# A BIOLOGICAL NEEDS ASSESSMENT FOR ANADROMOUS FISH IN THE SHASTA RIVER SISKIYOU COUNTY, CALIFORNIA

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## I. BACKGROUND

### Physical Setting

The Shasta River originates within the higher elevations of the Eddy Mountains lying southwest of the town of Weed in Siskiyou County, California. It flows for approximately 50 miles in a northerly direction, passing through the Shasta Valley. After leaving the valley, it enters a steep-sided canyon where it flows for a distance of 7 river miles before emptying into the Klamath River 176.6 river miles (RM) upstream from the Pacific Ocean (Figure 1).

Numerous springs and a number of small tributary streams enter the Shasta River as it passes through the Shasta Valley. Major tributaries include Parks Creek, Big Springs Creek, Little Shasta River, and Yreka Creek. Water diversions for agricultural and stock water needs exist on these and several other smaller tributary streams, reducing or eliminating their flow contribution to the Shasta River, particularly during the main irrigation season which runs April 1 to October 1. The Shasta River was dammed at RM 37 to form Dwinnell Reservoir (Lake Shastina) in 1928.

The Shasta River subbasin consists of approximately 507,000 acres. About 28 percent of this acreage (141,000 acres) is irrigable and exists primarily below Dwinnell Dam (DWR, 1964). The climate of the Shasta Valley is characterized by warm, dry summers and cool wet winters. Precipitation averages 12 to 18 inches annually with 75 to 80 percent of it occurring between October and March. The length of the average growing season is about 180 days (DWR, 1964).

### Water Development

Water development within the Shasta subbasin began in earnest with the arrival of the gold miners in the late 1800s. After the gold rush, agricultural development resulted in additional and more extensive use of water from the Shasta River. Dwinnell Dam was constructed in 1928 to capture winter and early spring run-off. Originally, the dam measured 1,265 feet in length, was 98 feet high and had an effective storage capacity of approximately 34,000 acre feet. In 1955, the height of the dam was raised which increased the total storage capacity to **50,000** acre-feet. When full, the reservoir has an average depth of 22 feet with a-maximum depth of 65 feet and a surface area of 1,824 acres (2.85 $mi^2$). Wales (1951) estimated that construction of Dwinnell dam eliminated access to about 22 percent of **the** total spawning habitat formerly available to salmon and steelhead and approximately 17 percent of the drainage area.

Seven major diversion dams and several smaller dams or weirs exist on the Shasta River below Dwinnell Dam. Numerous diversions and' associated dams exist on other major tributaries as well, including

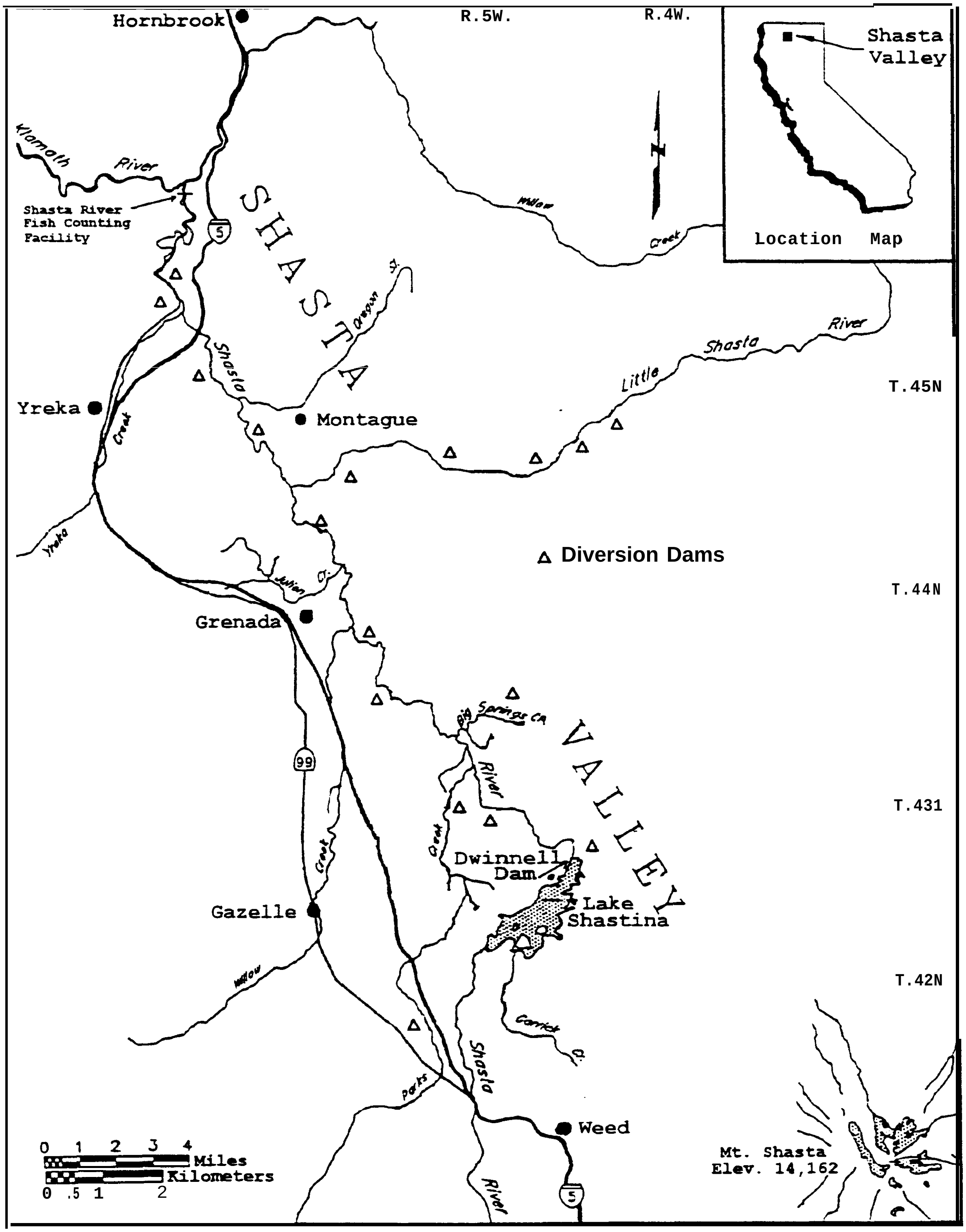



Figure 1. Shasta Valley showing location of major water diversion structures and the Shasta River Fish Counting Facility.

Big Springs Creek, Little Shasta River and Parks Creek (Figure 1). When all diversions are operating, flows are substantially reduced and in the case of the Little Shasta River, stream flows cease entirely in the lower several miles of stream during the summer and fall period.

Prior to the construction of Dwinnell Dam, four water service agencies had been formed in the Shasta Valley. The Shasta River Water Association (SRWA) was formed in 1912 and obtained a 1932 water appropriation notice that same year for 42 cubic feet per second (cfs) for the period April 1 through October 1 each year. The SRWA serves the west side of the Shasta Valley near the town of Montague. The Grenada Irrigation District (GID) (formerly known as the Lucerne Water District) was formed in 1921 and has a right to 40 cfs for the period April 1 through October 1. Prior downstream water rights have limited the ability of GID to take its full entitlement in some years. The GID serves about 1,800 acres located west of the town of Grenada. The Big Springs Irrigation District (BSID), formed in 1927, has a 30 cfs right for water from Big Springs lake and serves about 3,600 acres north of the lake. Since the late 1980s, BSID has used ground water in lieu of water diverted from Big Springs Lake.

The Montague Water Conservation District (MWCD), also known as the Montague Irrigation District, was formed in 1925. As a result of a 1932 adjudication, MWCD obtained appropriative rights for winter storage of the Shasta River and Parks Creek in Lake Shastina to meet irrigation needs in the Little Shasta Valley and the northeast portion of the Shasta Valley during the April 1 through October 1 irrigation season. Except during above normal water years, when Lake Shastina is full, the only flow release made to the Shasta River below the dam are those intended to satisfy the needs of several small users immediately downstream of the dam.

Since 1934, available water resources in the Shasta River have been apportioned by the California Department of Water Resources (DWR) Watermaster Service in accordance to a 1932 statutory adjudication (Decree No. 7035). However, riparian water users along the Shasta River below Dwinnell Dam were not included in this adjudication and are not regulated by the watermaster.

## II. SALMON AND STEELHEAD IN THE SHASTA RIVER

The Klamath River system ranks first in California in the number of coho salmon *(Oncorhynchus kisutch)* and steelhead (0. *mykiss)* produced and second after the Sacramento River system in the number of chinook salmon (0. *tschawytscha)* produced annually (Leidy & Leidjj, 1984). Historically, spring-run chinook salmon comprised the major portion of the chinook salmon run entering the Klamath until habitat destruction led to near extirpation of that race during the early part of this century (Snyder 1931). Fall chinook salmon have since predominated in the Klamath River basin and is the only chinook race believed to currently exist in the Shasta River basin. Coho salmon and fall and winter-run steelhead still occur in the Shasta River although little is known regarding their present abundance.

### Chinook Salmon

The California Department of Fish and Game (DFG) has monitored the Shasta River fall chinook salmon runs since 1930. The Shasta River Fish Counting Facility (SRFCF) was originally installed and operated near the mouth (at approximately 0.5 RM). Between 1938 and 1957, the SRFCF was moved 6.5 miles upstream from the Klamath River to an existing steelhead egg taking station. Since considerable Salmonid spawning is known to occur in the lower 6.5 river miles, actual spawner escapement was probably higher during this period than reported. Starting in 1958, the weir was moved back to its original, and current location.

Chinook salmon counts have ranged from nearly 82,000 fish in 1931 to just 533 (415 adults) in 1990 (Table 1). Between 1960 and 1992, the overall decline in returns of chinook to the Shasta River continued (Figure 3). However, during the years 1993 and 1995, the returns of fall chinook salmon increased coincident with the cessation of drought conditions and a total ban on ocean commercial harvest within the Klamath Management Zone. Ocean and in-river sport harvest as well as tribal net harvest allocations were also severely restricted between 1990 and 1995.

In 1995, over 13,500 fall chinook salmon returned to the Shasta River. Of this number, an estimated 5.8 percent (791 salmon) were Iron Gate Hatchery (IGH) strays (based on coded-wire tag expansions and observed hatchery marks). Although the 1995 run was considerably larger than the runs observed during the early 1990's and was 1.5 times larger than the previous 35-year average, it was only about a third of 1963 and 1964 run totals (Figure 3). The preliminary fall chinook salmon run size estimate for the 1996 season is 1,450; less than 11 percent of the previous years run.

### Coho and Steelhead

Information for coho salmon and steelhead observed at the SRFCF has been reported since 1932. In all but a few cases, the numbers reported do not represent the entire run since field activities were normally terminated before complete counts could be made. Available information for coho salmon and steelhead as well as the length of the trapping season is presented in Table 1. Coho salmon and steelhead observed at SRFCF since 1957 are shown in Figures 4 and 5.

### Spawning Locations

Chinook salmon spawning takes place in the Shasta River between the Klamath River confluence and Yreka-Ager Road (RM 10.5). Spawning also occurs in a reach extending from about one miie below the Big

Table 1. Shasta River Fish Counts, 1930 to 1996[1]

| Year | Dates of operation | Chinook Salmon Adult | Chinook Salmon Grilse | Chinook Salmon Total | Coho Salmon Adult | Coho Salmon Grilse | Coho Salmon Total | Steelhead ½ lb | Steelhead Adult | Steelhead Total | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1930 | 8-30 to 12-13 | 7,280 | 12,082 | 19,362 | N/D[2] | N/D | N/D | N/D | N/D | N/D | Weir located at mouth |
| 1931 | 8-30 to 12-13 | 61,811 | 20,037 | 81,848 | N/D | N/D | N/D | N/D | N/D | N/D | |
| 1932 | 8-30 to 12-13 | 30,534 | 5,058 | 35,592 | N/D | N/D | N/D | N/D | N/D | N/D | |
| 1933 | 8-30 to 12-13 | 4,700 | 6,886 | 11,586 | N/D | N/D | N/D | N/D | N/D | N/D | |
| 1934 | 8-30 to 12-13 | 26,614 | 21,807 | 48,421 | 671 | 0 | 671 | N/D | N/D | 3,579 | |
| 1935 | 9-1 to 1-4-36 | 65,240 | 9,948 | 75,118 | 186 | 13 | 199 | N/D | 1,683 | 1,683 | |
| 1936 | 8-1 to 1-31-37 | 33,264 | 14,749 | 47,933 | 387 | 0 | 387 | N/D | 2,114 | 2,114 | |
| 1937 | 8-25 to 12-2 | 32,027 | 1,229 | 33,256 | 195 | N/D | 195 | N/D | 1,121 | 1,121 | |
| 1938 | 8-16 to 4-18-39 | 8,313 | 19,670 | 27,983 | 2 | 0 | 2 | N/D | 2,646 | 2,646 | Weir moved 6.5 miles upstream of mouth |
| 1939 | 8-19 to 4-12-40 | 8,313 | 19,670 | 27,983 | 730 | 152 | 882 | N/D | 1,266 | 1,266 | |
| 1940 | 8-19 to 3-31-40 | 50,725 | 4,431 | 55,156 | 70 | 82 | 152 | N/D | 5,657 | 5,657 | |
| 1941 | 8-29 to 3-31-42 | 7,372 | 5,860 | 13,232 | 36 | 8 | 44 | N/D | 1,178 | 1,178 | |
| 1942 | 8-29 to 2-9-43 | 9,342 | 1,834 | 11,176 | 74 | 0 | 74 | N/D | 1,454 | 1,454 | |
| 1943 | 8-25 to 11-12 | 8,382 | 1,699 | 10,081 | N/D | N/D | N/D | N/D | 382 | 382 | |
| 1944 | 8-28 to 11-3 | 8,604 | 2,686 | 11,290 | 15 | 0 | 15 | N/D | 455 | 455 | |
| 1945 | 8-29 to 11-14 | 14,905 | 3,291 | 18,196 | 29 | 0 | 29 | N/D | 93 | 93 | |
| 1946 | 8-28 to 11-4 | 6,949 | 641 | 7,590 | 7 | 0 | 7 | N/D | 195 | 195 | |
| 1947 | 9-14 to 1-7-48 | 298 | 43 | 341 | 226 | 43 | 269 | N/D | 1,476 | 1,476 | |
| 1948 | 8-30 to 4-14-49 | 31 | 6 | 37 | 285 | 63 | 348 | N/D | 382 | 382 | |
| 1949 | 9-12 to 1-21-50 | 171 | 19 | 190 | 312 | N/D | 312 | N/D | 506 | 506 | |
| 1950 | N/D | 248 | N/D | 248 | N/D | N/D | N/D | N/D | N/D | N/D | Hole in weir. |
| 1951 | 8-2 to 10-30 | 1,565 | 459 | 2,024 | 160 | N/D | 160 | N/D | 110 | 110 | |
| 1952 | 8-27 to 10-31 | 1488 | 178 | 1,666 | 16 | N/D | 16 | N/D | 103 | 103 | |
| 1953 | 8-31 to 10-30 | 1,444 | 161 | 1605 | 22 | N/D | 22 | N/D | 128 | 128 | |
| 1954 | 8-31 to 10-29 | 1,768 | 857 | 2,625 | 2 | N/D | 2 | N/D | 112 | 112 | Est. Chinook run between 4,500 and 5,500 |
| 1955 | 8-24 to 11-8 | 1,620 | 197 | 1,817 | 0 | 0 | 0 | N/D | 77 | 77 | |
| 1956 | | | | | | | | | | | No count-storm damage |

**Table 1 cont. Shasta River Fish Counts, 1930 to 1996**[1/]

| Year | Dates of operation | Chinook Salmon Adult | Chinook Salmon Grilse | Chinook Salmon Total | Coho Salmon Adult | Coho Salmon Grilse | Coho Salmon Total | Steelhead ½ lb | Steelhead Adult | Steelhead Total | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1957 | 9-10 to 10-31 | 1,781 | 453 | 2,234 | 310 | N/D | 310 | N/D | 808 | 808 | Weir moved back to mouth. |
| 1958 | 8-24 to 10-31 | 4,694 | 1,375 | 6,069 | 147 | N/D | 147 | N/D | 871 | 871 | |
| 1959 | 8-30 to 10-30 | 8,619 | 1,256 | 9,875 | 36 | N/D | 36 | N/D | 171 | 171 | |
| 1960 | 8-24 to ? | 8,495 | 995 | 9,490 | 12 | N/D | 12 | N/D | 64 | 64 | |
| 1961 | 9-3 to 10-31 | 5,250 | 3,514 | 8,764 | 14 | N/D | 14 | N/D | 884 | 884 | |
| 1962 | 8-28 to 10-26 | 9,907 | 4,991 | 14,898 | 0 | 0 | 0 | N/D | 159 | 159 | |
| 1963 | 9-4 to 11-1 | 22,824 | 9,013 | 31,837 | 105 | N/D | 105 | N/D | 159 | 159 | |
| 1964 | ? To 10-30 | 30,715 | 3,648 | 34,363 | 5 | 0 | 5 | N/D | 1,763 | 1,763 | |
| 1965 | 9-1 to 11-1 | 7,136 | 775 | 7,911 | 0 | 0 | 0 | N/D | 580 | 580 | |
| 1966 | 9-3 to 10-26 | 5,573 | 451 | 6,024 | N/D | N/D | N/D | N/D | 265 | 265 | |
| 1967 | 9-11 to 10-28 | 10,478 | 1,836 | 12,314 | N/D | N/D | N/D | N/D | 652 | 652 | |
| 1968 | 8-25 to 10-29 | 13,039 | 1,003 | 14,042 | 2 | 0 | 2 | N/D | 515 | 515 | |
| 1969 | 9-5 to 10-30 | 10,576 | 3,049 | 13,625 | N/D | N/D | N/D | N/D | 1,092 | 1,092 | |
| 1970 | 9-5 to 11-16 | 12,693 | 712 | 13,405 | 186 | 55 | 241 | N/D | 842 | 942 | |
| 1971 | 9-7 to 10-29 | 4,970 | 1,649 | 6,619 | 69 | 5 | 74 | N/D | 1,578 | 1,578 | |
| 1972 | 9-10 to 11-13 | 2,802 | 839 | 3,641 | 114 | 50 | 164 | N/D | 414 | 414 | |
| 1973 | 9-4 to 11-14 | 4,516 | 4,902 | 9,418 | 121 | 35 | 156 | N/D | 468 | 468 | |
| 1974 | 9-3 to 11-1 | 7,376 | 2,729 | 10,105 | 131 | 31 | 162 | N/D | 91 | 91 | |
| 1975 | 9-2 to 10-29 | 11,821 | 4,211 | 16,032 | 165 | 31 | 196 | N/D | 504 | 504 | |
| 1976 | 9-3 to 10-29 | 4,154 | 1,919 | 6,073 | 123 | 1 | 124 | N/D | 512 | 512 | |
| 1977 | 9-1 to 11-12 | 5,478 | 1,969 | 7,447 | 280 | 25 | 305 | N/D | 268 | 268 | |
| 1978 | 9-11 to 4-11-79 | 12,024 | 7,707 | 18,731 | 748 | 151 | 899 | N/D | 375 | 375 | |
| 1979 | 9-1 to 3-30-80 | 7,111 | 1,040 | 8,151 | 194 | 141 | 335 | N/D | 1,866 | 1,866 | |
| 1980 | 9-7 to 5-9-81 | 3,762 | 4,334 | 8,096 | 321 | 97 | 418 | N/D | 1,990 | 1,990 | |
| 1981 | 9-23 to 1-5-82 | 7,890 | 4,330 | 12,220 | 32 | 1 | 33 | N/D | N/D | 218 | Flood damage. Incomplete counts |
| 1982 | 9-6 to 2-24-83 | 6,533 | 1,922 | 8,455 | 150 | 86 | 236 | 96 | 2,060 | 2,156 | |
| 1983 | N/D | 3,119 | 753 | 3,872 | 29 | 7 | 36 | 13 | 209 | 222 | |
| 1984 | N/D | 2,362 | 480 | 2,842 | 58 | 11 | 69 | 2 | 577 | 579 | |

Tab. cont. Shasta River Fish Counts, 1930 to 1996[1/].

| Year | Dates of operation | Chinook Salmon Adult | Chinook Salmon Grilse | Chinook Salmon Total | Coho Salmon Adult | Coho Salmon Grilse | Coho Salmon Total | Steelhead ½ lb | Steelhead Adult | Steelhead Total | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | 9-5 to early | 5,124 | 3 | 0 | 3 | 0 | 95 | 95 | | | |
| 1986 | 9-6 to 11-12 | 3,274 | 683 | 3,957 | 27 | 4 | 31 | N/D | N/D | 0 | |
| 1987 | 9-23 to 11-1 | 4,299 | 398 | 4,697 | 23 | 1 | 24 | 38 | 0 | 38 | |
| 1988 | ? to 11-12 | 2,586 | 256 | 2,842 | 3 | 0 | 3 | 1 | 22 | 23 | |
| 1989 | 9-8 to 10-21 | 1,440 | 137 | 1,577 | 5 | 1 | 6 | N/D | N/D | 12 | High water forced early removal |
| 1990 | 9-10 to 10-28 | 415 | 118 | 533 | 2 | 0 | 2 | 8 | 4 | 12 | Weir operated as marking station |
| 1991 | 9-12 to 11-11 | 716 | 10 | 726 | 4 | 1 | 5 | 1 | 11 | 12 | |
| 1992 | 9-8 to 11-11 | 520 | 66 | 586 | 2 | 1 | 3 | 10 | 0 | 10 | |
| 1993 | 9-9 to 11-12 | 1,341 | 85 | 1,426 | 4 | 0 | 4 | 2 | 2 | 2 | |
| 1994 | 9-21 to 11-6 | 3,363 | 1,840 | 5,203 | 15 | 2 | 17 | 3 | 3 | 6 | |
| 1995 | 9-17 to 11-11 | 12,816 | 695 | 13,511 | 15 | 2 | 17 | N/D | N/D | 9 | |
| 1996 | 9-16 to 11-3 | 1,305 | 145 | 1,450 | 0 | 0 | 0 | 0 | 5 | 5 | |

1/ Data from published reports and DFG weekly trapping summaries. Chinook counts between 1935 and 1948, 1959 through 1977 and 1996 should be considered preliminary. Coho and steelhead counts should also be considered preliminary.
2/ N/D = No data available.

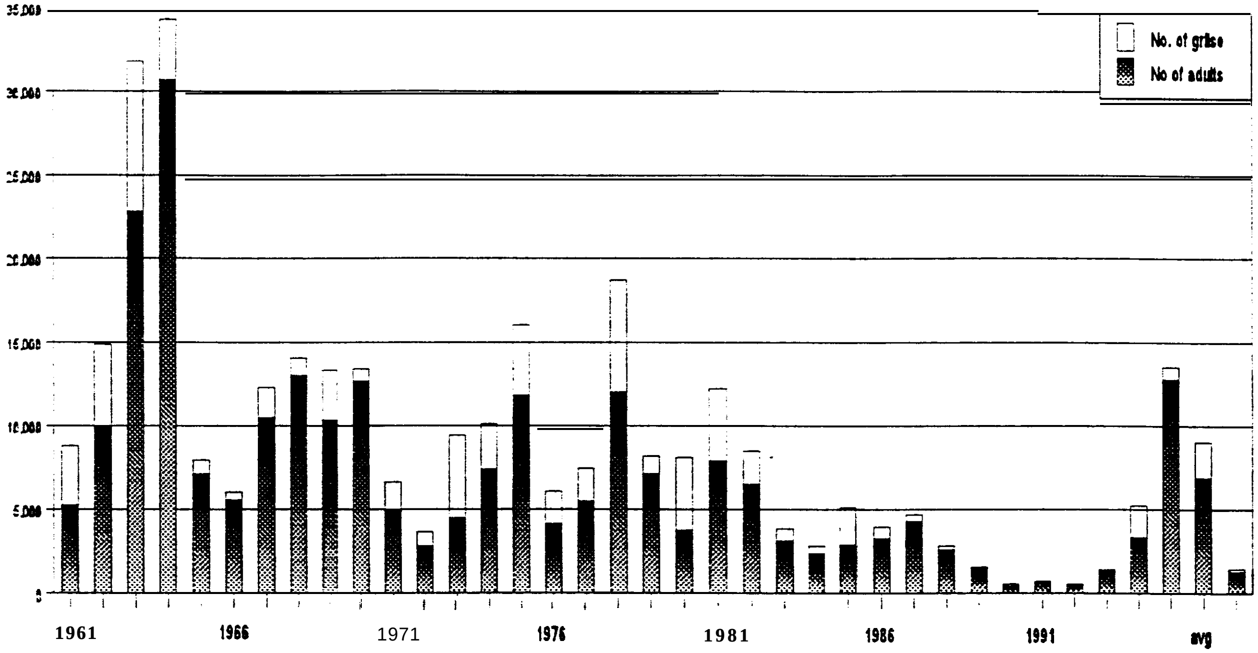



Figure 2. Shasta River fall chinook salmon escapement, 196 1 - 1995. Second column from far right column is the 35-year average. Far right cohmm is preliminary 1996 run size.

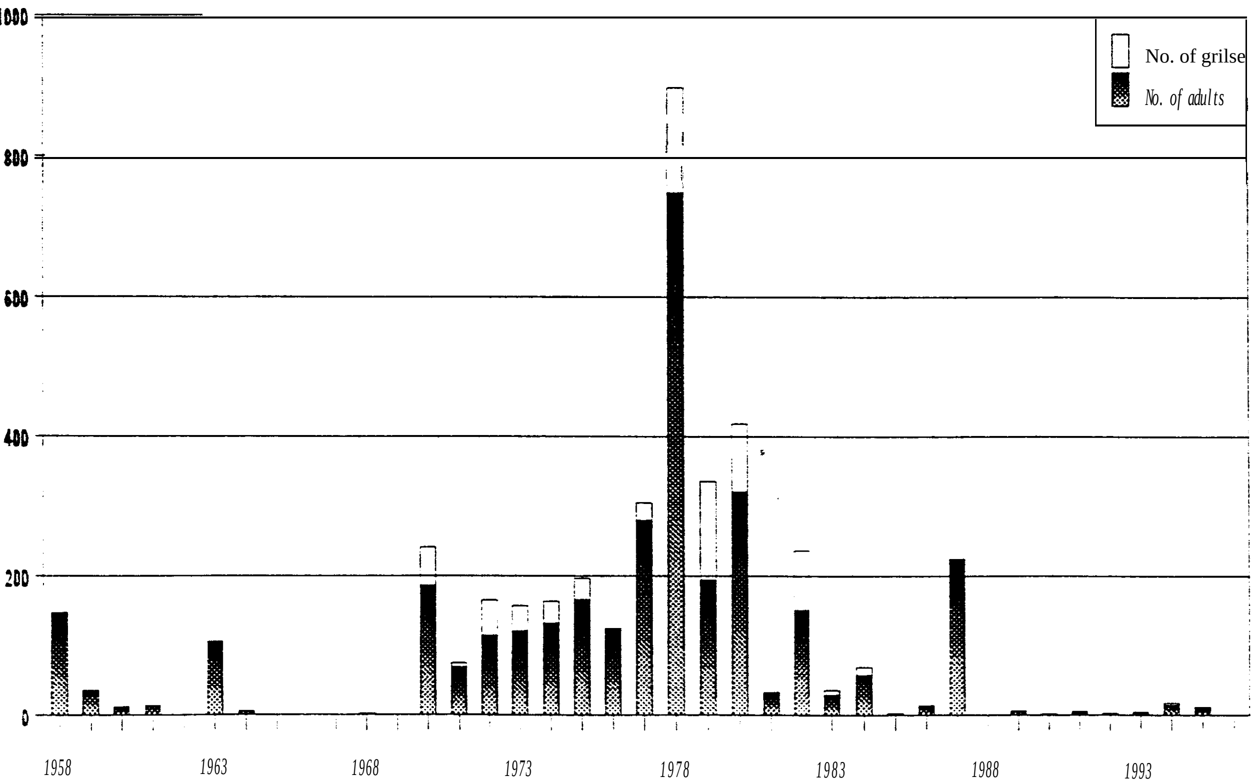



Figure 3. Number of coho salmon observed at the Shasta River Fish Counting Facility, 1957 to 1996. Years 1978 through 1982 were years of extended weir operations.

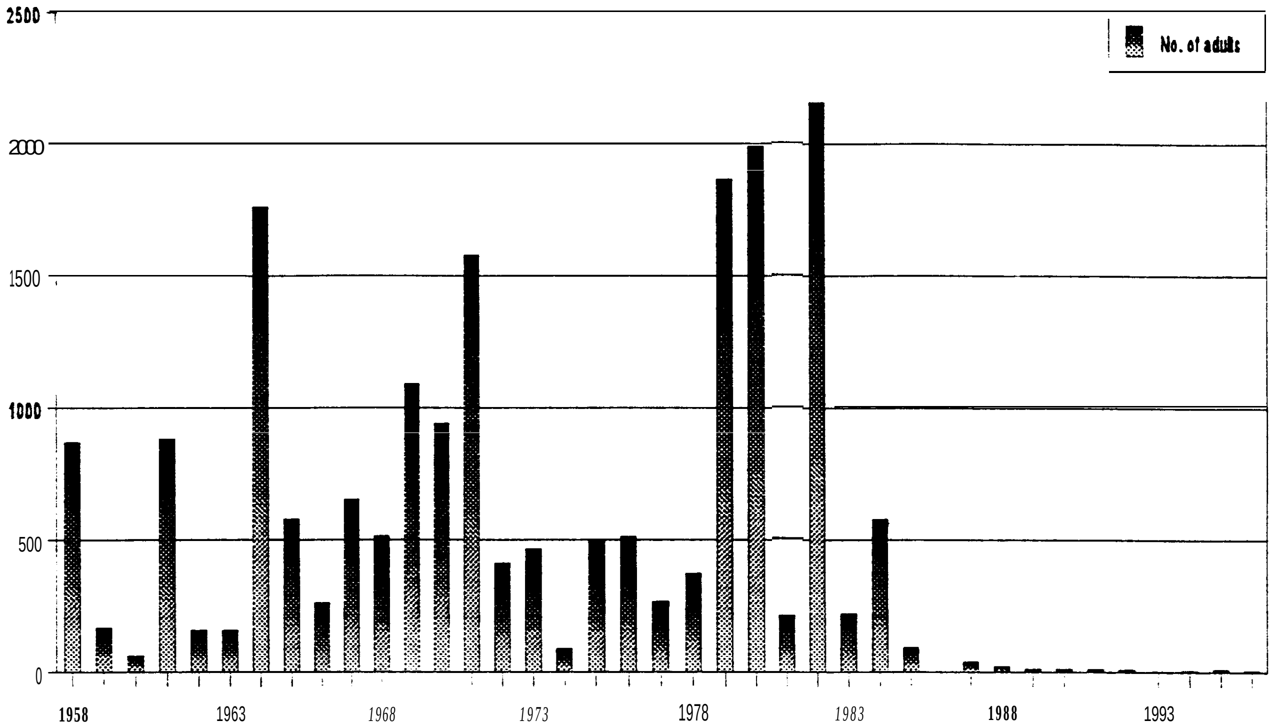


Figure 4. Number of steelhead observed at the Shasta River Fish Counting Facility, 1957 to 1996. Years 1978 through 1982 were years of extended weir operations_

Springs confluence (RM 30) to Louie Road (RM 31.3) and in the lower mile of Big Springs Creek. Very little spawning occurs in the Shasta Valley due to the paucity of gravel (DWR 1981, DFG files). During years of adequate streamflow, salmon are able to spawn in the Shasta River above Louie Road in the vicinity of Parks Creek and in Parks Creek (DWR, 1981, DFG files).

In 1937, the DFG fish counting station was moved from the mouth to approximately RM 6.5. Between 1937 and 1957, the DFG estimated that approximately one third of the chinook salmon spawning run occurred below the relocated counting station and two-thirds spawned above. In **1981**, the DFG (DWR, 1981) estimated that two-thirds of the spawning now occurs in the lower 8 river miles. In 1995, chinook salmon were observed in Little Shasta creek and spawning in Yreka Creek.

Very little information is available regarding the spawning distribution of coho salmon and steelhead in the Shasta subbasin. Skinner (1959) reported that adult steelhead spawn in the lower seven miles of the Shasta River, in Big Springs Creek, in the main Shasta River above Big Springs Creek and in Parks Creek when flows-were adequate. Steelhead are also known to spawn in the lower three miles of Yreka Creek. Skinner suggested that since coho salmon have similar spawning requirements as do steelhead, coho salmon probably spawn in the same areas. Additional and comprehensive monitoring of the timing and distribution of spawning is needed to understand spawning patterns in the Shasta subbasin.

**Life History**

Fall Chinook

Adult fall chinook salmon begin entering the Klamath River in late July, ascending the Klamath River and its tributaries between August and December, depending on the tributary and its location in the drainage. Chinook salmon begin entering the Shasta River in September with adult immigration continuing into November (Figure 5). The majority of spawning occurs during October and November. The period of egg incubation begins as soon as spawning occurs and is usually completed before March (Leidy & Leidy, 1984). Emergence, the period in which developing fish swim up through the gravel and enter the stream, takes place late January through March.

Three chinook salmon early life history phases involving river outmigration have been identified within the Klamath River basin (KRBFTF, 1991). The three phases or life history "types" are outlined below.

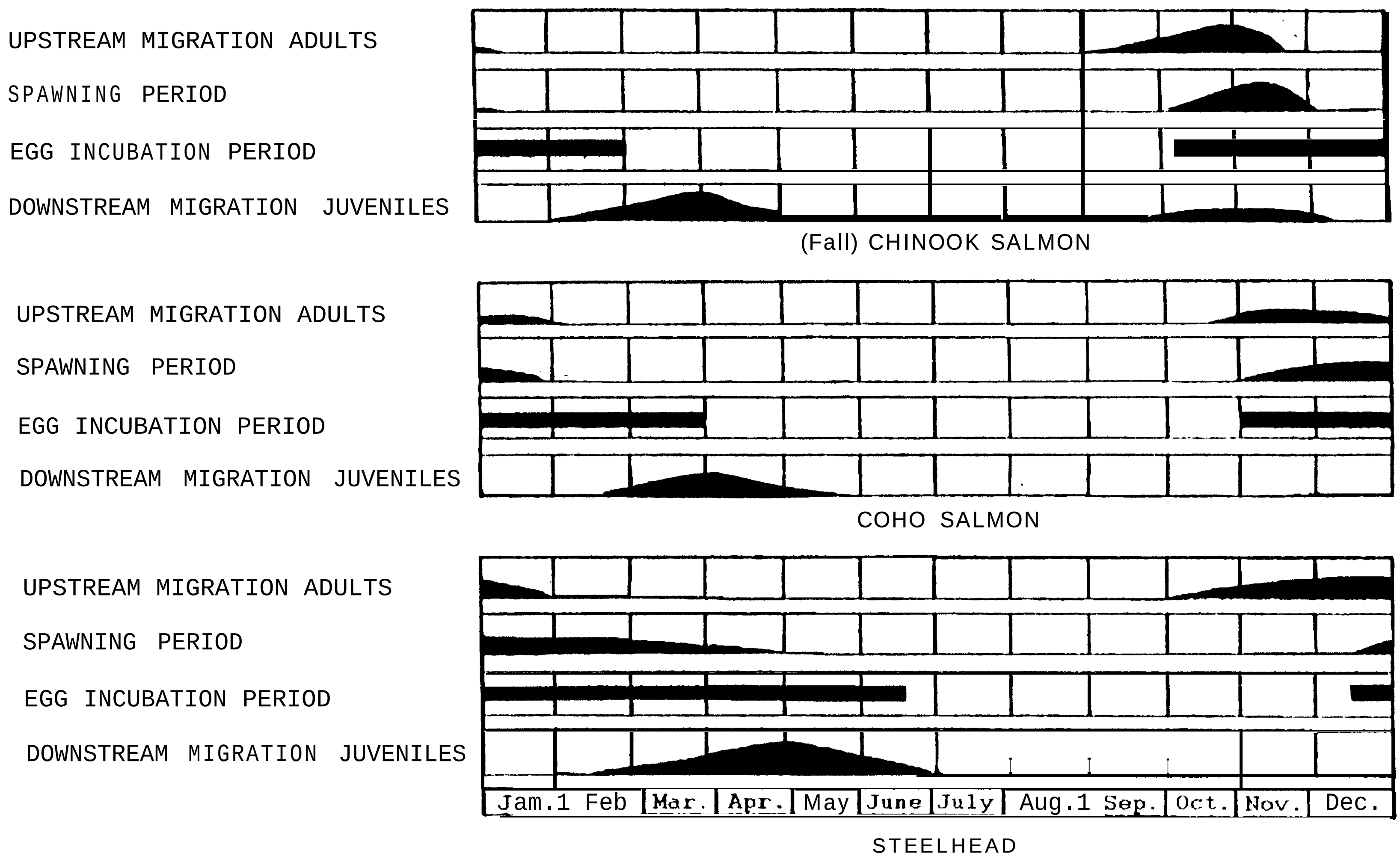
| | |
|---|---|
| Type I | Outmigration occurs in spring within several months of fry emergence. |
| Type II | Juveniles spend their first spring and summer in stream and outmigrate in the fall. |
| Type III | Juveniles spend an entire year in the stream and outmigrate in the spring of the following year. |

Juvenile salmon ready to descend their natal streams and enter the estuary and ocean are called "smolts". Smoltification is a process involving chemical/hormonal changes in the body that prepare the fish for a saltwater environment. Young-of-the-year (YOY) smolts from the Shasta River system generally outmigrate between February and mid-June (Type 1 life history phase) (Leidy and Leidy, 1984). Through the use of fyke traps, Jong, (1994) found YOY chinook leaving the Shasta River as early as January through and as late as late-June.

In recent years -we have observed juvenile chinook residing in the Shasta River beyond June. This indicates that not all juvenile chinook are following the "Type I" outmigration pattern. A relatively smaller outmigration of juvenile chinook salmon smolts has been noted in the fall. It is unclear whether this means that "Type II" or "Type III" outmigration tendencies exist among Shasta River chinook or if environmental conditions and irrigation diversion structures cause fish to remain in the upper

-Figure 5-

Spawning, egg incubation, and migration periods of anadromous fish for the Shasta River.



portion of the river beyond their normal tendency to do so. Additional studies are needed to evaluate Shasta River chinook salmon rearing and outmigration patterns.

After descending the Shasta River, fall chinook salmon enter the Klamath River en route to the estuary and ultimately the Pacific Ocean. In the ocean, chinook salmon normally mature at three to five years of age, although a small portion of each year's brood return are sexually mature two-year old males known as “jack“ or "grilse" salmon.

Coho Salmon

Little is known regarding the number of spawners, migration patterns and behavior of coho salmon produced in the Shasta River. We believe, however, these fish follow the migration patterns and emulate the behavior of coho salmon studied in other areas of the Klamath River basin and elsewhere.

Nearly all adult coho enter the Klamath River from mid-September through January as three-year old fish (USFS, 1972). A very small number of coho return to spawn at age four. Coho residing in the ocean for less than one year before returning to the Klamath River basin come back at age two as grilse. Coho generally select smaller tributaries for spawning with spawning occurring from November through January. Egg incubation begins in November with the initiation of spawning activity and continues through March. Hatching occurs in one to three months, depending on water temperature, with fry emergence occurring from February through mid-May (Figure 5).

Juvenile coho salmon remain in freshwater for approximately one year prior to outmigrating as yearling smolts between February and mid-June. Within the Klamath River basin, peak outmigration activity occurs during April and May (Leidy & Leidy, 1984).

Steelhead

Runs of steelhead identified in the Klamath River basin are spring-run (better known as summer steelhead), fall-run and winter-run. The runs are classified based on the season of the year they enter the Klamath River as adults. Spring-run, or summer steelhead, do not presently occur in the Shasta River. Because of their very similar life histories both fall- and winter-run steelhead will be discussed together.

The initial stages of the fall-run begin with the movement of small migrants called "half-pounders" during the months of August through October. Half-pounders spend one to three years in a freshwater environment and less than a year in the ocean. These small, immature fish spend several months in the Klamath River and its major tributaries tending to remain primarily in the lower portion of the Klamath River basin below the confluence of the Scott River.

The half-pounder run is unique in that it occurs in large numbers in only two river systems in California (Klamath and Eel rivers) and in Oregon's Rogue River (Rankel, 1978).

The arrival of greater numbers of larger, sexually mature steelhead in October and November marks the start of the fall-run. The winter-run steelhead migration overlaps the fall-run, with winter-run fish beginning to enter the Klamath River in December. The majority of the winter-run steelhead enter their natal streams to spawn from December through April. Steelhead spawning takes place in the Shasta River basin beginning around mid-December and continues through April (Leidy and Leidy, 1984) (Figure 5). It is uncertain whether fall-run and winter-run steelhead spawn at different times or select different locations for spawning within the Shasta subbasin. Steelhead may spawn more than once during their life, generally returning to the ocean after spawning.

Steelhead egg incubation occurs in the Shasta River from mid-December through mid-June (Leidy and Leidy, 1984). The actual incubation period is dependent on water temperature. Coldwater temperatures impede egg development and delay hatching. Emergence of Shasta River steelhead alevins generally occurs between March and June (Leidy and Leidy, 1984). Based on DFG trapping results in the Shasta River during the winter and springs of 1986-1989 and 1992 (Jong, 1994 and DFG files, Yreka), steelhead emergence can occur as early as the first week of February.

Juvenile steelhead usually spend one to three years (most two years) in their nursery stream environment before outmigrating to the ocean. Size appears to be a determining factor for smoltification and outmigration. Smoltification generally occurs when fish reach approximately six inches in length (USFS 1972 as reported in Leidy and Leidy). Outmigration of steelhead smolts is known to occur between February and June. After one to four years in the ocean, steelhead will enter the Klamath River system for their first spawning with the possibility of additional runs in subsequent years (Leiciy and Leidy, 1984).

## III. HABITAT NEEDS (Physical/Biological)

Anadromous salmonids change their habitat requirements during their residency within the Shasta River subbasin. Anadromous fish need holding, spawning, incubation and juvenile rearing habitat. The term habitat refers to the physical attributes of the stream (i.e., pools, runs, riffles, instream structures, etc.) and streambed type (i.e., sand, gravel, cobble, rubble and boulder dominated). Habitat also refers to food availability, water quality (i.e., temperature, dissolved oxygen, macronutrients, etc.) and (i.e., habitat space availability).

Habitat variables are generally discussed separately in terms of their impacts on fish. In reality, fish respond to the combined effects of physical, chemical, and biological variables in their surroundings. It is a mix of these environmental factors which sets the carrying capacity of **a** particular stream. As one or more of these habitat variables are altered, the carrying capacity of the stream is changed. A single sublethal environmental condition may illicit only a minor stress response, however, when combined with other sublethal conditions may lead to more serious problems or even death. This synergistic effect may be far more damaging than the effects of each sublethal factor acting separately.

## Habitat Criteria

Generally, salmon and steelhead require stream habitats that meet a narrow range of water velocity, depth, temperature and substrate criteria.

### Water velocity

Suitable water velocity is important for migration, spawning, incubation, and rearing of salmonids. It is usually considered a more important parameter than depth for determining the hydraulic suitability of a spawning area. Velocity also helps determine the amount of water which will pass over incubating eggs. Optimal spawning velocity for chinook salmon in the Central Valley streams of California is 1.5 feet per second (fps) with a range of 1.0 fps to **3.5** fps (Reynolds et al., 1990). Steelhead prefer slightly faster water (2.0 fps, range 1.0 to 3.6 fps) (Bovee, 1978 as reported in McEwan and Jackson, 1996).

Velocity is also an important factor in determining where young salmonids rear. The ability of fish to maintain position in the current is related to their size and swimming ability. Larger juveniles are more capable of maintaining their position in faster water than newly emerged fry which tend to stay-near the shore in relatively slower water Chapman and Bjornn, 1968 as reported in USFWS, 1983).

### Depth

Salmon usually spawn at a depth ranging from 0.5 to 3 .O feet (Reynolds et al., 1990), although they can spawn at much greater depths. Steelhead prefer depths ranging from 0.5 to 2.0 feet for spawning (Bovee, 1978 as reported in McEwan and Jackson, 1996). Chinook salmon juveniles generally prefer deeper water than steelhead in the same stream (Chapman and Bjornn, 1968 as reported in USFWS, 1983).

Depth directly affects the amount of rearing space available. In shallow streams, space may limit rearing capacity causing fish to redistribute downstream or outmigrate before they are ready.. Literature reviewed by Pauley et al. (1986) indicates water depth required by rearing salmonids may be closely tied to aquatic insect (food) production. In stream environments, areas of highest invertebrate production are those associated with riffles **when** flows and substrate are adequate.

Adult upstream migration is triggered by increases in river levels and changes in water temperature (USFWS, 1983) and insufficient water depth can become a barrier to that migration. Deep pools are required by returning spawners for holding and resting.

<u>Substrate</u>
To allow excavation of the redd (area of gravel in which the female salmon or steelhead lays her eggs) and to permit water and its dissolved oxygen to percolate through to incubating eggs, substrate composition must be low in fines and sand. Generally, 85 percent of incubating Salmonid eggs will suffer mortality when 15 to 20 percent of the voids (interstitial gravel spaces) become filled with sediment (Bell 1990). Chinook salmon prefer substrate which consists mostly of gravel from 0.75 to 4.0 inches in diameter with less than 20 percent fines (by volume) (Reynolds et al., 1990). Steelhead prefer a similar sized substrate with less than 5 percent fines (McEwan and Jackson, 1996).

<u>Temperature</u>
Water temperature influences the development and survival of salmonids by affecting different physiological processes such as growth and smoltification. Water temperature also affects the fishes' migration timing, ability to cope with predation, disease and exposure to contaminants. The preferred spawning temperature for chinook salmon is 52°F with acceptable upstream migration temperatures ranging between 57° and 67°F (Reynolds et al., 1990). Water temperatures above 70°F can delay adult migration (Bell 1990). Temperatures at which 100 percent mortality of Shasta River Salmonid stocks occurs have not been determined although Reisner and Bjomn (1979) report upper and lower lethal temperature levels for chinook are 79.6°F and 33.5°F, respectively. Preferred water temperatures for coho salmon range between 38°F and 69°F while upper and lower lethal temperature levels are 78°F and 32°F, respectively (Bell, 1990).

Preferred water temperatures for steelhead vary depending on life stage and stock characteristics. Generally, for adult migration, egg incubation and juvenile rearing, temperatures between 45° and 52°F are desired. Optimal temperatures for spawning range between 39° and 52°F (McEwan and Jackson, 1996). Bell (1990) reports the upper lethal limit is 75°F.

## IV. CURRENT HABITAT DEFICIENCIES AND THREATS

### Flows

Streamflow, a function of water velocity and depth, is an important consideration when dealing with anadromous fish. The United States Geological Survey (USGS) has collected streamflow records for the Shasta River since 1912. Initially, the stream gauge was located near the town of Montague and flow information was collected for years 1912-1913, 1917-1921 and 1924-1933. Since 1933 the California Department of Water Resources (DWR) water-master operates this gauge only during the irrigation season. In October 1933, the USGS began operating a new gauge located near the town of Yreka approximately 0.5 miles above the Klamath River confluence. The USGS located this new gauge approximately 14.5 miles downstream of the old gauge. With the exception of the period December 1941 through December 1944, this new gauge has been in continuous operation.

Construction of Dwinnell Dam and increased water diversions for agricultural, stockwater, recreational and domestic uses have resulted in changes to the annual flow regime of the Shasta River. In general, higher base flows existed in the river prior to the construction of Dwinnell Dam than exist currently for the spring, summer and early fall periods. Prior to Dwinnell Dam, mean daily flows in the Shasta during the spring (April through June) averaged 132 cfs. During the years 1985 through 1994, April through June flows averaged 87 cfs; a 34 percent reduction during the smolt salmon outmigration period. Average summer flows (July and August) for predam years is 42 cfs while during recent years it has averaged 28 cfs. Mean daily flows for the month of September for pre and postdam conditions are 79 and 61 cfs, respectively (Figure 6).

Under current conditions, flow reductions caused by the start of the irrigation season are more dramatic than the gradual flow declines observed for predam years. During the drought year of 1992, flows dropped from 105 cfs on March 31 to 21 cfs on April 5 due to the start of the irrigation season. Documented fish kills resulted.

It is likely that greater flow differences exist than those described above because of the location of the two gauges used for this comparison. Flows measured near the mouth account for nearly all of the accretions to the river while those measured 14.5 miles upstream at the old site would not. The reader is also reminded that considerable water development had already occurred in the Shasta Valley prior to the initiation of flow measurements by the USGS and the construction of Dwinnell Dam.

In dammed and diverted streams like the Shasta River, flows and resultant water velocity changes may be important factors affecting juvenile salmon outmigration and survival. Studies in the San Joaquin system of California have shown that survival of chinook salmon smolts is positively correlated with increases in flow

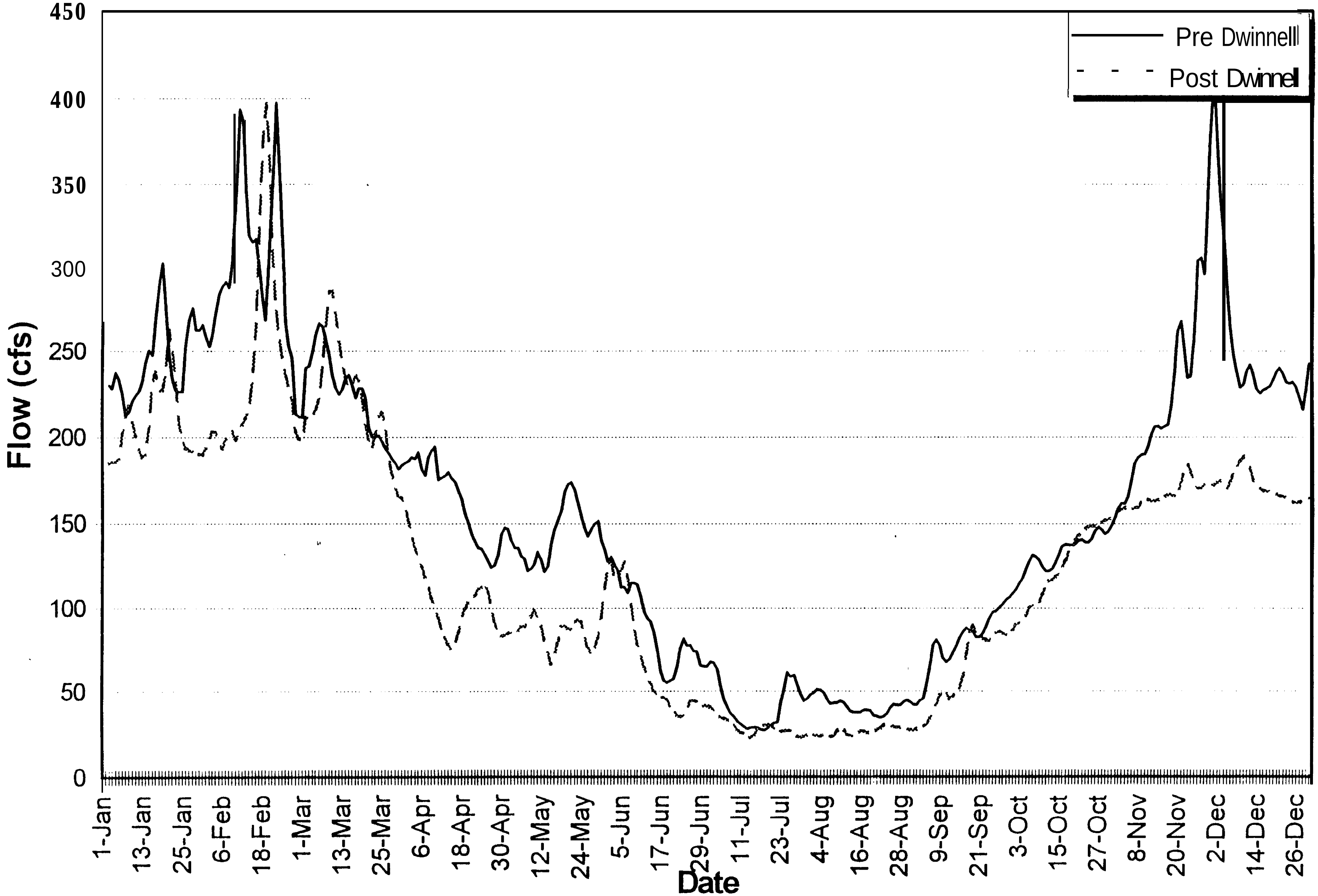



Figure 6. Mean daily flows for the Shasta River averaged for a ten year period pre and post Dwinneil Dam construction (smoothed by a running average of 3). Years used for pre Dam average: 1912-1 3, 19 17-2 l 1924-26. Post dam construction years used were 1985 through 1994 inclusive.

(Kjelson and Brandes, 1989). DFG studies showed decreased densities of rearing salmon in the Stanislaus and Tuolumne rivers and increases in their catch in the Sacramento/San Joaquin Delta near Mossdale following increased releases from Goodwin and Don Pedro dams (Pisano et al., 1992). Monitoring juvenile salmon movement in the lower Shasta River during the spring of 1993 showed increases in their catch coincident with increased flow (and velocity) resulting from a planned and organized cessation of water diversions by local irrigators.

In some years, the onset of the chinook salmon run into the Shasta River appears to be tied closely to the end of the main irrigation season (October 1) and resultant increases in flow (Figure 7). coots (1957, 1958) observed a similar relationship between flow changes in the Shasta River and adult fall chinook salmon run timing in the late 1950's. Between i933 and 1934, Brown (1938) reported that chinook salmon began their migration into the Shasta River during the first two weeks of September. Under present conditions, the start of the run has shifted to late September (Figure 7).

Flows can affect the distribution of spawning in the Shasta subbasin. Low flow conditions limit the ability of fish to access and utilize the Shasta River above Louie Road. Skinner (1959) noted that, with few exceptions, flows between Dwinnell Dam and Louie Road (Big Springs) have been inadequate in providing suitable

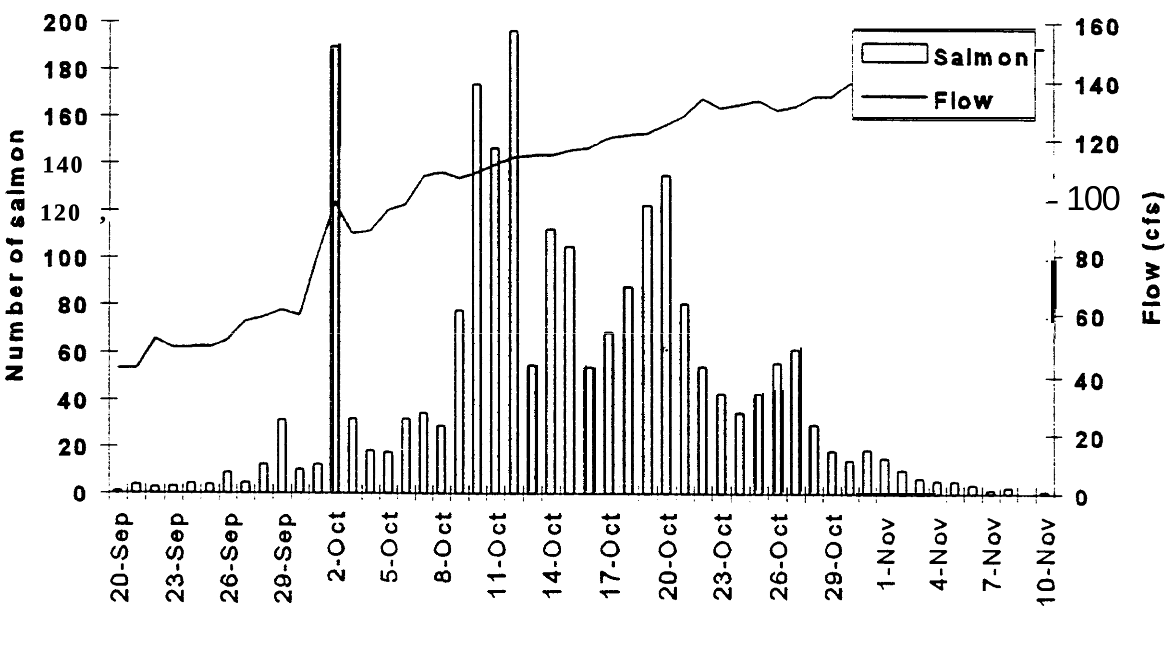



Figure 7. Number of chinook salmon counted by day and mean daily flows for the Shasta River averaged for the years 1992 through 1994.

spawning habitat. Salmon carcass surveys conducted by the DFG in 1980, 1993 and 1994 did not include the Shasta River above the Louie Road because of low flows. A check of the Shasta River between Parks Creek (RM 32) and the Hole in the Ground Ranch (RM 34) in 1994 revealed that no salmon utilized this area despite an apparent abundance of gravel. During the 1995 and 1996 seasons, years in which observed flows were higher than the previous few years, numerous redds were counted in this same area and in the lower half-mile of Parks Creek. In 1995 and 1996, the DFG also observed salmon spawning in Yreka Creek, near the town of Yreka.

Salmon and steelhead produced in the Big Springs area (RM 30) and above have much greater rearing opportunity (ie, >20 river miles) than fish produced in the lower section. Because of this, chinook and, particularly coho and steelhead originating from the Big Springs area, would likely be larger at outmigration than salmonids originating from the canyon section. Based on coded-wire tag (CWT) recovery information from IGH releases, chinook salmon out-migrating at a larger size generally exhibit higher survival rates than salmon released at smaller sizes. Assuming flow and water temperatures were adequate during their rearing and outmigration, salmon and steelhead produced in the vicinity of Big Springs and Parks Creek may contribute to future runs at a higher rate particularly following years when scouring flows occur in the canyon section during the incubation period. Although rearing habitat in the Shasta River has not been thoroughly quantified, we believe rearing space is very limited in the lower 8 river miles due to the physical nature (canyon) of the stream channel.

**Water Temperature**

Water temperatures in streams will increase when flows are smaller due to decreased depth and reduced volume of water subject to warming by the sun and ambient air. Water temperature has been a noted problem in the Shasta River since at least 1961 with levels reaching as high as 85°F between 1961 and 1970 (USDI 1985). High river temperatures generally exceeding 80°F primarily during June, July and August continue to plague the lower Shasta River. Low flows and high summer stream temperatures have been identified as the two primary constraints to salmon and steelhead production (USDI 1985 and KRBFTF 1991). A water quality study of the Shasta River conducted by Ouzel Enterprises in 1990 documented temperatures in the Shasta River as high as 89.6°F at the mouth and 82.4°F at the Highway 3 Bridge crossing (RM 12.5) (SVRCD 1991).

Extensive monitoring of water quality in the Shasta River between 1985 and 1995 revealed river conditions during this time often exceeded numeric and narrative criteria contained in the State's North Coast Regional Water Quality Control Board (NCRWQCB) Basin Plan (Plan) for the protection of salmon and steelhead (NCRWQCB, 1989).

## Dissolved Oxygen

The Plan's objective for dissolved oxygen (DO) is 7.0 mg/L with a median of 9.0 mg/L. DO levels of less than 5.0 mg/L (5ppm) have been found to occur in the Shasta River in recent years primarily in the morning hours. Levels under 5 mg/L are considered to be detrimental to salmon and steelhead. DO levels of less than 3.0 mg/L are considered lethal (Leitritz and Lewis, 1976). Of the 296 DO measurements recorded from July 1986 through June of 1992 by NCRWQCB personnel, 15.2 percent were less than the Plan objective level (7 mg/L and 3.4 percent were under 5 mg/L indicating serious DO problems.

## Dam and Diversion Structures

Dwinnell Dam blocks access to prime spawning and rearing habitat for anadromous salmonids and prevents the replenishment of new spawning gravel to the river downstream'of the dam. Further, water held back in Lake Shastina each winter reduces the frequency and magnitude of runoff events in the Shasta River below the dam allowing fine sediment to accumulate on existing spawning gravel. Winter flows are also reduced in Parks Creek as water is diverted to the Shasta River above Lake Shastina to help fill the reservoir.

Excessive amounts of fine sediments resulting from increased bank or upslope erosion findtheir way into spawning gravel thereby armoring the substrate and creating survival problems for eggs deposited by salmon and steelhead. Fines fill the small spaces between the gravel reducing interstitial water flow and depressing DO concentrations for incubating eggs. Additionally, emerging fry can become trapped in the gravel by sedimentation and may be unable to escape the stream substrate (Koski, 1966; Meehan and Swanston, 1977).

In a 1994 study of Shasta River gravel quality, Jong (1995) found that small sediment particles and fines (<4.75 mm) were present in quantities associated with excessive salmon and steelhead egg mortality (Figure 6). He also concluded that gravel quality had deteriorated since 1980 when the DWR performed similar work in the Shasta basin.

Recent evidence shows that water quality problems are associated with many of she smaller diversion structures on the Shasta River below Dwinnell Dam. These structures. **serve** as temperature and nutrient traps leading to conditions favorable for aquatic plant growth, areas of increased organic decay and elevated aerobic bacteria activity. Consequently, this creates localized DO and thermal problems which can kill salmonids trapped behind the diversion structures. The extensive water use and associated tailwater return may be exacerbating high stream temperatures and nutrient loading during the late spring and early summer months. (KRBFTF 1991).

Other problems associated with these diversion structures include the lack of suitable fish passage facilities in some places and predation on juvenile salmonids by resident trout and-warmwater fish species.

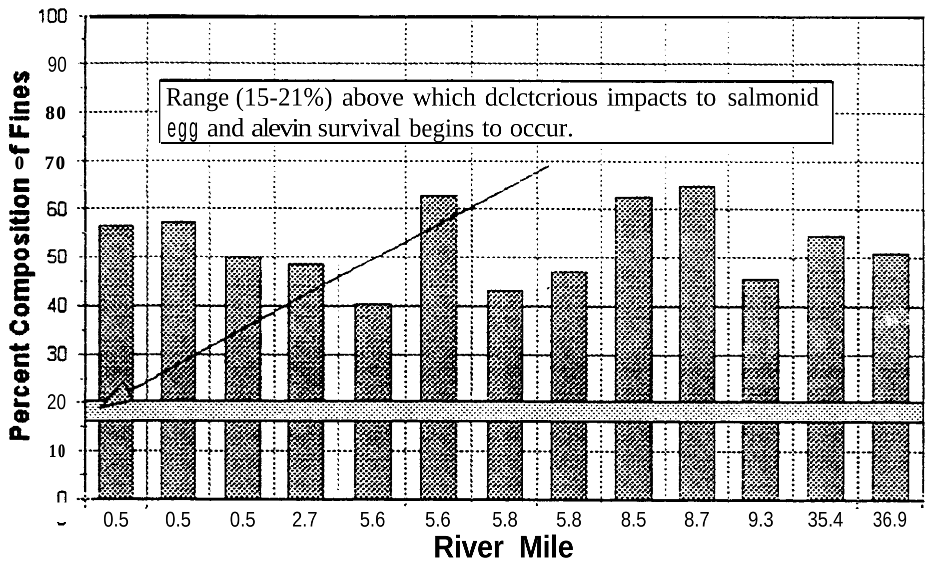



Figure 8. Percent composition of fine materials (e.g., sand. silt. clay < 4.75 mm) in the Shasta River. 1994.

## Grazing

Livestock grazing can affect nearly all components of the aquatic system. It does this by affecting the streamside environment by changing, reducing, or eliminating vegetation bordering the stream. This can lead to changes in channel morphology by accrual of sediment, alteration of channel substrate, disruption of pool to riffle ratios, and widening of the channel. Water quality and quantity in turn is affected by increased water temperatures, nutrient loading, increased levels of suspended sediment and by changes in the timing and volume of streamflow. Trampled stream banks coupled with the loss of vegetative armoring lead to sloughing of stream banks creating unstable vertical cut banks and increased erosion. Surveys conducted from 1991 to 1993 on the Shasta River identified 23,880 feet of unstable vertical cut banks between Grenada Irrigation District's Dam and State Highway 263 north of Yreka (DFG file data). In nearly every case where unstable banks were noted, riparian trees and other woody vegetation were lacking. We believe most, if not all, of those unstable sections could be improved by establishing and maintaining a healthy riparian corridor through grazing management or cattle. exclusion.

## Wells

Drilling of wells for agricultural, stock water or domestic use began to increase dramatically in the early 1960's and peaked during the late 1970's (Figure 8). Although the actual number of wells currently operating is unknown, their potential cumulative impact may be substantial. The effect water withdrawals from wells has had on Shasta River and its tributaries' flow has not been adequately determined.

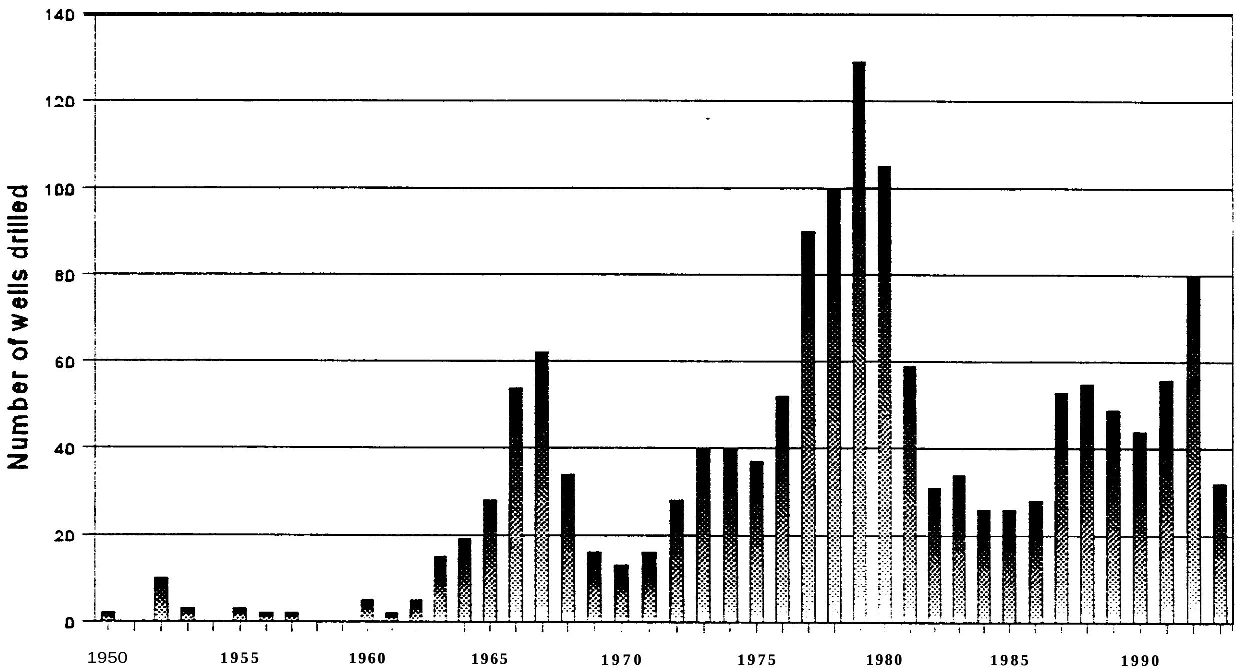



Figure 9. Reported number of new wells drilled in the Shasta Valley, 1950 - 1993 (data from DWR).

## Habitat Complexity

A healthy riparian corridor is a key element in maintaining a productive stream environment suitable for fish, particularly salmon and steelhead. Besides maintaining stable stream banks, riparian vegetation (including large woody debris originating from riparian timber) creates cover beneficial to anadromous salmonids, especially coho. For example, coho salmon production declined when woody debris was removed from second-order streams in southeastern Alaska (Dolloff 1983). During extensive habitat typing surveys, West et al. (1988/89) found that juvenile anadromous salmonids had a strong affinity for both large and small woody debris cover structures in a number of Klamath River basin tributary streams which they evaluated.

Woody debris deposited and redistributed during high stream flows and debris torrents are common and important channel features with both physical and biological consequences for fish habitat. Debris accumulations provide cover for resident and anadromous fish (Narver 1971; Hall and Baker 1975) and retain organic detritus entering the stream system.

A habitat study of the lower 7 miles of the Shasta River conducted by the US Forest Service (Klamath National Forest) concluded that riparian conditions were poor and that river temperatures during the summer were limiting juvenile Salmonid rearing and was, in their estimation, severe enough to cause die offs of salmonids (West et al. 1988/89). Similar findings resulted from cursory surveys of riparian and river conditions in and along the Shasta River between Grenada Irrigation District's diversion dam and the Interstate 5 crossing by DFG personnel over the past few years. An estimated 75 percent or more of the Shasta River lying upstream of Interstate 5 lacks suitable instream cover structure including woody debris structure.

## Harvest

Much concern has been expressed regarding the harvest of Shasta River origin salmon in a mixed stock fishery. Currently, it is not possible to distinguish Shasta River fish from fish originating from other streams within the Klamath system or from other river systems. Consequently, salmon produced from the Shasta River are combined with salmon originating from all other Klamath River tributaries and managed collectively.

Salmon management zones have been established by the Pacific Fishery Management Council (PFMC) to help protect fish stocks originating from various river systems such as the Klamath River. PFMC management objectives for the Klamath Management Zone (KMZ), which extends from Horse Mountain near Shelter Cove in northern California to Humbug Mountain in southern Oregon, are based on harvest rate goals. Goals for salmon originating from the Klamath Basin call for a 33 to 34 percent escapement rate with a minimum spawning floor of 35,000 naturally spawning adult chinook. Since adoption of these management goals in 1987, the minimum spawning floor has not been met five years out of ten (Table 2).

Harvest allocation of Klamath Basin origin salmon is the responsibility of the Klamath Fishery Management Council (KFMC). Because the KFMC has eleven members and operates by consensus, it has rarely made harvest recommendations to the PFMC (PFMC 1994). In the absence of KFMC harvest recommendations, the PFMC recommends harvest levels for the various fisheries to the Departments of Commerce and Interior and to the states of Oregon and California.

The Department of Commerce sets harvest regulations for the ocean between 3 and 200 miles off-shore. The states of California and Oregon set harvest levels for inriver sport anglers as well as harvest in the ocean occurring less than 3 miles off-shore. The Department of the Interior sets harvest levels for the inriver gill net (Indian) fishery.

Table 2. Natural fall chinook adult spawners in the Klamath Basin, 1987 through 1996.

| Year | Number of natural spawners |
|---|---|
| 1987 | **101,717** |
| 1988 | 79,386 |
| 1989 | 43,868 |
| 1990 | 15,596 |
| 1991 | 11,649 |
| 1992 | 12,028 |
| 1993 | 21,858 |
| 1994 | 32,333 |
| 1995 | 161,794 |
| 1996 | 101,046 |

1996 estimate preliminary.

Currently, equal sharing of harvest is required between non-Indian (ocean sport and commercial and in river sport) and inriver Indian fishers (Hoopa and Yurok tribes). Between 1990 and 1995, the PFMC prohibited commercial harvest of chinook salmon in the KMZ and severely restricted take by ocean sport anglers and Indian net fishers. Harvest by inriver sport anglers was also restricted. Harvest quotas for the 1996 season were liberalized based on pre-season ocean abundance projections and included ocean and inriver (Indian) commercial fisheries.

Concern that the timing of harvest in the lower Klamath River may be having an impact on the number of fall chinook salmon returning to the Shasta River and other upper Klamath River tributaries has been expressed by the SRCRMP. During the 1996 season, the actual number of CWT's collected in the Yurok net fishery indicated that catches of fall chinook salmon released from IGH peaked in late August and early September (preliminary data, Troy Fletcher, Yurok Tribe). IGH origin CWT's collected during sport angler creel surveys also peaked during the same time period (preliminary DFG data). Preliminary harvest data for the 1996 season showed the catch of fall chinook in the net and sport fisheries also peaked in late August and early September. Only two of the twenty-nine Trinity River Hatchery (TRH) CWT's recovered during the 1996 sport harvest season had been collected prior to the second week in September. This suggests, at least in some years, that harvest in the lower Klamath River may be targeting Klamath River bound (IGH fish) salmon more severely than TRH origin chinook salmon.

Between 1984 and 1989, the DFG applied CWT's to naturally produced emigrating YOY fall chinook salmon from the Shasta River. Similar work was performed on Bogus Creek during the years 1984 through 1990. Totals of 243,749 and 288,579 tagged fish were released from the Shasta River and Bogus Creek, respectively. This work was initiated to develop information on ocean distribution, adult inriver run timing, survival and contribution rates, age at harvest and straying for naturally produced fall chinook.

In a DFG memo, Jong (Bill Jong 1995 memo to Ralph Carpenter) identified seven Shasta River and Bogus Creek origin CWT'd fish recovered in the lower Klamath estuary. Specific data are presented in Table 3.

Table 3. List of Shasta River and Bogus Creek origin CWT's recovered in the Klamath River estuary. Preliminary data.

| Bicode | Brood Year | No. of fish | Recovery Location | Recovery Date |
|---|---|---|---|---|
| Shasta River | | | | |
| B6-08-03 | 1984 | 1 | Klamath River mouth | 08/13/87 |
| B6-08-03 | 1984 | 1 | Klamath River lower | 10/08/87 |
| B6-08-05 | 1985 | 1 | Boat ramp near Requa | 08/18/87 |
| B6-08-06 | 1985 | 1 | Highway 101 Bridge | 08/26/87 |
| B6-08-06 | 1985 | 1 | Boat ramp near Requa | 09/06/87 |
| Bogus Creek | | | | |
| B6-09-02 | 1984 | 1 | Highway 101 Bridge | 09/06/87 |
| B6-08-08 | 1985 | 1 | Highway 101 Bridge | 09/06/87 |
| | Total | 7 | | |

A more thorough review and analysis of all available CWT data is needed to begin assessing the relationship between harvest and adult spawner returns to the Shasta River.

## V. RECOMMENDATIONS:

### Research Needs

1) Develop a computer based predictive water quality model to help prioritize actions necessary to achieve water quality objectives in the most cost effective manner. Implement water quality monitoring designed to identify problem areas and trends.

2) Determine flow requirements of the various inriver life phases of anadromous fish in the Shasta subbasin. Work with DWR, irrigation districts and others to develop ways to provide the necessary flows.

3) Conduct a comprehensive sedimentation study in the river below Dwinnell Dam to identify sources of sedimentation, develop baseline sediment levels, measure effects of sedimentation on aquatic invertebrate production and Salmonid spawning and rearing habitat quality.

4) Determine temporal and spatial distribution of anadromous fish spawning in the Shasta subbasin and determine outmigration timing of their progeny.

5) Assess habitat conditions throughout the known anadromous Salmonid range within the Shasta River subbasin. This should include habitat typing to assess riparian and stream conditions.

6) Continue routine data collection of fall-run chinook entering the Shasta River including total number (count) and age class structure. Determine fork lengths, hatchery straying rates and sex ratios as well.

7) Continue to assess juvenile and adult migration problems associated with diversion structures. Implement improvements where appropriate.

8) Continue monitoring and evaluating fish screens. Implement improvements where appropriate.

9) Continue to improve working relationships with the SRCRMP and local landowners to facilitate implementation of necessary studies and action items.

10) Assess genetic composition of fall chinook salmon from the Shasta River and determine their relationship to chinook from other tributaries, IGH and other basins.

11) Evaluate the effects of increased ground water pumping from the Shasta subbasin on anadromous Eish.

12) Develop run-size information for steelhead and coho salmon using the counting weir and video equipment.

**Habitat Improvement**

13) Work with the SRCRMP to develop and implement a comprehensive habitat restoration plan for the Shasta River subbasin.

## LITERATURE CITATIONS


Bell, M.C. 1990. Fisheries handbook of engineering requirements and biological criteria. US Army Corps of Engineers, North Pacific Division, Fish Passage Development and Evaluation Program, Portland, Oregon.

Brown, M.W. 1938. The Salmon Migration in the Shasta River (1930-1934). California Fish and Game Vol 24. pp 61 - 65.

California Department of Water Resources. 1964. Shasta valley investigations, Bulletin No. 87.

California Department of Water Resources. 1981. Klamath and Shasta Rivers Spawning Gravel Enhancement Study. 178 pp.

California Department of Water Resources. 1990. Shasta valley water quality literature review. 25 pp.

California Regional Water Quality Control Board, North Coast Region. Water Quality Control Plan for the North Coast Region. 1989.

Coots, M. 1957. Shasta River, Siskiyou County, 1955 King Salmon Count, and Some Notes on the 1956 Run. DFG Inland Fisheries Administrative Report Number 57-5.

Coots, M. 1958. Shasta River King Salmon Count, 1957. DFG Inland Fisheries Administrative Report Number 58-4.

Dlloff, C.A. 1983. The relationship of wood debris to juvenile salmonid production and microhabitat selection in small southeastern Alaska streams. Doctoral dissertation. Montana State University, Bozeman, MT.

Duff, D.A. 1983. Livestock grazing impacts on aquatic habitat in Big Creek, Utah. pages 129-142 in Menke (1983).

Hall, J.D., and R.L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. pp 355-375 in Northcote (1969b).

Jong, B. 1994. Juvenile Anadromous Salmonid Outmigration Studies, Bogus Creek and Shasta River (Klamath River basin), 1986 through 1990. Calif. Dept. Fish Game, In. Fish. Div., Arcata. Unpublished Rept.

Jong, B. 1995. Results of McNeil Sediment Sampling, Shasta River, 1994. Calif. Dept. Fish Game, In. Fish. Div., Arcata Memo. Rept. 21 PP.

Kjelson, M.A., and P.L. Brandes. 1989. The use of smolt survival estimates to quantify the effects of habitat changes on Salmonid stocks in the Sacramento-San Joaquin Rivers, California. pp 100-115. IN: C.D. Levings, L.B. Holtby, and M.A. Henderson [ed.] Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks. Canadian Special Publication in Fisheries and Aquatic Sciences 105.

Klamath River Basin Fisheries Task Force. 1991. The long range plan for the Klamath River basin conservation area fishery restoration program. US Fish and Wildlife Service, Klamath River Fishery Resource Office, Yreka, California.

Koski, K.V. 1966. The survival of coho salmon (Oncorhynchus kisutch) from egg deposition to emergence in three Oregon coastal streams. Master's thesis: Oregon State University, Corvallis.

Leidy, R.A., and G.R. Leidy. 1984. Life stage periodicities of anadromous salmonids in the Klamath River Basin, Northwestern California. US Fish and Wildlife Service, Division of Ecological Services, Sacramento, California.

Leitritz, Earl, and R.C. Lewis. 1976. Trout and salmon culture (Hatchery methods). California Department of Fish and Game, Fish Bulletin 164, 197pp.

McEwan, D., and T. Jackson. 1996. Steelhead Restoration and Management Plan for California. California Department of Fish and Game, Inland Fisheries Division, Sacramento, California.

Meechan, W.R., and D.N. Swanston. 1977. Effects of gravel morphology on fine sediment accumulation and survival of incubating salmon eggs. US Forest Service Research Paper PNW-220.

Narver, D.W. 1971. Effects of logging debris on fish production. pp 100-111 in Krygier and Hall (1971).

Pacific Fishery Management Council. 1994. Klamath River Fall Chinook Review Team Report: An Assessment of the Status of the Klamath River Fall Chinook Stock as Required Under the Salmon Fishery Management Plan. Draft report presented to the PFMC.

Pauley, G.B., B.M. Bortz, and M.F. Shepard. 1986. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates_ US Fish and Wildlife Service. Biol. Rep. 82(11). US Army Corps of Engineers, TR EL-82-4.

Pisano, M.S., S.N. Shiba, and S.J. Baumgartner. 1992. San Joaquin River Chinook Salmon Enhancement Project Annual Report Fiscal Year 1990 - 1991. Federal Aid in Sportfish Restoration Act. Proj. No. F-51-R-4; Sub project No. IX; Study No. 5; Jobs 3 and 4. 34pp.

Rankel, G. 1978. Anadromous fishery resources and resource problems of the Klamath River basin and Hoopa Valley Indian Reservation with a recommended remedial action program. US Fish and Wildlife Service, Fisheries Assistance Office, Arcata, CA. 99 pp.

Reiser, D.W., and T.C. Bjornn. 1979. Habitat requirements of anadromous salmonids. 54 pp. *in* W.R. Meehan, ed. Influence of forest and range Management on Anadromous Fish Habitat in Western America. Pacific NW Forest and Range Exp. Sta. USDA For. *Serv.,* Portland. Gen. Tech. Rep. PNW-96.

Reynolds, Forrest L., Robert L. Reavis, and Jim Schuler. 1990. Central Valley Salmon and Steelhead Restoration and Enhancement Plan. California Department of Fish and Game. 115pp.

Skinner, J.E. 1959. Preliminary Report of the Fish and Wildlife in Relation to Plans for Water Development in Shasta Valley. California Department of Water Resources; Shasta valley investigations, Bulletin No. 87.

Snyder, J.O. 1931. Salmon of the Klamath River, California. Calif. Div. Fish & Game. Fish Bull. No. 34. 130pp.

US Fish and Wildlife Service. 1983. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates. US Fish and Wildlife Service, Division of Biological Services, FWS/OBS-82/11. US Army corps of Engineers, TR EL-82-4. 15pp.

US Forest Service. ‘1972. Klamath National Forest fish habitat management plan. US Dept. of Agriculture, California Region. 82pp.

Wales, J.H. 1951. The Decline of the Shasta River King Salmon Run. Unpublished manuscript, Bureau of Fish Conservation, California Department of Fish and Game. 79pp.

West, J.R., 0. J. Dix, A.D. Olson, M.V. Anderson, S.A. Fox and J.H. Power. 1989. Evaluation of Fish Habitat condition and utilization in Salmon, Scott, Shasta, and Mid-Klamath Sub-basin Tributaries 1988/1989. Annual Report for Interagency Agreement 14-16-0001-89508. Klamath National Forest, Yreka, Ca. 90 pp.