1981). Continuing timber harvest in basins currently impaired might require off site erosion control to mitigate for any increase in sediment expected from logging. Large conifers must be left in stream side zones, not just for shade but for the important habitat elements they provide (Seddel et al 1988).

In interior basins, water conservation and riparian restoration could reverse habitat declines and help restore fisheries while maintaining agricultural productivity. Increasing efficiency of water use in the Central Valley could reduce demands on Trinity River water and allow further increases for in-stream flows. Increased flows in the Trinity River recently awarded to the Hoopa Indian Tribe, in recognition of their reserve rights, should help restore the productivity of that river. Sufficient flows to maintain channel integrity below dams must continue for long term fish habitat maintainance. 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 except in gill net fisheries. It is possible that current planting levels may be far higher than optimal (Riesenbichler and Emlen 1988), and reduced levels of planting would also help reduce costs of hatchery operations and marking costs if universal marking were embraced. Catch-and-release fisheries for wild steelhead may be necessary as well.

Humboldt AFS does not in any way question the sovereign right of Indian Tribes to fish nor to manage their own fisheries, however, recent low escapements and numerous depleted Klamath River stocks pose a serious conservation challenge. Since selective harvest does not work in gill net fisheries, Indian fishermen should consider shifting effort away from times when stocks at risk are most likely to be impacted.

Stock transfers of all anadromous salmonids in California should cease (Humboldt AFS 1987). Salmon and steelhead hatcheries should be fully integrated into restoration efforts and optimal levels of smolt production determined by scientific methods. Emphasis on yearling programs for chinook salmon, especially at Iron Gate Hatchery, may provide greater cost efficiency and exert less impact on wild stocks stemming from competition. A complete re-evaluation of hatchery operation in California, similar to that recently completed in the Columbia River Basin (Riggs 1990), is needed in light the current status of anadromous salmonids in the state.

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 in the Shasta Valley are very capable of arriving at the best solutions for improving efficiency of water use in their area. Similarly, forestry professionals could also 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 also be a major source of jobs for displaced timber workers. Long term economic benefits to rural communities from increased tourism as fishing improves could also be considerable.

It is the hope of the Humboldt Chapter of AFS that by clearly portraying the severity of the problems facing salmon in northwestern California, all parties will recognize the need to cooperate and willingly join efforts to prevent loss of salmon and steelhead populations. If we fail to take immediate action, wide spread 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.

REFERENCES

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

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, R.J. 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, Calif. USA.

Berst, A.H. and R.C. 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. Horner. 1980. Biological criteria for classification of Pacific salmon and steelhead as threatened or endangered under the Endangered Species Act. Report to NMFS, Seattle, Wash.

Brodeur, G. 1990. Are juvenile salmon food resources limited in the coastal environment? In: Proceedings from Estuary and Ocean Productivity Workshop, USFWS, Klamath Field Office, Yreka, Calif. p 29-60.

Brown, L.R. and P.B. Moyle. 1990. Eel River Survery: Final Report. Dept of Fish and Wildlife, Univ. of Calif., Davis. Contract F -46-R-2 for the Calif. Dept. 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, Calif.

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

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

Calif. Dept. of Water Resources. 1982a. Watershed Management for Unstable and Erodible Areas in Northwestern California. Prepared for U.S. EPA and the Calif. State Water Resources Control Board. 68 p.

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

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

Carver, G.A., T.A. Stephens, and J.C. Young. 1983 Quaternary thrust and reverse faulting on the Mad River fault zone, coastal northern California. Geo. Soc. of Amer. abstracts with programs. Vol. 15, no.5.

Carver, G.A., and R.M. Burke. 1987. Late Pleistocene and Holocene paleoseismicity of Little Salmon and Mad River thrust fault systems, NW California. Implications to the seismic potential of the Cascadia Subduction Zone. Geo. Soc. of Amer. abstracts. Vol. 9, no. 7.

Cedarholm, C.J. 1983. Clearwater River wild steelhead spawning timing. Proceedings of Olympic Wild Fish Conference. Peninsula College, Port Angeles, Washington.

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

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, R.N. and T.O. Miller. 1981. Cumulative silvicultural impacts on watersheds: a hydrologic and regulatory dilemma. Environmental Management. 5(2):147-160.

Earth Science Associates. 1981. Lower Klamath Basin Investigation. For the USDI, Bureau of Indian Affairs, Palo Alto, Calif. 141 p.

Estey, D.F. 1981. Annual Report Warm Springs Salmon and Steelhead Hatchery, 1981-82. Region 3, Calif. Dept. of Fish and Game, Inland Fisheries Div.

Foote, J.S. 1990. Disease survey proposal for salmonid populations in the Trinity River. USFWS memo. Coleman Fish Hatchery, Anderson, Calif.

Fraidenberg, M.E. and R.H. Lincoln. 1985. Wild Chinook Salmon Management: An International Conservation Challenge. No. Amer. Jour. of Fisheries Mgmnt. 5:311-329.

Frissell, C.A. and T.Harai. 1988. Life history patterns, habitat change, and productivity of fall chinook stocks of southwest Oregon. In: Proceedings of 1988 Northeast Pacific Chinook and Coho Workshop. Ed. B. Shepard. American Fisheries Soc.

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, Calif.

Gilpin, M.E. and M.E. Soule. 1990. Minimum Viable Populations: Processes of Species Extinction. In Michael Soule (ed.): Conservation Biology: The Science of Scarcity and Diversity, Univ. 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., N.Y., N.Y.

Hankin, D.G. 1985. Analyses of recovery data released from fall chinook salmon released from Iron Gate Hatchery and Trinity River Hatchery, and implications for management of wild and hatchery chinook salmon stocks in the Klamath River system. Contract with USDI BIA, Northern California, Hoopa. 117 p.

Hankin, D.G. 1990. Effects of monthly releases of hatchery-reared chinook salmon and size at age of maturity and fishery contribution rate. ODFW, 90-4 Portland, Ore. 37p.

Haskins, D.M. and R.A. Irrizarry. 1988. A Holistic Appraisal of Cumulative Watershed Effects on Watershed Conditions and

Healy, M.C. 1982. Juvenile Pacific salmon in estuaries; the life support system. pp.315-341. In V. Kennedy (ed.) Estuarine Comparisons. Academic Press. N.Y.,N.Y. 709 pp.

Hedrick, R.P., S.E. LaPatra, J.L. Fryer, T. McDowell, and W.H. Wingfield. 1987. Susceptibility of coho (Oncorhynchus 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 Cons. Ser., Eureka, Calif.

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

K Hofstra, T.D. 1983. Management alternatives for Redwood Creek Estuary. Redwood National Park, Arcata, Calif. USA.

Humboldt AFS. 1975. Letter to Region 1 CDFG by President Hank Pennington regarding stock transfers. Humboldt AFS files, Arcata, Calif.

Humboldt AFS. 1987. Stock Transfer Policy Resolution to California Salmon and Steelhead Advisory Committee. Ratified by Membership at 1987 annual meeting. Humboldt AFS files, Arcata, Calif.

Humboldt AFS. 1987. Chapter position on State Water Resources Control Board Data Base on Impaired Water Bodies. Letter to Don Maughn, Chair SWRCB. April 26, 1987. Humboldt AFS files.

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

Humboldt AFS. 1992. Comments to Board of Forestry on Revision of Forest Practice Rules. Letter to Dean Cromwell, Exec Sec. BOF, February 23, 1992. Humboldt AFS files, Arcata, Calif.

Janda, R.J., K.M. 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, Calif. 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: 3395-3401.

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

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.

Kojan, E. 1976. Mass erosion sensitivity analysis, Hitchcock Creek Zone, South Fork Mountain, Shasta-Trinity National Forest. USDA Forest Service Project no. 14447.

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

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, Calif.

Lichatowich, J.A. and J.D. McIntyre. 1987. Use of hatcheries in the management of Pacific anadromous salmonids. American Fisheries Society 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. Fish. Research Institute, Univ. of Wash., Seattle. FRI-UW-8816.

Lisle, T.E. 1981. 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, Calif. p 31-41.

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, Calif.

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, Calif.

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

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

Murray, R. 1967. The Lewiston Trapping Facility, Second Year of Operation, 1959-60. CDFG Inland Fisheries Division, Region 1, Redding, Sacramento, Calif.

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, Wash.

National Marine Fisheries Service (NMFS). 1987. Endangered and threatened species, winter run chinook salmon. Federal Register 52:6041-6048.

030727

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, O.S.U. Corvalis, Oregon. Performed under contract for Ore Dept. of Fish and Wildlife.

Nehlsen, W., J.E. Williams, J.A. Lichatowich. 1991. 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 ODFW. Ore St. Univ. Extension Ser. Corvalis, Ore.

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 : Proceedings of 1988 Northeast Pacific Chinook and Coho Workshop. Ed.: B. Shepard. 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.

Nelson, K. and M. Soule. 1986. Genetical Conservation of Exploited Fishes. In: Population Genetics and Fisheries Management Eds. Ryman and Utter. University of Washington Press. Seattle, Washington.

PFMC. 1990. Pre-season Report I: Stock abundance analysis for 1990 ocean salmon fisheries. PFMC. Portland, Ore.

PNFHPC (Pacific Northwest Fish Health Protection Committee) 1989. Model Comprehensive Fish Health Protection Program. 1002 N.E. Holladay Street, Portland, Oregon, 97232-4181.

Payne, T.R. and Assoc. 1989. Lower Klamath River tributary delta study. U.S. Dept. of Interior, BIA, Redding, Calif.

Puckett, L.K. 1977. The Eel River Estuary - Observations on Morphometry, Fishes, Water Quality, and Invertebrates. Cal. Fish and Game under contract with Cal. Dept. of 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, Corvalis, Ore.

Ricker, W.E. 1972. Heredity and environmental factors effecting certain salmonid populations. In: Stock Concept of Pacific Salmonids. H.R. MacMillan Lecture on Fisheries. Vancouver B.C.

030728

Ricker, W.E. 1980. Causes of decrease in age and size of chinook salmon (Oncorhynchus tshawytscha). Canadian Tech. Report 944. Dept. 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 34:123-128.

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 Workshop. Western Div. AFS. Pacific NW Chapter, Penticton, B.C., Canada.

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

Riley, J. 1967. Annual Report for Iron Gate Salmon and Steelhead Hatchery, First Year of Operation, 1965-66. CDFG Inland Fisheries, Region 1, Redding, Calif.

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, California.

Royal, L.A. 1972. An Examination of Anadromous Trout Program of the Washington State Game Program. Mimeographed Report. Wash. Department of Game. Olympia, Washington.

Sanders, S.W. 1980-1983. Annual Report Hollow Tree Creek Egg Taking Station. Region 3, Calif. Dept. of Fish and Game, Inland Fisheries Div.

Sanders, S.W. 1979-1982. Annual Report Noyo River Egg Collecting Station 1964 through 1978. Region 3, Calif. Dept. of Fish and Game, Inland Fisheries Div.

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 U.S. Dept. of Interior, BLM. Gen. Tech. Report PNW-GTR-229. Portland, Ore.

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. N.Y., N.Y. 709 pp.

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

Simon, R.C., J.D. McIntyre, H. Hemmingson. 1986. Family size and effective population size in a hatchery coho salmon population. Canadian Journal of Fisheries and Aquatic Sciences 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, R.U. and S.W. Sanders. 1979. Summary of Operations Noyo River Egg Collecting Station 1964 through 1978. Region 3, Calif. Dept. of Fish and Game, Inland Fisheries Div.

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. 14 p. Oregon Dept. of Fish and Wildlife. Portland, Oregon.

Sommerstrom, S., E.M. Kellogg, and J.L. Kellogg. 1990. Scott River Basin Granitic Sediment Study. Coop agreement 14-16-001-89506 Siskiyou RCD, and Klamath River Task Force, USFWS Yreka, Calif.

Stempel, M. 1988. Possible implications of integrating hatchery and natural production of salmon and steelhead in the Trinity River Basin. USFWS, Weaverville, California.

Steward, C.R. and T.C. Bjornn. 1990. Supplementation of salmon and steelhead stocks with hatchery fish: a synthesis of published literature. Idaho Cooperative Fisheries and Wildlife Research Unit, Univ. of Idaho, Moscow, Id. 83843. Tech. Report 90-1.

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

U.S. Fish and Wildlife Service. 1988. Klamath River Fisheries Assessment Program-Annual Report 1988. Fish. Assistance Office, Arcata, California.

U.S. Fish and Wildlife Service. 1990a. Klamath Fisheries Assessment Program: Investigations on lower tributaries Klamath River. Fish. Assistance Office, Arcata, Calif.

U.S. Fish and Wildlife Service. 1990b. Klamath-Trinity River Basin spring chinook salmon stock evaluation and run-size forecast. USFWS Fish. Assistance Office, Arcata, Calif. 31 p.

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

Utter, F.M. 1981. Biological criteria for definition of species and distinct intraspecific populations of anadromous salmonids under the U.S. Endangered Species Act of 1973. Canadian Jour. of Fisheries and Aquatic Sci. 38:1626-1635.

Wahrhaftig, C. 1976. Statement of Erosion Problems in Redwood Creek. Memo to the Board of Forestry. January 15, 1976. From CDFG files, Eureka, California.

Will, R.D. 1976-78. Annual Report Mad River Salmon and Steelhead Hatchery. Calif. Dept. of Fish and Game, Region 1, Inland Fisheries Division.

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

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