# HOW HEALTHY ARE HEALTHY STOCKS?

## Case Studies of Three Salmon and Steelhead Stocks in Oregon and Washington, including Population Status, Threats, and Monitoring Recommendations

**Prepared for the Native Fish Society**

**April 2001**

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## Case Studies of Three Salmon and Steelhead Stocks in Oregon and Washington, including Population Status, Threats, and Monitoring Recommendations

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**Sponsored by the Native Fish Society and the U.S. Environmental Protection Agency.**

**April 2001**

*Please cite this document as follows:*

Bahls, P. 2001. How healthy are healthy stocks? Case studies of three salmon and steelhead stocks in Oregon and Washington, including population status, threats, and monitoring recommendations. David Evans and Associates, Inc. Report. Portland, Oregon, USA.

# EXECUTIVE SUMMARY

Three salmon stocks were chosen for case studies in Oregon and Washington that were previously identified as "healthy" in a coast-wide assessment of stock status (Huntington et al. 1996): fall chinook salmon (*Oncorhynchus tshawytscha*) of the Wilson River, summer steelhead (*O. mykiss*) of the Middle Fork John Day (MFJD) River, and winter steelhead (*O. mykiss*) of the Sol Duc River. The purpose of the study was to examine with a finer focus the status of these three stocks and the array of human influences that affect them. The best available information was used, some of which has become available since the 1996 assessment of healthy stocks was conducted. Recommendations for monitoring were developed to address priority data gaps and most pressing threats to the species. Each stock is a member of a larger basin-wide and regional grouping of stocks that were identified as healthy and, thus, the findings of this study may have broader implications.

The three stocks are diverse in terms of their life histories, geographic range, and ecological habitat requirements. These stocks are affected by an array of hatchery, harvest, hydropower, and habitat impacts. The "healthy" ratings are probably not warranted for these stocks, two of which have experienced recent large declines (Wilson River fall chinook and MFJD River summer steelhead) and one of which is depressed in the early portion of the run (Sol Duck River winter steelhead). However, the available data is relatively poor and stocks are being managed with a high degree of uncertainty and risk in many respects. Monitoring, research and evaluation are proposed to get an accurate assessment of stock status on a watershed level and a better understanding of the level of threats to long term survival of the stocks. The following provides a summary of the broad commonalties between stocks and reasons for relative health of these populations, as well as threats, data gaps, and priority monitoring recommendations.

- The watersheds are all relatively large and historically have maintained large populations. Smaller populations are more vulnerable to extinction. The populations themselves are relatively poorly understood. Better information is needed on population sizes of spawners and juveniles and their use of habitats at various stages in their life histories.

- Major dams do not occur in any of the watersheds. John Day Basin is one of the largest watersheds in the Columbia Basin without a dam, but it is upstream of three hydropower dams on the Columbia that cause an impact (although not as severe as for fish populations in watersheds located further upstream on the Columbia).

- Hatchery stocking does not occur in these watersheds on a regular basis. The Snyder Creek brood stock program on the Sol Duc River is an exception, but appears to make a very low contribution to escapement. Straying of hatchery fish into all three watersheds from downstream areas with high levels of stocking is a concern and needs monitoring.

- Ocean, tribal, and recreational harvest levels appear to be relatively low for all stocks. Monitoring needs to be increased in some cases, particularly for recreational fisheries of Tillamook Bay.

- Habitat conditions vary greatly among watersheds. The MFJD River is in the poorest condition with clear loss of rearing habitat; the Wilson River has serious sediment and riparian problems, but may be in recovery since the 1950s following damage from fires and salvage logging. The headwaters of the Sol Duc River are partly in Olympic National Park, which provides an unusual degree of watershed protection, but the remainder of the watershed has been heavily logged and contains streams impacted by riparian loss and sedimentation. Although major habitat problems have been documented, the relation to fish survival is poorly understood. Intensive restoration actions are underway, especially in the John Day Basin. Restoration actions need to be more carefully monitored to evaluate their effect on fish populations.

- Nutrient deficiency in watersheds due to the decline in salmon carcasses and fluctuations in climate and ocean productivity were not addressed in this study, although they probably had dramatic effects on survival for all three stocks.

- None of the stocks are being managed to meet ecosystem-based spawning escapement goals. These goals would take into account the role of anadromous fish as keystone species in the ecosystem, particularly the importance of carcasses as a source of food and nutrients to juvenile salmon production and enrichment of aquatic and terrestrial food chains.

The identification of 99 healthy stocks by Huntington et al. (1996) may be a significant over-estimate of the number of healthy stocks that currently exist. A preliminary assessment of the available data indicates that other stocks in the Tillamook Basin, John Day Basin, and Olympic Coast region that were originally listed as healthy appear to have continued to decline to low levels in recent years. Yet, these populations are probably still "less sick" than most others in Oregon and Washington and represent perhaps our best opportunity to protect and restore salmon strongholds in the region. To do so, good monitoring data is urgently needed to track stock status and threats. Specific monitoring actions are recommended for each of the three stocks. These monitoring efforts should be incorporated into a Natural Production Accounting System as a systematic means of compiling the pertinent data on all native salmon stocks and their habitat.

## TABLE OF CONTENTS

## LIST OF TABLES



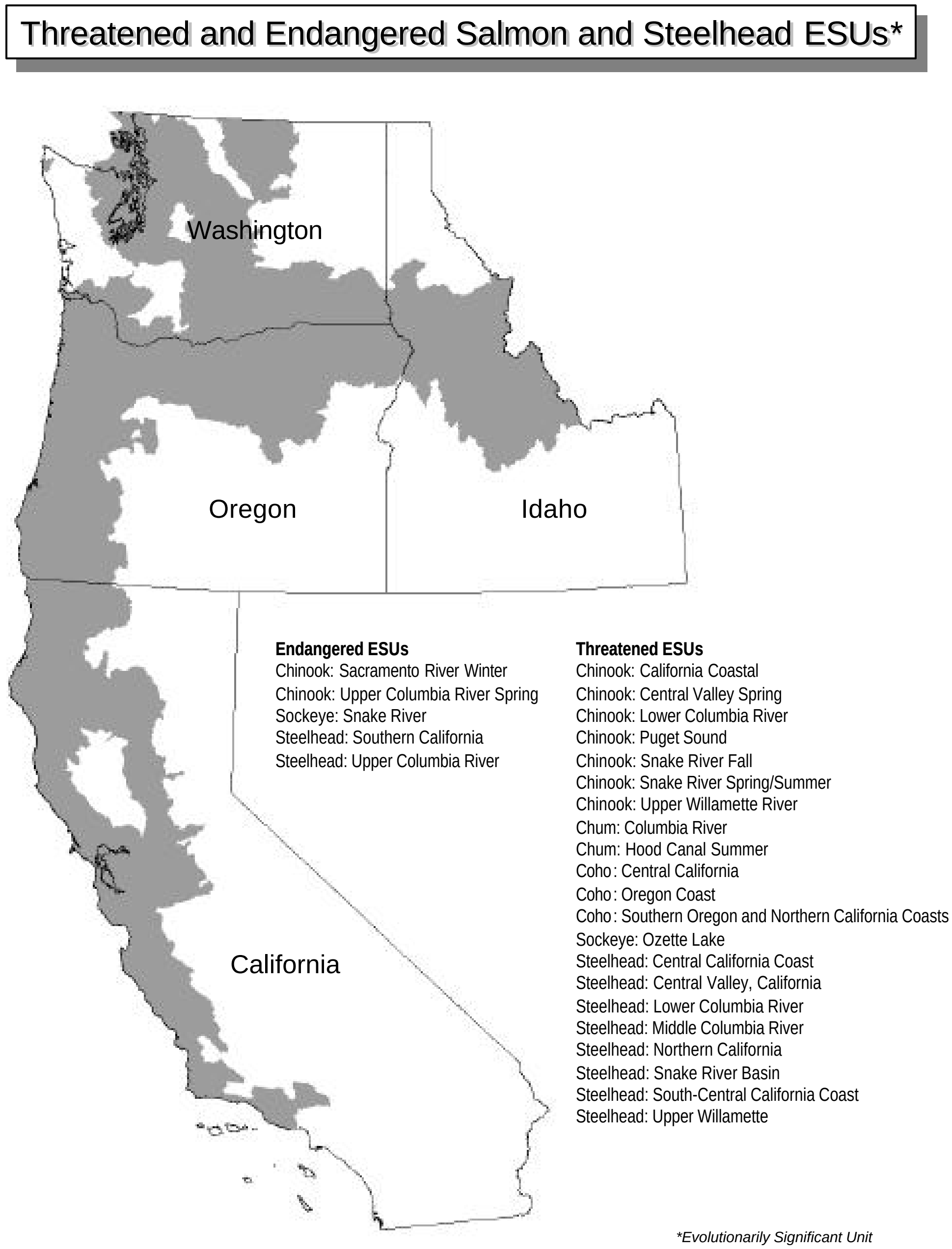
## LIST OF FIGURES

# INTRODUCTION

Native anadromous salmonids are in trouble throughout large areas of the Pacific Northwest and California. The crisis was brought to the forefront of public attention almost ten years ago, with publication of *Pacific Salmon at the Crossroads* (Nehlsen et al. 1991). This scientific report documented 214 native, naturally spawning Pacific salmon stocks whose persistence was in jeopardy: 101 at high risk, 58 at moderate risk, 54 of concern, and one listed as threatened under the Endangered Species Act. One hundred six extinct populations were also documented. Since 1991, many populations have been listed as threatened or endangered under the Endangered Species Act by the National Marine Fisheries Service (NMFS). Salmon stocks in specific geographic regions were grouped into Evolutionarily Significant Units (ESUs). An ESU is defined as a population that 1) is substantially reproductively isolated from conspecific populations and 2) represents an important component of the evolutionary legacy of the species (Busby et al. 1996). Salmon and steelhead were listed in 26 ESUs that blanketed most of the Pacific Northwest and California (NMFS 2000) (Figure 1).

The salmon crisis also heightened the recognition of the importance of the remaining healthy stocks for conservation and research. In the only comprehensive survey that has focused on healthy stocks, Huntington et al. (1996) identified 99 healthy native wild stocks of salmon and steelhead that biologists considered at least one-third as abundant as would be expected without human impacts, including 20 considered at least two-thirds as abundant. These stocks are critically important for much of the current native salmon productivity in the region. Because maintaining salmonid populations is more cost-effective and feasible than trying to restore them, they also provide what are likely the best opportunities for region-wide conservation of the species (Huntington et al. 1996).

Several years after publication of *Pacific Salmon at the Crossroads*, Nehlsen (1994) reported on a prioritization process and case studies in progress for stocks at risk. The intent of the case studies was to review the history of the river basins and their salmon populations, identifying the human, environmental, and biological factors that led to the depletion of the salmon. The case studies were intended to serve as detailed examples of some of the commonalities among




Source: NMFS 2000

**Figure 1 – Geographic Extent of Evolutionarily Significant Units (ESU) for Steelhead and Salmon Listed under the Endangered Species Act in the Pacific Northwest and California.**

populations that would become evident as the prioritization process was carried out (Nehlsen 1994). Such case studies have indeed occurred at the ESU level as part of the NMFS status reviews of salmon stocks considered for listing under the Endangered Species Act. Yet just as urgent is the need for case studies of healthy stocks.

The purpose of this report is to present case studies of salmon and steelhead stocks considered healthy by Huntington et al. (1996). The goal of the case studies is to examine with a finer focus the status of these relatively healthy stocks and the array of human influences that affect them. The status of each stock, its unique life history, and the human impacts of hatcheries, fish harvests, habitat alteration, and hydropower development are presented, based on the best available information. The three case studies include a range of stocks from diverse geographic locations in Oregon and Washington. As such, these detailed examples may provide broader insight into some of the commonalities between populations of healthy stocks, as well as their unique characteristics.

The second major purpose of this report is to identify gaps in current monitoring efforts, based on the review of the available data, and to recommend appropriate monitoring where needed. As the efforts to restore salmon stocks intensifies, the important role of monitoring is increasingly recognized (Botkin et al. 2000, Botkin et al. 1995). Without good monitoring, the status of healthy stocks and their habitat cannot be assessed until an obvious crisis exists. The current status of healthy stocks is no guarantee of their long-term survival (Huntington et al. 1996). Monitoring is also essential to determine the success or failure of restoration efforts. The current salmon crisis in the Pacific Northwest and failure of conventional restoration approaches is partly a result of inadequate monitoring and adaptive management (Botkin et al. 2000).

# METHODS

Three stocks were chosen for case studies: fall chinook of the Wilson River watershed, summer steelhead of the Middle Fork John Day River watershed, and winter steelhead of the Sol Duc River watershed. These stocks inhabit diverse ecological habitats, from the Oregon coastal temperate forest, to the high desert of eastern Oregon, and to the rain forests and mountains of the Olympic Peninsula (Figure 2). These populations also represent three major clusters of stocks listed in Huntington et al. (1996). Healthy fall chinook stocks were mainly concentrated in the Oregon Coast. The populations in Tillamook Bay, of which the Wilson River watershed

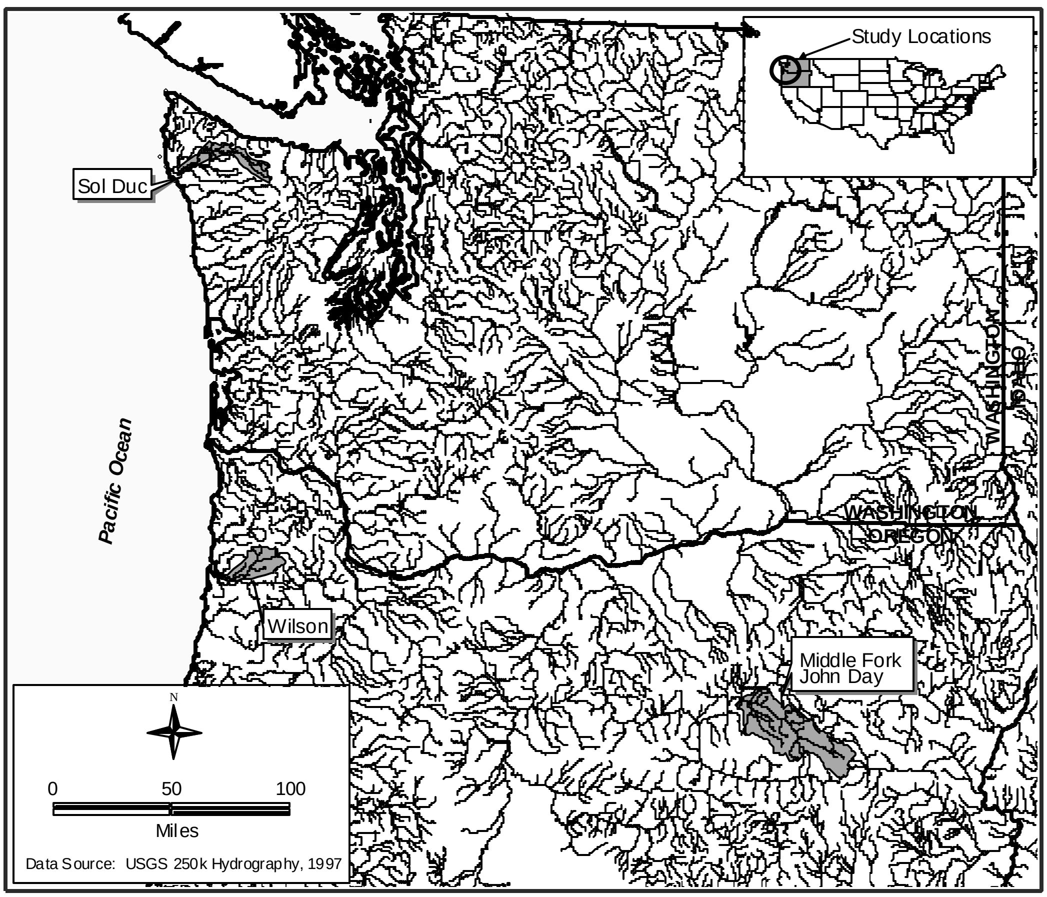



**Figure 2 – Location of the Wilson River, Middle Fork John Day, and Sol Duc Watersheds in Oregon and Washington**

is a part, represented 20 % of the total number of healthy fall chinook stocks. Healthy summer steelhead stocks were few in number, but five of the six stocks were identified in the watersheds of the John Day Basin, including the Middle Fork John Day River. Healthy winter steelhead stocks had the greatest north-south distribution, with a substantial number of healthy populations in the western Olympic Peninsula.

The case studies were based on available reports and interviews with more than 20 biologists and others knowledgeable on one or more stocks considered. Databases of fish population and habitat data were also obtained where available. The case studies were intended to summarize the population status, life history, and the influence of the big H's – hatchery, harvest, habitat, and hydropower impacts – on the population. The case studies provide a concise synthesis of each stock, its life history, and the range of human factors influencing the marine and freshwater persistence of the population.

Critical deficiencies or gaps in monitoring of these stocks were identified based on the review of the available information. Extensive monitoring efforts are currently underway in these basins and can always be improved given an unlimited budget. The goal of this study is not to propose the ideal monitoring plan, but to identify holes in current monitoring plans that needed to be filled to determine 1) stock status and 2) anthropogenic causes for change in status (habitat, hatchery influence, harvest, or hydropower). The second objective is obviously problematic; changes in population may never be known with certainty given the complex life cycle and multitude of influences on the species and natural fluctuations due to changing climate and ocean conditions (Beamish and Bouillon 1993, Lawson 1993, Hare and Francis 1995). However, this report provides recommendations for additional monitoring that are needed to fill critical gaps that may enable managers to make informed decisions in the face of threats to the species.

# RESULTS AND DISCUSSION

## FALL CHINOOK SALMON OF THE WILSON RIVER, OREGON

### Watershed Overview

The Wilson River is one of five rivers that drain into Tillamook Bay on Oregon's North Coast (Figure 3). The North Coast contains six of the most robust fall chinook populations in the lower 48 states, and five of these are found in the Tillamook Basin (Huntington and Frissell 1997, Huntington et al.1996). The Wilson River drains one of the largest watersheds in the Tillamook Basin. Most of the watershed is composed of the steep, forested hills of the Coast range. The lower several miles of the river flow through a low-lying floodplain before entering Tillamook Bay. Prior to Euro-American colonization, the Tillamook Nation of Native Americans lived in villages at the mouths of the major rivers, fishing for salmon and other fish (Coulton et al. 1996). Lewis and Clark estimated that the population of the Tillamook Nation was about 2,200 in 1806, but by 1849, it had decreased to 200 because of disease introduced by contact with Euro-Americans (Coulton et al. 1996). During this time, the mountains were largely covered with old-growth coniferous forest and the valleys were active floodplains. The lower rivers consisted of multiple channels flowing through a mosaic of forest and prairie vegetation and wood jams (Coulton et al. 1996). Currently, most of the upper watershed is owned by the Oregon Department of Forestry and private timber companies and is managed as industrial timberland. The Wilson River valley is now dominated by dairy farms and also includes the residential and commercial development of the City of Tillamook.

### Life History

The Wilson River fall chinook are included within one of nine genetically-defined groups of populations found in a broad coastal area from Vancouver, B.C., to Northern California (Utter et al. 1989). Significant genetic differences exist between and within these groups (Utter et al. 1989). ESUs were defined by NMFS while conducting reviews for protection under the federal Endangered Species Act. Wilson River fall chinook are considered part of the Oregon Coastal ESU, which is considered to be very different in marine distribution, age structure, and genetic characteristics from the adjacent Southern Oregon and Lower Columbia ESUs (Myers et al.

1998). The Oregon Department of Fish and Wildlife (ODFW) has further divided the Oregon coastal ESU into four Genetic Conservation Areas (GCAs). These GCAs are usually subsets of ESUs and were defined by ODFW either as part of implementation of the Wild Fish Management Policy or as part of monitoring associated with implementation of the Oregon Plan for Salmon and Watersheds (Jacobs et al. 2000). The Wilson River chinook are within the North-Mid Coast GCA.

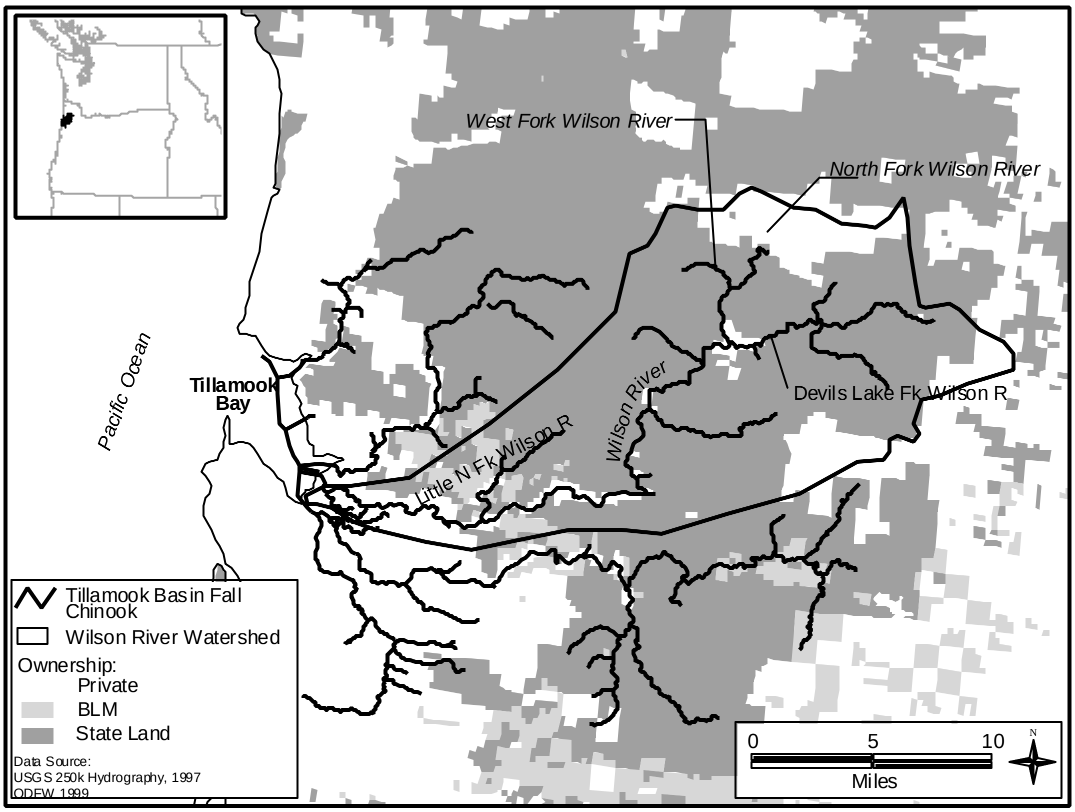



**Figure 3 – Distribution of Fall Chinook and Land Ownership in the Wilson River Watershed and the Tillamook Bay Basin**

Nicholas and Hankin (1988) provide a comprehensive overview of the life history of Oregon coastal chinook salmon and information on specific populations, including the Wilson River population. Due to the general lack of research studies, they rated the life history data for fall chinook in the Wilson as fair to poor.

Fall run chinook salmon in the Wilson River area generally have a peak entry to freshwater about late October, based on recreational catch data. These fish spawn from October through mid-March, with a peak usually in early December. Historic records from the fish packing plants on Tillamook Bay indicate that between 1893 and 1946 chinook salmon were present in the bay every month of the year, although at least some of these may have been local feeders moving in and out of the bays following the sardines (J. Lichatowich, personal communication). The current spring and fall chinook populations may represent only a subset of the historical run timing. These fish are classified as late-maturing, with return of females dominated by age five fish and, on average, returns at age four and age six about equal (Nicholas and Hankin 1988). Tillamook Basin fall chinook, including Wilson River fall chinook, are among the largest in the Oregon Coast range, both because they are older upon returning to spawn and because they are generally larger for their age than most South Coast stocks (Nicholas and Hankin 1988). Chinook salmon spawn throughout long reaches of Oregon coastal river basins, but the species is characterized by dense aggregations of spawners in short stream reaches of mainstems or large tributaries, rather than by an even distribution of spawners throughout river basins (Nicholas and Hankin 1988, Nickelson et al. 1992).

The parents normally exhibit homing to their natal stream. The female digs a redd in the gravel and lays 3,000 to 6,000 eggs, depending on her age and size. The adults die soon after spawning. Eggs and alevins incubate in the substrate during winter. Fry emerge and begin dispersing throughout the river basin during the spring and early summer (Nickelson et al. 1992).

Juvenile chinook of the Oregon coast are highly dependent upon both mainstem rivers and estuaries as rearing habitat (Aitkin 1998, Nicholas and Hankin 1988). Juvenile fall chinook of the Wilson River are thought to have an extended freshwater rearing period, defined as relatively abundant throughout the mainstem river and estuary throughout the summer months. The extent to which some juveniles remain in the riverine reaches during the summer is thought to be related to water temperature, with “cooler” systems supporting rearing juveniles over a more extended duration (Nicholas and Hankin 1988). Juvenile chinook are present throughout the entire mainstem, the lower reaches of the North Fork, and in the tidal reaches of the Wilson River Channel through at least mid-September.

There is a probable downstream flow of migrants during the spring and summer rearing period (Nicholas and Hankin 1988). Rotary screw traps were used from mid-April to mid-May in 1998 and 1999 in the Little North Fork Wilson River to monitor outmigration (Dalton 1999). The chinook fry and fingerlings counted in 1998 and 1999 were 1,223,944 and 451,236, respectively—the highest juvenile chinook densities found of 12 coastal streams monitored. Most of the outmigrants were fry. Based on scale sampling, it appears that yearling migrants are a small (5 to 10%) but consistent component of the chinook salmon population (Nicholas and Hankin 1988). Many of these juveniles are believed to migrate from the Wilson River channel to continue rearing in Tillamook Bay throughout the summer and fall (Nicholas and Hankin 1988). Wild juvenile chinook were present in ten estuaries, including the Tillamook, through the summer and fall (Nicholas and Downey 1983).

Data on recoveries of chinook salmon tagged with coded wire provide a general indication of the geographic distribution of oceanic rearing by immature chinook salmon. Oregon coastal chinook stocks exhibit three distinct patterns of oceanic migration: north coastal stocks migrate north, south coastal stocks migrate south, and several mid-coast stocks migrate both north and south. The Wilson River fall chinook run is grouped with other north coastal stocks that migrate north. In the Tillamook Bay system, the Trask River fall chinook is the only stock that has been consistently monitored using coded wire tag recoveries in ocean fisheries. Most of the recoveries of Trask River fish are from Alaska and British Columbia fisheries (Lewis 2000). After the first summer in the ocean, a small proportion of the males attain sexual maturity and return to spawn as jacks (Nickelson et al. 1992). Because this is a late maturing stock, most fish mature and return between age four and six, with rare seven-year-old spawners.

**Stock Status**

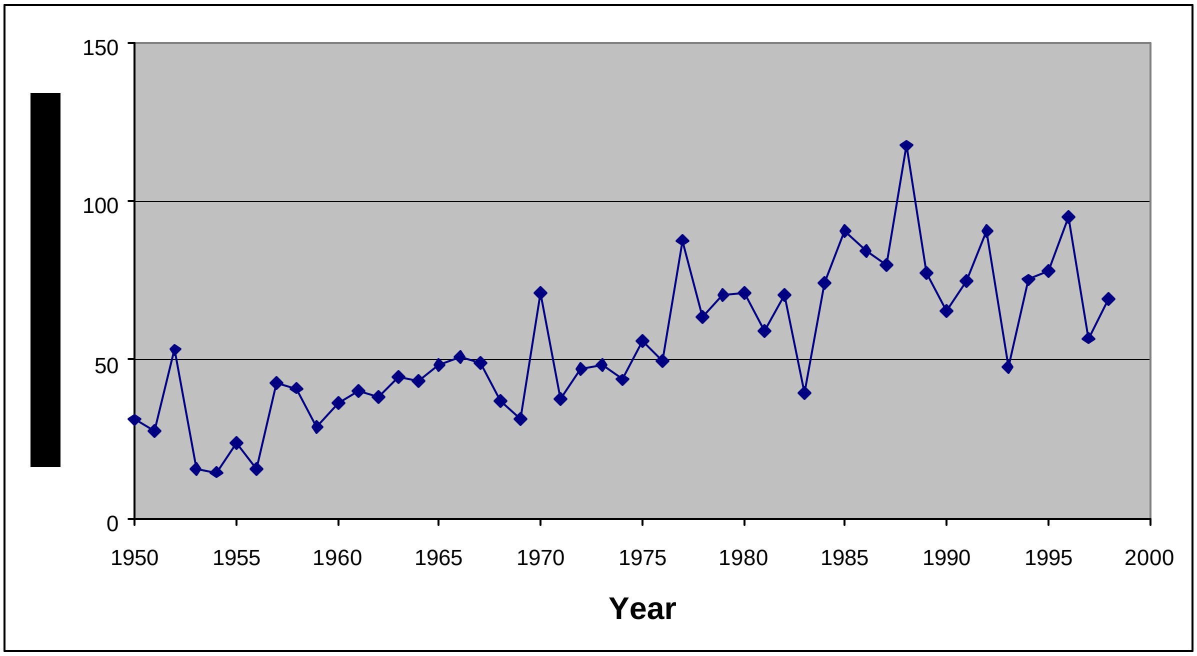
Assessments have generally found the North Coast and Wilson river stocks to be healthy and increasing. For Oregon’s coastal streams as a whole, Lichatowich (1989) estimated that the production potential of chinook salmon was about 150,000 fish greater in 1989 than the historical production (circa 1900), estimated to be 305,000 fish. In an evaluation of fall run chinook stock size for collective populations of the Tillamook Basin, Nicholas and Hankin (1988) considered the run size to be similar to historic abundance, based on an analysis of historical fish packing records and comparison with recent recreational catches. Historical cannery records showed wide fluctuation in catches, which may be related to market conditions, local conditions in the cannery, and other factors unrelated to run strength (Nicholas, ODFW, personal communication). The cannery packing records show a relatively stable catch of 12,000 to 31,000 fish annually between 1893-1919 and a substantial decline in catch from 1947 through 1961 (which may also have reflected more restrictive fishing regulations and seasons). The recreational catch has averaged about 12,400 fish annually from 1977 to 1985, with fall-run fish accounting for about 85% (Nicholas and Hankin 1988).

Nicholas and Hankin (1988) also reported that all north-migrating stocks were judged to have either increased (10 stocks) or exhibited no clear trend (8 stocks) since the 1950s. They listed the Wilson River fall chinook population as generally increasing since the early 1970s, with an average adult run size of 12,000. Nickelson et al. (1992) listed the Wilson River fall chinook population as healthy. They concluded that the north-migrating coastal chinook salmon populations were generally healthy, whereas the south-migrating populations generally were not.

In the NMFS 1998 coast-wide status review of chinook salmon, the biological review team unanimously concluded that:

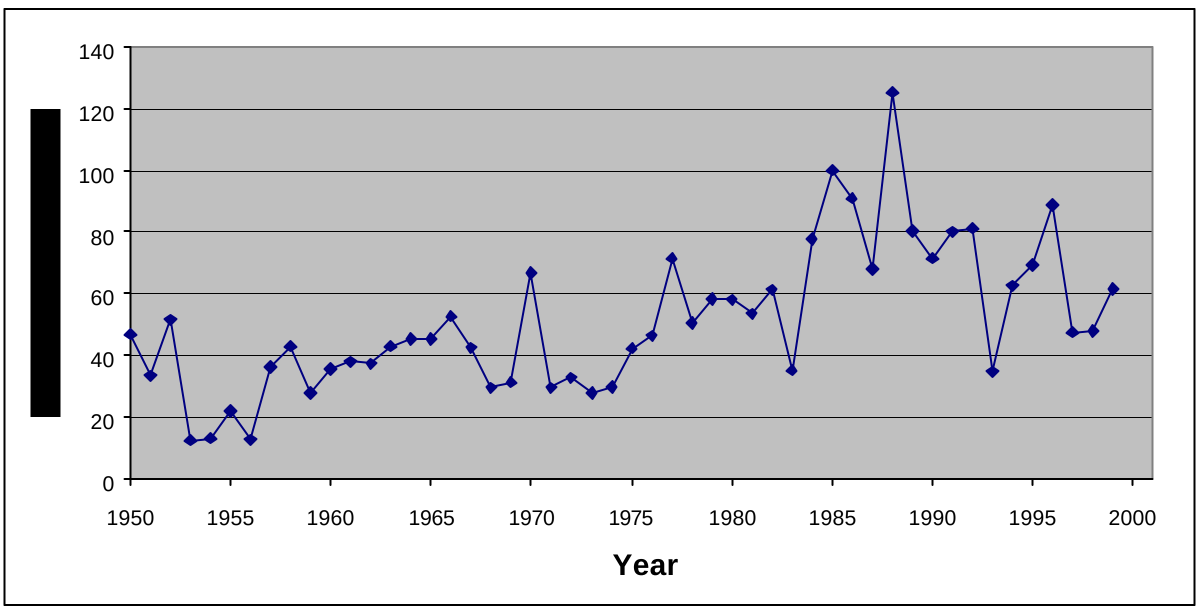
> "Chinook salmon in the Oregon Coast ESU is neither presently in danger of extinction nor are they likely to become so in the foreseeable future. Abundance in this ESU is relatively high, and fish are well distributed among numerous, relatively small river basins. Some suitable spawning habitat remains blocked, but access of chinook salmon to spawning areas is better than it was at the turn of the century." (Myers et al 1998)

ODFW recently completed an assessment of the status of adult anadromous salmonids inhabiting coastal basins of Oregon (Jacobs et al. 2000). Indices of spawner abundance in the Oregon coastal ESU show a significant increase from 1950 to 1998 (Figure 4). However, regression analysis of spawner abundance in the North-Mid Coast GCA showed a decline by an average of 5% per year between 1986 and 1998 (Figure 5). Jacobs et al. (2000) considered this decline relatively minor, and spawner densities in survey areas remain relatively high. Given this, Jacobs concluded that, overall, stocks in this GCA are at healthy levels of abundance.




Source: Jacobs et al. 2000

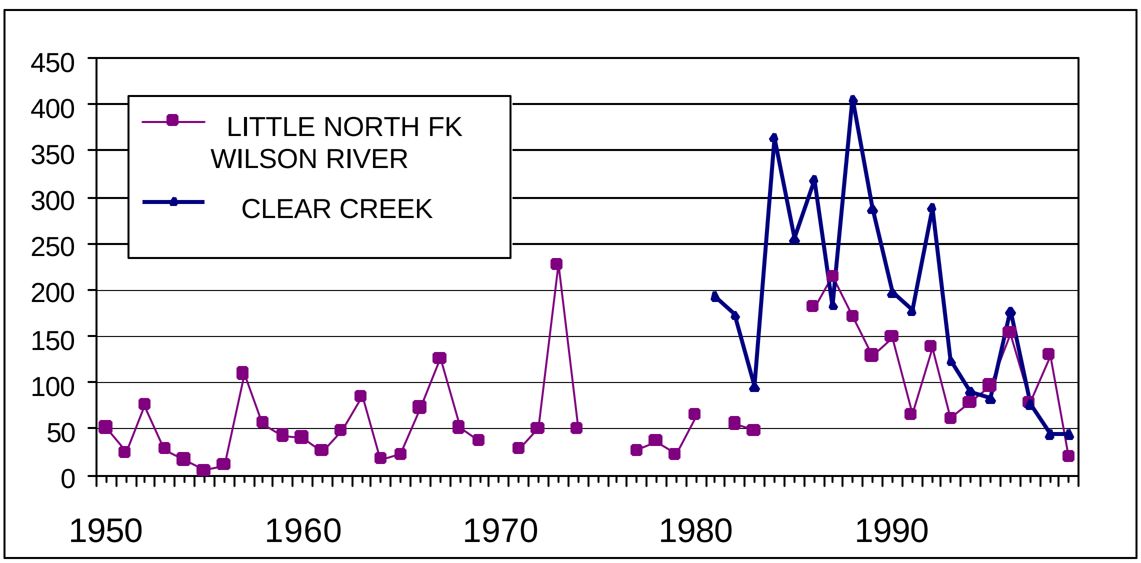
**Figure 4 – Trends in Spawner Abundance of Oregon Coastal Fall Chinook.**




Source: Jacobs et al. 2000

**Figure 5 – Trends in Spawning Escapement of Fall Chinook Salmon in the North-Mid Coast Gene Conservation Area (GCA) of the Oregon Coast**

Evaluation of the Wilson River fall chinook population by itself is problematic since very little data on the abundance of spawners are available. Only two index reaches have been consistently surveyed for chinook salmon—a total of 3.5 miles of survey length in Cedar Creek (2.8 miles) and the Little North Fork (0.8 miles) in the entire watershed. Trends in spawning counts in these two reaches show marked declines in spawner abundance since the late 1980's (Figure 6). Although data are not yet available for the 2000-2001 survey year, spawners appear to be even fewer than last year, which was a year of extremely poor returns (S. Jacobs, ODFW, personal communication). Monitoring of juvenile chinook outmigrants from the Little North Fork indicated that the abundance of migrants decreased by about half from 1998 to 1999 (Dalton 1999). Adult spawners that produced those broods were estimated to have dropped from 2000 to 4000 fish in 1998 to 750 to 1500 fish in 1999, corroborating the rapid decline indicated by the spawning survey data (Dalton 1999). Although the data may not be representative of the entire Wilson River population, the significant decline in these index streams over the past ten years is cause for concern.




Source: ODFW 2000A

**Figure 6 – Trends in Spawning Escapement of Wilson River Fall Chinook in Cedar Creek and Little North Fork Index Areas**

## Hatchery

Wilson River chinook are considered to be almost all wild fish, although no direct estimates of the proportion of hatchery fish in the run are available (Nicholas and Hankin 1988). In 1990, the hatchery contribution to the Tillamook Bay fishery was estimated to be 15% (Kostow 1995 in Myers et al. 1998) and Nicholas and Hankin estimated that hatchery chinook made up 5% of the run of fall chinook to the Tillamook Bay system in the 1986-1988 period (T. Nicholas, ODFW, personal communication). Prior to 1988, hatchery fish were not released into the Wilson River on a regular basis. The Trask River hatchery is the only hatchery facility in the Tillamook Basin. About 200,000 Trask River fall-run fry were released in the Wilson River for the 1982 brood year; about 100,000 Trask River spring-run fingerling were released annually for the 1973 through 1975 brood years; and from 60,000 to 130,000 Trask River Hatchery spring-run smolts were released from brood years 1976, 1977, and 1981. The Salmon Trout Enhancement Program has released 16,000 to 110,000 Trask River stock spring- and fall-run fry in the Wilson River annually since 1983 (Nicholas and Hankin 1988).

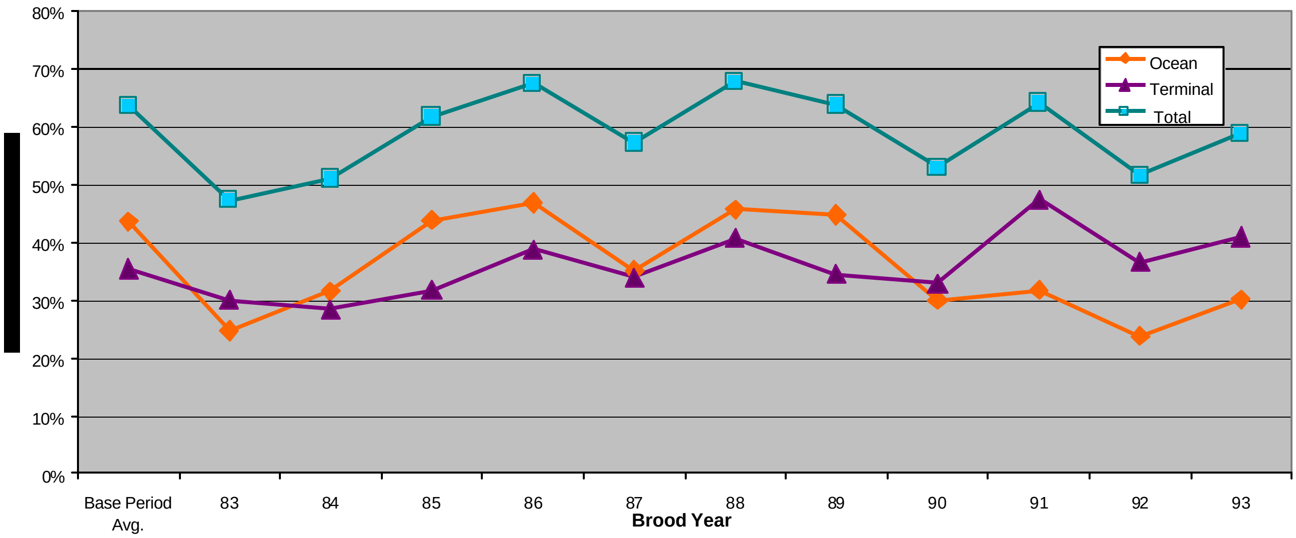
Release of hatchery chinook smolts, fry, and fingerlings within the larger North-Mid Coast GCA has remained at a high level between 1990 and 1999, averaging over two million smolts and one million fry and fingerlings released annually (Lewis 2000). Releases in the past several years have declined substantially.

## Harvest

Wilson River fall chinook are harvested in both recreational and commercial ocean fisheries and recreational fisheries in Tillamook Bay and the Wilson River. The historic commercial harvest, based on Tillamook Bay cannery records, was discussed above under stock status. The more recent ocean harvest of Trask River hatchery fall chinook is tracked through recovery of coded wire tags. Average ocean contribution rate of Trask River fish (number caught per 1,000 pounds of hatchery fish released) was extremely low (5.2) for the 1984-1993 brood years, and was zero for the most recent 1993 brood year (Lewis 2000). More than 80% of the fish were caught in Alaska and B.C. fisheries. The low recovery in recent years indicates either very low fishing pressure or poor natural survival of hatchery smolts released.

Jacobs et al. (2000) suggested that the high escapements in the late 1980s may have been a result of harvest reductions associated with implementation of the Pacific Salmon Treaty between the U.S. and Canada. The treaty was initiated for North Eastern Pacific ocean salmon fisheries in 1984 to regulate fisheries that intercept mixed stocks of salmon originating from both countries. One of the key conservation programs addressed in the treaty was the need to halt the decline and increase the abundance of natural chinook salmon stocks (Nuzum and Williams 1991). Overall catch from ocean fisheries declined from 2.3 million in 1985 to 1.56 million, mostly produced in Oregon and Washington (Busch 1995). In 1995, Alaska unilaterally adopted a new method for setting the catch limit, triggering a dispute between Alaska, British Columbia, and Washington, Oregon and California (Busch 1995). In accordance with the Pacific Salmon Commission program, ODFW developed intensive monitoring of the Salmon River hatchery stock to estimate catch and escapement for north-migrating fall chinook stocks. The most recent analysis of this indicator stock suggests that ocean harvest rate has dropped substantially since initiation of the treaty (ODFW 2000B). However, the data suggest that recreational harvest has increased, causing little change in overall harvest rate (Figure 7).

Collectively, chinook salmon that return to Tillamook Bay tributaries support the largest recreational fishery for fall-run chinook in Oregon coastal rivers. For the period 1977 through 1985, the average annual catch of fall-run fish was about 7,400 fish caught in tributary streams and about 3,300 caught in the bay (Nicholas and Hankin 1988). In the Wilson River itself, “punch card” estimates of catch of fall-run fish have ranged from about 1,000 to about 4,000 fish from 1969 through 1985 (Nicholas and Hankin 1988), with an average of 3,000 fish from 1977 through 1985. Thus, about 41% of the total catch of fall run chinook in the five rivers of Tillamook Bay came from the Wilson River during this period. Fishing pressure on fall chinook in Oregon coastal bays, and particularly Tillamook Bay, has noticeably increased in recent years (R. Williams, ODFW, personal communication). The increased recreational harvest rates noted for the Salmon River indicator stock (Figure 7) may be as high or higher for




Source: ODFW 2000B

**Figure 7 – Comparison of Harvest Rates of Northern Oregon Coastal Natural Population Indicator Stock (Salmon River Hatchery Stock) between Base Period (1977-1982 Broods) and Brood Years 1983-1993. Harvest Rate is the Total Impact of Landed Catch plus Incidental Mortality and Interannual Natural Mortality.**

the Wilson River, given the high fishing pressure in Tillamook Bay. However, the harvest rate for the Salmon River is probably not representative of the harvest rate for the Wilson River rate due to the large differences in the recreational fisheries (J. Nicholas, ODFW, personal communication). Because Tillamook Bay supports a mixed-stock recreational fishery of chinook from five river systems, there is also the risk of over-harvest of a particular stock. However, without more intensive monitoring of harvest and escapement of all the stocks, it is impossible to determine changes in total harvest impacts for the Wilson River or the Tillamook Bay system (Jacobs et al. 2000).

## Hydropower

No hydro-electric dams or other hydropower facilities occur in the Wilson River watershed.

## Habitat

Euro-American colonization and resource exploitation began altering chinook habitat in the Oregon coastal streams in the mid-1800s (Lichatowich 1989). In *An Environmental History of Tillamook Bay Estuary and Watershed*, Coulton et al. (1996) provide a detailed history of the area, recounted here. Prior to Euro-American settlement the floodplain valley was a braided network of floodplain channels and large woody debris jams, with a mosaic of spruce forest and prairies. Euro-American settlers removed wood jams, constructed levees, and cleared the floodplain beginning in the late 19$^{th}$ century. Most of the Tillamook valley had been cleared by 1920. Significant reductions in river channel complexity—the pools, riffles, and backwater channels that provided good rearing habitat—were documented between 1860 and 1937 (Benner and Sedell 1987 in Coulton et al. 1996). Log drives occurred from 1893 to 1908 in the lower 22.5 miles of the Wilson River. However, there is no record of splash dams on the Wilson River, probably because they were not necessary to float logs down the relatively high-gradient, confined river.

The wildfires and salvage logging of old growth forest that occurred in the upper portions of the Wilson River between 1933 and 1951 led to major increases in landslides and sediment delivery to the estuary (Tillamook Bay Task Force 1978). About 2,262 miles of roads, most of which were constructed for salvage logging, were in place in the Wilson River watershed by 1975 (Coulton et al. 1996), with road densities over large areas of the Tillamook burns exceeding16 mi/mi$^2$ (Tillamook Bay Task Force 1978). In a detailed erosion and sediment study, the Tillamook Bay Task Force found that roads, landslides, and recently cut forests were the primary sources of sediment in the watershed. Most of the landslides were human-caused, with 1,870 human-caused landslides and 86 natural landslides documented by the Tillamook Bay Task Force (1978). Sedimentation affects not only instream habitat for spawning and rearing, but also the estuarine rearing habitat for fall chinook. Since 1867, the volume of Tillamook Bay has been reduced by an estimated 35%, potentially affecting estuarine rearing habitat in a myriad of ways (Nehlsen and Dewberry 1995).

Currently, numerous major habitat problems have been reported that have implications for survival of fall chinook salmon of the Wilson River. ODFW has collected quantitative habitat data using the Aquatic Inventory Survey protocols for most tributaries of the Wilson River, although not for the mainstem river itself (ODFW 2000C). This data indicates a lack of pool habitat and large wood in most tributaries, which can reduce holding pools for adults and rearing areas for juveniles. Excessive sedimentation and lack of riparian forest are two major problems identified by Nehlsen and Dewberry (1995). The Wilson River was also one of the areas of highest disturbance from the severe floods in the winter of 1995-1996, with increased landslides, debris flows, and channel erosion (Myers et al. 1998). Streambed scour or aggradation can reduce spawning success for fall chinook and loss of riparian shade can increase water temperatures and reduce potential rearing areas for juveniles. The low spawning counts in recent years may be a reflection of poor survival of the age four and five returns whose parents spawned during the 1995-96 season of flooding (S. Jacobs, ODFW, personal communication).

The Tillamook Bay Comprehensive Conservation and Management Plan identified four priority problems—habitat loss and simplification, erosion and sedimentation, water quality, and flooding (Tillamook County Performance Partnership and Tillamook Bay National Estuary Project 2000). In terms of the water quality problem, the entire mainstem Wilson River is on the state's 303(d) list for exceeding temperature standards for spawning and rearing salmon. The Oregon Department of Environmental Quality (ODEQ) recently conducted extensive stream temperature monitoring in the Wilson River drainage and detailed modeling to predict the effect of existing and potential riparian conditions on temperature (ODEQ 2000). The primary reason for high stream temperatures are the on-going and past removal of riparian vegetation and channel widening (ODEQ 2000). The analysis is currently being used by ODEQ to develop Total Maximum Daily Load allocations for non-point pollutants as required under the federal Clean Water Act (ODEQ 2000).

The flooding problem that now affects many landowners is largely a result of development on the floodplain that historically provided critical rearing habitat for salmonids. Others have cited low summer streamflows and high temperatures, exacerbated by water withdrawals, as a problem for Tillamook Bay tributaries (Bottom et al. 1985 in Myers et al. 1998). They also cited serious modification of stream structure by logging and widespread removal of beaver dams, but concluded that recent efforts have resulted in more stream miles being accessible to anadromous fish now than 100 years ago. Although numerous habitat alterations have been documented, their impact on fall chinook productivity and overall trends in abundance are largely unknown.

With the major habitat problems documented for the Wilson River, it is difficult to understand how fall chinook may have increased in abundance since the early 1900s. Lichatowich (1989) concluded that the apparent increase in chinook salmon may reflect the early destruction of habitats favored by chinook salmon before fishery data was available beginning in 1900 followed by the gradual recovery of their habitat following the Tillamook burns and salvage logging. Alternatively, he speculates that the increase in abundance of chinook salmon may be the result of a shift from pristine habitats, which favored production of coho salmon, to the present altered habitat, which favors production of chinook salmon. Nicholas and Hankin (1988) stated that the north-migrating fall chinook stocks have been exposed to overall exploitation rates (ocean fishery plus in-river fishery) that would have allowed the stocks to either maintain or increase their number. They speculate that the combination of moderate fishery exploitation rates, generally favorable rearing environment in the ocean off the coast of British Columbia and Alaska, and gradual recovery of some damaged freshwater habitats has allowed many of the runs in this group to increase.

Despite their habitat problems, the Tillamook Bay Basin and Wilson River watershed are generally considered salmon strongholds of exceptional importance because of their relatively abundant and diverse fish populations compared to other watersheds (Nehlsen 1997, Huntington and Frissell 1997, Huntington et al. 1996, and Ecotrust et al. 2000). Four watershed prioritization methods and conservation strategies have identified the Wilson River, or portions thereof, as top priorities for protection (Nehlsen 1997, Huntington and Frissell 1997, Ecotrust et al. 2000, and Noss 1993 in Huntington and Frissell 1997). The Little North Fork, North Fork, and Devil's Lake Fork of the Wilson River appear to be particularly important (Huntington and Frissell 1997).

**Summary**

Limited spawning survey data suggests that substantial declines have occurred in the Wilson River fall chinook stock since the high counts of the late 1980s. These declines may have been caused by recent severe floods, combined with degraded watershed conditions, and an increasing recreational fishery. For whatever cause, the apparent steep drop in spawners over the past decade and very low counts of spawners in the past several years suggests that the initial healthy ranking of this stock by Huntington et al. (1996) is no longer warranted.

## Monitoring Recommendations

Some of the following monitoring actions have been recommended in previous reports, as citations indicate, but were not implemented. The monitoring actions are organized under the same headings as the preceding section.

### *Life History*

Conduct stream surveys to identify specific stream reaches that support relatively high densities of spawning chinook salmon. Sampling should be sufficient to determine whether these reaches vary annually depending on stream flow during the spawning period (Nicholas and Hankin 1988). Because chinook tend to spawn in aggregations, an accurate understanding of the location of those preferred areas is necessary to design representative spawning surveys and habitat protection plans.

### *Stock Status*

Expand the spawning surveys in the Wilson River as necessary to obtain a representative baseline for long-term escapement monitoring. The current survey of 3.5 stream miles out of a total of over 30 miles of habitat is probably not adequate to assess trends in population in this watershed (S. Jacobs, ODFW, personal communication). The survey expansion should be designed based on the results of the life history investigation described above and using a random selection of stream reaches, similar to the coho survey improvements made by ODFW.

### *Hatchery*

To allow adequate monitoring of the wild population, discontinue stocking of fall or spring chinook in the Wilson River. These irregular stockings do not appear to provide a significant contribution to the populations, which are managed as wild stocks. However, they do add one more variable that clouds an understanding of the health and status of wild stocks in the Wilson River. Without solid justification for a continued outplanting program, it should be discontinued. If outplanting is continued, it must be accompanied by adequate monitoring.

*Harvest*

Increase monitoring of recreational and commercial harvest. Currently, the Salmon River and the Trask River provide the only coded wire tag recovery data for estimating harvest. More intensive mark recapture and angler catch monitoring is needed to better understand the relation between escapement and total harvest for the Wilson River population and other populations (Jacobs et al. 2000).

*Hydropower*

No monitoring is required since no hydropower facilities occur in the Wilson River watershed.

*Habitat*

Expand the ODFW Aquatic Inventory Surveys to include the entire mainstem of the Wilson River, and re-survey all areas every ten years with an analysis of trends in habitat quantity and quality. Currently, ODFW has surveyed most tributaries, but not the mainstem. The mainstem Wilson River provides important spawning and rearing habitat for fall chinook and should be surveyed to obtain a baseline of habitat conditions.

Determine the relationship of riparian condition, elevated water temperatures, and other habitat parameters to chinook survival. Poor riparian condition was identified as a major problem for aquatic habitats in the Tillamook Basin (Nehlsen 1997). Poor riparian condition is a primary cause for the documented poor condition of other habitat parameters, such as elevated summer stream temperatures, low levels of large woody debris and pool habitat, and excessive stream bank erosion. Detailed riparian assessments and stream temperature monitoring and modeling has been conducted, but intensive research aimed at documenting the complex relationships between these variables and chinook survival and production are needed.

Conduct a sediment source assessment to identify historical, existing, and potential landslide areas and triggering mechanisms, as well as areas of surface and bank erosion. Sedimentation was identified as one of the largest problems for fish habitat in the Wilson River watershed; much of the sediment was from landslides associated with the forest road system (Nehlsen and Dewberry 1995). As part of a watershed analysis framework, Nehlsen and Dewberry (1995) recommended identifying erosion sources and sedimentation as a priority.

Designate the Little North Fork Wilson River watershed and, if possible, the entire Wilson River watershed as a salmon sanctuary for long-term baseline protection and monitoring of native salmon stocks. This will establish a significant anchor habitat for regional protection of salmon stocks (Nehlsen 1997, Huntington and Frissell 1997, Ecotrust et al. 2000, and Noss 1993 in Huntington and Frissell 1997). In terms of monitoring, this will help ensure that some watersheds in the region are set aside as baseline monitoring areas against which to assess the effects of human actions in other watersheds. Although complete protection is not possible, the existence of substantial state and federal lands makes this recommendation feasible in the near term for the Little North Fork Wilson River watershed.

## SUMMER STEELHEAD OF THE MIDDLE FORK JOHN DAY RIVER, OREGON

### Watershed Overview

The John Day Basin is an area of 8,100 square miles, roughly the size of Massachusetts, located in the high desert of northeastern Oregon (Oregon Water Resources Department [OWRD]1986) (Figure 8). The John Day River supports the largest wild steelhead populations remaining in eastern Oregon, and one of the largest remaining in the Columbia River Basin (Olsen et al. 1994). The Middle Fork John Day (MFJD) watershed is approximately 806 square miles, or 10% of the entire John Day Basin area. The MFJD River, a tributary to the North Fork John Day River, supports about 30% of the steelhead in the entire John Day system (Figure 9) (Confederated Tribes of the Umatilla Indian Reservation [CTUIR] 1984). The MFJD watershed

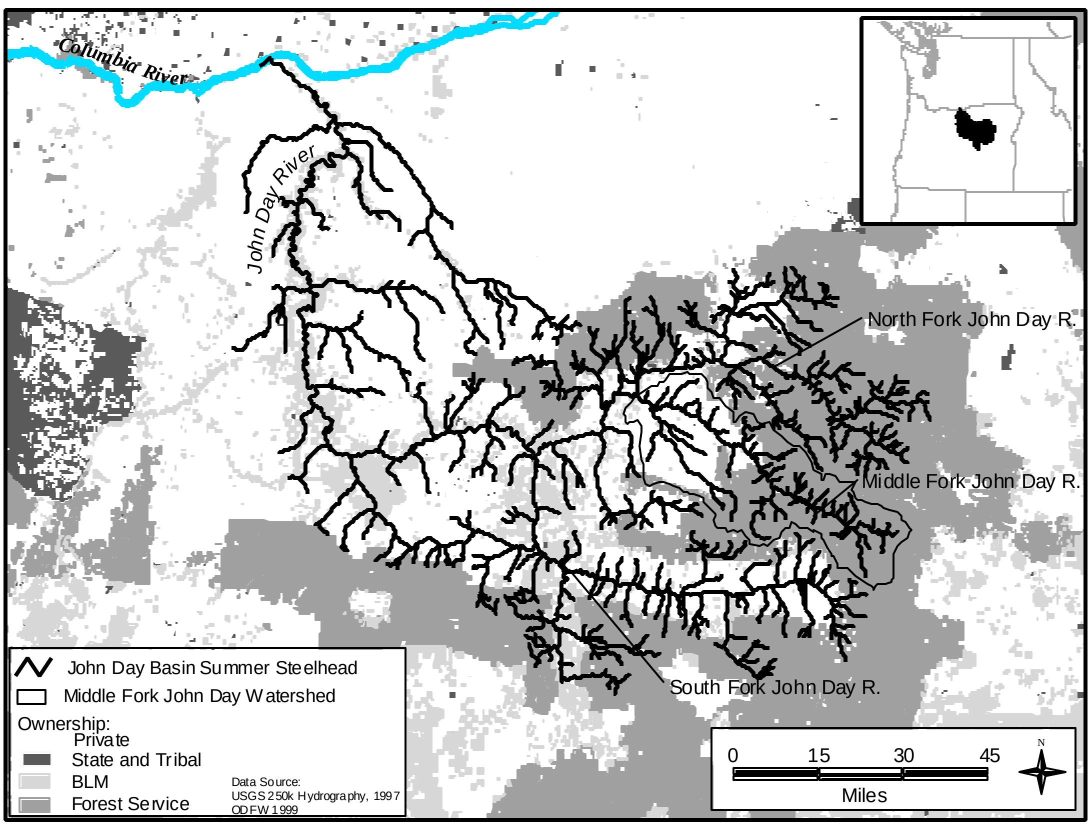



**Figure 8 – Distribution of Summer Steelhead and Land Ownership in the John Day Basin**

has highly varied terrain, with elevations ranging from about 2,200 feet near the mouth to over 8,100 feet in the headwater areas. The climate is semi-arid, with an average annual precipitation of about ten inches (OWRD 1986). The entire basin is within the Usual and Accustomed Area (U&A) of the Confederated Tribes of the Umatilla and Warm Springs reservations. The Tribes retain fishing, hunting and gathering rights within their U&A under treaty with the United States. Nearly three-quarters of the land in the watershed, and nearly all of the headwaters, is owned by the U.S. Forest Service. About 75% of the Forest Service land is grazed. Most of the private lands are pasture lands located along the river valleys. Some widely dispersed parcels along the lower and middle reaches of the Middle Fork and Long Creek are owned by the Bureau of Land Management.

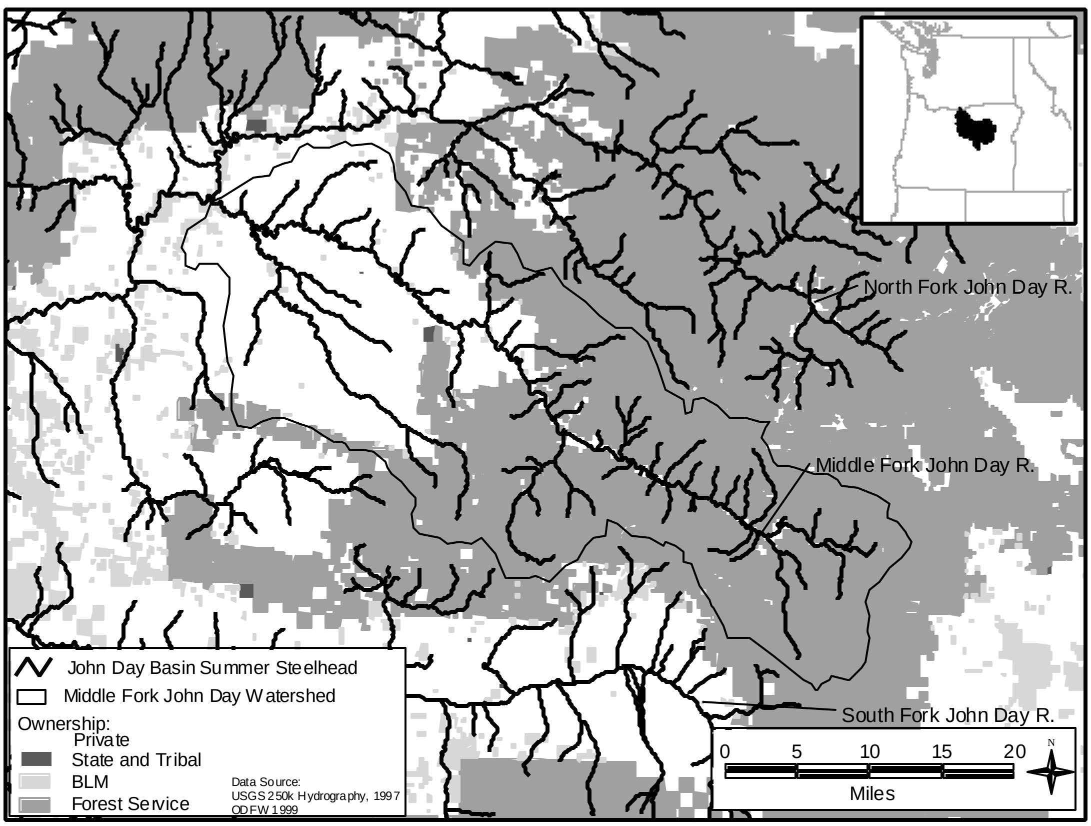



**Figure 9 – Distribution of Summer Steelhead and Land Ownership in the Middle Fork John Day Watershed**

Historically, the MFJD River is generally considered to have had some of the best fish habitat in the John Day system due to its relatively low gradient and unconfined valleys (C. Torgerson, OSU, personal communication). However, the river has also suffered some of the worst habitat impacts of any John Day tributary (Li et al. 2000). Current and historic impacts of mining, gold dredging, grazing, and timber harvest have severely reduced habitat for cold water fishes in the MFJD river (Li et al. 2000).

**Life History**

The summer steelhead populations of the John Day River are part of a broad inland group located east of the Cascades that are genetically distinct from those populations to the west of the Cascades (Schreck et al. 1986). Winter steelhead populations are rare east of the Cascades (Busby et al. 1996). NMFS further classified the John Day River populations into a Middle Columbia ESU, based on genetic evidence that separates this ESU from the Snake River populations to the east and the lower Columbia populations west of the Klickitat Basin in Washington and Fifteenmile Creek in Oregon (Busby et al. 1996). Within the John Day River, ODFW has identified five distinct populations based on geographic isolation: the Lower Mainstem, Upper Mainstem, North Fork, Middle Fork, and South Fork (Chilcote 1998).

Adults are considered part of the “A” run for fishery management purposes under both timing and size definitions. Until recently, fishery agencies distinguished runs based on timing; “A” run fish passed Bonneville Dam before August 25 and group “B” steelhead passed after August 25 and generally migrated further upstream to the Clearwater and Salmon Rivers in Idaho (U.S. v. Oregon Technical Advisory Committee 1997). The classification criteria were changed recently from run timing to size. Steelhead less than 78 centimeters in total length are considered “A” run, and larger fish are considered “B” run (Curt Melcher, ODFW, personal communication). Fish begin migrating up the John Day River in September when water temperatures cool and flow increases (Howell et al. 1985 in Olsen et al. 1994). The steelhead over-winter in the river and spawning begins in the lower tributaries of the John Day River in mid-March and continues through mid-June in the upper tributaries (Olsen et al. 1994).

The life history of juvenile steelhead in the John Day Basin was obtained from records at bypass traps on irrigation diversions, analysis of scale samples, and limited life history studies.

Fry emerged in Tex Creek in early July (Olsen et al. 1994). Peak downstream movement of smolts generally occurs from April through May (E. Claire, personal communication). Age one+ juveniles periodically migrate to new rearing habitats, especially in the late summer and fall, corresponding with increased flows (ODFW et al. 1985). The larger tributaries and mainstem may be particularly important habitats during these latter stages of juvenile rearing prior to migration out of the John Day system the following spring (ODFW et al. 1985). In a study of juvenile rearing in the MFJD and two other tributaries in the basin, Leitzinger (1992) found that steelhead select microhabitats by age class. These microhabitats could be distinguished by such characteristics as the water depth and velocity at the fish's focal point and total depth and velocity of the habitat.

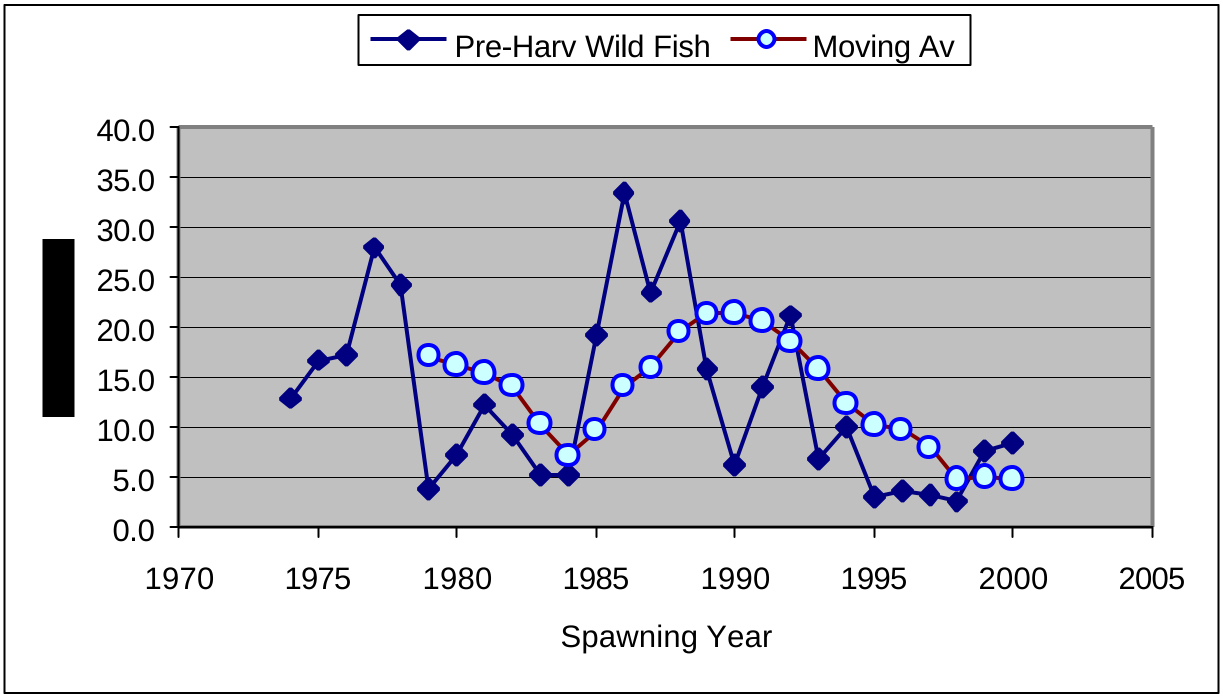
Scale analysis indicates that about 62% of the steelhead smolt at two years and the remainder smolt at three years (Busby et al. 1996). About 51% of the adults spend one year at sea, with most of the remainder spending two years at sea (Busby et al. 1996). However, rearing time in freshwater may be much longer for a small proportion of juveniles. In the Wenatchee River, another mid-Columbia Basin watershed, juvenile steelhead spent up to seven years in freshwater before emigrating to sea (Peven 1990).

**Stock Status**

Although the Columbia River once was among the most productive river basins for anadromous salmonids on the West Coast of North America, its current runs are less than 10% of historical levels (Independent Scientific Group 1999). Within the John Day Basin, steelhead abundance has fluctuated greatly since the first spawner surveys were conducted in the 1950s. Redd counts reached a low point in the 1970s, peaked in the late 1980s, and recently have exhibited lows similar to the 1970s (Chilcote 1998). These fluctuations may at least partly reflect larger patterns of climate and ocean productivity (Cooper and Johnson 1992). Broad estimates of West Coast steelhead abundance in 1972 and 1987 were similar, but there has been a significant increase in the proportion of hatchery fish (Light 1987, Busby et al. 1996). In the Middle Columbia ESU, about 80% of the steelhead are hatchery fish (Busby et al. 1996). The NMFS status review of West Coast steelhead concluded that the majority of stocks within the Middle Columbia ESU were declining, including those in the John Day River, which is the largest producer of wild steelhead (Busby et al. 1996). Steelhead within this ESU were listed as a federally threatened species on March 25, 1999 (Federal Register 64 FR 14517). A 1998 status review of steelhead in Oregon conducted by ODFW rated the Middle Columbia ESU populations as "sensitive" (at some degree of risk of extinction), particularly in the John Day Basin (Chilcote 1998).

The ODFW status report indicated that the steelhead population of the MFJD River was generally depressed in the 1990s, but with a spike in abundance for the 1992 spawner year (Chilcote 1998). This stock assessment was updated in November 2000, and draft data and graphs made available (M. Chilcote, ODFW, personal communication). The data indicates continued declines for all John Day populations, including the MFJD river (Figure 10). The MFJD River data is based on spawning surveys conducted in only two tributaries, Lick Creek and Camp Creek, totaling 8.8 miles of total stream length that was surveyed fairly consistently between 1971 and 1999. The spawning redds per mile data were converted to fish per mile (based on the number of females per redd), and then converted to pre-harvest fish per mile (using a constant harvest rate of 12% for the John Day River and variable rate estimate for the Columbia River). The population trend data indicates a potentially serious 1990s decline in the MFJD population and other John Day Basin populations.

Steelhead abundance estimates have been based on a relatively solid long-term database of redd counts for the John Day Basin (M. Chilcote, ODFW, personal communication; E. Claire, personal communication). The redd counts, usually conducted just after the estimated peak of spawning, in some years covered more than 100 miles of stream reaches and date back to the 1950s, among the longest term spawning data records in the state (E. Claire, personal communication, ODFW et al. 1985). However, data from limited spawning surveys conducted in the MFJD River is probably not sufficient to provide a good estimate of trends in abundance for this watershed. Furthermore, because Columbia River fish runs had already declined substantially by the late 1890s (U.S. v. Oregon Technical Advisory Committee 1997), the spawning data does not indicate the magnitude of historical production prior to Euro-American colonization of the region.




Source: ODFW 2000D

**Figure 10 – Trend in the Estimated Total Return of Adult Summer Steelhead Spawners to Two Tributaries in the Middle Fork John Day River, 1971-1999**

## Hatchery

The John Day Basin is managed under Oregon's Wild Fish Management Policy (OAR 635-07-525) Option A, Management Exclusively for Wild Fish. The intent of Option A is to ensure that the life history characteristics and productivity of the locally adapted wild stock are not altered by man's activities (ODFW et al. 1990). Non-indigenous summer and winter steelhead were released into the subbasin in 1966, 1967, and 1969 (Olsen et al. 1994). Few fish likely survived due to the use of improper stocks and hauling mortality (ODFW et al.1990). With the exception of these releases, subbasin production has been entirely from native stock (Olsen et al. 1994), and potentially from hatchery or wild fish strays from out of the basin.

Hatchery fish are widespread and escaping to spawn throughout the Middle Columbia ESU, with potential impacts to John Day populations (Busby et al. 1996). NMFS considers that the major threat to genetic integrity for steelhead in this ESU comes from past and present hatchery practices (Busby et al. 1996). A primary trouble spot identified in ODFW's 1998 steelhead status review of the Middle Columbia ESU was the Deschutes steelhead (Chilcote 1998). Over the previous four years, the population has been in almost complete reproductive failure. Stray hatchery fish dominated the spawning populations (greater than 75%) and were likely causing severe genetic impact to the innate productivity of the wild stock (Chilcote 1998).

Information on hatchery strays in the John Day River is weak and based on relatively few angler reports with varying estimates from various sources. Hatchery strays accounted for 15% and 4% of the fish sampled during the 1982-83 and 1983-84 sport fishing seasons, and they were found in upriver locations (ODFW et al. 1985). According to a more recent stock assessment, strays were believed to account for 4% to 8% of the run (Olsen et al 1994). Chilcote (1998) notes the possible increase in hatchery strays in recent years, but assumes that without better information, they constitute less than 5% of the naturally spawning population. A dramatic increase in straying, as occurred in the Deschutes, would probably not have been noticed in the John Day River.

**Harvest**

The John Day Basin supported a popular sports fishery with harvest of wild steelhead allowed until 1996. ODFW has used the count of wild A-run steelhead over Bonneville as a trigger mechanism to enact emergency regulations. When the count was less than 40,000, emergency rules were proposed to the Oregon Fish and Wildlife Commission and were enacted for the 1990, 1993, 1994 and 1995 run years. These regulations allowed retention of only two wild fish per year. For the 1996 run year, the Commission enacted regulations requiring catch and release of all wild steelhead for the John Day River because of concern for continued low returns of wild steelhead over Bonneville dam. Although there have been over 40,000 wild A-run steelhead counted at Bonneville for the last two years, there is still no sport harvest of wild steelhead allowed in the Columbia River or its tributaries (T. Unterwegner, ODFW, personal communication).

Run year specific estimates of sports harvest averaged about 2,000 fish and ranged from 305 to 9,675 fish from 1958 through 1991 (ODFW et al. 1990, Olsen et al. 1994). According to Errol

Claire (personal communication), sports harvest was limited by high flows and turbid water conditions that made fishing impossible much of the time. For example, for the 1996 run year, ODFW had a statistical creel program to monitor harvest, location of stray hatchery steelhead, and incidence of strays. However, from the second week in December until early March the river was so high and muddy that nobody was fishing (T. Unterwegner, ODFW, personal communication). Sport harvest data on the MFJD indicate an average annual catch of about 71 fish, ranging from 0 to 250 fish from 1975 through 1987 (ODFW et al. 1990).

The Umatilla and Warm Springs Confederated Tribes have reserved Usual and Accustomed fishing sites in the John Day River subbasin (ODFW et al. 1990). Tribal harvest has been a minimal subsistence harvest only, and the commercial fishery has been closed since 1978 to restore runs to harvestable levels (ODFW et al. 1990). Most (96%) of the treaty Indian harvest in the Columbia Basin has come from the mainstem Columbia River and averaged 11.3% of the Bonneville count between 1985 and 1995 (U.S. v. Oregon Technical Advisory Committee 1997). Both the Tribal and sport fisheries in the Columbia River catch an unknown number of MFJD River steelhead in a mixed stock fishery situation.

Ocean fisheries do not appear to be a significant form of harvest. Since 1977, less than 1% of the upriver summer steelhead accounted for by coded wire tag recoveries of harvested hatchery fish came from the ocean (Pacific States Marine Fisheries Commission database in U.S. v. Oregon Technical Advisory Committee 1997). However, high seas drift nets may have harvested steelhead and have been implicated as one potential cause for the 1990-1991 coastwide decline in winter steelhead stocks (Cooper and Johnson 1992).

The Columbia River Fishery Management Plan (CRFMP) goal for production of wild summer steelhead was 62,200 group “A” fish passing Bonneville Dam (U.S. v. Oregon Technical Advisory Committee 1997). The sub-basin plans, under the Northwest Power Planning Council (NWPPC) have a goal of a 45,000 summer steelhead return to the mouth of the John Day River, with 33,750 for escapement and 11,250 for tribal and sports harvest (NWPPC 1996). The CRFMP goal was met twice between 1985 and 1994, and runs continued to decline (U.S. v. Oregon Technical Advisory Committee 1997). Estimates of total escapement to the John Day River are considered unreliable since they are based on extrapolation to the whole basin from a relatively small length of spawning surveys (T. Unterwegner, ODFW, personal communication).

### Hydropower

The John Day River is the largest tributary without major dams in the Columbia River Basin, a system that is otherwise full of dams (Figure 11). However, seasonal pushup dams and small impoundments for irrigation and livestock watering are still used (OWRD 1986). Three major dams occur on the mainstem Columbia River downstream of the John Day River (Figure 12).

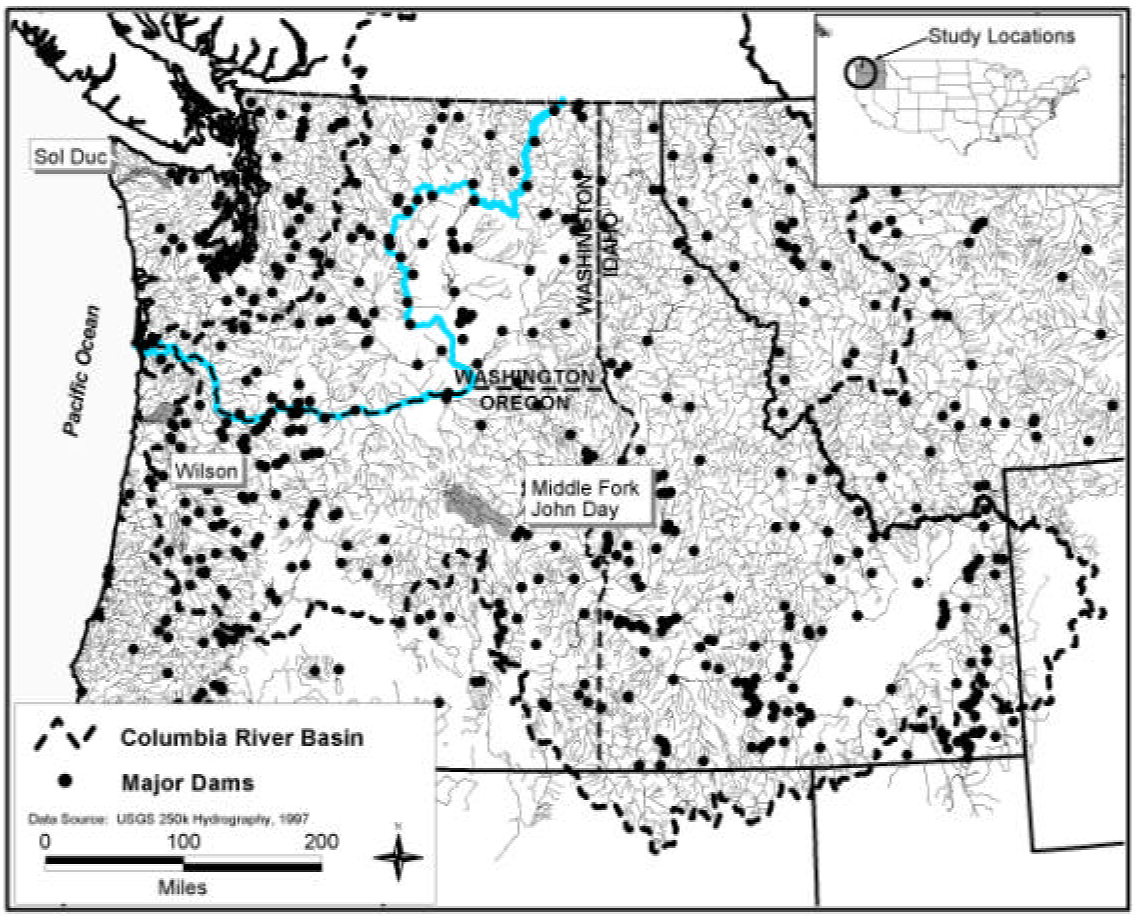
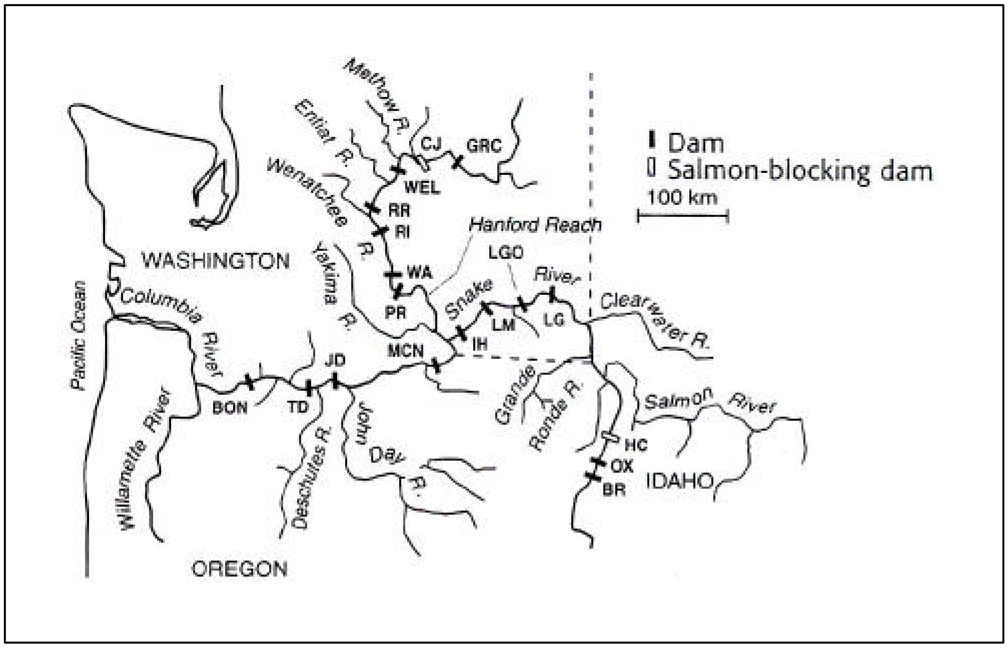



**Figure 11 – Location of Major Dams in the Columbia River Basin**

These dams and their reservoirs are major sources of mortality for juvenile steelhead and other salmon species that migrate downstream and get caught in the turbines. Losses of smolts were estimated at 10% to 20% of the total population at each dam, with an estimated 51% to 73% survival through all three dams to the Pacific Ocean (Raymond 1979, 1988, Skalski 1998 in Li 2000). In a study of wild spring chinook salmon in the John Day River, Lindsay et al. (1986) attributed spring chinook declines since the 1970s primarily to mortality at dams. He stated that juvenile numbers were far below stream carrying capacity and that instream habitat improvements would not increase production until passage survival increased. The dams also provide habitat for pikeminnow, which consume an estimated 16 million juvenile salmon migrants in the Columbia River per year, or 8% of the population (Beamesderfer et al. 1996).




Source: Independent Scientific Group 1999

**Figure 12 – Mainstem Dams of the Columbia River and Its Major Tributaries. There is no fish passage upstream of Chief Joseph and Hells Canyon dams. (Dam identifiers are BON=Bonneville, TD=The Dalles, JD=John Day, MCN=McNary, PR=Priest Rapids, WA=Wanapum, RI=Rock Island, RR=Rocky Reach, WEL=Wells, CJ=Chief Joseph, GRC=Grand Coulee, IH=Ice Harbor, LM=Lower Monumental, LGO=Little Goose, LG=Lower Granite, HC=Hells Canyon, OX=Oxbow, BR=Brownlee).**

Nevertheless, the relatively few dams that John Day River summer steelhead need to pass is considered a major reason for the relatively healthy status of John Day populations. In comparison, smolts migrating from the Grande Ronde Basin have an estimated survival of 18% to 43% survival through all eight dams to the Pacific Ocean (Raymond 1979, 1988, Skalski 1998 in Li 2000). Li et al. (2000) compared spring chinook in the MFJD River and Wenaha River, a tributary in the Grande Ronde Basin. They found that while adult returns were higher in the John Day Basin, per capita productivity of juvenile spring chinook salmon was far greater in the Grande Ronde drainage than in John Day Basin. Furthermore, raw counts of juvenile salmon per kilometer was much higher in the Wenaha River than in the John Day Basin. They concluded that habitat conditions were much better in the Grande Ronde and that dam mortality is the major source of decline for the Grande Ronde stock. Alternatively, the relatively few dams that the John Day River smolts migrate past limits mortality related to dams, even though habitat conditions are generally much worse within the basin. These findings on the effect of dams collaborate the findings of a broad study that related stock status to a variety of anthropogenic variables. In a study of 202 watersheds in Washington, Oregon, California, and Idaho, Mrakovcich (1998) attempted to relate stock status to variables such as hatcheries, dams, and human population. She found that the strongest statistical relationship was with dams. The greater the number of dams downstream of watersheds where salmon spawn, the less healthy was the stock.

The Independent Scientific Group (1999) of the Northwest Power Planning Council reviewed regional salmon management actions of the Columbia River Basin Fish and Wildlife Program and concluded that the current program is unlikely to recover declining steelhead and salmon stocks. The Independent Scientific Group recommended major changes to move away from technological fixes and toward restoring normative river processes and functions, including mainstem passage conditions.

**Habitat**

Steelhead habitat in the Middle Fork John Day River has been highly degraded by over 150 years of resource exploitation, including activities such as widespread beaver trapping, mining, dredging, surface water withdrawals for agriculture, channelization and flood plain clearing for agriculture and pasture land, and timber harvest and road building (OWRD 1986, ODFW et al.

1990, and Busby et al. 1996). Extensive and varied habitat and watershed studies have been conducted to assess the problems, as summarized below.

- In a comprehensive assessment of the water resources of the John Day Basin, OWRD (1986) concluded that land uses were causing accentuated flooding in winter and subsequent erosion and sedimentation, as well as low flows in summer.

- NMFS listed the major problems for fish in the Middle Columbia ESU as high summer and low winter temperatures, and extensive riparian impacts (Busby et al. 1996).

- Two watershed analyses have been conducted in the MFJD watershed by the U.S. Forest Service. For the Galena Watershed, a subwatershed encompassing about 25% of the upper Middle Fork John Day, the U.S. Forest Service (USFS) (USFS 1999) documented high road densities, forest roads in floodplains of creeks, impacts of mine tailings and livestock grazing, and high stream temperatures. The loss of beaver and their dams were considered a major loss to hydrologic function and habitat.

- In the Upper Middle Fork John Day watershed analysis, it was noted that the Hudson Bay Trading Company completely trapped out beaver in the John Day Basin in the 1840s to discourage American fur trappers from colonizing the area (USFS 1998). Impacts were similar to those discussed for the Galena watershed. Major salmonid habitat limiting factors were considered to be a lack of pool habitat, excessive sedimentation, low flows, and elevated stream temperatures (USFS 1998).

- ODFW Aquatic Inventory Surveys provide quantitative data on instream and riparian habitat conditions, but only cover the upper mainstem and three tributaries (Bridge, Granite Boulder, and Big Creeks) (ODFW 2000C).

- Historic Physical and Biological Surveys conducted by ODFW were completed for the Middle Fork John Day River in the 1960s. Although these surveys do not have the same level of resolution as the Aquatic Inventory Surveys, they provide some valuable baseline data (T. Unterwegner, ODFW, personal communication).

- Several studies have been conducted to better understand the human-caused changes to MFJD River channel itself. The MFJD River is composed of two types of riparian habitat: wide valley floodplains that have mostly been converted to pastureland and narrow forested ravines (McDowell 2000). The most productive habitats for fish were the areas that have been altered the most—the wide floodplains that historically contained multiple channels and extensive shrub and tree riparian vegetation. These floodplains were cleared for pastureland and now consist of a single shallow channel in most locations, with few pools and little riparian cover (McDowell 2000, Grant 1993 and 1994, Welcher 1993).

- Extensive research has documented the significant impacts of cattle grazing on riparian habitats, channels, and water temperature (Tait et al. 1994, Maloney et al. 1999, and Li et al. 1994). Likewise, research has documented the rapid restoration of floodplains, riparian vegetation, wildlife species, and even stream flow following fencing of riparian zones in semi-arid inland watershed (Winegar 1977, CTUIR 1984).

- Using temperature as an indicator, Li et al. (2000) recently completed a broad-based assessment to characterize the status, integrity, and functioning of watersheds in the Oregon high desert. The MFJD river was one of their primary study streams. They found that fish assemblages could be clearly related to longitudinal temperature profiles. As stream temperatures increased in a downstream direction, coldwater salmonid communities were replaced by warmwater fish communities. Greater than 70% of the mainstem MFJD River reached temperatures higher than $25^{o}$ C, the incipient lethal temperature for salmonids. More than 20% of the mainstem was between $19^{o}$ C and $24^{o}$ C. A noticeable lack of salmonid use was found in areas where stream temperatures exceed $22^{o}$ C for more than six hours at a time (H. Li, OSU, personal communication). This study and a previous study by Torgerson et al. (1999) also document the patchy distribution of adult chinook within the longitudinal profile: chinook were able to persist in extreme temperatures by keying into deep, cooler pools that served as localized refugia. Juvenile steelhead have been documented to select seeps and other cold water refugia to survive otherwise extremely high water temperatures (J. Ebersole, OSU, personal communication). However, it is clear that the high water temperatures limit the distribution and potential production of steelhead and other salmonids in the basin. Warmwater species dominate the majority of the MFJD

River, and few salmonids have been observed in snorkel surveys downstream of Galena (H. Li, OSU, personal communication). However, stream temperature is only one problem resulting from impacts to channels, floodplains, and riparian areas.

> We conclude that the temperature signals indicate the value of riparian vegetation as a component for salmon habitat in the Blue Mountain ecoregion. The loss of riparian forests not only decreased stream shade, but diminished the capacity of the stream to restore itself. The effects of humans have reduced interactions of the stream with its floodplain. Streams have been channelized, rivetments gird the banks, and much of the exploited streams will not be able to adjust their gradient, sinuosity or structure without human intervention. Grazing has removed vegetation and compacted riparian soils. The combination of compaction and loss of organic mulch caused increased soil density, diminished soil porosity and subsequently reduced water infiltration. This increases runoff to the stream, decreases recharging of the floodplain aquifer, increases silt deposits on riffles and pools (thereby reducing hyporrheic interactions) and results in higher rates of bank erosion because of the absence of tensile strength provided by plant roots. Grazing on plants decreases root production by riparian plants. We also found that organic inputs to the stream from meadows can range from 1.6 to 3.8 times higher than from the riparian forest. Meadows are a common landscape feature in the Blue Mountain ecoregion, but the relative influence on stream productivity has not been well documented. As most meadows in the Blue Mountains are intensively grazed, their capacity to contribute to the salmon food chain has been greatly lowered (Li et al. 2000).

Riparian restoration appears to be the priority for habitat improvement in the MFJD River. In a review of restoration projects in the MFJD watershed, Beschta et al. (1991) recommended that the USFS place greater emphasis on protecting and restoring riparian ecosystems. The OWRD (1991) prepared a plan for a stream restoration program for the MFJD River based on their comprehensive assessment. The Confederated Tribes of the Umatilla Indian Reservation (1984) also prepared a restoration plan that identified 143.7 miles of stream in need of improvement in the MFJD watershed (fencing, large wood, rip rap). The Bureau of Land Management (BLM) has proposed a new plan for managing federally designated Wild and Scenic River sections of the John Day River, but has proposed only minor improvements to the current grazing system (BLM 2000).

Much riparian and floodplain restoration has occurred in the MFJD River in recent years. The Nature Conservancy purchased a 1,220-acre ranch in the floodplain of the MFJD River and has conducted much of the historical research necessary to plan restoration (Grant 1993, 1994, Welcher 1993). The Bonneville Power Administration (BPA) has spent 10 to 15 million dollars on habitat improvements in the John Day Basin since 1980 (E. Claire, personal communication). Annual reports of John Day River fish enhancement efforts funded by the BPA document an impressive amount of riparian fencing that has been completed (ODFW 1984-1998).

**Summary**

Limited spawning surveys indicate an overall steep decline of summer steelhead of the MFJD River since the late 1980s. NMFS concluded that the majority of stocks within the Middle Columbia ESU, including the John Day River, were declining (Busby et al. 1996). Steelhead within this ESU were listed as a federally threatened species in 1999. Since 1996, the MFJD River summer steelhead have continued to decline, probably due to a combination of highly degraded watershed conditions and high mortality of smolts during downstream migration through the dams. The initial assessment of healthy stocks by Huntington et al. (1996), which relied upon expert judgements of area biologists, appears to have been overly optimistic for John Day Basin stocks.

**Monitoring Recommendations**

*Life History*

Conduct detailed monitoring of juvenile steelhead migrations and habitat use in relation to habitat variables. Very little is known about steelhead use of various habitats at various stages in their life history (T. Unterwegner, ODFW, personal communication). This information is critical for obtaining a better understanding of habitat-limiting factors and for prioritizing and monitoring restoration actions.

*Stock Status*

Conduct random stratified spawning surveys, similar to ODFW's efforts for coastal coho, to develop accurate extrapolations of total escapement to the John Day River Basin and to the MFJD River and other rivers, based on the limited spawning surveys conducted. Currently, spawning counts are not considered accurate enough to use for overall escapement estimates (T. Unterwegner, ODFW, personal communication). Thus, there is no reliable way to determine whether the spawning escapement goals, established under existing fishery management plans for the John Day Basin, are actually being met (U.S. v. Oregon Technical Advisory Committee 1997, NWPPC 1996).

*Hatchery*

Determine the extent of hatchery straying within the MFJD watershed. High straying rates have been documented for the Deschutes River, and increasing straying rates for the John Day Basin may pose a major threat to the survival and genetic integrity of the wild populations.

*Harvest*

Investigate methods to improve the catch estimates for John Day fish harvested in mixed stock fisheries of the mainstem Columbia River.

*Hydropower*

Adopt a rigorous program of evaluation, monitoring, and research to test the conceptual foundation of salmonid restoration as recommended by the Independent Scientific Team (1999). Successful salmon restoration is not occurring in the Columbia River Basin partly because monitoring has been insufficient to identify problems and conduct adaptive management.

*Habitat*

Conduct surveys to understand the relationships between juvenile steelhead distribution and stream temperatures. This work has largely been focussed on adult chinook (Li et al. 2000), and could be expanded to include juvenile steelhead.

Conduct detailed monitoring of juvenile steelhead use in relation to restoration of riparian and floodplain habitat. Despite large amounts of funding devoted to riparian fencing, there is little research to document the results in terms of steelhead response.

Establish the John Day Basin as a salmon reserve, or refuge, with an increased emphasis on protection, restoration, and monitoring of wild steelhead and salmon and their habitat that would provide the basis for testing the normative river concept advocated by the Independent Scientific Team (1999).

## WINTER STEELHEAD OF THE SOL DUC RIVER, WASHINGTON

### Watershed Overview

The Sol Duc River supports perhaps the healthiest native winter steelhead population in Washington, according to Washington Department of Fish and Wildlife (WDFW) (B. Freymond, WDFW, personal communication). The river and its tributaries form one of the major river systems within the northwest corner of the Olympic Peninsula of Washington (Figure 13). Rainfall is generally more than 90 inches over the winter and several inches during the summer (USFS 1995). The Sol Duc River flows westward from the Olympic National Park and joins the Bogachiel River to form the Quillayute river close to the Pacific Ocean. The Quillayute Basin includes the Sol Duc and Bogachiel Rivers, as well as the Calawah, Sitkum,

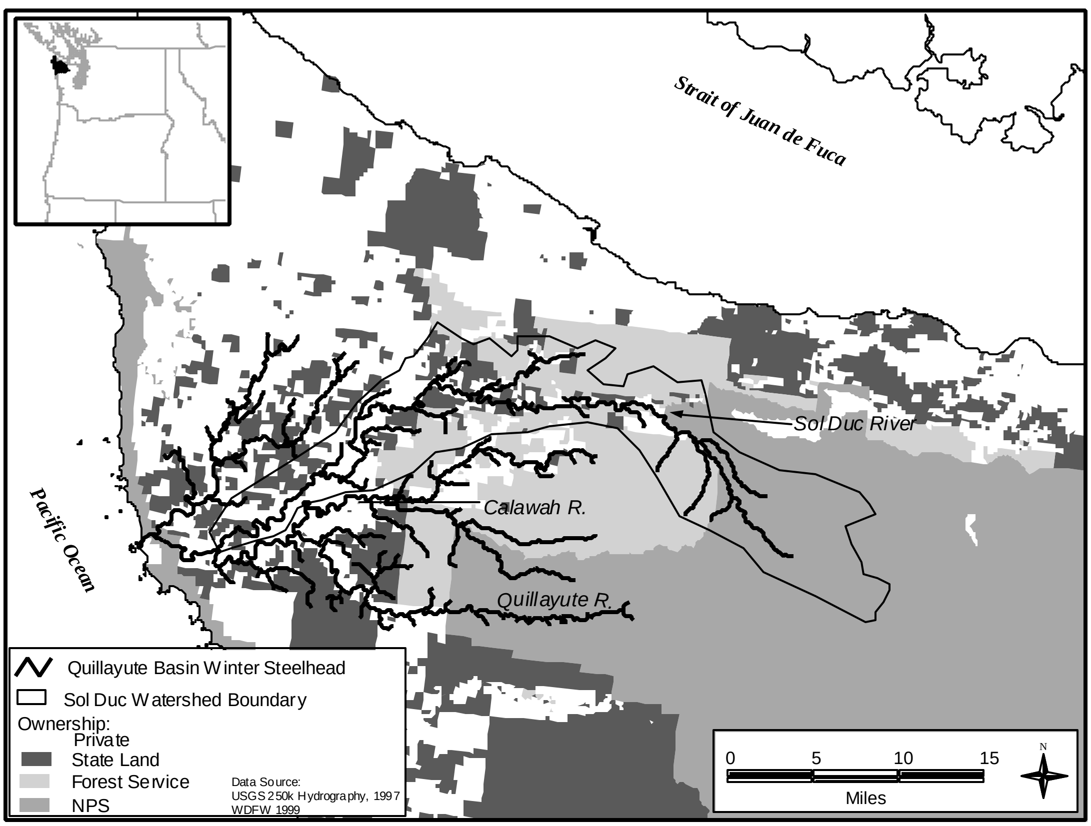



**Figure 13 – Winter Steelhead Distribution and Property Ownership within the Sol Duc River Watershed and Quillayute Basin of the Northwest Olympic Peninsula, Washington**

and Dickey Rivers. The Quileute Tribe has lived in the region for thousands of years and retains treaty reserved rights to fish, shellfish, and other natural resources within their U&A. Euro-American colonization of the area began in the mid to late 1800s, with the more accessible lowlands along the river railroad logged from the 1920s to 1940s. Logging road development increased dramatically in the 1950s (USFS 1995). While the higher elevations in the Sol Duc watershed is protected as National Park (31.9% of the watershed area), extensive timber harvest has occurred at lower elevations on Forest Service ownership (32.1%), State of Washington lands (13.4%), and large private industrial timberland holdings (22.5%) (USFS 1995). Rural residential development is scattered along the main river valley.

**Life History**

The Sol Duc winter steelhead is considered a distinct stock due to the geographic isolation of the spawning population in the Sol Duc River and tributaries, according to Washington's Salmon and Steelhead Stock Inventory (SASSI) (Washington Department of Fisheries et al. 1993). SASSI categorizes the stock as wild and maintained by natural production. The stock is part of the North Coast Genetic Diversity Unit established by WDFW. Genetic analysis of fish from this Genetic Diversity Unit formed two clusters. Cluster B fish, which include the Sol Duc River winter steelhead, have a high similarity to the Chambers Creek hatchery strain (Phelps et al. 1997). The Chambers Creek hatchery strain was planted in the Sol Duc on an irregular basis in the 1950s and 1960s and continue to be planted in other rivers of the Quillayute Basin (WDFW 2000a). The Sol Duc genetic analysis was based on a sample of 52 juvenile winter steelhead collected in 1994 from the Sol Duc River; a sample which may not adequately represent the wild population (B. Freymond, WDFW, personal communication). The Sol Duc winter steelhead stock is also included in the Olympic Peninsula ESU defined by NMFS (Busby et al. 1996). NMFS considers the Olympic Peninsula steelhead genetically distinct from other steelhead ESUs. Genetic differences were further supported by the zoogeographical, habitat, and climatic differences between the Olympic Peninsula and adjacent ESUs.

Sol Duc winter steelhead first enter the river in late November and are still entering freshwater in April and May (Cederholm et al. 1984). Recreational catch records indicate that the majority of the population is composed of late-spawners, entering the river from February through April.

However, as discussed below, this may be an artifact of the early portion of the wild run having been severely depressed by hatchery influence and the over-harvest that began in the 1950s (McLachlan 1994, Cederholm et al. 1984, WDFW Commission 1996). The English translation for the Quillayute term for the month of January is “the beginning of the spawning of steelhead salmon,” and February was the “regular or strong spawning time of salmon,” indicating that steelhead were prominent in the rivers at this time (Lane 1973 in McLachlan 1994). In the Clearwater River, a nearby drainage, steelhead were observed spawning in the tributaries as early as January and February, although the peak of the spawning activity, including spawning in the mainstem river, was observed in April and May (Cederholm 1984).

The natural genetic strain of the wild Sol Duc winter steelhead is unusually large, averaging ten to 12 pounds, with many in the 20- to 25-pound range (Cederholm et al. 1984). Research on Queets River wild steelhead supports the observation that native coastal stocks of the Olympic Peninsula are generally late maturing, with more than 35% of the spawning population having spent three years in saltwater (Noggle in prep., in Cederholm et al. 1984). By comparison, only 3.7% of the hatchery fish caught in seven Olympic coastal rivers were found to have spent more than two years in saltwater (Noggle in prep., in Cederholm et al. 1984). However, early maturation does not appear to be pronounced for hatchery fish of the Quillayute System in recent years, where three salt hatchery steelhead have averaged 21.8% of the total hatchery in the last 9 years (Freymond, WDFW, personal communication).

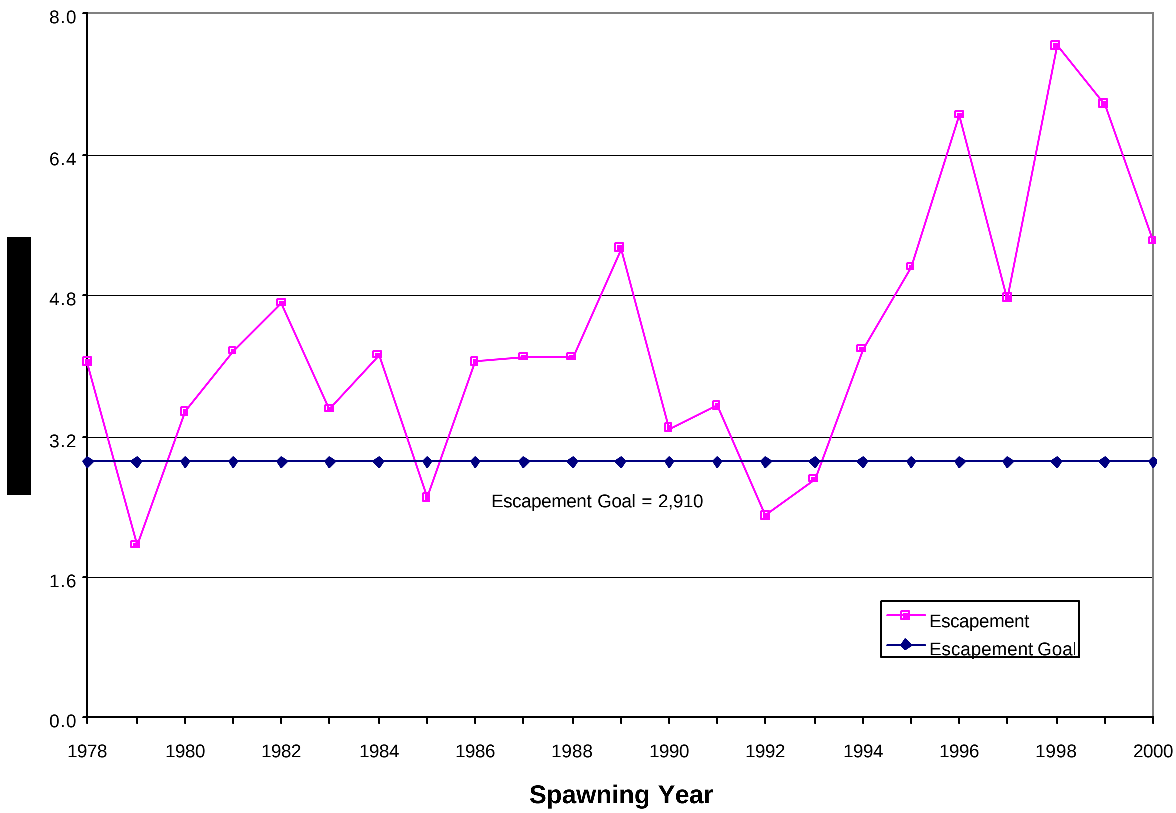
Sol Duc winter steelhead spawn in the mainstem and tributaries. Most species of salmon die after spawning, whereas steelhead may spawn more than once. Repeat spawners appear to be less than 10% of the typical spawning population of the Quillayute River (Busby et al. 1996). Eggs incubate in the gravels for several months, and fry emerge in the spring or summer to rear in freshwater. Information on juvenile life history in the Sol Duc watershed is limited (B. Freymond, WDFW, personal communication; Busby 1996). For the Quillayute River as a whole, most of the juveniles rear in freshwater for two years, with an estimated 10% of the juveniles rearing for three years before migrating to sea (Busby et al. 1996). Steelhead generally do not make use of estuaries for rearing (Aitkin 1998).

**Stock Status**

The Sol Duc River supports perhaps the healthiest wild steelhead stocks in Washington, in marked contrast to the general trend (B. Freymond, WDFW, personal communication). Abundance of steelhead stocks along the West Coast of North America was relatively stable between estimates made in 1972 and 1987; however, the proportion of the hatchery fish in the population increased (Light 1987). In the coastal Washington and Puget Sound region, an estimated 70% of the fish were hatchery fish by 1987 (Light 1987). Declining abundance of winter steelhead in the late 1980s was marked by a record low harvest of Washington coastal steelhead in 1991 (Cooper and Johnson 1992).

Previous stock assessments have consistently rated the Sol Duc winter steelhead stock as healthy (WDF et al. 1993, McHenry et al. 1996). Nehlsen et al. (1991) identified no stocks at risk on the entire Olympic Peninsula. In their 1996 status review under the federal Endangered Species Act, NMFS determined that population trends within the Olympic Peninsula ESU were generally upward, with some stocks declining (Busby et al. 1996). The trend in total escapement between 1978 and 1994 for the Sol Duc stock was considered to be generally stable (-0.1 annual change, with a standard error of 1.4). Since 1994, the spawning escapement has increased dramatically, far exceeding the escapement goal set by WDFW of 2,910 fish (Figure 14).

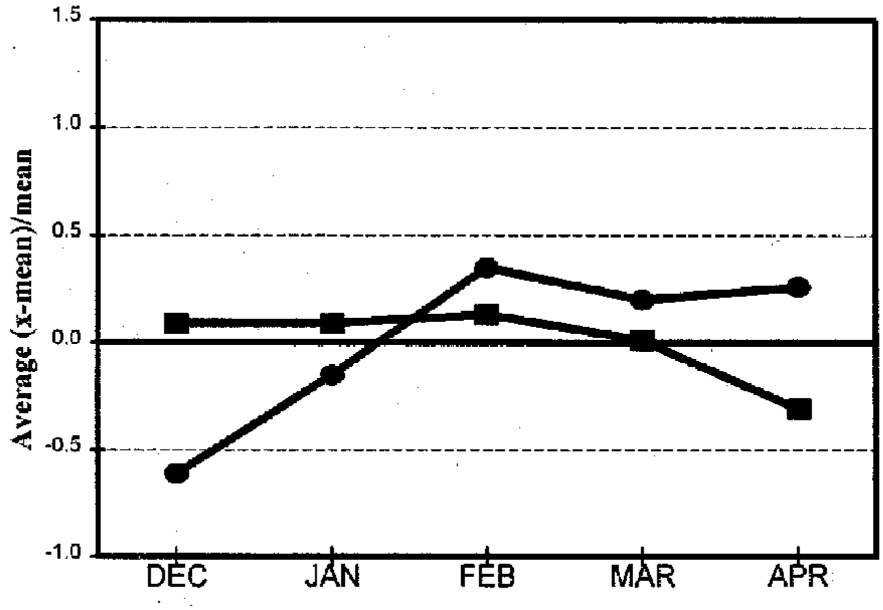
Escapement estimates for Sol Duc steelhead are based on extensive spawning surveys, with some of the most complete coverage in Washington (B. Freymond, WDFW, personal communication). Surveyors walk stream reaches, totaling 31 miles of the Sol Duc River and its tributaries, every seven to 14 days during the spawning season and count and mark redds. The mainstem Sol Duc River is surveyed from a helicopter six times per season. Most of the Sol Duc River spawning grounds are surveyed. The observed escapement is expanded to account for unsurveyed areas, which probably contribute less than 10% to the total escapement estimate (B. Freymond, WDFW, personal communication).




Source: WDFW 2000A

**Figure 14 – Wild steelhead spawner escapement for the Sol Duc stock from 1978 to 2000.**

The early timed portion of the Sol Duc spawning population (November-December-January) may be severely depressed. This early portion of the run may constitute a genetically distinct sub-stock (WDFW Commission 1996). An analysis of historical and recent harvest patterns showed a significant decline in the December sports harvest for the Sol Duc and Bogachiel/Quillayute portions of the watershed that appears to have started in the 1960s (Figure 15 ) (WDFW Commission 1996). In some of the limited data available, a marked hatchery return timing experiment found that 186 of 397 (47%) of the wild steelhead that returned from December through April of the 1954-1955 season returned in December and January (Royal 1972 in McLachlan 1994). The December and January component of the run historically appears to have provided over 30% of the total harvest of wild steelhead (WDFW Commission 1996). In recent years, this has been reduced to about 16% (WDFW Commission 1996).




Source: WDFW 1996

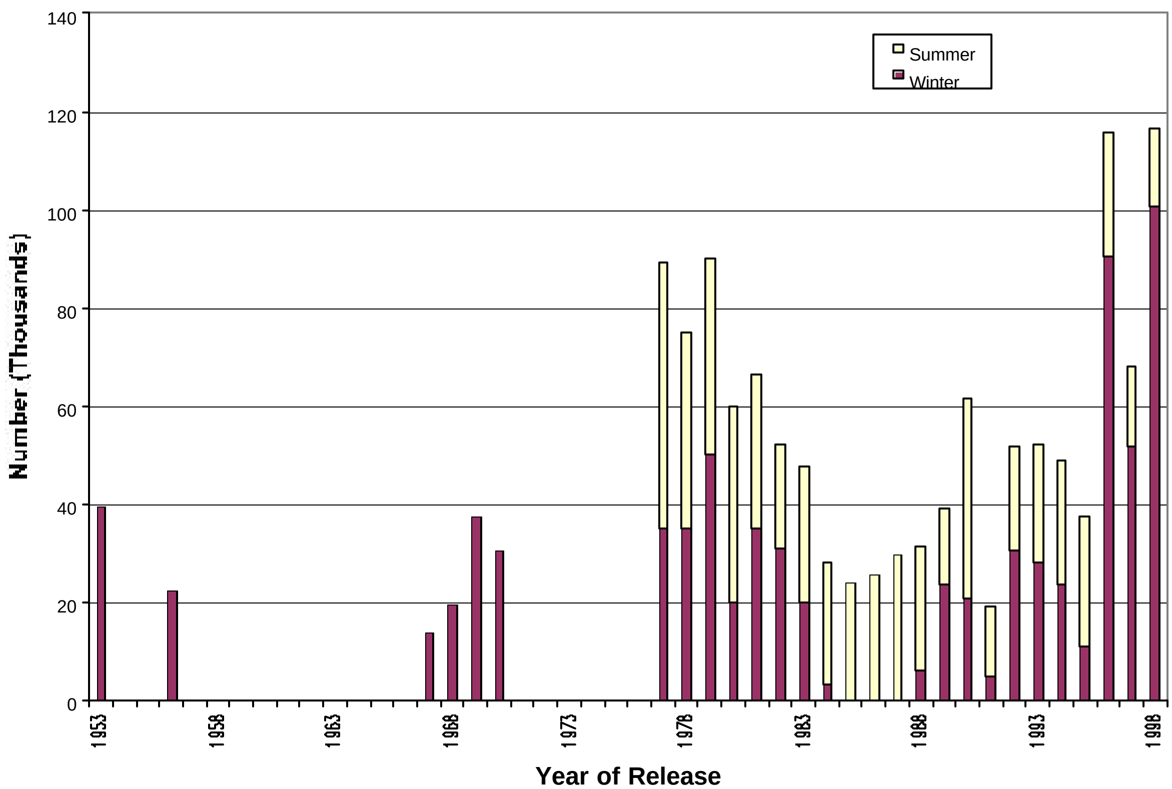
**Figure 15 – Average Deviation and Mean of Harvest per Day in the Sol Duc River. Line with squares is 1953-54 to 1960-61, line with circles is 1978-79 to 1994-95.**

### Hatchery

Hatchery influence on the Sol Duc winter steelhead stock began with early stocking of Chambers Creek hatchery fish in 1953, 1956, and between 1967 and 1970. The program was ended in 1970 because of pressure from local anglers on Washington Department of Game. The anglers were concerned with the declining sports catch of native stock, believed to have been caused by excessive sport and commercial fishing pressure on the early portion of the wild run when the Chambers Creek hatchery fish also returned (Cederholm et al. 1984). To boost the wild run, the Sol Duc Native Steelhead brood stock program was begun by local anglers in 1976, who then curtailed the brood stock collection in 1983. As Cederholm et al. (1984) wrote:

> As the years went by it became a feeling among the steelhead chapter members that the project was to have a beginning and an end point, to avoid creating a hatchery fish situation of our own, and to avoid promoting long-term excessive fishing pressure on the Sol Duc stock.

However, the program restarted in 1986 as the Snyder Creek project of the Olympic Peninsula Guides Association, and stocking levels in recent years were two to three times as large as the annual plantings of Chambers Creek fish in the 1950s and 1960s (Figure 16). Limited monitoring data indicate that Snyder Creek hatchery fish contributed only about 2% of the sport caught fish from 1994-95 and 1995-96 (WDFW 2000b). In addition to the Snyder Creek stocking in the Sol Duc River itself, a permanent rearing facility was developed in the 1950s on the Bogachiel River that has outplanted an increasing number of Chambers Creek stock, mainly in the Bogachiel and Calawah Rivers. Since 1990, a total of about 150,000 Chambers Creek stock hatchery smolts, and 40,000 Snyder Creek brood stock smolts were planted annually in the Quillayute Basin (WDFW 2000a).




Source: WDFW 2000A

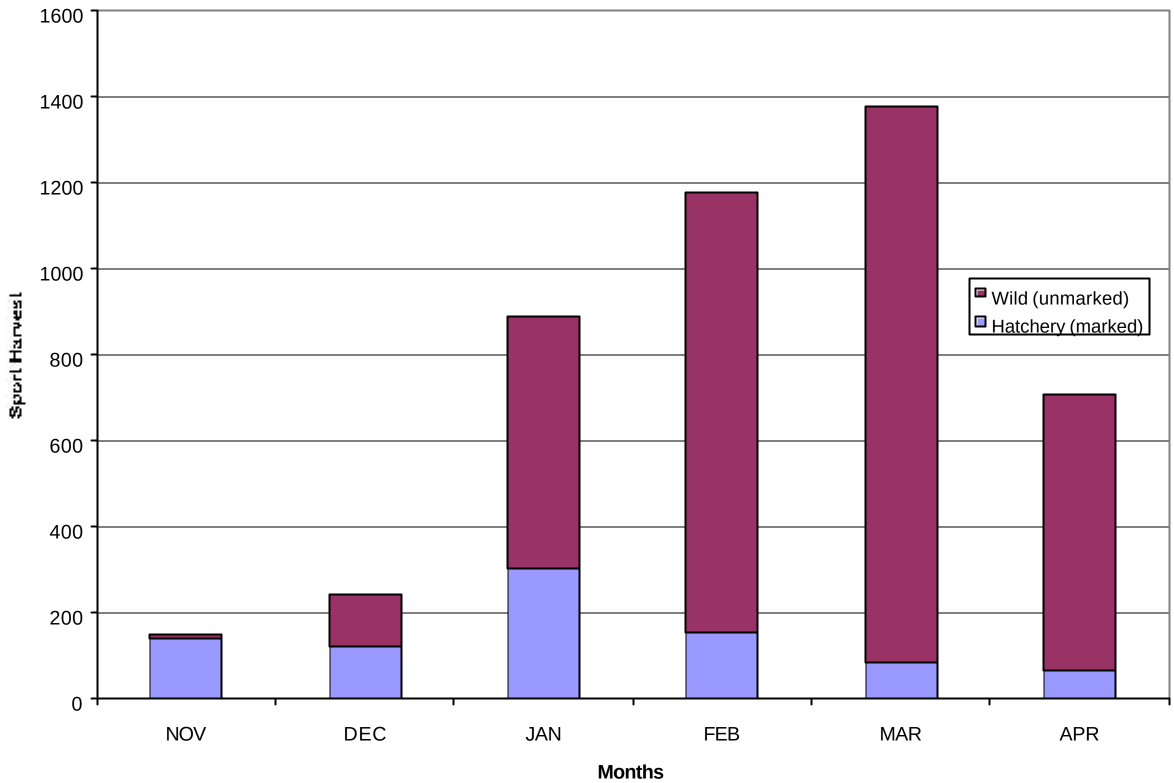
**Figure 16 – Number of Winter and Summer Steelhead Smolts Released into the Sol Duc River from 1953 to 1998.**

During the 1997-98 season, the Bogachiel River hatchery return crashed to the extent that the recreational fishery was closed to harvest (B. Freymond, WDFW, personal communication). A total of about 5,240 hatchery fish returned. During the same year, the wild winter steelhead return was strong, with over 12,352 wild fish, suggesting that the resilience of hatchery fish under fluctuating ocean conditions may be substantially lower than that of wild fish. Steelhead return rates for hatchery steelhead range between 0.015 and 0.14. No data are available on wild return rates.

Straying of hatchery fish can have major genetic impacts on wild fish (Quinn 1993, Waples and Teel 1990, W. Stewart Grant [editor] 1997, Lichatowich and McIntyre 1987), although potential impacts have not been well documented (Campton 1995). Low levels of gene flow can rapidly break down a wild population’s genetic structure. There appears to be no genetic justification for allowing gene flow as high as 5% hatchery strays in the population (Grant 1997). Impacts of hatchery strays pose a threat to wild steelhead in the Sol Duc River, where the early part of the run is mostly hatchery fish (Figure 17). Between 1994-95 and 1998-99 season, the average sports harvest of winter steelhead in November was nearly 100% hatchery fish, harvest in December was about 50% hatchery fish, and by January had dropped to about 30% hatchery fish. Because the Snyder Creek brood stock program was found to contribute less than 2% of the total sports catch in limited monitoring conducted during 1994-95 and 1995-96 seasons, most of these hatchery fish are probably hatchery strays from the Bogachiel facility. However, there hasn’t been an analysis of the Snyder Creek project’s contribution in recent years and it could be higher than in the past (B. Freymond, WDFW, personal communication).

### Harvest

Commercial and recreational harvest is negotiated between the Quileute Tribe and Washington State, based upon pre-agreed spawning escapement goals established in a long-term harvest management plan and annual harvest agreements (WDFW and Quileute Tribe 1998, 1999). The Tribe and WDFW agreed upon a Sol Duc River spawner escapement of 2,910, 49% of the total escapement goal of 5,900 for the Quillayute Basin system (Cooper 2000).

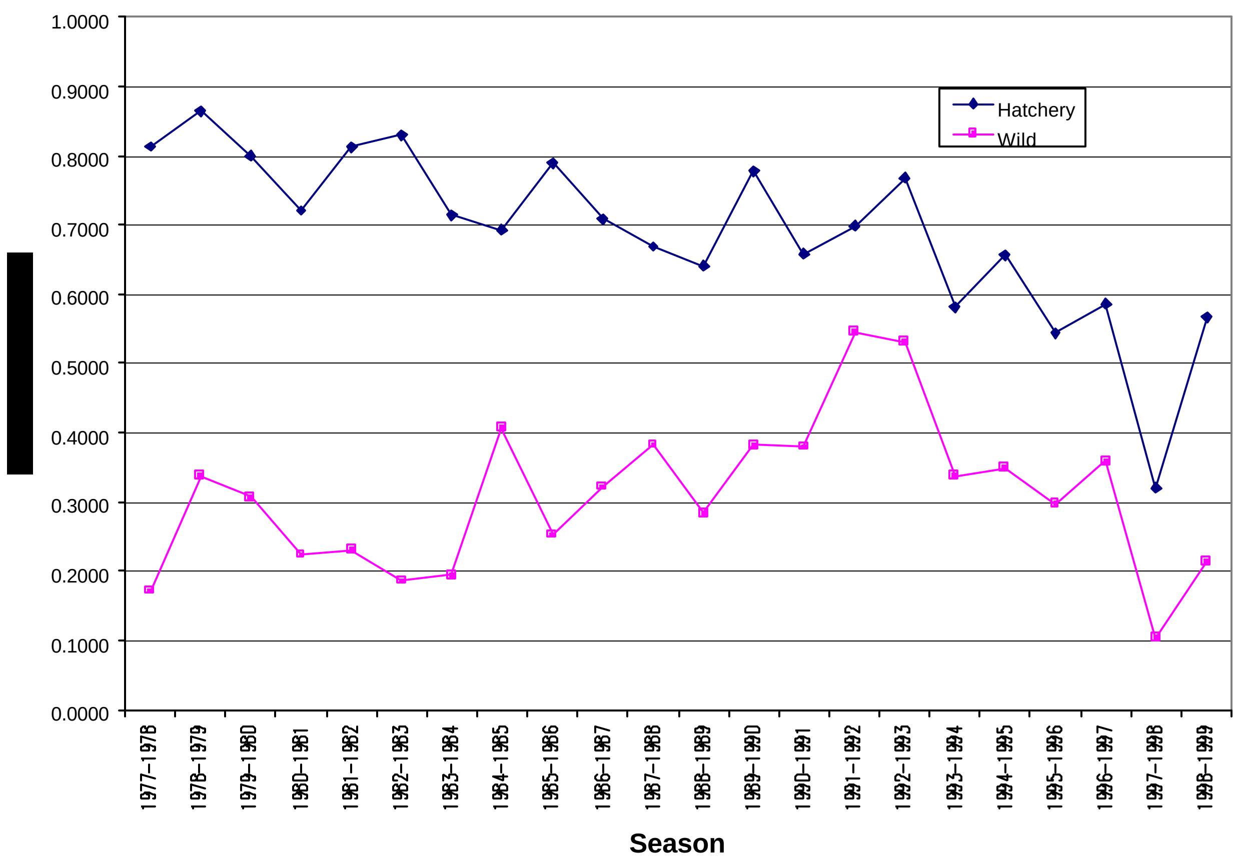



Source: WDFW 2000A

**Figure 17 – Comparison of Sport Harvest of Hatchery and Wild Winter Steelhead in the Sol Duc River by Month, for Combined 1994-95 through 1998-99 Seasons.**

Spawning escapements for watersheds of the Quillayute Basin were determined by estimating the potential steelhead that could be produced based on the river's surface. A portion of the total production is allocated to escapement based on the observed relationship between numbers of spawners and recruits produced and formulas for maximum sustained yield (Gibbons et al. 1985). This escapement estimate has been repeatedly called into question as extremely low by long-time anglers (Rose 2000). The method assumes that the parr densities actually surveyed to derive the escapement estimate for a river were the result of an escapement yielding maximum recruitment (Gibbons et al. 1985). It seems highly unlikely that parr densities during surveys of the Sol Duc River in the late 1970s were at "carrying capacity", especially considering the significantly larger escapements in recent years. In addition, parr densities surveyed in the Sol Duc were very low in relation to other rivers surveyed (Gibbons et al. 1985). Unfortunately, actual historical data on spawning escapements prior to the 1950s are not available (Busby et al. 1996) to help resolve the debate over sufficient spawning escapement levels upon which to base harvest management plans.

The total exploitation rate (recreational and tribal) for Sol Duc winter steelhead can only be approximated based on overall rates for the Quillayute River, since tribal and recreational fisheries harvest an unknown number of Sol Duc stock fish downstream of the Sol Duc River in the mainstem Quillayute. Between the 1978-79 season and the 1998-99 season, annual catch of Quillayute Basin wild fish fluctuated between 10 and 55% of the total wild fish returning to spawn that year (Figure 18). Hatchery fish had a much higher estimated exploitation rate, up to




Source: WDFW 2000A

**Figure 18 – Total Exploitation Rates for Quillayute River Hatchery and Wild Winter Steelhead.**

90% (Figure 18). Since the early 1990s, the exploitation rates have dropped substantially due to decreases in both sport and tribal harvest rate. The drop in sport catch may be partly due to recreational fishing regulations adopted in 1996 that allow harvest of one wild fish per day and a total of five for the season. The decreased catch is probably not due to fewer fishermen, as anglers and managers have observed dramatic increases in non-tribal fishing pressure on West End rivers in recent decades (Rose 1997).

The recreational fishing regulations for Sol Duc River winter steelhead have generated political controversy in recent years (McLachlan 1994, 1996; Rose 1997, 2000). In most rivers in Washington, wild steelhead must be released unharmed. Some guides and anglers were not pleased that WDFW allowed killing wild winter steelhead in the Sol Duc River, one of the few healthy populations of steelhead remaining in the Pacific Northwest. Anglers killed about 1,000 wild Sol Duc winter steelhead per year between 1953-54 and 1998-99 (WDFW 2000a). During the 1997-98 season, early hatchery and early wild returns were so poor that managers closed the Quillayute Basin to sports harvest early; only 77 fish were harvested that year in the Sol Duc River (B. Freymond, WDFW, personal communication). After political pressure from guides and anglers in 1996, the Washington Fish and Wildlife Commission passed new rules that restricted the catch on the Sol Duc River to one fish per day with a five fish annual limit. Only catch and release was allowed upstream of the salmon hatchery at River Mile 30. Controversy erupted a second time when WDFW proposed, in their 2000 rule package, to raise the limit to a harvest of two fish per day and 30 fish per season on the Quillayute system, based on the perceived healthy status of the winter steelhead stocks. After protest by guides and anglers concerned about over-harvest, the proposed rules were modified (Rose 2000). For the Sol Duc, the catch was increased beginning in the 1999-2000 season from five to ten fish per year, instead of 30 fish, and the one fish per day limit was not changed to two fish per day (WDFW 2000a).

In many of Washington’s coastal river systems, fishery managers have attempted to reduce the risk of hatchery-wild interbreeding by encouraging heavy (80% to 90%) harvest of early-spawning hatchery fish and allowing sizeable escapements of late-spawning wild steelhead (Huntington et al. 1996). In the Quillayute Basin, the State-Tribal annual fishery management agreements have generally focused tribal fishing effort on the early part of the run, with up to five days a week open to the gillnet fishery, as opposed to fewer days later in the season (WDFW and Quileute Tribe 1999).

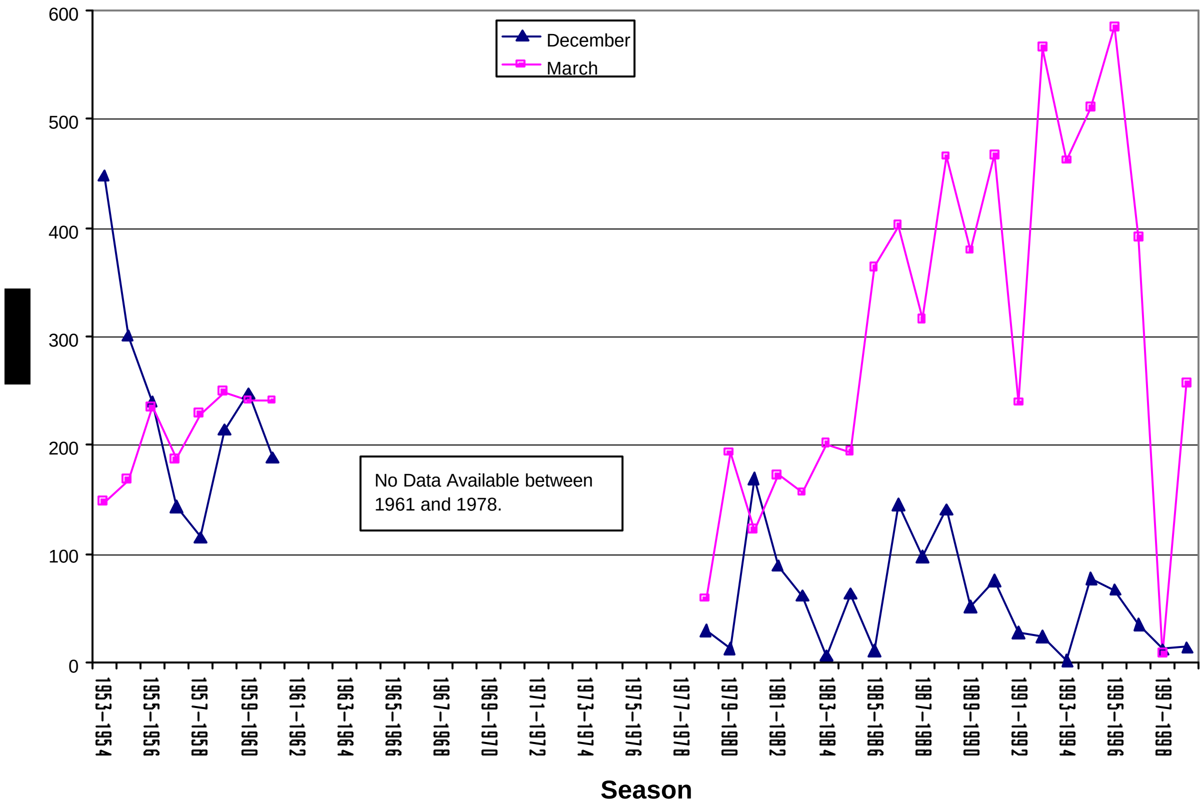
However, the inverse result of this management strategy was to potentially establish a mixed stock fishery situation of hatchery and wild fish, with excessive harvest rates on the early timed portion of the wild winter steelhead population (Cederholm et al. 1984). Such harvest can have profound effects on the genetic characteristics and health of the population as a whole:

> The differential harvesting of fish within a population is perhaps the area of fishery management in which genetic considerations are the most important, because the potential effects are the most pervasive. All populations of fish that are included in the sport and commercial fishery will inevitably be genetically changed by harvesting (Allendorf et al. 1987 in McLachlan 1994).

In the Sol Duc River, the initiation of stocking in the 1950s with Chambers Creek stock, which return early, may have increased overall fishing pressure at this time of year and resulted in excessive harvest on the early timed component of the wild run (Cederholm et al. 1984). Tribal and recreational harvest has continued to be high on the early portion of the wild run in the Sol Duc River. The harvest rate on early (December-January) hatchery and wild steelhead in the Sol Duc and Bogachiel/Quillayute portions of the Quillayute Basin averaged 67% during five seasons from 1990-91 to 1994-95. This is substantially higher than the 43% that occurred for the wild steelhead as a whole for the same time period (WDFW Commission 1996). Because these harvest patterns began in the 1960s and 1970s, WDFW Commission (1996) concluded that "recent management plans that focus higher harvest rates on the early-timed portion of the winter steelhead run are not responsible for the shift [in population abundance], though they may be preventing the rebuilding of the wild early-timed component." Figure 19 compares the trend in recreational catch of wild steelhead for the months of December and March, illustrating the decline in December catch of wild fish since the mid-1950s, even though fishing pressure is generally highest during this early part of the season.

**Hydropower**

No hydro-electric dams or other hydropower facilities were built in the Sol Duc River watershed.




Source: WDFW 2000A

**Figure 19 – Comparison of Trend in December and March Recreational Harvest of Wild Steelhead from 1953 to 1998 in the Sol Duc River.**

## Habitat

West-end rivers are generally in better condition than many watersheds on the Olympic Peninsula due to protection provided by Olympic National Park and the wetter climate (McHenry et al. 1996). Two watershed-level habitat assessments have been conducted for the Sol Duc River watershed. The U.S. Forest Service completed the *Sol Duc Pilot Watershed Analysis* in 1995 (USFS 1995). The Washington State Conservation Commission (WSCC) completed a habitat limiting factors analysis for Watershed Resource Inventory Area 20 (the Sol Duc and Hoh watersheds) (Smith 2000). In the WSCC report, the Sol Duc River watershed assessment is based largely on a review of data contained in the Forest Service report. The

Lower Elwha S'Klallam Tribe completed the *Status of Pacific Salmon and Their Habitats*, but this report does not detail the Sol Duc River (McHenry et al. 1996).

The following excerpt from the Executive Summary of the WSCC report (Smith 2000) provides a concise summary of the state of the knowledge regarding habitat limiting factors in the Sol Duc watershed:

> The Soleduck sub-basin lies partly within the Olympic National Park (upper reaches) and partly in timber-managed, agricultural and residential development. The contrast between the pristine habitat conditions within the Park is sharp compared to conditions further downstream. Outside of the Park boundaries, numerous major habitat problems exist. Excessive sedimentation is a problem and stems mostly from landslides. High road densities are associated with the sedimentation problems. High levels of fine sediments are found in many Soleduck tributaries which degrade the quality of spawning habitat. Areas of "poor" LWD and riparian conditions are other problems. The Soleduck drainage is naturally limited in wetland habitat, yet continued loss of wetlands and off-channel habitat occurs. Warm water temperatures are a problem in the summer, potentially impacting adult migration and spawning of summer chinook and a unique summer coho run. A large potential habitat problem is the over-allocation of water from the river. Contributing to summer low flows and warm water temperatures is the "poor" hydrologic maturity (loss of fog drip, change in hydrology) outside of the Park boundaries. Blockages are a known major problem within Gunderson and Tassel Creeks.

The degraded condition of the Quillayute River estuary was also mentioned as a major problem (Smith 2000). However, steelhead are not known to make extensive use of estuaries for rearing (Aitkin 1998), so the impact of estuarine loss on steelhead may be much less than for other salmonid species.

Harvest of steelhead in Washington reached a record low during the 1990-91 season, although the wild return to the Sol Duc remained fairly stable. The Washington Department of Fish and Wildlife began a study in 1991 to try to explain the factors responsible for the recent continued decline in steelhead abundance (Cooper and Johnson 1992). They found that such factors as freshwater and estuarine rearing conditions and incidental harvest in commercial fisheries did not explain the decline. A combination of factors were hypothesized to contribute to the coastwide decline, especially poor ocean conditions, competition for food with increased hatchery smolts released, and catch of steelhead in high seas drift nets (Cooper and Johnson 1992). More recently, the very low returns of the Quillayute 1997-98 hatchery steelhead, and the strong return of wild Sol Duc steelhead in the same year, similar to the 1990-91 season, suggest that the wild steelhead population may be more resilient in the face of such changing ocean conditions.

## Summary

The spawning returns of Sol Duc winter steelhead have far exceeded the escapement goal in most years since intensive monitoring began in the late 1970s. The population as a whole appears to be stable or increasing. However, the escapement goal, based on limited data and questionable assumptions, may be too low to provide an accurate gauge of true historic or potential production. Also, the early portion of the run (December-February) has been significantly depressed from historic levels, probably by continued mixed stock fishing pressure on wild and hatchery fish. Hatchery strays, probably originating from the hatchery facility downstream on the Bogachiel River, jeopardize the health of the wild steelhead run, particularly the early portion of the run. In recent years, hatchery fish comprised an average of 50% of the steelhead caught in the Sol Duc River in December. Due to the depressed status of the early portion of the run and questionable size of the current population in relation to historic abundance, the stock as a whole is not considered healthy (1996).

## Monitoring Recommendations

Some of the following monitoring actions have been recommended in previous reports, as citations indicate, but were not implemented. The monitoring actions are organized under the same headings as the proceeding section.

### *Life History*

Conduct research on juvenile life history. Very little information is available on juvenile use of freshwater and estuarine rearing habitats. A high priority is to conduct parr surveys during summer low flow in tributaries and the mainstem of the Sol Duc River to update the parr density data that was used to set the escapement goal (Gibbons et al. 1985). Obtaining this information is needed to evaluate the potential production of the habitat, appropriate spawning escapements, and the potential impacts of habitat alterations on steelhead production.

*Stock Status*

The present monitoring activities conducted by WDFW are providing good stock status information. No new monitoring is recommended.

*Hatchery*

Evaluate the hatchery straying rate into the Sol Duc River. Hatchery strays from the Bogachiel hatchery facility appear to be a threat to maintaining the genetic integrity of the early timed portion of the wild winter run.

Cease operation of the Snyder Creek brood stock facility. The facility does not seem to be making a significant contribution to the catch and is taking wild spawners off the spawning grounds with unknown genetic risks to the wild population. In terms of monitoring, the Snyder Creek releases are another variable that clouds an assessment of stock status.

*Harvest*

Evaluate the strategy of 100% wild production versus continued hatchery supplementation for long term sustainability and production of winter steelhead in the Quillayute River system. The major concerns in the Sol Duc River revolve around the impacts of hatchery production facilities in the Quillayute, in terms of mixed stock fishery in depressing the early timed portion of the wild run and potential genetic impacts from straying of hatchery fish. The Tribe and some sports fisherman rely on hatchery produced steelhead for a substantial portion of their catch. However, restoration of the early timed run to the Sol Duc River, and possibly other tributaries of the Quillayute, along with higher escapements in the basin, may provide more fish for harvest than currently provided with hatchery supplementation and at much lower risk to the survival of the wild populations.

*Hydropower*

No monitoring actions are recommended for hydropower, since no hydropower facilities were built in the Sol Duc watershed.

*Habitat*

Conduct comprehensive instream flow monitoring to assess existing flows, water rights, and impact of existing surface water diversions. Over-allocation of water is listed as a large potential habitat problem that needs further study (Smith 2000). Much more flow gauging is needed for both tributaries and the mainstem (Smith 2000).

Conduct a detailed sediment and road survey for the watershed to identify all sediment sources and evaluate the relation to instream habitat conditions. Increased sedimentation from landslides and surface erosion has been documented as perhaps the largest problem for fish production in the Sol Duc River (Smith 2000, USFS 1995). Detailed assessment of the road systems, slopes, and streambanks are needed to prioritize restoration actions.

Increase monitoring of riparian condition and evaluate the relation of riparian condition to other habitat parameters and winter steelhead survival. Poor riparian conditions in some areas were identified as a major problem for aquatic habitats in the Sol Duc (Smith 2000, USFS 1995). Poor riparian conditions are the probable cause for the documented poor condition of other habitat parameters, such as elevated summer stream temperatures, low levels of large woody debris and pool habitat, and excessive stream bank erosion. Detailed mapping or riparian habitats is needed, as is intensive research aimed at documenting the complex relationships between riparian condition, other habitat parameters, and steelhead survival and production in their freshwater rearing habitats.

Conduct a comprehensive fish passage barrier survey in the Sol Duc watershed. Tributary and off-channel habitat are naturally limited in the watershed (Smith 2000). Significant fish passage barriers have been identified. A comprehensive assessment is needed to identify all barriers and prioritize them for restoration based on upstream habitat gain.

# CONCLUSIONS AND RECOMMENDATIONS

Three salmon stocks were chosen for case studies in Oregon and Washington that were identified as “healthy” in a coast-wide assessment of stock status (Huntington et al. 1996). The purpose of the study was to assess current stock status and impacts on the species based on the best available information. Recommendations for monitoring were developed to address priority data gaps and most pressing threats to the species. Each stock is a member of a larger basin-wide and regional grouping of stocks that were identified as healthy and, thus, the findings of this study may have broader implications.

The three stocks are diverse in terms of their life histories, geographic range, and ecological habitat requirements. They probably share the good fortune of being “less sick” than many other salmon stocks in the Pacific Northwest. However, the “healthy” rating was probably not warranted for any of these stocks. Wilson River fall chinook and MFJD River summer steelhead have been declining since the late 1980s and appear to have reached very low levels in recent years. The early timed portion of Sol Duc River winter steelhead run remains significantly depressed from historic levels. Other stocks in the John Day Basin, Tillamook Basin, and Olympic Coast region were also listed as healthy by Huntington et al. (1996). A cursory inspection of recent data indicates similar patterns of decline in these other stocks. These case studies of small subset of stocks indicates that the count of 99 healthy stocks listed by Huntington et al. (1996) may greatly over-estimate the number of healthy stocks.

The three stocks are threatened by an array of potential hatchery, harvest, hydropower, and habitat impacts (Table 1). The relationships between impacts and fish survival are generally poorly understood. However, the potential impacts do appear to vary in intensity depending on the stock. For example, dams are considered to be a high impact on the MFJD River summer steelhead, but not on the other two stocks. The overall level of human impact was considered to be moderate for Sol Duc winter steelhead and high for Wilson River fall chinook and MFJD River summer steelhead.

The available data needed to accurately assess and manage the stocks is relatively poor in many cases. The quality of existing monitoring data, as estimated by the author, is summarized in

Table 2. In general, managers appear to be operating with only 44 to 61% of the basic information needed. ODFW has very little of the watershed and stock specific data needed to assess or manage the Wilson River fall chinook and MFJD River summer steelhead stocks. For the Sol Duc River winter steelhead, extensive assessment and monitoring data has been collected. However, pertinent data is still missing that is needed to address management concerns, such as data on parr densities that could be used to revise escapement goals. The limited data available adds significant uncertainty and risk in managing these wild salmon and steelhead stocks. The data gaps considered of highest priority for monitoring are highlighted in Table 2.

Monitoring, research and evaluation are proposed to get an accurate assessment of stock status on a watershed level and a better understanding of the level of threats to long term survival of the stocks. These monitoring recommendations are summarized in Table 3. The monitoring recommendations in this report should be incorporated into a Natural Production Accounting System (B. Bakke, Native Fish Society, personal communication). The accounting system would ensure that a standard set of the most pertinent information is collected on each stock and watershed. This information could be compiled and summarized for use and distribution in Streamnet.

The following provides a summary of the broad commonalities between stocks and reasons for relative health of these populations, as well as threats, data gaps, and priority monitoring recommendations.

- The watersheds are all relatively large and historically have maintained large populations. Smaller populations are more vulnerable to extinction. The populations themselves are relatively poorly understood. Better information is needed on population sizes of spawners and juveniles and their use of habitats at various stages in their life histories.

- Major dams do not occur in any of the watersheds. John Day Basin is one of the largest watersheds in the Columbia Basin without a dam, but it is upstream of three hydropower dams on the Columbia that cause an impact (although not as severe as for fish populations in watersheds located further upstream on the Columbia).

- Hatchery stocking does not occur in these watersheds on a regular basis. The Snyder Creek brood stock program on the Sol Duc is an exception, but appears to make a very low contribution to escapement. Hatchery straying into all three watersheds from high levels of stocking in the larger basins is a concern and needs monitoring.

- Ocean, tribal and recreational harvest levels appear to be relatively low for all stocks. Monitoring of harvest needs to be increased in some cases.

- Habitat conditions vary greatly among watersheds. The MFJD River is in the poorest condition with clear loss of rearing habitat; the Wilson River has serious sediment and riparian problems, but may be in recovery since the 1950s following fires and salvage logging. The headwaters of the Sol Duc River are partly in Olympic National Park and provide an unusual degree of watershed protection, but the remainder of the watershed has been heavily logged with sedimentation and riparian impacts. Although major habitat problems have been documented, the relation to fish survival is poorly understood. Habitat limiting factors should be identified, as well as field studies to identify specific restoration priorities. Intensive restoration actions are underway, especially in the John Day Basin. Restoration actions need to be more carefully monitored to evaluate their effect on fish populations.

- Nutrient deficiency in watersheds due to the decline in salmon carcasses and fluctuations in climate and ocean productivity were not addressed in this study, although they probably had dramatic effects on survival for all three stocks (Gresh et al. 2000, Cederholm et al. 1999, Bilby et al. 1998, Lawson 1993).

This report only evaluated single stocks. While a focus on single stocks has advantages, a multi-species, ecosystems approach is also useful. Single species management, using escapement goals set by theories of spawner-recruit relationships and Maximum Sustained Harvest has been the prevalent method of fishery management for decades (Gibbons et al. 1985). Scientists and fishery managers are only recently beginning to recognize the necessity of managing for ecosystem-based escapement goals. These goals take into account the role of anadromous fish as keystone species in the ecosystem (Willson and Halupka 1995), particularly the importance of carcasses as a source of food and nutrients to juvenile salmon production and enrichment of aquatic and terrestrial food chains (Gresh et al. 2000, Cederholm et al. 1999, Bilby et al. 1998). As our understanding of salmon ecology has shifted, so must our management goals and monitoring methods used to evaluate those goals also change.

This report indicates that healthy stocks are not healthy, they are just less sick than some others and are threatened by a variety of anthropogenic influences. Yet, these relatively healthy populations represent perhaps our best opportunity to protect and restore salmon strongholds in the region. To do so, good monitoring data is urgently needed to track stock status and threats. Monitoring efforts may be difficult and expensive, but they are imperative (Botkin et al. 2000):

> A vast sum of money has already been spent in the Pacific Northwest with the intent of benefiting salmon, with little or no confirmation of success – or failure. Without effective validation monitoring program in place, the actual response of salmon populations to conservation strategies will remain largely unknown, and the validity of theorized relationships between habitat and salmon populations will be untested. Decision makers and the general public are increasingly concerned that government and natural resource managers are effectively using public funds to truly improve the condition of salmon populations. Validation monitoring provides the accountability that is necessary for a viable, long-term salmon conservation effort in the Pacific Northwest.

**Table 1 – Summary of Stock Status and Estimated Impacts from On-going Hatchery, Harvest, Hydropower, and Habitat Modification.**

| | **Wilson River Fall Chinook** | **Middle Fork John Day River Summer Steelhead** | **Sol Duc River Winter Steelhead** |
|---|---|---|---|
| **Stock Status** | **At risk**- rapid recent declines | **At risk** - rapid recent declines | **At risk** - early portion of run severely depressed |
| **Hatchery** | **Moderate impact**- occasional stocking in river, and high stocking in Tillamook Basin | **Moderate impact**-some straying from high stocking in Columbia River Basins | **Moderate impact** - high level of straying in early portion of run, from stocking in Quillayute Basin |
| **Harvest** | **Moderate impact**- ocean catch low but recreational catch increasing | **Low impact** - low ocean and recreational catch | **Moderate impact** - low catch overall, high catch on early timed wild run |
| **Hydropower** | **No impact** | **High impact** - estimated 51-73% survival through three downstream dams | **No impact** |
| **Habitat** | **Moderate impact** - landslides, riparian condition, water temperature identified as problems | **High impact** - about 70% of the mainstem habitat lost due to elevated summer temperatures, also major losses of channel sinuosity, flood plain and riparian condition, sedimentation problems | **Moderate impact** - Olympic NP protects headwaters, but remainder heavily logged with landslides, culvert barriers and poor riparian condition identified as problems |
| **TOTAL IMPACT LEVEL** | HIGH | HIGH | MODERATE |

**Table 2 –Quality of Available Data (0-4) and Highest Priorities for Additional Monitoring (shaded). Ranking is Based on the Judgement of the Author.**

**4 = excellent, 3 = good, 2 = fair, 1 = poor, 0 = very poor or no data.**
**High priority areas identified for further monitoring are shaded.**

| Pertinent Data Needs for Stock Assessment | Wilson Chinook | MFJD Steelhead | Sol Duc Steelhead |
|---|---|---|---|
| **Life History Data** | | | |
| **Spawner habitat use** | 1 | 2 | 2 |
| **Juvenile habitat use** | 2 | 1 | 0 |
| **Status Data** | | | |
| **Spawning escapement trends** | 1 | 3 | 4 |
| **Spawner abundance** | 1 | 1 | 3 |
| **Hatchery Data** | | | |
| **Hatchery fish straying rate** | 2 | 0 | 3 |
| **Stocking history** | 4 | 4 | 4 |
| **Harvest Data** | | | |
| **Accurate escapement goal set** | 1 | 1 | 2 |
| **Exploitation rate data** | | | |
| **In-river/bay sports fishery** | 2 | 3 | 4 |
| **In-river tribal fisheries** | 4* | 1 | 3 |
| **Ocean fisheries** | 3 | 3 | 3 |
| **Habitat Data** | | | |
| **Watershed assessment** | 1 | 3 | 4 |
| **Habitat trends** | 2 | 3 | 2 |
| **Major problems identified** | 3 | 4 | 3 |
| **Limiting factors identified** | 1 | 3 | 1 |
| **Potential smolt production** | 0 | 0 | 1 |
| **Current smolt production** | 0 | 0 | 0 |
| **TOTALS** | 28 | 32 | 39 |
| **Percent of Maximum Score** | 44% | 50% | 61% |
| **Risk and Uncertainty Rating** | High | High | Moderate |

* Note: no in-river tribal fisheries in the Wilson River or Tillamook Basin

## Table 3 – Summary of Recommended Monitoring Actions

| Monitoring Topics | Wilson River Fall Chinook | MFJD River Summer Steelhead | Sol Duc River Winter Steelhead |
|---|---|---|---|
| **Life History** | Identify primary spawning areas. | Monitor habitat use by juveniles. | Monitor habitat use by juveniles. |
| **Stock Status** | Expand spawn surveys for abundance estimate. | Expand spawn surveys for abundance estimate. | n/a |
| **Hatchery** | Discontinue irregular stocking in watershed. | Monitor for hatchery strays. | Study hatchery/wild interactions; cease Snyder Creek stocking program. |
| **Harvest** | Increase monitoring of sport and commercial harvests. | Monitor percent harvested in mixed stock Columbia River fishery. | Evaluate harvest potential of wild fish only management for Quillayute Basin. |
| **Hydropower** | n/a | Improve monitoring of Columbia River restoration efforts. | n/a |
| **Habitat** | Expand ODFW habitat survey to mainstem; identify sediment sources; identify habitat limiting factors; establish salmon reserve. | Identify habitat limiting factors; improve monitoring of restoration efforts; establish salmon reserve; monitor instream flows and withdrawals. | Monitor instream flows; identify sediment sources; identify habitat limiting factors; survey fish passage barriers. |

# ACKNOWLEDGMENTS

This report was made possible by the generous assistance of many individuals. Thanks goes to the professionals who contributed their knowledge and data toward a better understanding of these three salmon stocks: Jay Nicholas, Keith Braun, Mark Lewis, Michelle Long, Ron Williams, Steve Jacobs, Tim Unterwegner, Mark Chilcote, Kim Jones, and Tom Nickelson of the Oregon Department of Fish and Wildlife; Shawn Robertson, Confederated Tribes of the Warm Springs Indian Reservation; Don Reynolds, consultant for the Tillamook County Performance Partnership; Dr. Hiram Li, Christian Torgersen, and Joseph Ebersole of Oregon State University; Robert Stubblefield , John Day River Watershed Council; Errol Claire, consulting fish biologist and retired ODFW fish biologist in John Day; Chuck Huntington, Clearwater Biostudies; Mary Lou Wilby, Malheur National Forest; Doug Rose, free-lance fisheries writer; John Meyer, Olympic National Park; Mike McHenry, Lower Elwha S'Klallam Tribe; Bill Freymond and Randy Cooper, Washington Department of Fish and Wildlife; and Jeff Cederholm, Washington State Department of Natural Resources.

The author greatly appreciates the assistance of Kathy Hemphill, librarian; Sharon Johnson, administrative assistant; Aaron Turecek, GIS analyst; Leslie Anderson, technical editor/cartographer; Ryan LeProwse, data analyst; and Kevin O'Hara, senior ecologist and technical reviewer; all at David Evans and Associates, Inc.

Generous review of the draft manuscript was provided by Bill Bakke, Native Fish Society; Jim Lichatowich, Alder Fork Consulting; Chuck Huntington, Clearwater Biostudies; Jay Nicholas and Tim Unterwegner, Oregon Department of Fish and Wildlife; and Bill Freymond, Washington Department of Fish and Wildlife. Errors and deficiencies in the report are, of course, the sole responsibility of the author.

Funding for this project was provided by the Native Fish Society and the U.S. Environmental Protection Agency.

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