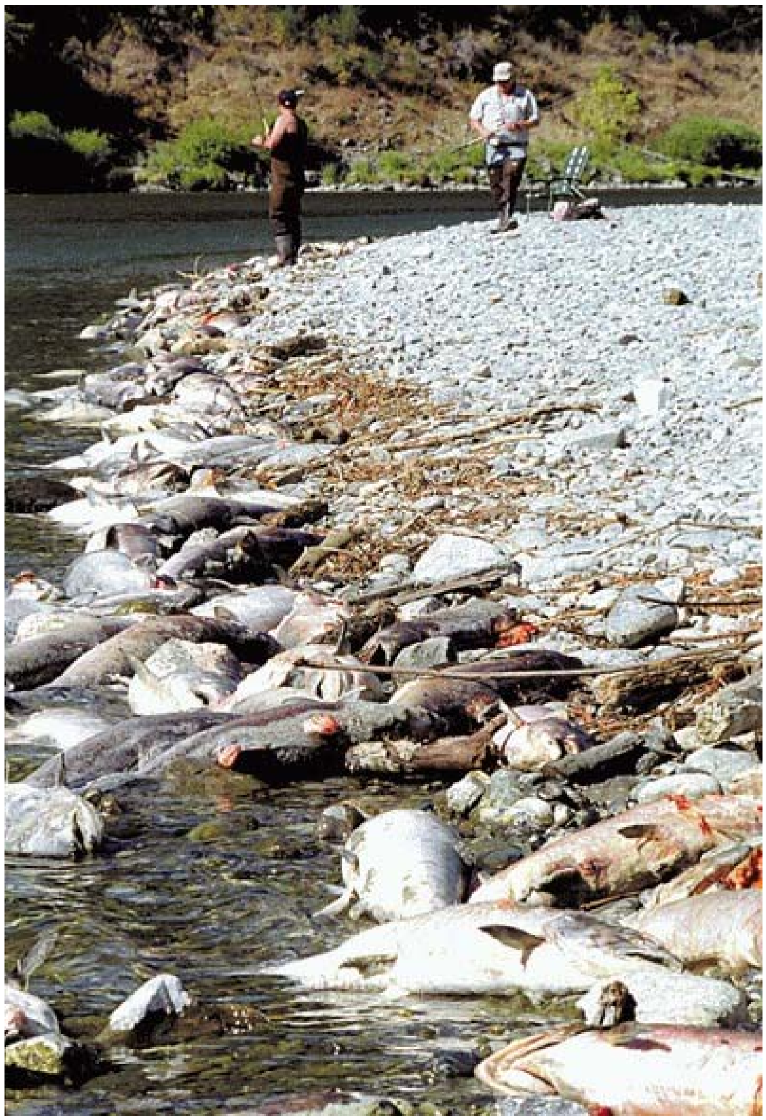
State of California
The Resources Agency
DEPARTMENT OF FISH AND GAME

September 2002 Klamath River Fish Kill: Preliminary Analysis of Contributing Factors



by

Northern California-North Coast Region
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With January 21, 2003 Errata

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1.0 Introduction

This report provides a preliminary analysis of factors leading to the September 2002 fish kill and compares 2002 and other low flow years in the Klamath River when major fish kills were not observed. Factors examined by the Department of Fish and Game (DFG) include fall Chinook salmon run size and timing, ambient atmospheric conditions and in-river environmental conditions. Because some information has yet to be compiled and analyzed, this report will not address the long term impacts of the fish kill on fisheries of the Klamath and Trinity rivers. The DFG will address these impacts to the fishery at a later date.

2.0 The 2002 Fish Kill

2.1 Number of Fish Killed

The first observations of the fish kill were reported to the DFG office in Eureka, California, on September 19, 2002. Subsequently, a cooperative effort including the DFG, U.S. Fish and Wildlife Service (USFWS) and the Yurok, Hoopa, and Karuk tribes was organized to evaluate the numbers of fish killed. Surveys of the lower 36 miles of the Klamath River between the mouth and Coon Creek Falls (Figure 1) were conducted by the cooperators on September 20, 24, and, 27, 2002. Final results are expected in a report by the USFWS at a later date.

Because limited time and resources prevented surveying the entire length of the river bank by foot, the extent of the fish kill was determined from boats. Biologists conducting the boat surveys expressed concern regarding their ability to observe and count all of the dead fish. Therefore, the fish kill estimate should be considered as very conservative. For example, one crew walked a short stretch of the shoreline near the 101 Bridge to collect biological data from the dead fish. The crew stopped walking when they had counted 200 fish. A DFG Senior Fisheries Biologist noted that the counts made during the walking survey were at least four times greater than those made from a boat over the same distance and during the same time frame (Phil Bairrington, DFG Senior Fisheries Biologist, Arcata, personal communication).

Figure 1. Map of the Klamath River Basin showing pertinent features.

As further evidence of the conservative nature of the fish kill estimate, the DFG can relate experience in conducting salmon carcass surveys on the Shasta and Scott rivers to estimate run size. The DFG jaw tags all fresh carcasses encountered on one day and resurveys the same river reach within two to five days to determine the recovery rate for those marked carcasses. The recovery rates for tagged carcasses ranged from 45% to 86% for 1992, 1993, 1994, and 1998 on the Scott and Salmon rivers which suggests a significant portion of the carcasses are missed, eaten by scavengers, or float downstream during each survey (Mark Hampton, DFG Fisheries Biologist, Yreka, personal communication). These recovery rates are from walking surveys done on relatively small rivers which generally have very good water clarity and visibility. Considering the size of the Klamath River, its deep pools and reduced visibility due to poor water quality, it is reasonable to assume that the ability to observe carcasses from a boat during the 2002 fish kill would be even less than the carcass recovery rates on the Scott and Shasta rivers.

The American Fisheries Society (AFS 1992) states: "Estimates of losses based on countable dead fish will be conservative," and adds, "Very seldom will counts represent more than a modest fraction of the fish killed…." Fish kill estimates most often underestimate the true magnitude of losses due to difficulties in conducting such surveys. Limited access; water clarity; the ability to observe dead fish in deep pools, under debris, or in heavily vegetated areas; and losses of carcasses to predators or scavengers are just some of the factors that lead to low estimates. Therefore, the estimates in the lower Klamath River for September 2002 should be viewed as a minimum number of fish killed and may have significantly underestimated the actual numbers of dead fish.

Based on the fish kill surveys, the USFWS reported at the October 9-11, 2002, Klamath Fishery Management Council meeting in Yreka, California, that their preliminary analysis indicated 33,000 fish were killed in the lower Klamath River from September 20–27, 2002.

2.2 Species Composition of Fish Kill

A DFG crew sampled the lower Klamath River (mouth to Blue Creek [Figure 1]) on September 27 and 30, 2002. During the September 27 survey, the crew recorded all fish observed. Because of the decaying nature of the fish, the September 30, 2002, survey did not include complete enumerations of observed fish. Only nondecayed fish were counted to ensure positive identification of fish species. The September 27 data was used for a limited species composition analysis. On this date, a total of 631 dead fish of were identified; of which 601 (95.2%) were Chinook salmon, 3 (0.5%) were coho salmon and 27 (4.3%) were steelhead trout. These percentages differ slightly from the preliminary USFWS estimates, where out of the 33,000 anadromous fish that were killed, 96% were Chinook salmon, 1.5% were coho salmon and 2.0% were steelhead trout. Carcasses of sculpin, Klamath River smallscale sucker, speckled dace, coastal cutthroat trout, and green sturgeon were also identified during the fish kill.

2.3 Natural vs. Hatchery Fish Composition

During the September 27 and 30, 2002, sampling effort, 661 Chinook salmon carcasses were examined and adipose fin-clips were detected on 29 (4.4%) of those fish. Coded wire tags (CWT) recovered from the marked Chinook salmon were analyzed (and expanded for the proportion of hatchery fish that are marked) indicating that 87 fish of the total were of Trinity River Hatchery origin and 122 were of Iron Gate Hatchery origin. Consequently, 209 (32%) of the 661 fall Chinook salmon sampled were of hatchery origin. Therefore, the best available estimate is that 68% of the Chinook salmon that died were naturally produced fish.

Although the September 30 survey was not used for a species composition analysis, the fin-clip subtotals for each species were used to gauge the number of coho salmon and steelhead of hatchery origin. Over the two days of sampling, 13 coho salmon were observed with ten having a right maxillary clip indicating Trinity River Hatchery origin and three unmarked fish of natural origin. In addition, a total of 106 steelhead were observed, 49 (46.2%) of which were adipose fin clipped and of hatchery origin and 57 (53.8%) were unmarked natural fish. Consequently, a larger proportion of naturally produced Chinook salmon and steelhead died during the fish kill than hatchery origin fish of those species.

3.0 Potential Contributing Factors

3.1 Pathogens

The cause of death for adult Chinook and coho salmon and steelhead during September 2002 was disease from the ciliated protozoan *Ichthyopthirius multifilis* (ICH) and the bacterial pathogen *Flavobacter columnare* (columnaris) (Attachment 1 and 2). These parasites occur naturally, are common worldwide, and are present at all times in the Klamath River and other aquatic systems. Fish entering the lower Klamath River during mid-September 2002 encountered low flows and high water temperatures (69˚F or 20.5˚C). Temperatures in this range are stressful to coldwater fish species, and provide favorable conditions for certain fish pathogens such as ICH and columnaris. During September 26 and 27 examinations of dead fish, DFG's Fish Health Laboratory found ICH and columnaris to be the principal disease present. Fish caught by sport fishermen (those still healthy enough to be feeding) were primarily infected with ICH. Dead and dying fish were infected with both ICH and columnaris.

High water temperatures and low flows present in September favored amplification (rapid development) of ICH. The life cycle of the parasite is direct (needing no intermediate host), with the adult phase of the protozoan (trophozoites) residing on fish, cysts being formed by mature trophozoites leaving the fish to find substrate, and infective tomites (immature stage of the protozoan) leaving cysts to infect new fish. This cycle is temperature dependent and accelerated with warmer temperatures. At water temperatures of 69˚F (20.5˚C) trophozoites will reside on fish for approximately five or six days. Mature trophozoites leave the fish and are free swimming for two to six hours. They then attach to the substrate, secrete a thin protective membrane over their body forming a cyst, and reproduce by multiple fission, producing up to 2,000 tomites per cyst. This process takes about 16 to 18 hours at 69˚F (20.5˚C). The tomites then break from the cyst and swim to a new fish host. Those not finding a host within about 24 hours will die. Successful tomites penetrate fish skin and gills to feed on host tissues, growing in size to adult trophozoites. The cycle then repeats. Success in finding a new host is aided by low water flows and high fish density. Both of these conditions prevailed during mid- to late September 2002. The amplification of ICH proceeds quickly at the temperatures such as those in the lower river during September, resulting in heavy parasite burdens on fish. When large numbers of tomites are being released, mortality can result from "super infections". Dickerson and Dower (1995) state: "In early stages of infection large numbers of theronts (tomites) can actually kill a fish before the parasite becomes visible, and death is caused by massive damage to the gill epithelia."

ICH infestation of gill tissue results in hyperplasia (an abnormal increase in the number of gill epithelial and mucus cells) which increases the distance between oxygen-carrying erythrocytes (blood cells) and oxygen-supplying water. Combined with the lower oxygen content of warmer water, the ability of fish to obtain necessary oxygen is greatly impaired. Death is by asphyxiation. Additionally, skin infections by ICH disrupt the integument (outer layer of skin) resulting in the loss of sodium and magnesium ions causing osmoregulatory (diffusion of fluids and ions through membranes) disturbances.

ICH can be found on fish at any temperature, but typically only cause disease and mortality in salmonid species at water temperatures above 58˚F (14.4˚C) and in crowded conditions such as those experienced with the low flow in the lower Klamath River during September 2002.

In British Columbia beginning in 1994, severe prespawning mortality was observed in sockeye salmon in the Babine River (Skeena River system). Losses of 80% to 90% of adults occurred in spawning channels. Warm water (18 to 22˚C, or 64.4 to 71.6˚F) for one to two weeks in late August, coupled with a high density of fish were the primary contributing factors. In contrast, records show that low numbers of fish returning to warm water have not experienced significant losses. On the other hand, occasional losses can be experienced when high numbers of fish return, even at cooler temperatures (10˚C or 50˚F). This emphasizes the effects of high fish density on ICH infestations. Similar losses have been observed in the Fraser River system for sockeye and Chinook salmon. Generally, the combination of warm water and high fish density sets the stage for severe ICH outbreaks (Mark Higgins, Dept. Fisheries and Oceans, Canada, personal communication).

Columnaris is common worldwide and present at all times in the aquatic environment. Columnaris disease in coldwater fishes is generally seen at water temperatures above 15˚C (59˚F), and the disease can become explosive at 18˚C (64˚F). In natural infections, disease is often chronic to subacute (not resulting in death), affecting skin and gills. Columnaris lesions are commonly seen in Chinook at some California hatcheries (Nimbus, Feather River, Merced), but prespawning mortality has not been a problem. In contrast, during August 2002, spring Chinook returning to Butte Creek (Butte County, California) became seriously infected with columnaris. Severe prespawning mortality was attributed to water temperatures in the mid 70s˚F, stressing fish and favoring bacterial multiplication on the debilitated salmon.

3.2 Flow

The U.S. Geological Survey (USGS) records for September flows are relatively complete since 1951 for the Klamath River near Klamath, California (KNK, USGS 11530500) and since 1961 for the Klamath River below Iron Gate Dam, California (KIG, USGS 11516530) (Figure 2). The KNK data was used to identify other low flow years (1988, 1991, 1992, and 1994) where average September flows were either similar to or less than those occurring during the 2002 fish kill. The average September flow in 2002 for the KNK (2,129 cfs) used in this analysis is provisional (may be subject to change) and does not reflect daily flows after September 26, 2002. This is the period when the U.S. Bureau of Reclamation (USBR) directed Pacificorp to increase releases from Copco and Iron Gate reservoirs from 760 cfs to 1,300 cfs in an effort to abate the fish kill. Although flows were substantially higher in September 2001 than 2002 as a requirement of the 2001 Biological Opinion for operation of the Klamath Project, 2001 was actually a drier year and has been included in this analysis. For the purposes of this preliminary analysis, the focus is on the similarities and differences in September between the low flow years of 1988, 1991, 1992, 1994, 2001, and 2002 when the fish kill took place.

The 1988 data (Figure 3) show September flows near the mouth of the river at Klamath (KNK) were comparable to provisional flows in 2002 (approx. 2100 cfs). Discharges from Iron Gate Dam and flows in the river at Klamath during September 1991 and 1992 were some of the lowest on record for the past 50 years (Figure 2). Releases and flows were less than those during

Figure 2. Average September flows for the Klamath River at Klamath, Del Norte County, California since 1950 and below Iron Gate Dam, Siskiyou County since 1961 (2002 data is provisional and may be subject to change).

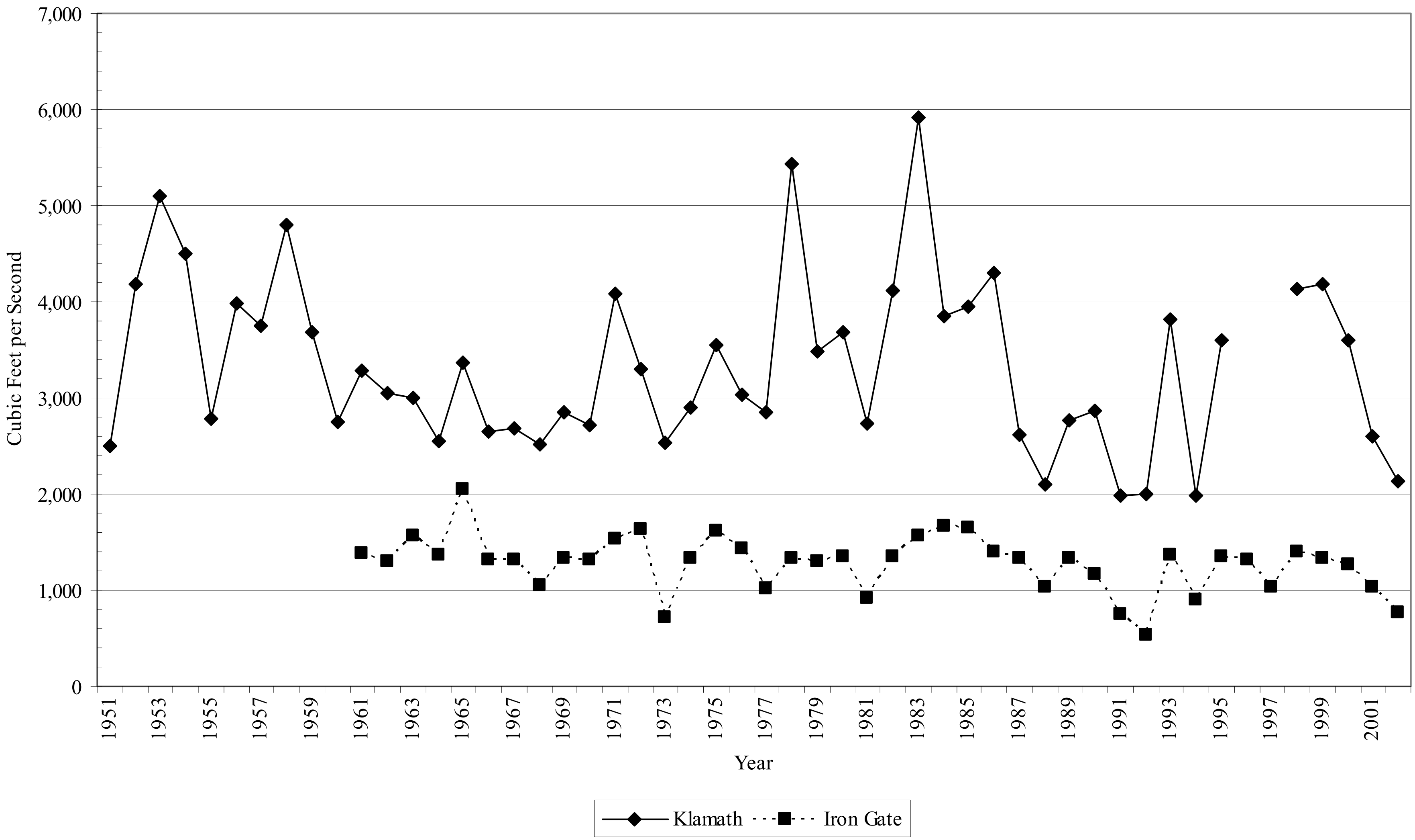
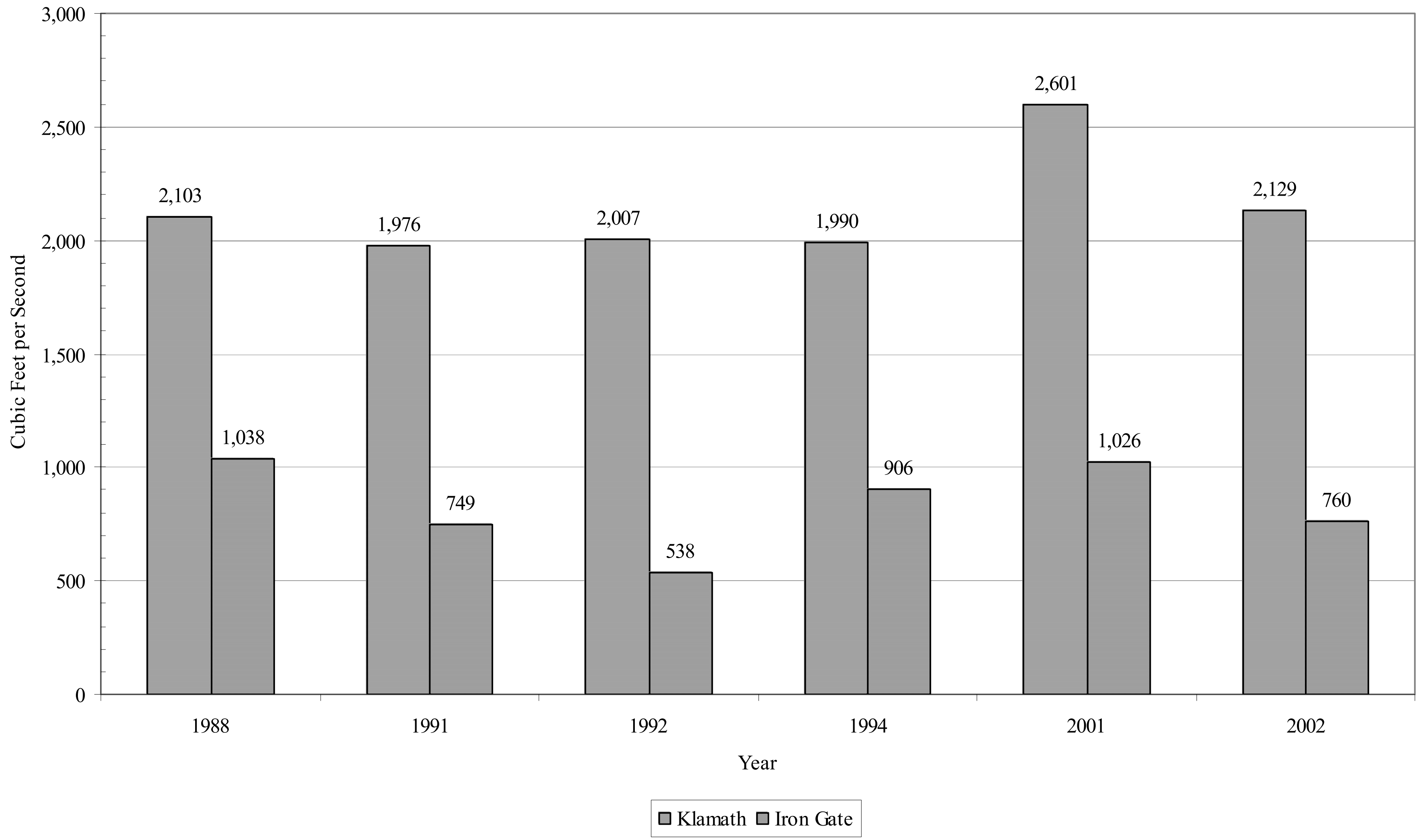


Figure 3. Average September flows for the Klamath River at Klamath, Del Norte County, California and below Iron Gate Dam, Siskiyou County for low flow years (2002 data is provisional and may be subject to change).



the 2002 fish kill. Discharges at Iron Gate Dam were greater in September 1994 (906 cfs) than in 2002 (760 cfs). Flows in the lower river near Klamath, however, were lower in 1994 (1,990 cfs) compared to 2002 (2,129 cfs). Discharges at Iron Gate Dam were 1,026 cfs in 2001 compared to 760 cfs for 2002, while September flows in the lower river were almost 500 cfs greater in 2001 than 2002.

While the KNK data shows similar or lower average flows in 1988, 1991, 1992, and 1994 compared to September 2002 (2002 data is provisional), these low flows occurred in only 8% of the years for the period of record since 1951. These low flow years mostly coincide with the prolonged drought of the early 1990s (Figure 2). In 92% of the years since 1951, average September flows were higher at KNK than during 2002. Prior to 1988, average September flows never approached the low level observed during 2002. Flow releases from Iron Gate Dam show a similar trend. Average September flow records for KIG were lower in 1973, 1991, and 1992 than those observed in 2002 (Figure 2). The KIG records show that in 93% of the years since 1961, flow releases from Iron Gate Dam were higher than the flows during the September 2002 fish kill.

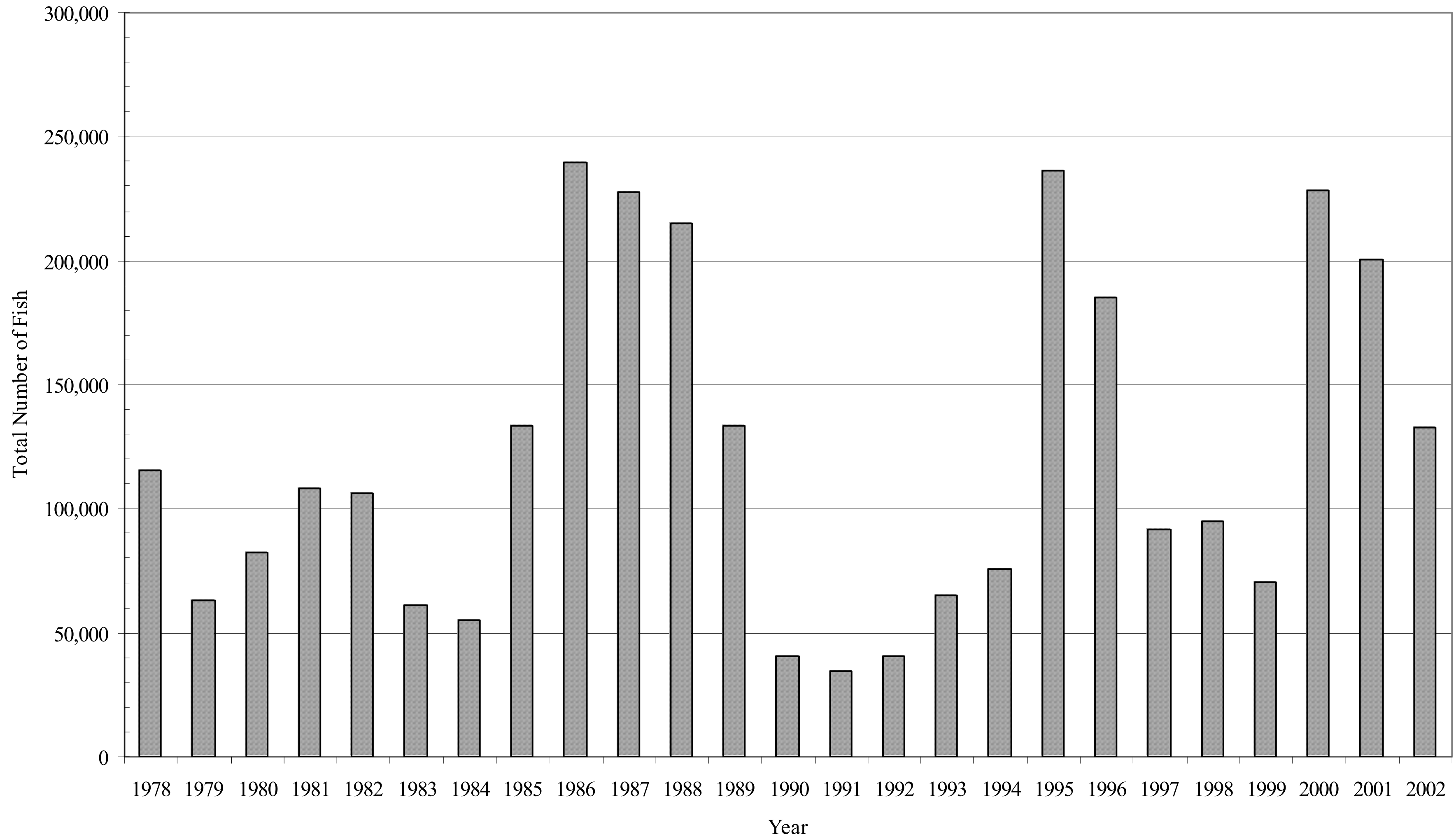
There have been stakeholder concerns that the 2002 fish kill may have been related to high agricultural water diversions from the Shasta and Scott rivers, resulting in abnormally low flows in the lower Klamath River. The California Department of Water Resources (CDWR) has reconstructed estimates of the unimpaired flow contributions (natural flow that would occur if there were no dams or diversions) for various Klamath Basin drainages to the total Klamath River outflow (CDWR 1997). CDWR found that over a period of record from 1945 to 1994, the Shasta and Scott rivers if unimpaired would contribute 1.5% and 3.6%, respectively, of the total average annual flow to the Klamath River. In addition, CDWR estimates that current annual water use in the Shasta River and Scott River basins equal 110,000 acre-feet and 71,800 acre-feet, respectively. In comparison, average annual irrigation and urban water use above Keno Dam in Oregon totaled 503,700 acre-feet (CDWR 1997).

3.3 In-River Run Size for Fall-Run Chinook Salmon

Fall Chinook salmon represented the majority of the adult fish mortalities that were observed during the September 2002 fish kill. This was expected since fall Chinook are the predominant run of salmon entering the Klamath River system during September of each year. Thus, fall Chinook salmon were used in the analysis of run-size and timing. The size of the projected preseason 2002 total in-river fall Chinook salmon run was compared with historic estimates of run size for the years 1978–2001, to ascertain the relative abundance of the 2002 run. The projected 2002 run was then compared with estimated fall Chinook salmon runs that occurred during years (1988, 1991, 1992, 1994, and 2001) when September Klamath River flows were similar to or less than those seen in 2002 to determine how the 2002 fall Chinook run compared in size to other low flow years.

There were stakeholder claims that the 2002 fall-run of Chinook salmon in the Klamath River Basin was very large. Since 1978, the DFG has kept records of the Klamath River Basin fall Chinook salmon spawner escapement, in-river harvest, and run size estimates in what is commonly referred to as the "megatable." Figure 4 shows the total in-river run size for fall Chinook salmon for the period of record since the megatable has been kept. The 2002 run size of 132,600 fish represents a preseason projection and actual estimates will not be available until February of 2003. Runs have varied in size from a low of 34,353 fish in 1991 to a high of 239,366 fish in 1986 (Figure 4). The mean run-size for the twenty-four-year period of record is 120,983 fish, slightly lower than the 2002 preseason projection of 132,600 fish. The projected 2002 Klamath River fall Chinook salmon run is only 9.6% above average in size. If the 2002 preseason projections hold, the 2002 run will be the tenth largest recorded since 1978. Therefore, it is more appropriate to refer to the 2002 projections for in-river run size of fall Chinook salmon as representing a slightly above-average run.

Figure 4. Total in-river run estimates for fall Chinook salmon in the Klamath Basin since 1978 (2002 is a preseason projection and subject to revision).



The projected 2002 run was also compared to runs associated with five other low flow years occurring in 1988, 1991, 1992, 1994 and 2001 (Figure 5). Returning numbers of fall-run Chinook salmon were the lowest of record in 1991 (34,353) and 1992 (40,346) and were substantially lower than the 2002 projection (132,600). The 1994 returns (75,936) were also below average and only 57% of the 2002 projections. The number of in-river fall Chinook salmon was actually higher in 1988 (215,322) than in 2002. Similarly, the run size in 2001 (200,579) was nearly 70,000 fish higher than during the 2002 fish kill. Thus, of the six years analyzed, the 2002 projected run is of medium size with two years of significantly larger runs (1988 and 2001) and three years of significantly smaller runs (1991, 1992, 1994) (Figure 5). Both 1988 and 2001 represent the only low flow years when flow discharges from Iron Gate Dam were above 1,000 cfs (Figure 3).

3.4 Run Timing for Fall-Run Chinook Salmon

The run-timing of the 2002 fall Chinook salmon run in the lower Klamath River was compared to the runs of the aforementioned low water years to evaluate potential differences in run-timing characteristics that may have influenced the fish kill. This was accomplished by examining the in-river sport and tribal fishery data for the lower Klamath River below Coon Creek Falls, River Mile (RM) 36. Complementary data was also evaluated for the timing of runs at the Willow Creek Weir on the Trinity River, Trinity River Hatchery, Shasta River Fish Counting Facility and the Iron Gate Hatchery.

3.4.1 Beach Seining Records and Creel Census Data for the Klamath Estuary

The DFG collected beach seining data for the Klamath River Estuary in 1977, 1979, 1981, and 1984 – 1990. This information was used to evaluate the timing of Chinook salmon runs in the lower Klamath River. During the period of record (1977 – 1990), Chinook salmon runs peaked in the estuary from mid-August to mid-September (Figure 6). On average, these runs peaked in early to mid-September (Figure 7), during the time period corresponding to the beginning of the 2002 fish kill.

Figure 5. Total in-river run size estimates for fall Chinook salmon in the Klamath Basin for low flow years (2002 is a preseason projection and subject to revision).

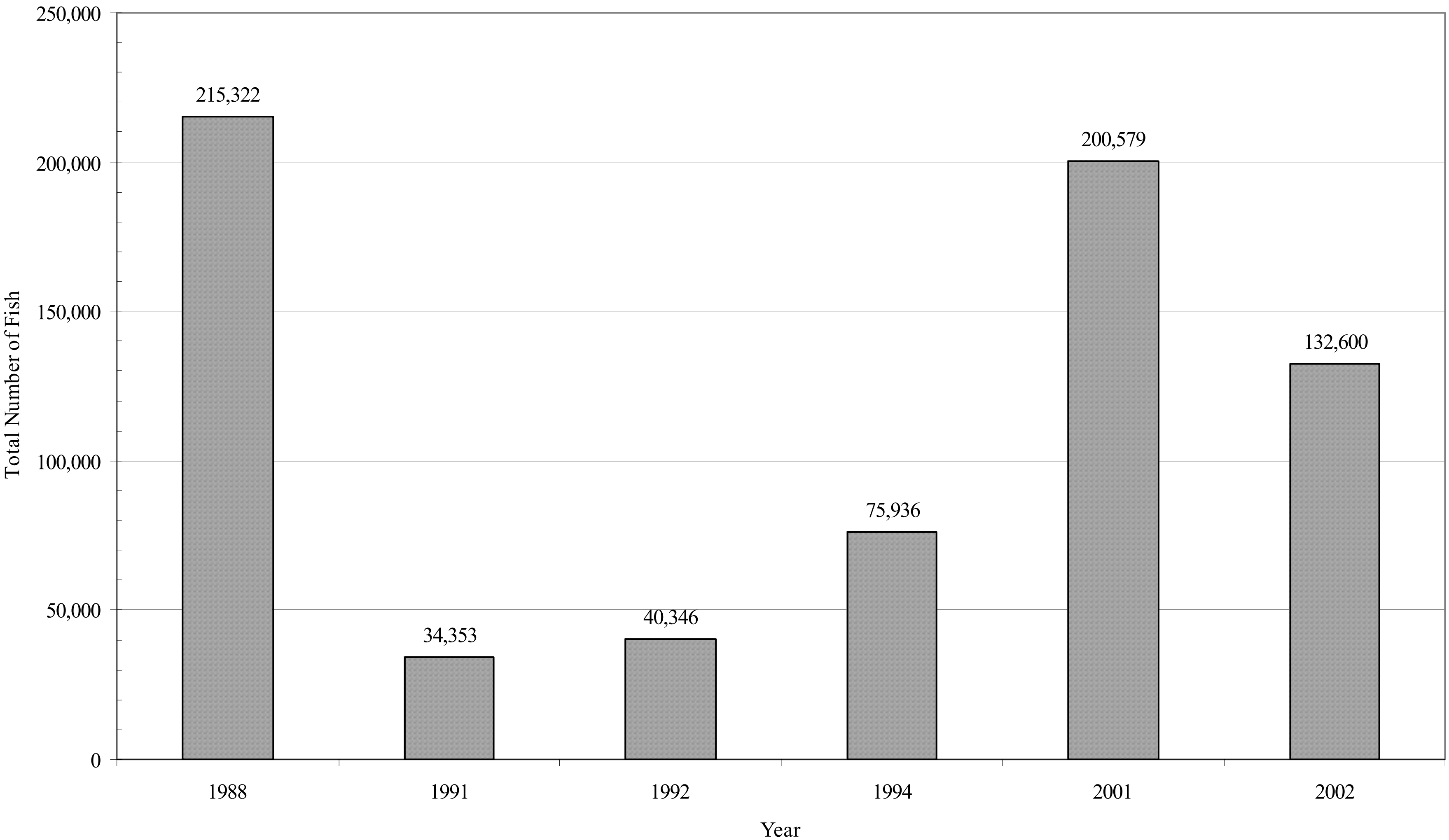


Figure 6. Run timing for Chinook salmon in the Klamath River Estuary, Del Norte County as the number of fish collected by beach seining during 1977, 1979, 1981, and 1984 through 1990.

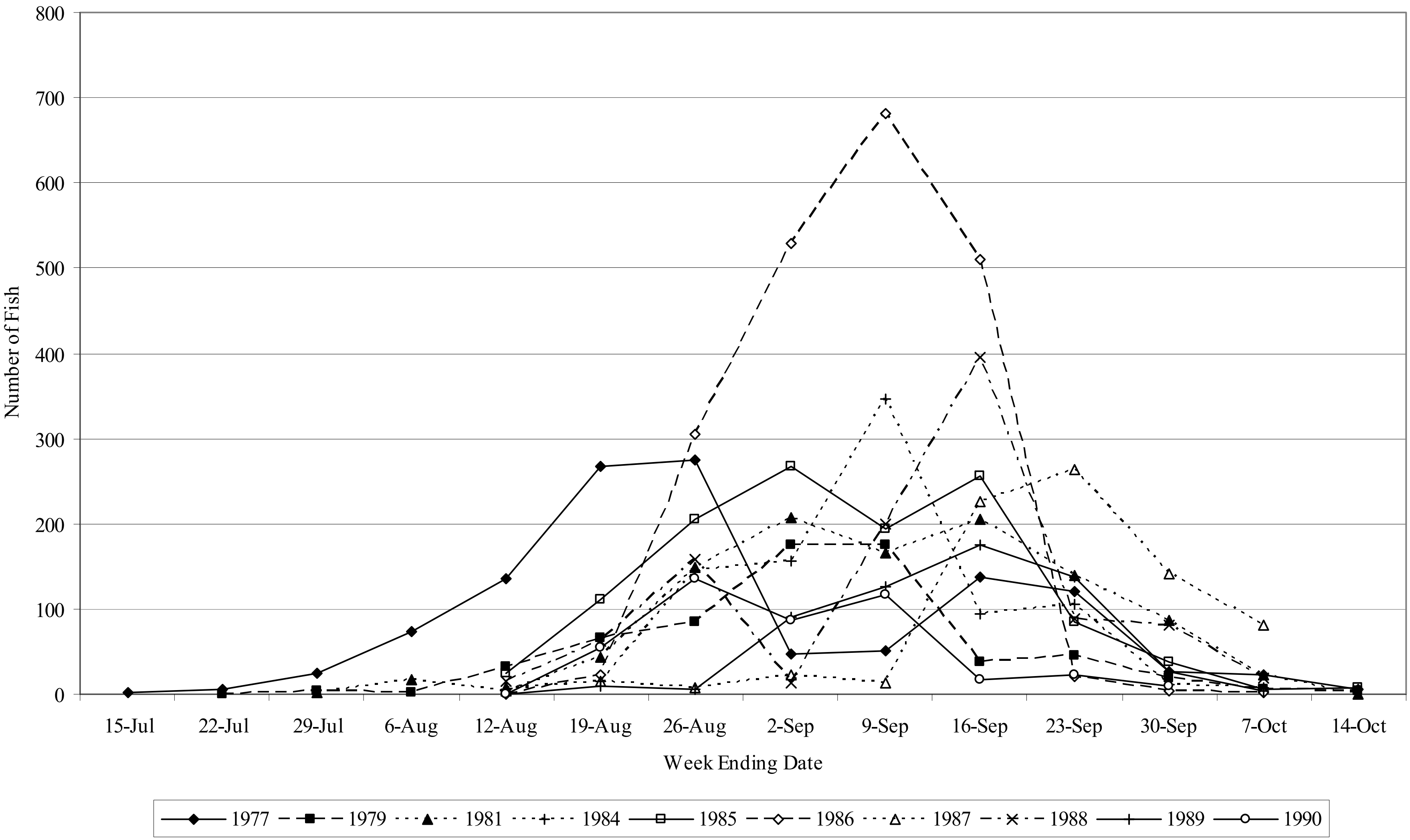
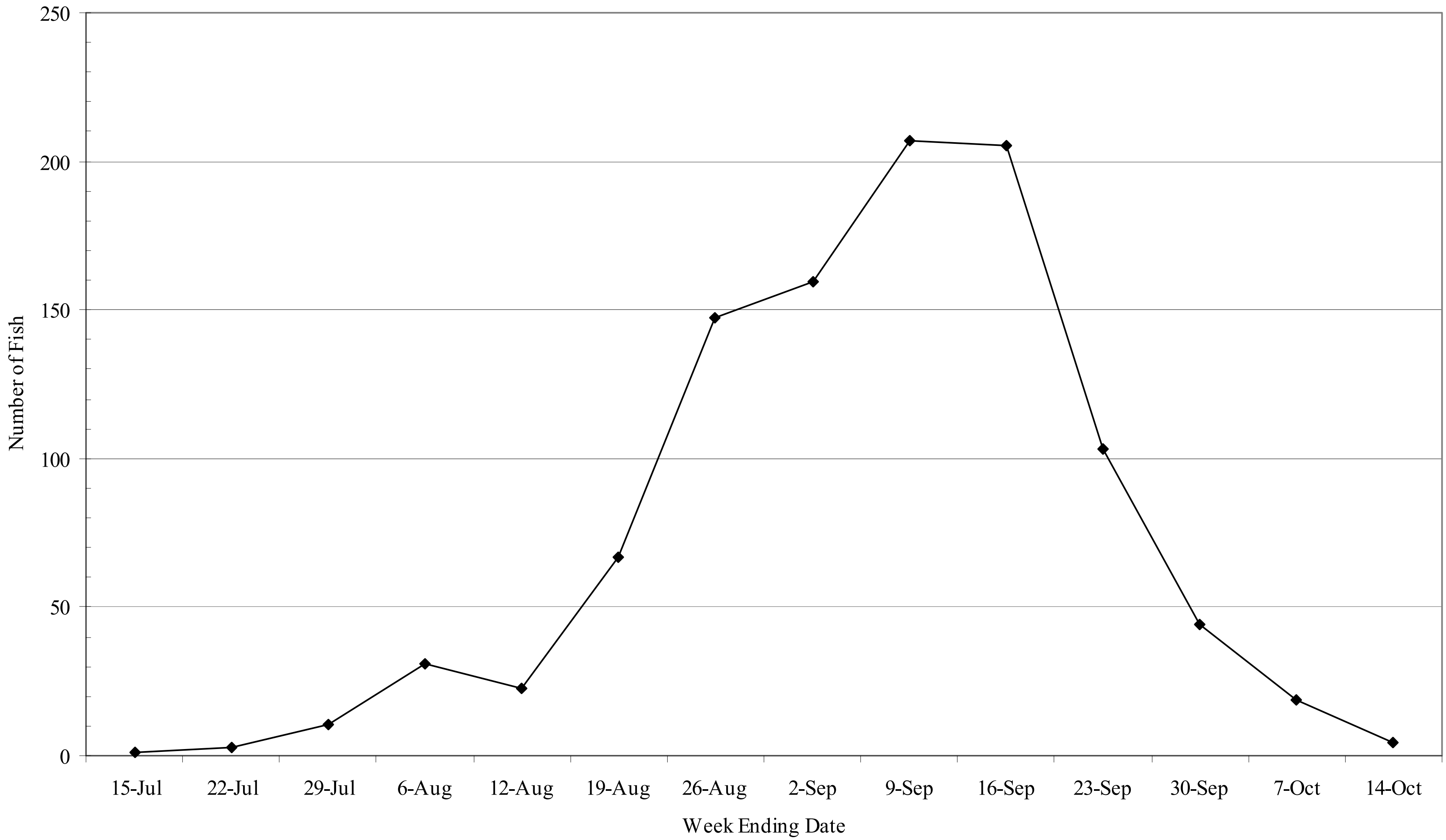
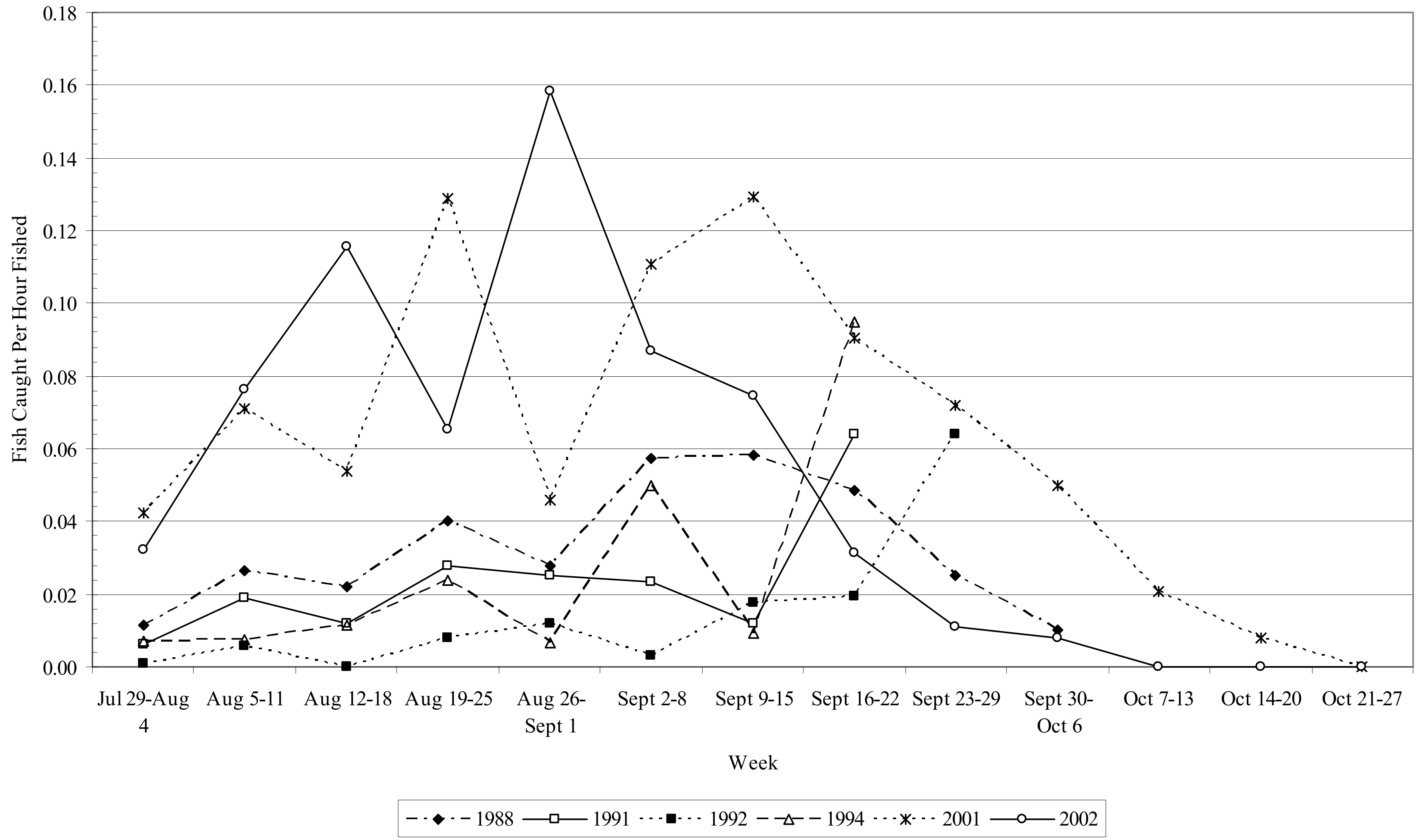


Figure 7. Run timing for Chinook salmon in the Klamath River Estuary, Del Norte County as an average of the number of fish collected by beach seining during 1977, 1979, 1981, and 1984 through 1990.



Creel census data collected by DFG on the sport fishery of the lower Klamath River was also evaluated for low flow years. Weekly catch per unit effort (CPUE = numbers of adult Chinook salmon caught by sport anglers per the number of hours fished) was used as an indication of timing for the presence of Chinook salmon in the lower river (Figure 8). The CPUE data for 1991, 1992 and 1994 indicated an increasing run size during mid to late September, but surveys ended at that point as the sport fishing harvest quotas were exceeded. The large runs of Chinook salmon (over 200,000 fall-run) returning in 1988 and 2001 showed a surprisingly similar trend in CPUE (Figure 8). Both years had two peaks (bi-modal) in CPUE with the first peak during the week of August 19-25 and the second peak during the week of September 9–15. Prior to the fish kill in 2002, the CPUE also showed two peaks, the first in the week of August 12–18 and the second in the week of August 26–September 1. It appears that this moderate sized run of fish in 2002 peaked a week or two earlier than in other low flow years. However, relatively high CPUEs, when compared to other low flow years, were still observed from September 2 to 15, 2002, indicating the presence of a large number of fish. Caution should be used in interpretation of CPUE data starting the week of September 16–22, 2002, when the fish kill was first evident. The CPUE data after the beginning of the fish kill will likely be biased to the low side since angler effort and the numbers of fish available for anglers to catch would be expected to decline. The DFG is uncertain if the CPUE would have declined as dramatically in September of 2002 if the fish kill had not occurred. It is important to understand that the run timing data for the lower Klamath River from past beach seining and creel census studies includes both spring-run and fall-run Chinook salmon, whereas the fish kill in 2002 affected only fall-run fish (indicated by recovered coded wire tags). In some years, the run exhibits two peaks (bi-modal) with spring-run Chinook peaking in mid-August followed by a fall-run peak in mid-September. This bi-modal run timing was particularly evident in 1977, 1988, and 2001; was less clear but evident in 1985, 1990, 1991, 1992, 1994, and 2002; and not evident in 1979, 1981, 1984, 1986, 1987, and 1989 (Figures 6 and 8).

Figure 8. Weekly catch per unit effort (adult Chinook salmon caught per angler hour fished) for the lower Klamath River, Del Norte County creel census as an indicator of run timing during low flow years.



3.4.2 Willow Creek Weir, Trinity River

The Willow Creek Weir (WCW), located on the Trinity River at RM 66 (Figure 1), is operated from late August through early to mid-November as a fish tagging facility, but does not provide direct estimates of total run size. Estimates of total (natural and hatchery runs) fall Chinook run size for the Trinity River above the WCW are based on mark and recapture statistics of WCW tagged fish recovered at the Trinity River Hatchery. However, there is generally a strong correlation between the number of fish trapped and marked each year at the WCW and that year's Trinity River run size (Wade Sinnen, DFG Fisheries Biologist, Arcata, personal communication). The WCW, therefore, provides an index of relative run size that can be compared among different low flow years.

For the six low flow years analyzed, the WCW index of run size has varied from a low of 348 fall Chinook trapped in 1992 to a high of 2,819 in 1988 and 2,800 in 2001 (Figure 9). The index of run size was moderately low in 1991 (954 fish), moderately high in 1994 (2,165 fish) and low (614 fish) in 2002. To evaluate the significance of the low 2002 WCW index of run size, a comparison was made of the ratios of the index to the estimated total basinwide in-river run for each year. This ratio represents the relative (not actual) contribution of the Trinity River (above the WCW) to the total basinwide run. The ratios, from lowest to highest were as follows: 0.005 (2002), 0.009 (1992), 0.012 (2001), 0.013 (1988), 0.028 (1991), and 0.029 (1994). The 2002 ratio was 44% smaller than the next lowest ratio (1992), suggesting strongly that the September 2002 fish kill severely impacted the Trinity River run size. Potential impacts to the Trinity River fall Chinook salmon run will be evaluated at a later date.

The date that the Trinity River fall Chinook run commences at the WCW varies from the last week in August to the first week in September. It is determined by real-time coded wire tag analysis that separates fall from spring-run Chinook salmon. The run generally peaks during the last week of September and/or first week of October and then drops off to a trickle by early to mid-November (Figures 10 and 11). A closer inspection of the 2002 and 2001 runs shows that during the October 1-15, 2001, period, the run peaked and 873 fall Chinook salmon were trapped

Figure 9. Total count of trapped fall Chinook salmon at the Willow Creek Weir (WCW), Humboldt County and total returns to Trinity River Hatchery (TRH), Trinity County for low flow years (no TRH data was available for 1988 and 2002 data is provisional).

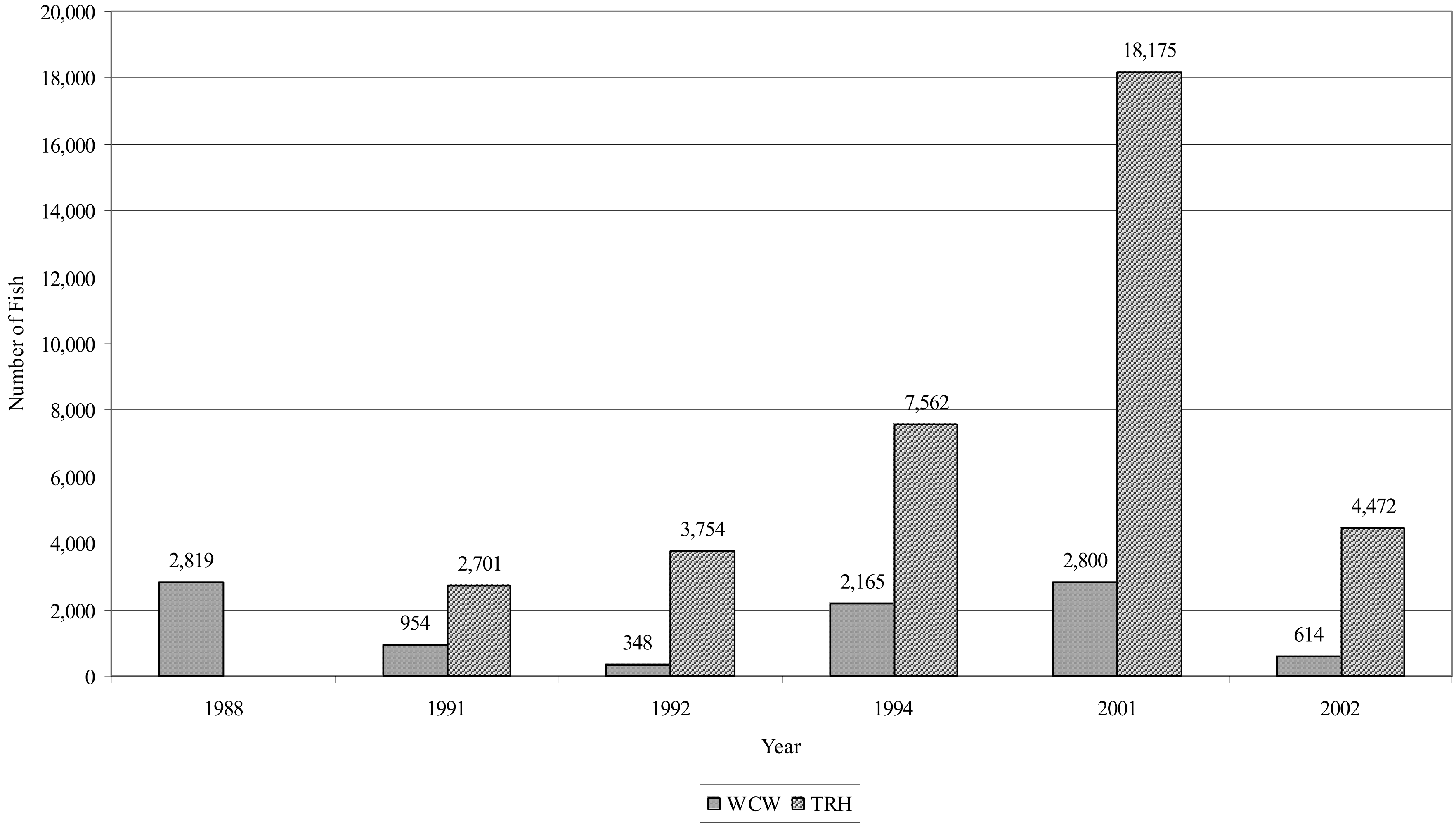


Figure 10. Run timing for fall Chinook salmon from the Willow Creek Weir (WCW), Humboldt County on the Trinity River for low flow years 1988, 1991, 1992 and 1994.

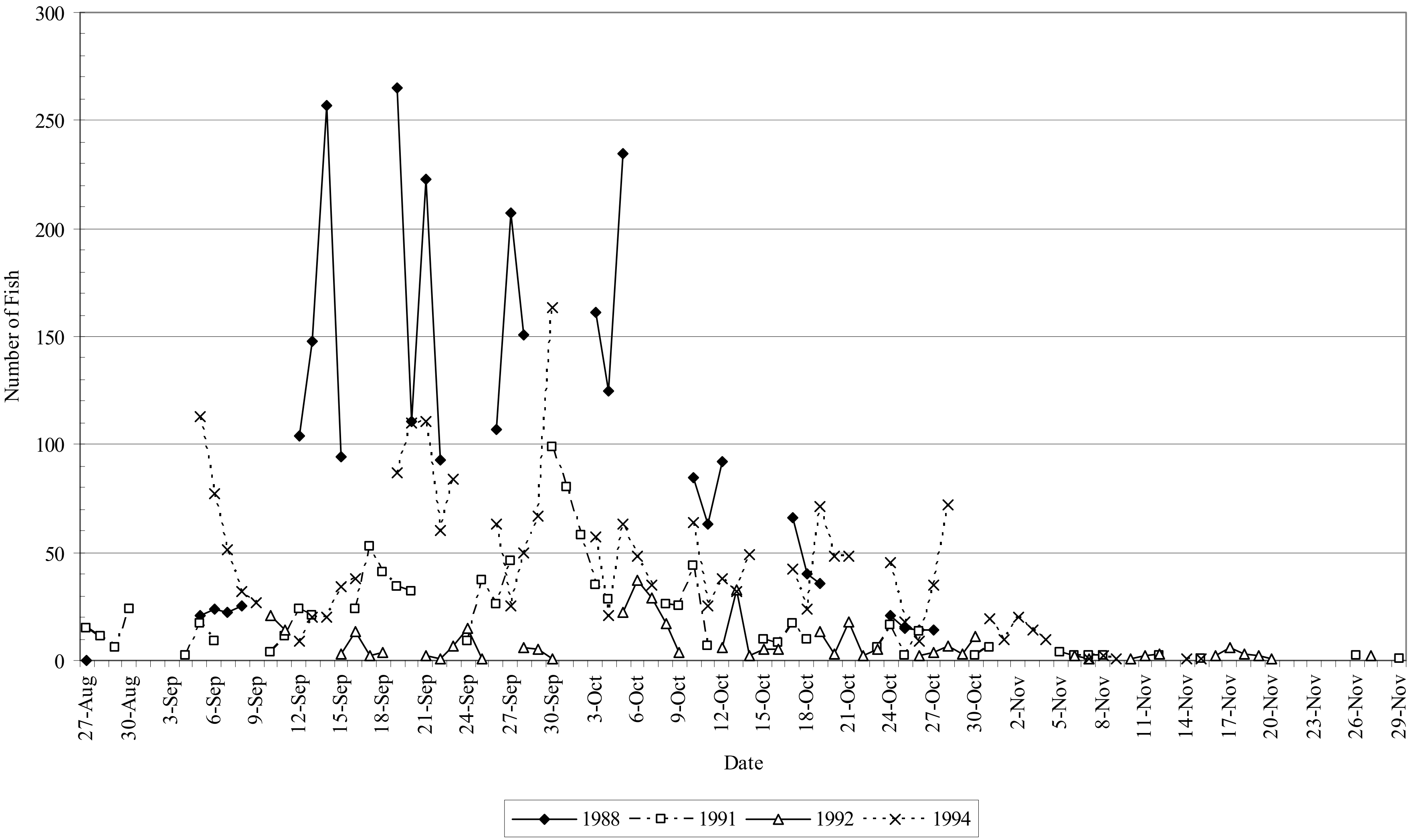
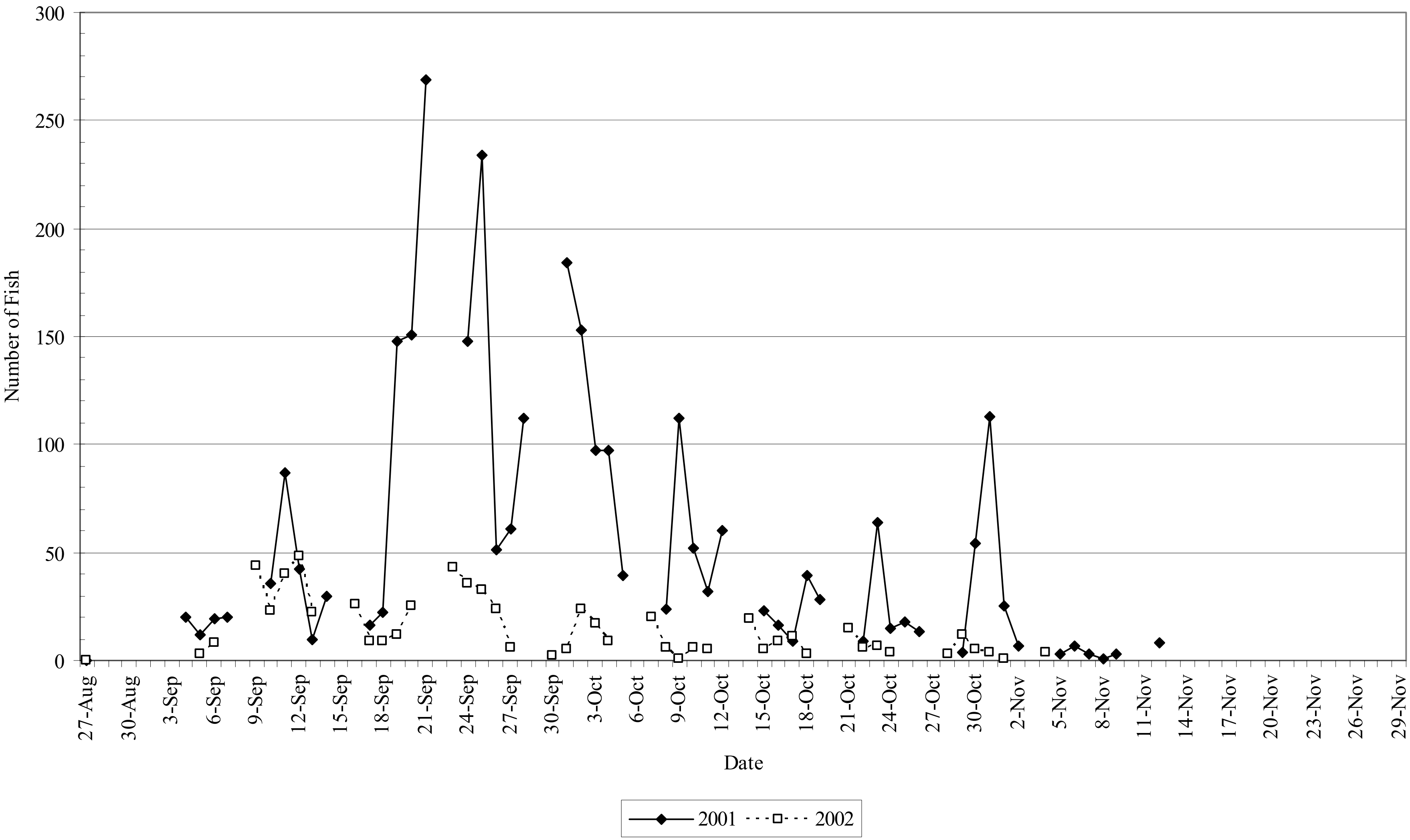


Figure 11. Run timing for fall Chinook salmon from fish counts at the Willow Creek Weir (WCW), Humboldt County on the Trinity River for low flow years 2001 and 2002.



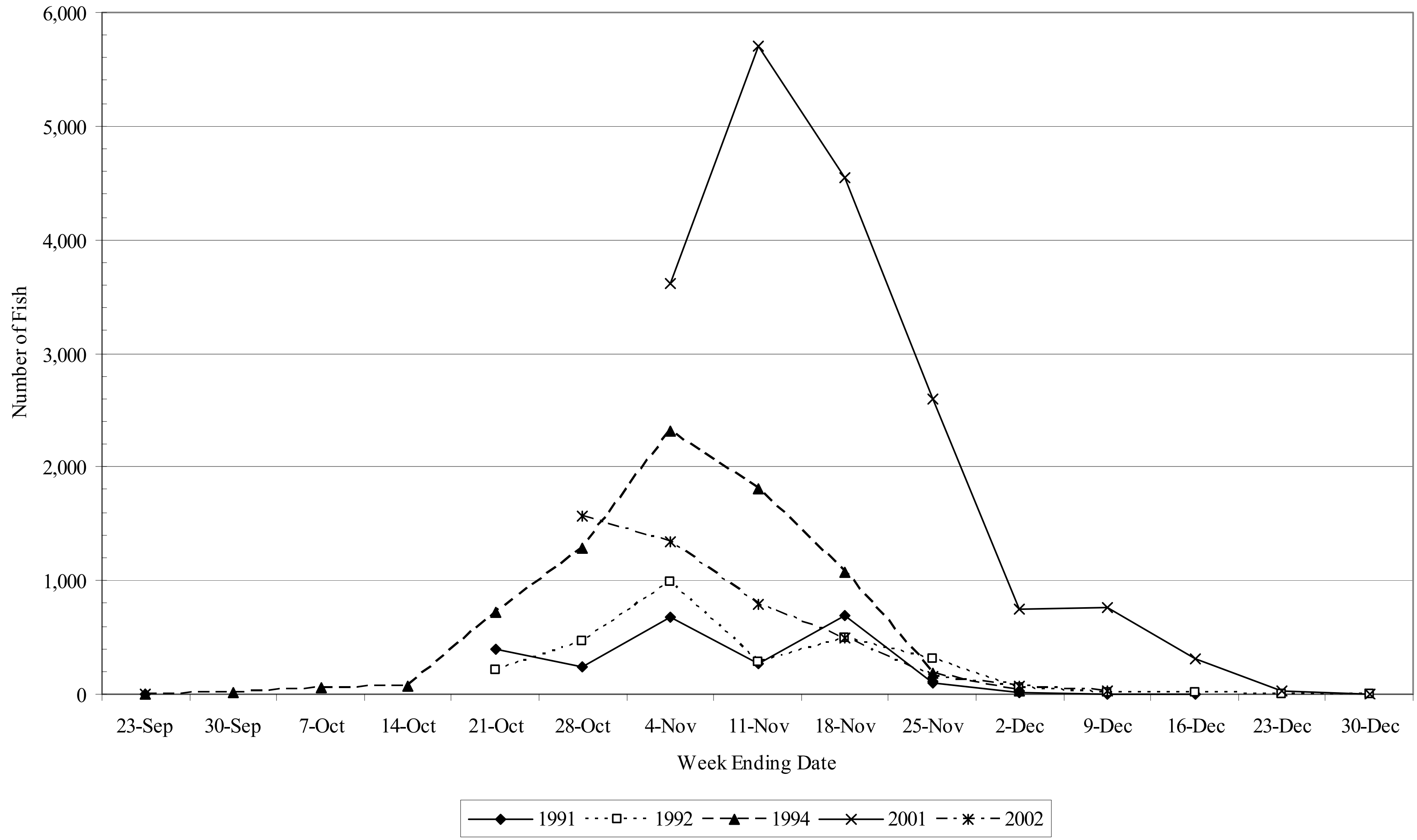
at the WCW. During this same period in 2002, when the run was expected to also peak, it instead declined and only 117 fish were trapped (Figure 11). Given that the projected size of the 2002 run was about 2/3 the size of the 2001 run, it would be expected that the 2002 run would have contributed approximately 500–600 fish during this period. Studies of migration rates between the WCW and Trinity River Hatchery have determined that, on average, fall Chinook salmon travel approximately 2.3 miles per day. Therefore, it would take a Chinook salmon approximately 13 days to travel from Coon Creek Falls (RM 36), the approximate upper limit of the fish kill, to the WCW (RM 66) (30/2.3 = 13). Given that the fish kill was first detected on September 19, it would not be until approximately October 2, thirteen days later, that the impacts of the kill would be felt at the WCW. This is exactly what the run-timing data for 2002 show.

3.4.3 Trinity River Hatchery

Trinity River fall Chinook salmon begin entering TRH during mid-October. The run reaches its halfway point in the first week of November and concludes by the second or third week of December (Figure 12).

The run size for Trinity River Hatchery (TRH) fall Chinook salmon mimicked the trends of the total basinwide in-river run for the low water years of 1991, 1992, 1994, and 2001 (Figure 9). There is no data available to evaluate the 1988 TRH run. When total basinwide in-river runs were large, returns to TRH were high and when total in-river runs were small, TRH returns were likewise low. The exception is 2002, when the returns to TRH are, to date, far below what would be expected given the projected basinwide run size. For the years 1991, 1992, 1994, and 2001, the contribution of the TRH fall Chinook run accounted for an average 9.2% (range: 7.8–10.1%) of the total basinwide in-river run. Unlike the contribution of Iron Gate Hatchery, which changed little between 2001 and 2002, the 2002 TRH contribution to the total run diminished substantially from 9.1% in 2001 to only 3.2% in 2002. As would be expected with the larger runs of returning salmon to IGH, the coded wire tag recovery data showed a higher number of IGH fall Chinook were killed than TRH fish (see section 2.3). However, since fall Chinook salmon runs are smaller at TRH than IGH, it appears that a higher proportion of the total number of returning TRH fish were lost during the fish kill than IGH fish.

Figure 12. Weekly returns of hatchery fall Chinook salmon to the Trinity River Hatchery, Trinity County during low flow years.



Detailed run timing for TRH was not determined since fish are not counted until they are processed at the hatchery. There is often a delay in processing that is dependent on run size. Any differences that may exist in run-timing are masked by artifacts of hatchery operation and the limitations inherent in the handling of large numbers of fish. Count data are aggregated into weekly time steps that do not provide the resolution to detect within week count variations.

3.4.4 Shasta River Fish Counting Facility

The Shasta River Fish Counting Facility (Figure 1) conducts complete counts of adult fall Chinook salmon escapement to the Shasta River and is generally operated from early September through mid-November, flow conditions permitting.

Shasta River's run size and timing were highly variable during the low water years analyzed (1988, 1991, 1992, 1994, 2001, and 2002). Runs were relatively large in 2001 (11,093 fish), moderate in 1994 (5,203 fish) and 2002 (6,903 fish), extremely low in 1988 (846 fish) and 1991 (646 fish), and a record low in 1992 (521 fish) (Figure 13). An anomalous situation occurred in 1988 when a large run (215,322 fish) returned to the Klamath Basin, yet the Shasta River contributed only 846 fish (0.4%) to this run. During the low run years of 1991 and 1992, the contribution rate of the Shasta River to the basinwide run was 1.9% and 1.3%, respectively. During 1994, 2001, and 2002, the Shasta River contributed 6.9, 5.5 and 5.2%, respectively; to the total Klamath Basin fall Chinook run.

The peak of the Shasta River fall Chinook run varies depending on run size. In years of large runs, the peak is well defined and occurs early. For instance, in 2001 when the run exceeded 11,000 fish, the peak occurred from September 29-October 3 (Figure 14). In low run years, the peak of the run has occurred later and is less well defined. For example, in 1988, the peak of the run occurred from October 22-25 but a number of other minor peaks were also present (Figure 15). In 1991, the peak was from October 13-22 and in 1992, it occurred from October 14-22 (Figure 15). The 1994 run, which was intermediate in size, had three peaks occurring on October 2, from October 9-12 and from October 18-20 (Figure 14).

Figure 13. Fall Chinook salmon returns at the Shasta River Fish Counting Facility, Siskiyou County during low flow years.

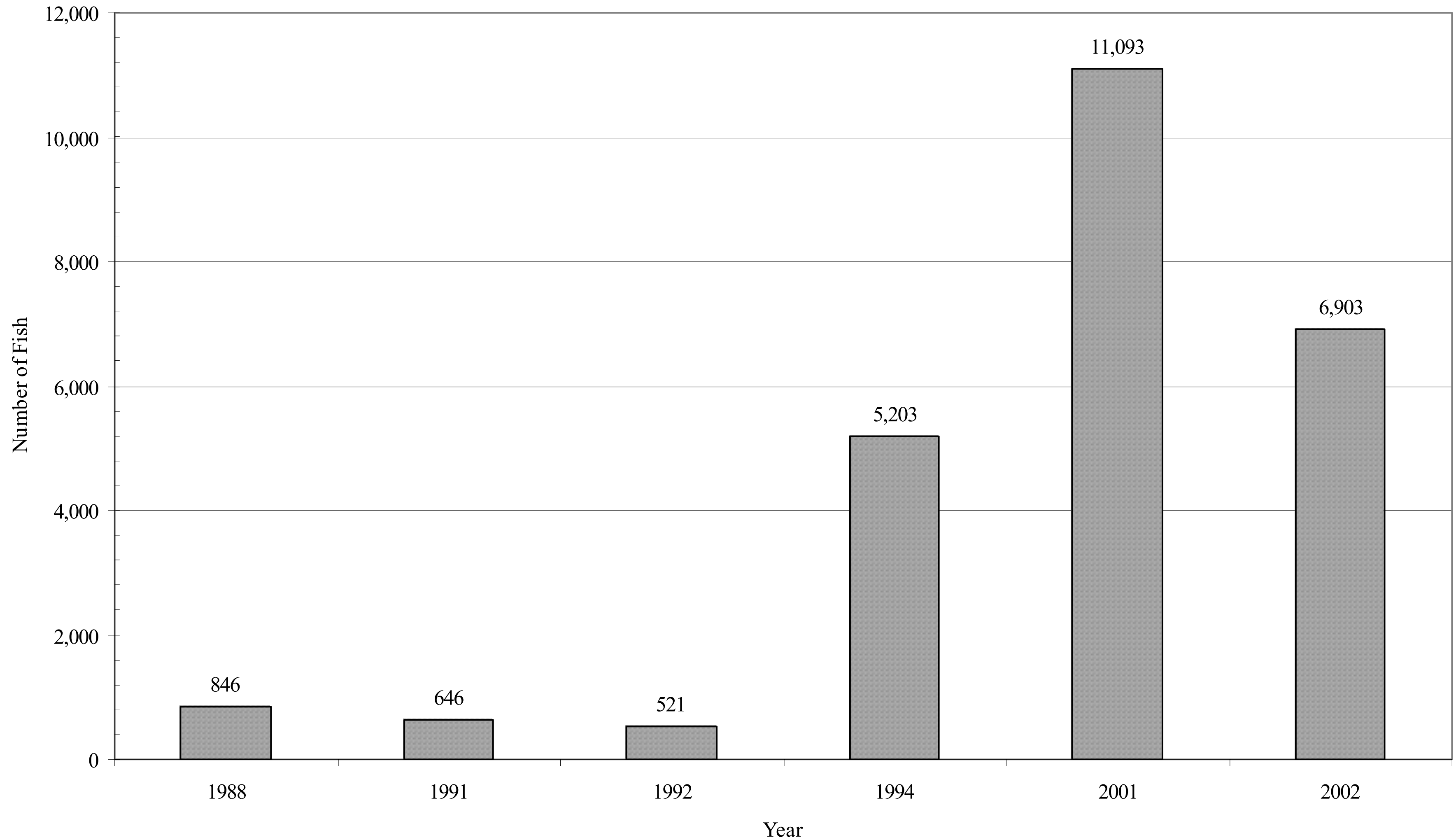


Figure 14. Run timing of fall Chinook salmon through the Shasta River Fish Counting Facility, Siskiyou County, CA for 1994, 2001 and 2002.

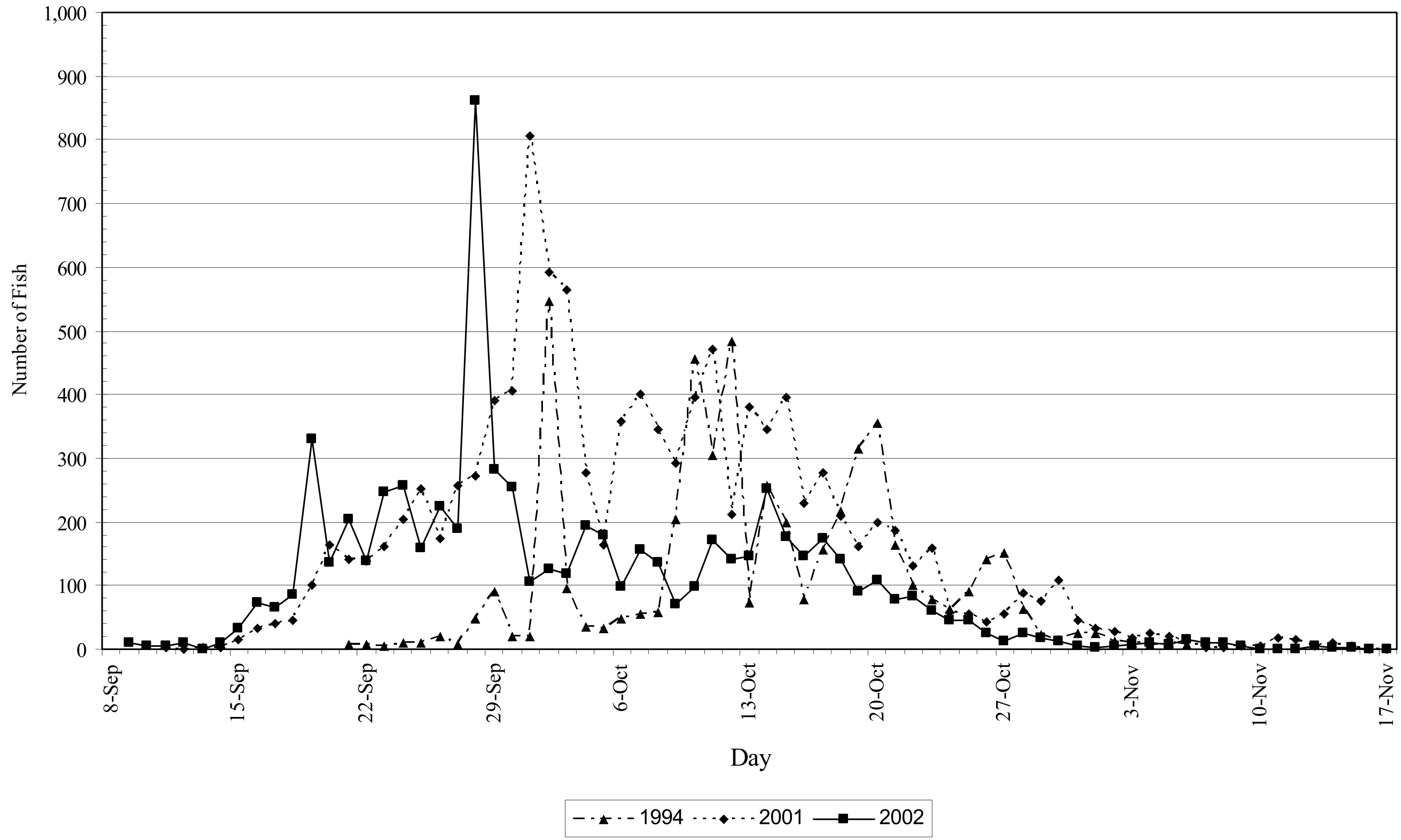
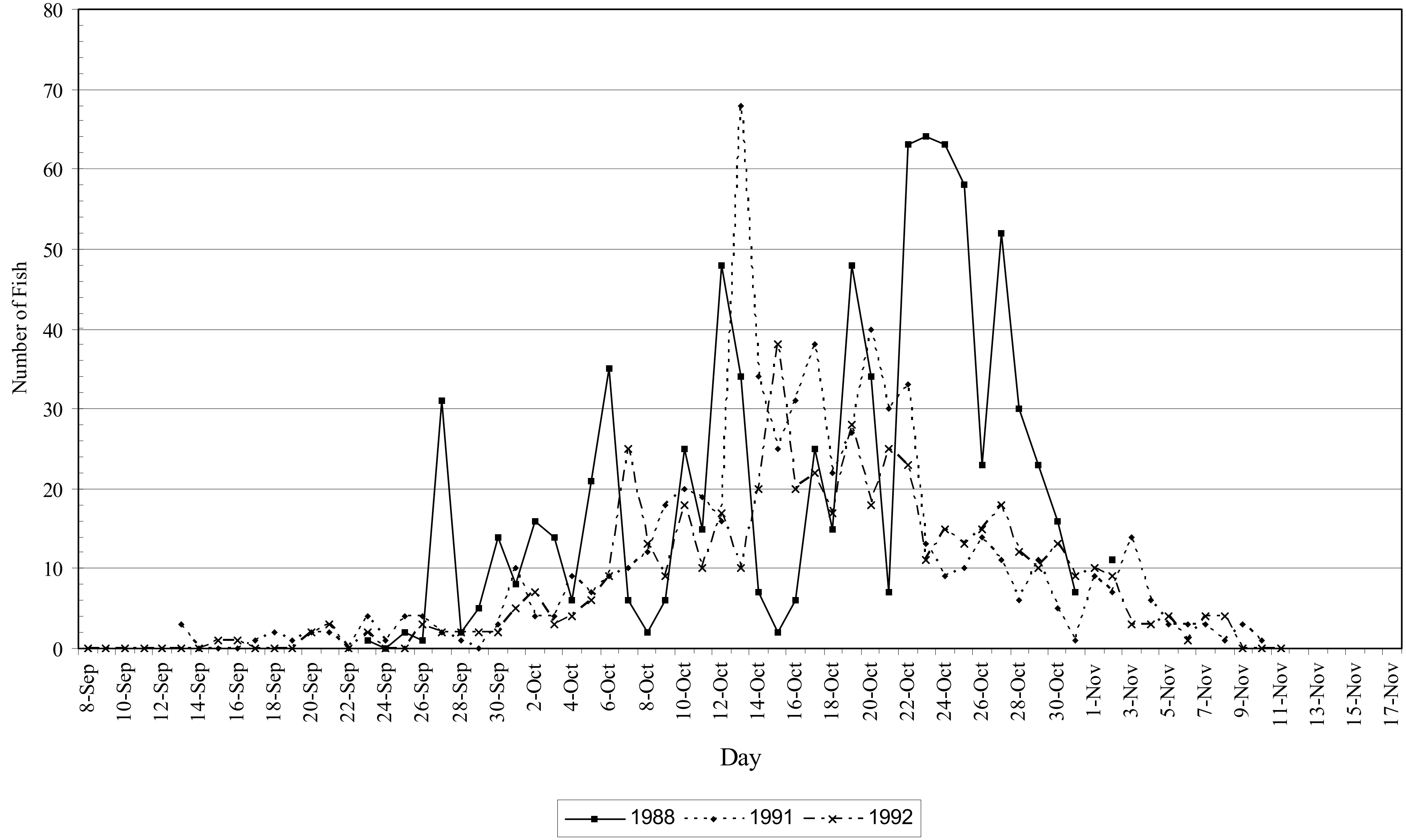


Figure 15. Run timing of fall Chinook salmon through the Shasta River Fish Counting Facility, Siskiyou County, CA for 1988, 1991 and 1992.



The 2002 run, which was moderate in size and coincided with the fish kill, had a very pronounced peak on September 28 of 861 fish, but then declined precipitously to 283 fish on September 29 and declined further to 106 fish by October 1 (Figure 14). This sharp decline of 755 fish (87.6%) over a three day period is the largest and most sudden decline of all the runs examined during low flow years. An important factor that can delay run timing and exaggerate the peak of the run in some years is the fact that the irrigation diversion season ends on October 1. Shasta River flows, during good water years, can increase five fold from approximately 20 cfs to 100 cfs or more within a day or so. There have been occasions, such as in 1994 and 2001, when fall Chinook salmon have congregated in large numbers below the mouth of the Shasta River showing a reluctance to move upstream until flows increased substantially after termination of the irrigation season. However, the steep decline during 2002 occurred before the end of the irrigation season and suggests that the Shasta River fall Chinook run may have been impacted by the fish kill. The DFG will conduct a more detailed examination at a later date to investigate the potential relationship between the fish kill and the sharp declines in the numbers of returning fall Chinook to the Shasta River in 2002.

Shasta River fall Chinook salmon run-size characteristics may be confounded by the possibility that Shasta River fish suffer greater rates of mortality during some years than do other stocks of Klamath Basin fall Chinook. Some information suggests that during low water years, Shasta River fall Chinook young-of the-year may be forced out of the Shasta River prematurely (DFG 2000; DFG 2002) due to high temperatures and a lack of suitable rearing habitat. These fish then have to rear and out-migrate a greater distance than most other populations of fall Chinook under low flow, poor water quality, and high temperature conditions of the main stem Klamath River. This results in greater mortality rates during the fry and smolt life stages. There is also a possibility that returning adult Shasta River fall-run Chinook salmon, which is one of the first stocks to enter the Klamath River, may be susceptible to a higher rate of harvest and catch-and-release mortality than other Chinook stocks. These two factors working individually or together may in some years result in Shasta River run size fluctuations that are not representative of the total Klamath Basin in-river run.

3.4.5 Iron Gate Hatchery

In general, the size of fall Chinook salmon runs returning to Iron Gate Hatchery (IGH) paralleled the trends of the total in-river run for the low water years being analyzed (Figure 16). When total in-river runs were high, returns to IGH were high. When total in-river runs were low, IGH returns were also low. In four years (1992, 1994, 2001, and 2002), IGH contributed between 18.1 and 19.2% of the total basinwide in-river run (Figure 17). However, the IGH contribution rate was significantly lower in 1988 (7.8%) and 1991 (11.8%) (Figure 17). The contribution of IGH returns to the total in-river run for 2002 (18.8%) was very similar to the 2001 (19.2%) contribution rate (Figure 17).

There was no attempt to use this information to determine run-timing. As with the TRH, any differences that may exist in run-timing are masked by artifacts of hatchery operation and the limitations inherent in the handling of large numbers of fish. Count data are aggregated into weekly time steps that do not provide the resolution to detect within week count variations.

While IGH will meet its allotments for returning adult hatchery fall Chinook salmon in 2002, there are still concerns related to the fish kill that need further investigation after this year's fishery data is finalized. For example, DFG hatchery staff did notice health problems (gill deterioration) occurring in fish being processed starting on October 7, 2002. The effects of the September disease outbreak and fish kill in the lower Klamath River on the health and egg viability of returning IGH spawners will be addressed at a later date.

Figure 16. Total returns of fall Chinook salmon to Iron Gate Hatchery, Siskiyou County during low flow years.

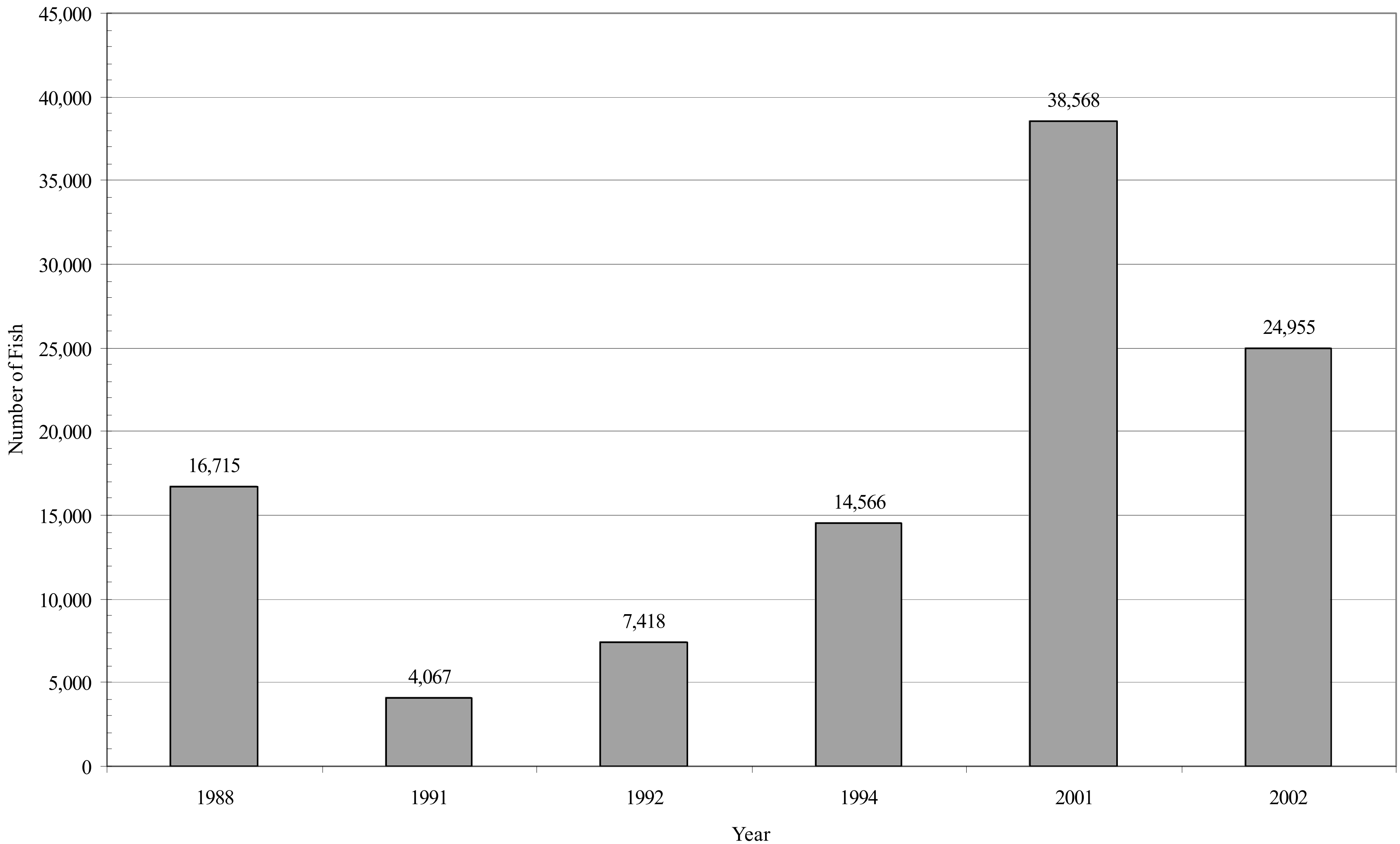
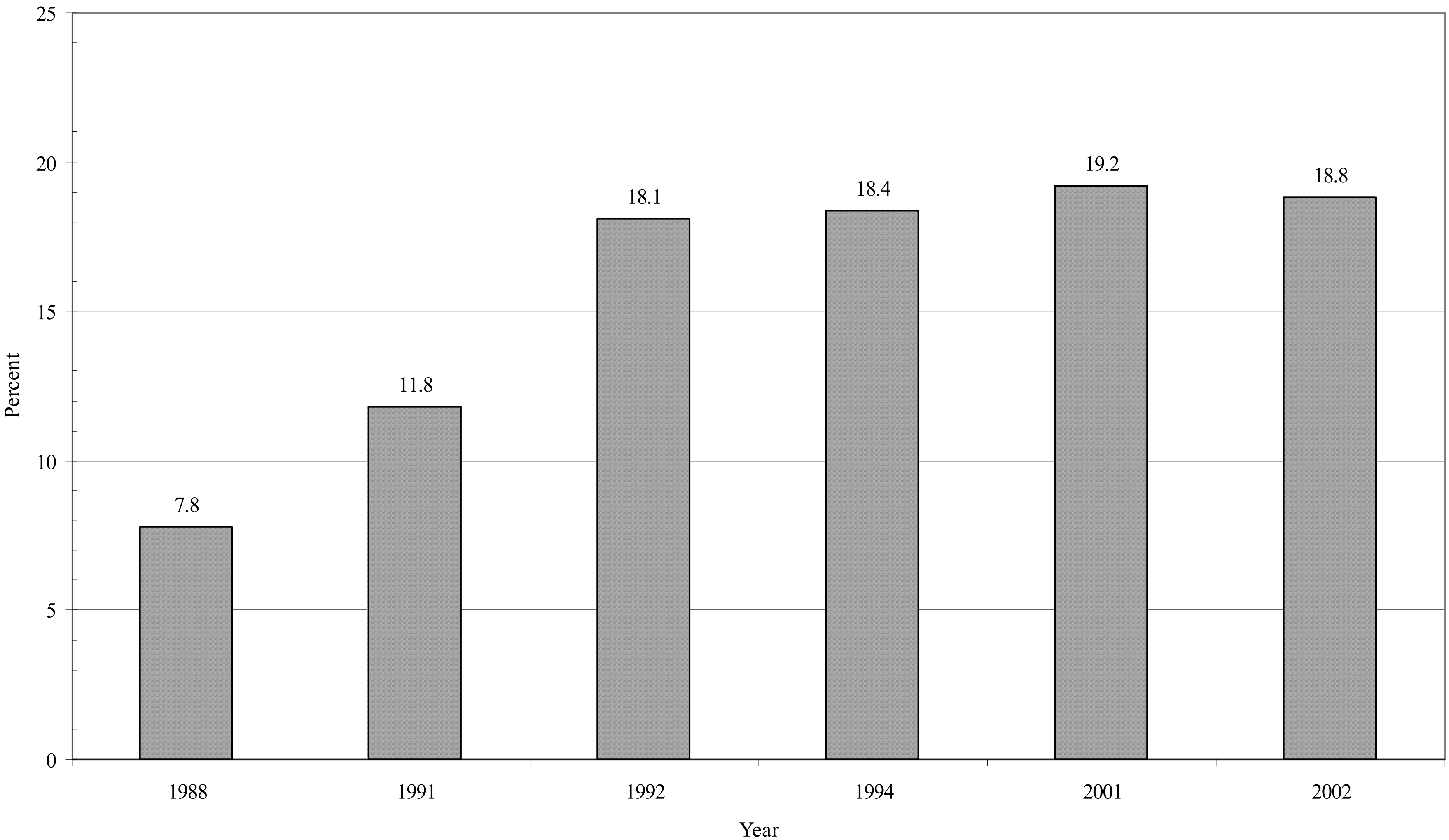


Figure 17. Percent contribution of fall Chinook salmon returns to Iron Gate Hatchery, Siskiyou County of the total in-river run for low flow years.



3.5 Air Temperatures

There has been much speculation by stakeholders that temperatures were substantially higher in September 2002 than in previous years. The DFG accessed data from the Western Regional Climate Center to investigate this concern. Figure 18 presents average September air temperatures since 1982 for the North Coast Division of California (NCDC) and the South Central Division of Oregon (SCDO). These two divisional data sets encompass the Klamath basin. The NCDC encompasses the Klamath basin within California and includes coastal and coast range areas from the Oregon border to the San Francisco Bay Area. The SCDO encompasses the upper Klamath basin within Oregon. The average NCDC air temperature for September 2002 was 63.6˚F and was almost equal to the 25-year September average of 63.7˚F (Figure 18). Average September 2002 air temperature for the SCDO was 57.8˚F and was slightly higher than the 25 year average of 57.4˚F.

Extracting the low flow analysis years of 1988, 1991, 1992, 1994, 2001, and 2002, the DFG found that average 2002 September air temperatures for NCDC are actually the lowest of any of the low flow years (Figure 19). The SCDO data shows higher average September temperatures in 1991, 1994, and 2001 and similar temperatures in 1988 and 1992 when compared with 2002. Consequently, it appears that atmospheric temperatures were close to average in September 2002 and are actually lower than have been observed during other low flow years.

Figure 18. Average September air temperatures for the South Central Division of Oregon and the North Coast Division of California from U. S. climatic data since 1982.

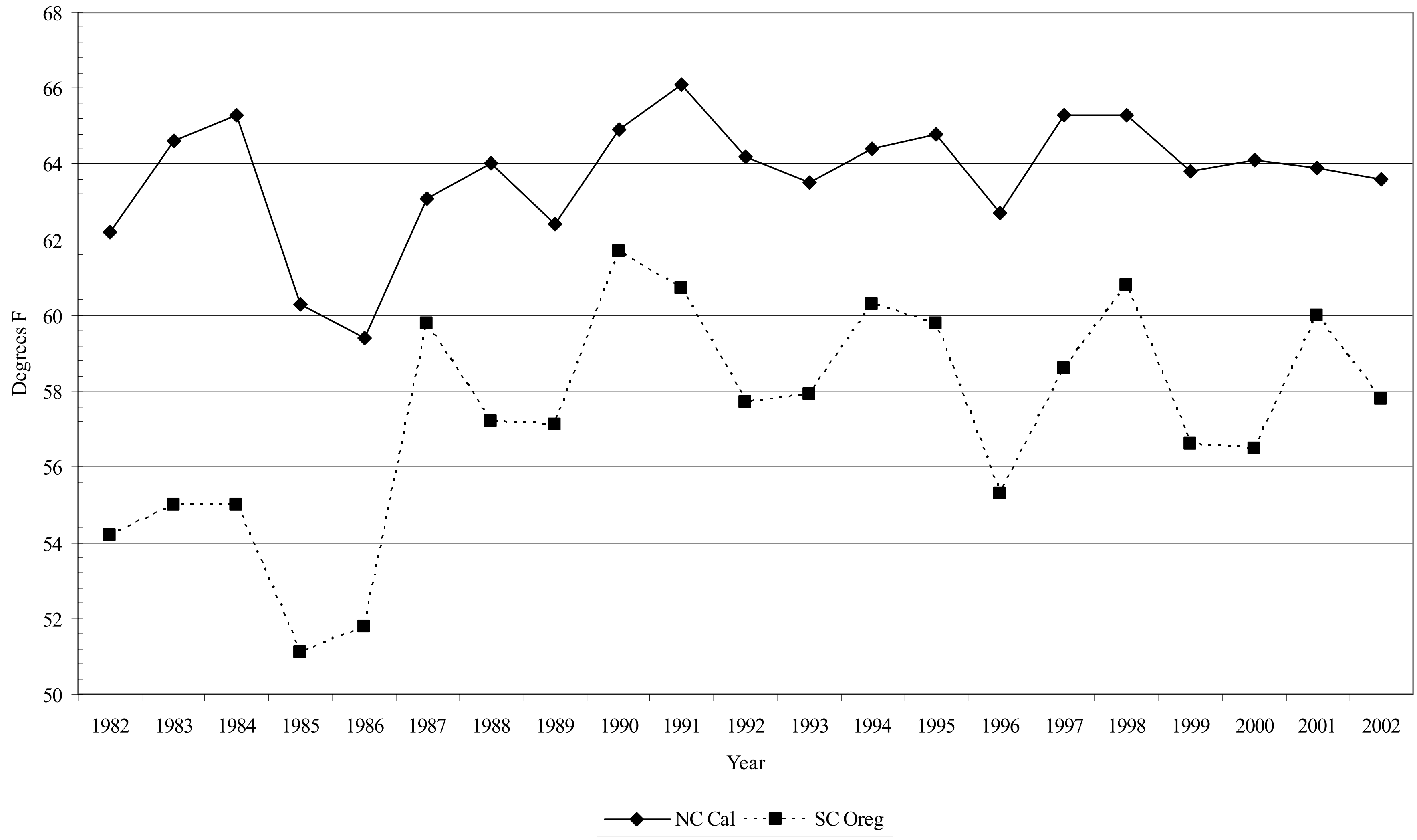
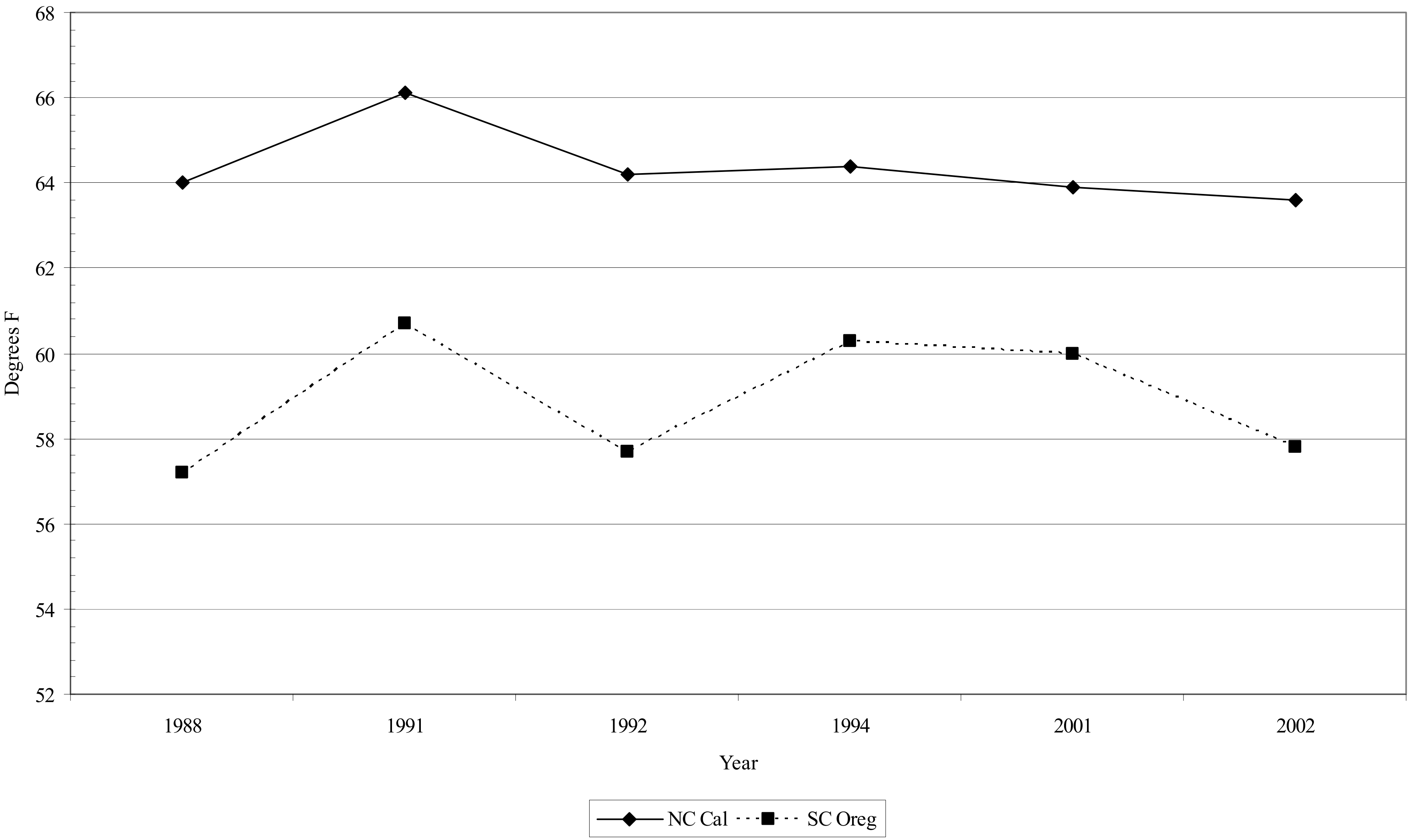


Figure 19. Average September air temperatures from the South Central Division of Oregon and the North Coast Division of California from U S climatic data for low flow years.



The Western Regional Climate Center also has data for specific climatic stations. Average maximum, minimum, and mean September temperatures for the low flow years are presented in Figure 20 for Klamath, California, Figure 21 for Orleans, California, and Figure 22 for Yreka, California. The 2002 data was not available for the Klamath and Orleans stations when this report was in preparation but 2002 data is presented for the Yreka station. Comparisons between stations of dry year air temperatures during September show Orleans experiences the highest temperatures and the greatest diurnal fluctuation followed closely by Yreka. The Klamath station shows substantially cooler air temperatures and less diurnal fluctuation compared to the up-river stations as would be expected, due to the marine layer near the mouth of the Klamath River. Comparison of average September air temperatures (maximum, minimum, and mean) between low flow years at all three stations show similar trends as observed in the divisional data presented above. The Yreka station shows that 2002 air temperatures were not substantially different than other dry years (Figure 22). There is no evidence that unusually high air temperatures in 2002 were a factor in the fish kill.

3.6 Water Temperature

Historic water temperature records are less available for the Klamath River than atmospheric data. The USFWS maintained a series of temperature recording devices on the Klamath River during 2001 and 2002. This information is expected to be available at a later date.

Temperatures in the Klamath River Estuary typically approach a maximum of 70˚F or higher during September and are at levels high enough to favor disease outbreaks (see Pathogen Section). Figure 23 shows the results of periodic handheld thermometer readings taken by DFG staff during September fishery surveys for low flow years. In all five years, maximum water temperatures reached 70˚F or greater. The DFG obtained provisional daily water temperature information for the Terwer Gage in the lower Klamath River for September of 2001 and 2002.

Figure 20. Average September maximum, minimum and mean air temperatures for low flow years at Klamath, California, Del Norte County.

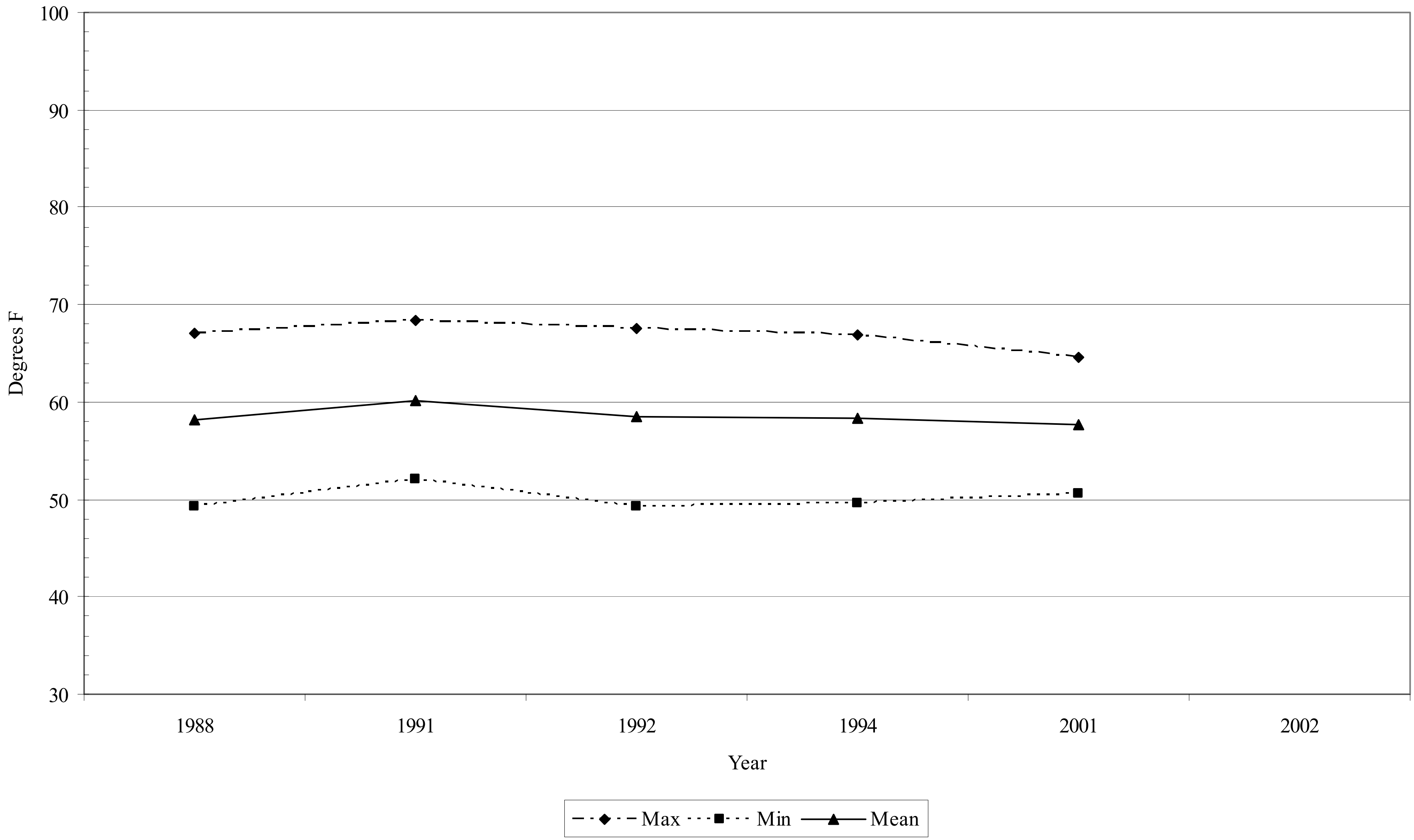


Figure 21. Average September maximum, minimum and mean air temperatures for low flow years at Orleans, California, Humboldt County.

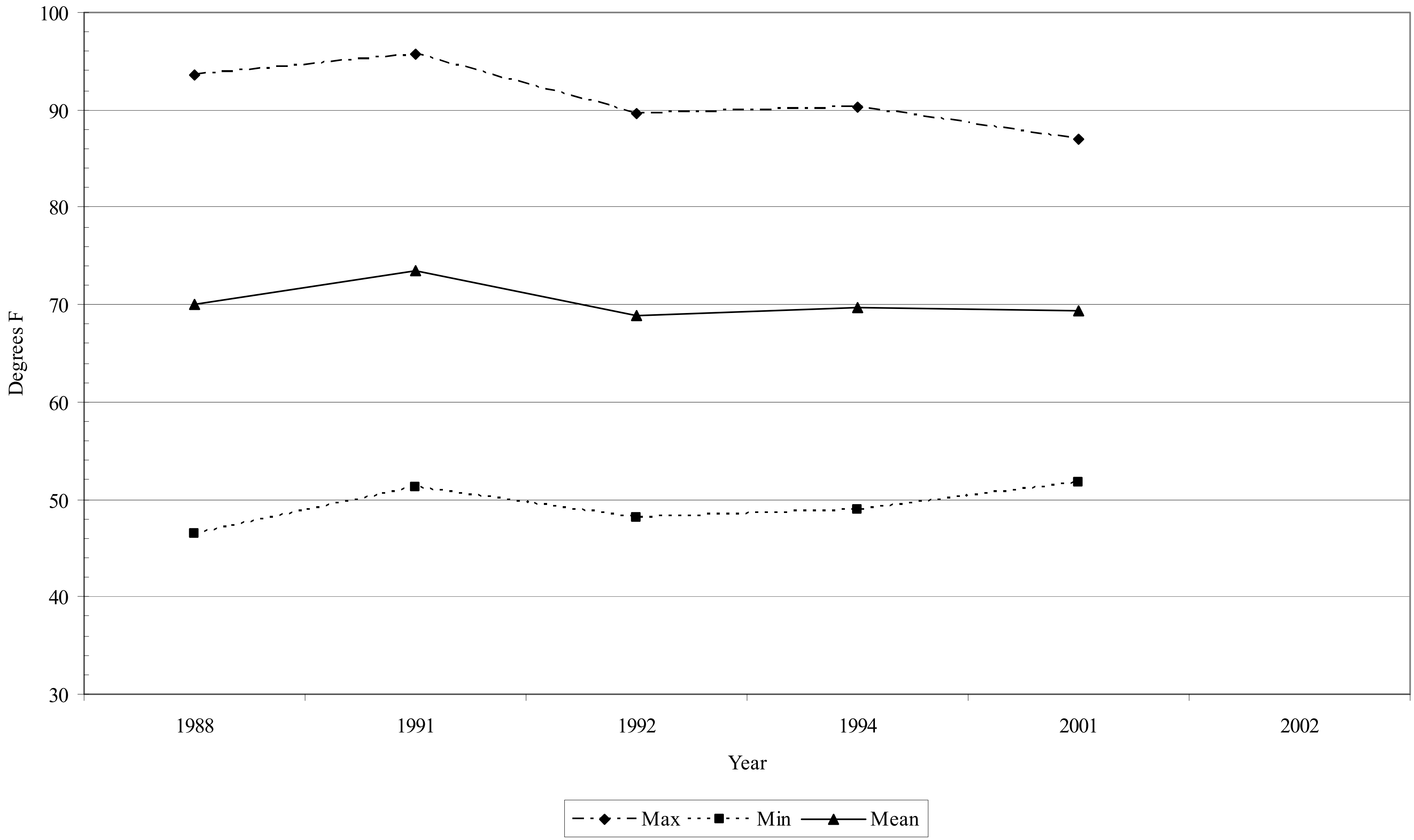


Figure 22. Average September maximum, minimum and mean air temperatures for low flow years at Yreka California, Siskiyou County.

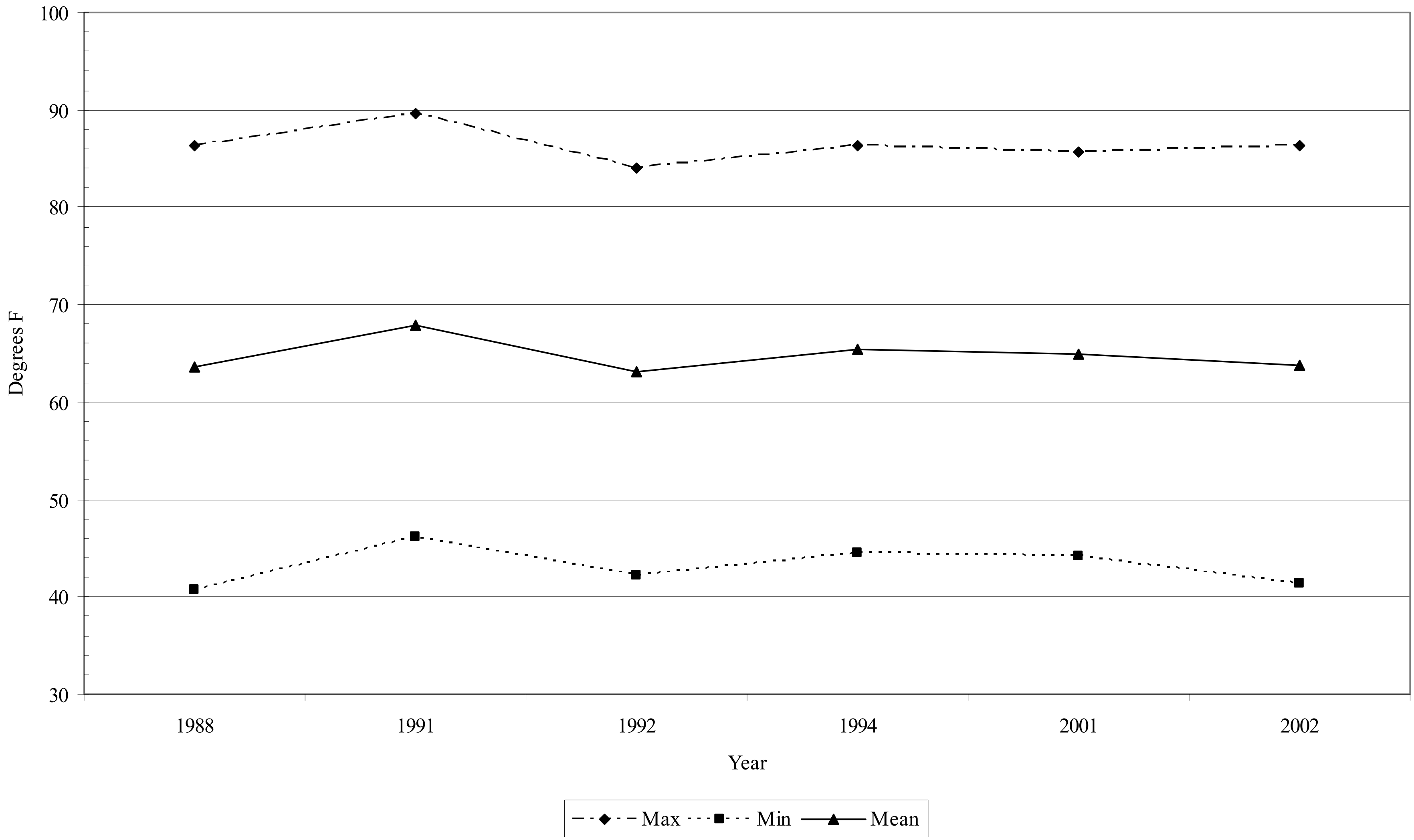
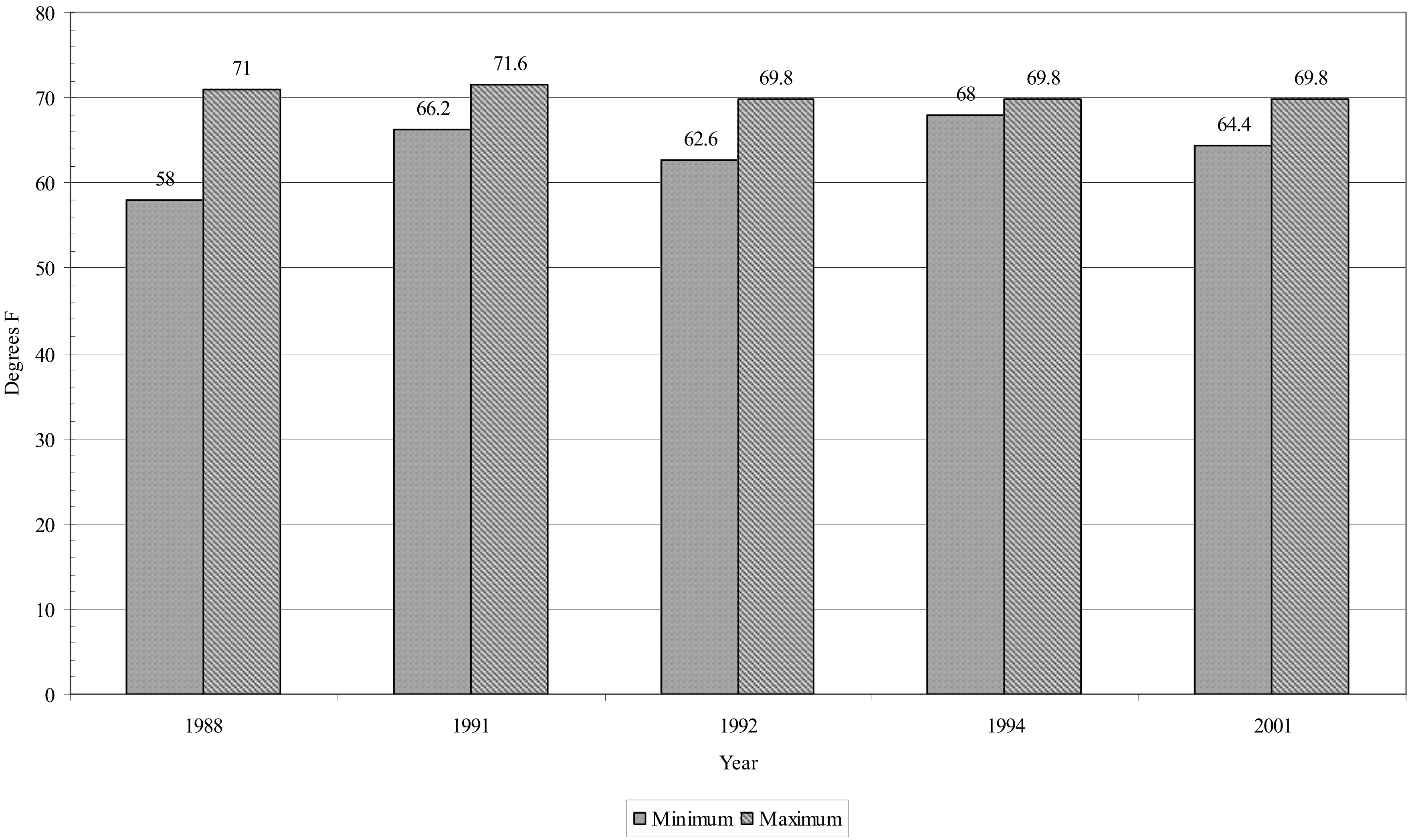


Figure 23. September maximum and minimum water temperatures for the Klamath River Estuary, Del Norte County from grab samples collected periodically by DFG during low flow years.



Since this data is provisional, it may be subject to change. It does appear that maximum daily water temperatures in 2002 did begin to increase on September 14 and were somewhat elevated prior to the initial report of the fish kill on September 19 (Figure 24). However, the water temperatures reached during this time frame were not unusually high for the lower Klamath River and were actually lower than temperatures observed during 2001. Although the provisional data set is incomplete for September 2001, higher maximum water temperatures were recorded from the September 5 through 8 of 2001 than occurred in 2002. While flows were higher in 2001, the maximum water temperature observed in September 2001 was 71.6˚F on September 5 while the maximum recorded for 2002 was 70.0˚F on September 16.

The DFG also obtained historic thermograph data for September collected by the Karuk Tribe during 1992, 1993, and 1994 for the Klamath River at Ishi Pishi Falls (River Mile 66) (Figure 25) and collected by the U S Forest Service (USFS) during 1993, 1994, 2001, and 2002 for the Klamath River upstream of Oak Flat Creek (River Mile 100) (Figure 26). Water temperatures in September 1992 through 1994 at Ishi Pishi Falls ranged from a low of 60.4˚F on September 24, 1994, to a high of 73.9˚F on September 6, 1992. Upstream of Oak Flat Creek, water temperatures ranged from 62˚F on September 25, 2001, to 79˚F on September 10, 1994.

There is no evidence that water temperatures in the lower Klamath River were unusually high in September 2002 compared to past years. Water temperatures typically approach or exceed 70˚F in the lower Klamath River and are at levels high enough to favor a disease outbreak of ICH and columnaris. Therefore, water temperatures in and of themselves, were not the factor causing the 2002 fish kill.

Figure 24. Provisional maximum daily water temperatures for September of 2001 and 2002 at the Terwer Gage in the lower Klamath River, Del Norte County.

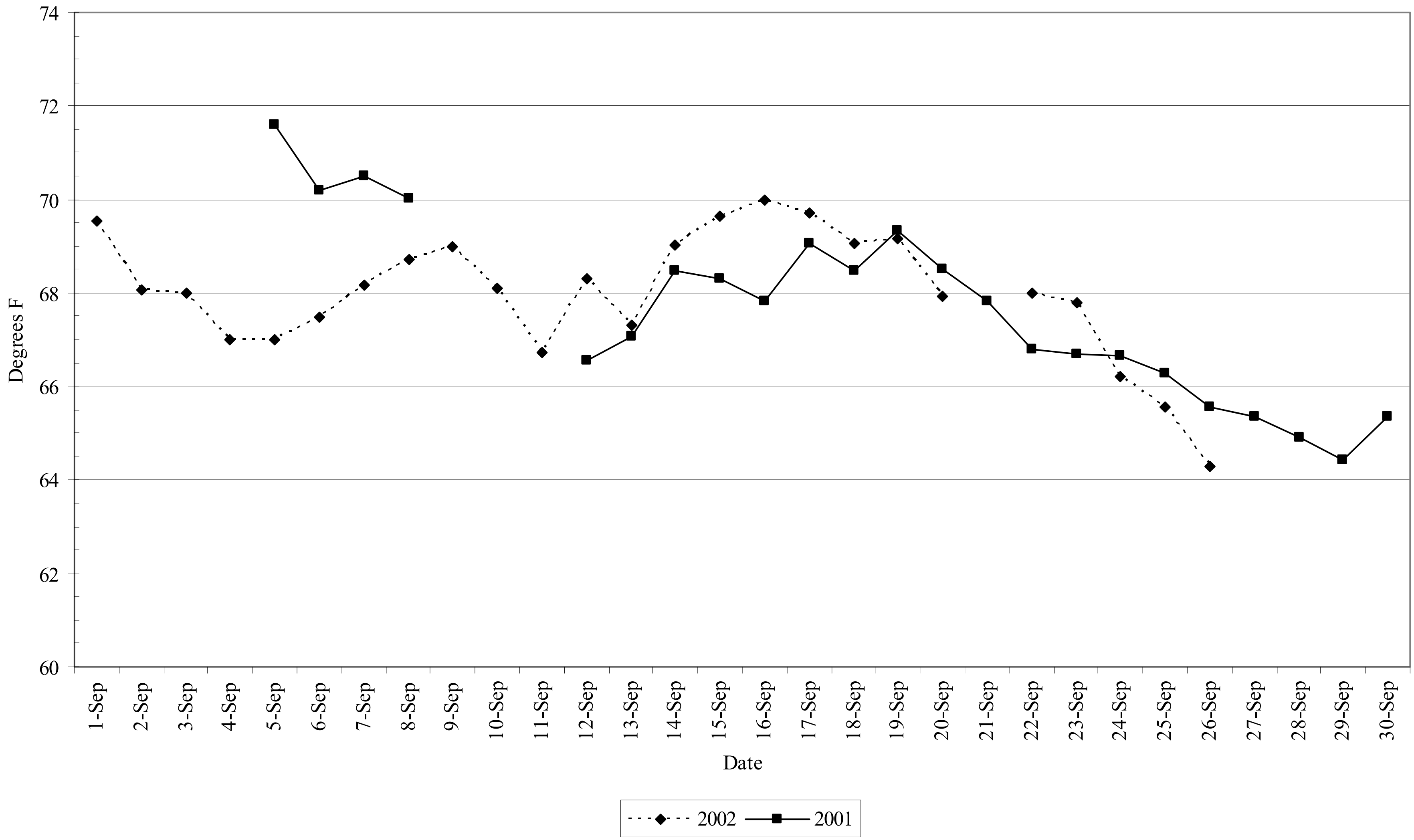


Figure 25. Daily mean September water temperatures for the Klamath River at Ishi Pishi Falls, River Mile 66, Siskiyou County, collected by the Karuk Tribe.

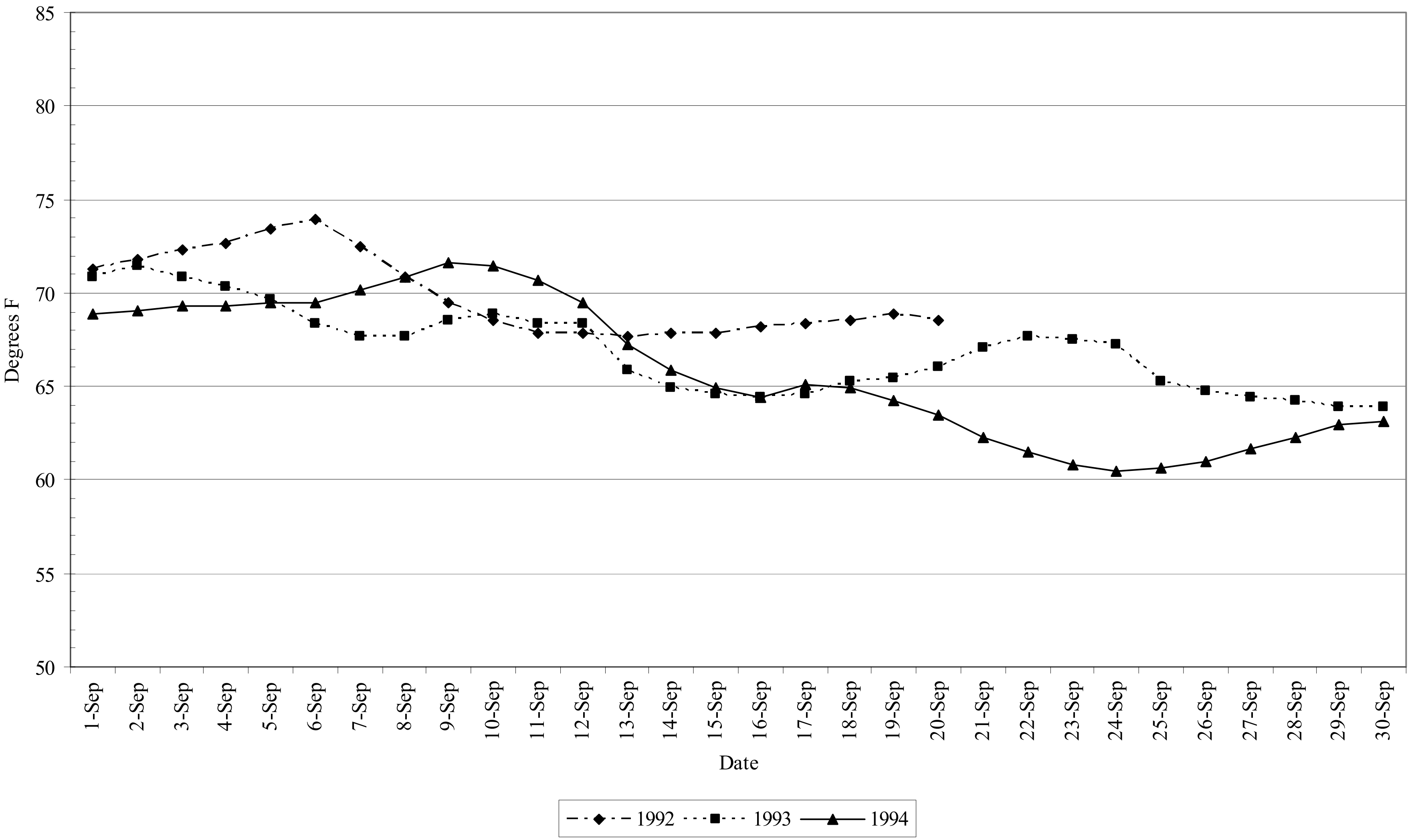
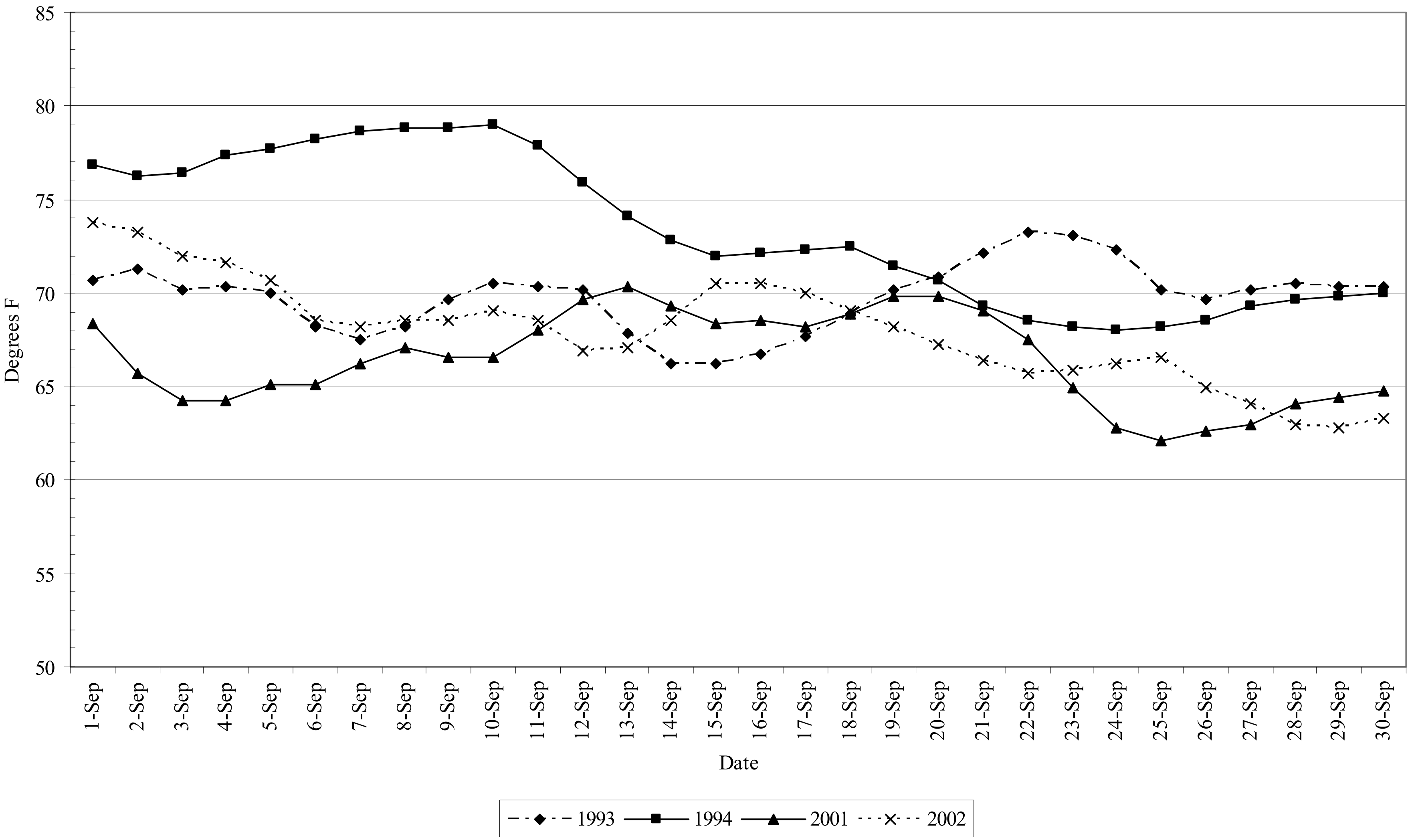


Figure 26. Daily mean September water temperatures for the Klamath River upstream of Oak Flat Creek, River Mile 100, Siskiyou County, collected by Happy Camp Ranger District, USFS.



3.7 Toxic Substances

Soon after the fish kill manifested itself, claims were made that toxic substances may have been the cause. The North Coast Regional Water Quality Control Board staff collected samples from five locations on September 26, 2002 to determine if any toxic substances were present at concentrations toxic to fish. North Coast Laboratories LTD. of Arcata, California, analyzed the samples for nutrients and EPA scans 547, 608 and 619. These scans test for a broad spectrum of organic compounds including organochlorine pesticides, triazine pesticides, PCBs, and Glyphosate. No substances were found at concentrations toxic to fish and therefore, were not a factor in the 2002 fish kill.

3.8 Fish Passage

The issue of fish passage requirements for adult salmon and steelhead in the lower Klamath River probably presents the most pressing need for further evaluation, particularly given the severity of this year's 2002 fish kill. At flows present in the lower Klamath River during 2002, some level of adult fish passage did occur. This is evident, since DFG monitoring at the Willow Creek Weir on the Trinity River and the Shasta River Fish Counting Facility began observing returning adults prior to the fish kill. However, observations by biologists working on the lower Klamath River suggest that low flows in 2002 may have impeded upstream passage of salmon and steelhead. USFWS biologists reported difficulty in navigating their jet boat over shallow riffles in the lower Klamath River during 2002 where they had no difficulties in the past. In addition, they observed that water depth at the Pecwan and Ah Pah riffles (Figure 1) appeared shallow enough to act as a partial adult fish passage barrier (Tom Shaw, USFWS, Arcata, Personal Communication). Minimum depth criteria for passage of adult salmon and steelhead have been recommended by Thompson (1972) and Lauman (1976). Those recommendations for minimum depths to allow adequate passage of fish migrating upstream were 0.8 feet (9.6 inches) for adult Chinook salmon and 0.6 feet (7.2 inches) for steelhead and coho salmon. The argument can be made that lower or similar flows have occurred with no adult fish kill in 1988, 1991, 1992, and 1994. However, in 1997 and 1998 high flow events occurred in northern California that could have altered the channel of the Klamath River. The influx of sediments under high flow events can result in the filling of pools and shallowing of riffle in depositional areas such as the lower Klamath River. Therefore, flows that may have been adequate to pass fish in other low flow years prior to 1997 may not have been adequate in September 2002. Further investigation is necessary to determine discharge requirements to allow unimpaired upstream passage of adult fish for the Klamath River under the current channel configuration. Such an investigation should also address the subject of delays in passage that may occur during low-flow conditions.

4.0 Discussion

The death of at least 33,000 adult salmon and steelhead in the lower Klamath River was caused by infection from the ciliated protozoan *Ichthyopthirius multifilis* (ICH) and the bacterial pathogen *Flavobacter columnare* (columnaris). These pathogens are found worldwide in aquatic ecosystems and are present at all times in the Klamath River System. Disease can sometimes manifest itself under certain environmental conditions that include low flows, high fish densities and warm water temperatures such as occurred in September 2002 in the lower Klamath River. Several years have been identified where low flow conditions have also occurred in the Klamath River without resulting in adult fish kills. The DFG has evaluated available information in a matrix to identify potential causative factors for the 2002 fish kill compared to other historic low flow years (Table 1). The DFG concludes that toxic substances were not a factor, since the North Coast Regional Water Quality Control Board found no elevated concentrations of nutrients or pesticides in samples collected immediately after the fish kill.

As part of the overall assessment of potential causative factors leading to the fish kill, the role of fish density was investigated. Fish density can be thought of as the number of fish found at any time at any one river location at a given river flow. Fish densities become greater as the numbers of fish increase and/or flow decreases. Densities become less as the numbers of fish decrease and/or flow increases. Fish densities can be influenced by the overall size of a given spawning run, run timing, existing flow conditions and impediments to migration. Run timing is important because the characteristics of a run (i.e. onset of the run, duration of the run and magnitude of the run peak[s]) can either exacerbate or ameliorate the effects of a large run. Fish whose migration has been delayed and are highly concentrated in water of marginal quality and temperature, become further stressed and are susceptible to rapid transmission of disease pathogens that can lead to death.

Table 1. Matrix of potential causative factors for the 2002 Klamath River fish kill, comparing September 2002 to other low flow years.

Factors		1988	1991	1992	1994	2001	2002
Pathogens (ICH and columnaris)		Present No Kill	Present No Kill	Present No Kill	Present No Kill	Present No Kill	Present Fish Kill
Average Sept. Flow below Iron Gate Dam, California		1,038 cfs	749 cfs	538 cfs	906 cfs	1,026 cfs	760 cfs[1]
Average Sept. Flow at Klamath, California		2,130 cfs	1,976 cfs	2,007 cfs	1,990 cfs	2,601 cfs	2,129 cfs[1]
In-River Run Size for Fall Chinook Salmon		215,322	34,353[2]	40,346[2]	75,936	200,579	132,600[3]
Peak Run Timing for Fall Chinook Salmon		Sept 2-15	Sept 16-22	Sept 23-29	Sept 16-22	Aug 19–25 & Sept 9-15	Aug 26–Sept 1
Average Sept. Air Temp. SCDO[4]		57.2˚F	60.7˚F	57.7˚F	60.3˚F	60.0˚F	57.8˚F
Average Sept. Air Temp. NCDC[5]		64.0˚F	66.1˚F	64.2˚F	64.4˚F	63.9˚F	63.6˚F
Sept. Max. Water Temp	Klamath[6]					71.6˚F	70.0˚F
	Estuary[7]	71˚F	72˚F	70˚F	70˚F	70˚F	
	RM 66[8]			73.9˚F	71.6˚F		
	RM 100[9]				79.0˚F	70.3˚F	73.8˚F
Fish Passage		Pre 1997 Flood	Pre 1997 Flood	Pre 1997 Flood	Pre 1997 Flood	Post 1997 Flood	Post 1997 Flood

[1] Average flow is provisional and does not include data after September 26, 2002 when the U. S. Bureau of Reclamation (USBR) directed Pacificorp to increase releases at Copco and Iron Gate reservoirs from 760 cfs to 1,300 cfs in an effort to relieve the fish kill.
[2] Represents lowest number of returning fall-run Chinook salmon on record.
[3] Represents preseason estimate of number of returning fall-run Chinook salmon and may be subject to change.
[4] SCDO = the South Central Division of Oregon and encompasses the upper Klamath basin within Oregon.
[5] NCDC = the North Coast Division of California and encompasses the Klamath basin within California and includes coastal and coast range areas from the Oregon border to the San Francisco Bay Area.
[6] Provisional thermograph data for the lower Klamath River at the Terwer Gage.
[7] Periodic handheld temperature measurements by DFG in the Klamath River Estuary.
[8] Thermograph data collected by the Karuk Tribe at River Mile 66 on the Klamath River.
[9] Thermograph data collected by the USFS at River Mile 100 on the Klamath River upstream of Oak Flat Creek.

4.1 Comparison of 1988 with 2002

The 1988 data show flows near the mouth of the river at Klamath, California were comparable to provisional flows in 2002 (approx. 2,100 cfs). The number of in-river fall Chinook salmon was substantially higher in 1988 (215,322) than projected for 2002 (132,600). However, releases at Iron Gate were 1,038 cfs in 1988 compared to only 760 cfs during the 2002 fish kill. September 1988 water temperatures from DFG grab samples reached a maximum of 71˚F and were similar to the maximum recorded for 2002 at the Terwer Gage. Meteorological data indicates that air temperatures during September 1988 were very similar to those in 2002. Creel census data (CPUE) indicates that the Chinook salmon run in the lower Klamath River peaked a week or two later in 1988 than in 2002. However, there is uncertainty in what the 2002 data would have shown after mid-September had the fish kill not occurred. Even with the peak run occurring later in 1988 than 2002, the CPUE was considerably lower from September 2 through 15 in 1988 than in 2002. This may reflect a higher density of fish in 2002. Fish passage concerns under the low flow conditions during 1988 versus 2002 is an uncertainty but a major difference between the two years is the potential channel altering flow events in 1997 and 1998. Therefore, while the run size was substantially larger in 1988 than in 2002, flow releases at Iron Gate Dam were also substantially higher. The channel configuration in 2002 may be very different from 1988 due to the major storm events in 1997 and 1998.

4.2 Comparison of 1991 and 1992 with 2002

Discharges from Iron Gate Dam and flows in the river at Klamath, California during September 1991 and 1992 were some of the lowest on record over the past 50 years. Releases and flows were actually less than during the 2002 fish kill. However, the returning numbers of fall-run Chinook salmon were also the lowest of record (34,353 in 1991 and 40,346 in 1992) and substantially lower than returns projected for 2002 (132,600). The CPUE data for 1991 and 1992 indicated increases in the numbers of fish during mid- to late September but surveys ended at that point as the sport fishing harvest quotas were exceeded. The peak in 2002 occurred at the end of August but there is uncertainty in what the 2002 CPUE data would have shown after mid-September had the fish kill not occurred. Meteorological data indicates that September air temperatures were higher in 1991 than 2002 and similar in 1992 and 2002. Maximum water temperatures from grab samples in the estuary for 1991 and 1992 were similar to the maximum recorded for 2002 at the Terwer Gage. Maximum water temperatures at RM 66 (Ishi Pishi Falls) in 1992 were also very similar to those at RM 100 (upstream of Oak Creek) in 2002. Therefore, while flows were lower and atmospheric and water temperatures were either similar or higher, the numbers of fall Chinook returns were substantially lower in 1991 and 1992 than in 2002. Similar to 1988, fish passage and channel conditions in 1991 and 1992 may be different than in 2002 due to the 1997 flood. Low numbers, and consequently low densities, of returning salmon in 1991 and 1992 suggest that fish densities were never present to promote a disease outbreak when compared to 2002.

4.3 Comparison of 1994 with 2002

While discharges at Iron Gate Dam were greater in September 1994 (906 cfs) than in 2002 (760 cfs, provisional data), flows in the lower river near Klamath were lower in 1994 (1,990 cfs) compared to 2002 (2,129 cfs, provisional data). The fall run totaled nearly 76,000 fish in 1994 but was substantially less than the numbers projected in 2002 (132,600). CPUE data for 1994 indicated an increasing number of fish during the week of September 16 to 22 but surveys ended at that point as the sport fishing harvest quota was exceeded. The peak in 2002 occurred the week of August 26 to September 1 but there is uncertainty in what the 2002 CPUE data would have shown after mid-September had the fish kill not occurred. Air temperatures during September 1994 were slightly higher than those in 2002. Maximum water temperatures at RM 100 were substantially higher in 1994 than in 2002. Maximum water temperatures in the estuary from handheld readings, on the other hand, were very similar to those recorded for 2002 at the Terwer Gage. Therefore, while flow releases from Iron Gate Dam, air temperatures and water temperatures were either similar or higher in 1994, flows in the river near Klamath were lower and run size was substantially lower in 1994 than in 2002. Once again, although fish passage issues need to be studied further, low returns of adult fish in 1994 were likely not at levels high enough to produce densities to result in a disease outbreak when compared to 2002.

4.4 Comparison of 2001 with 2002

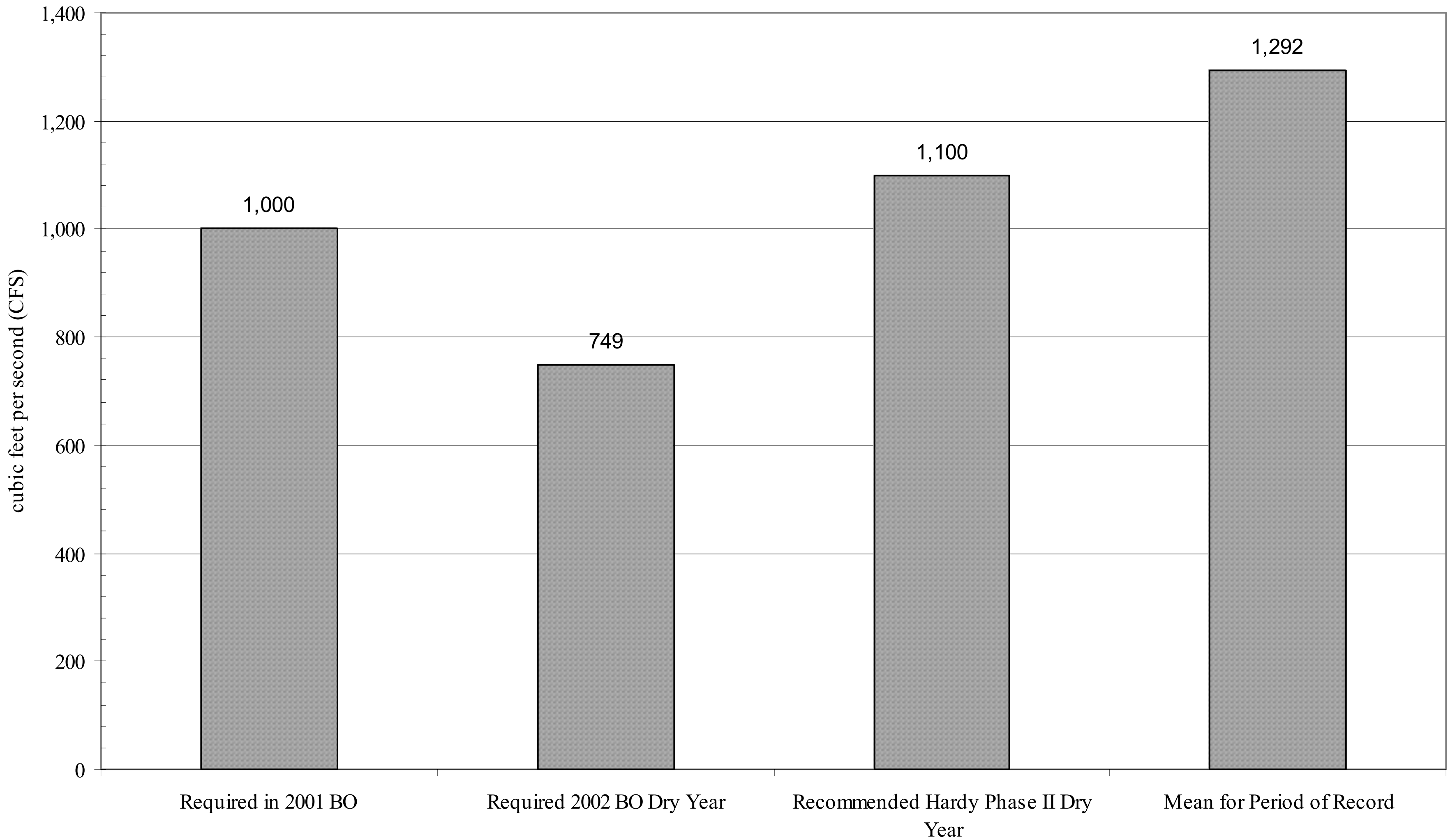
The best year to evaluate conditions necessary to prevent an adult fish kill is 2001 when compared to 2002. The year 2001 was a drier hydrologic year than 2002. Discharges at Iron Gate Dam were higher (1,026 cfs) in 2001 compared to 2002 (760 cfs, provisional data). Flows in the lower river were almost 500 cfs greater in 2001 than provisional flows in 2002. The run size of 200,579 fall Chinook salmon in 2001 was nearly 70,000 fish higher than during the 2002 fish kill. Creel census data (CPUE) indicates that the 2001 Chinook salmon run in the lower Klamath River had two peaks; one which occurred a week earlier than the peak in 2002 and one which occurred a week later than in 2002. As previously noted, there is uncertainty in what the 2002 data would have shown after mid-September had the fish kill not occurred. Peak CPUE values after September 2 were higher in 2001 than those in 2002. This may reflect a higher number of fish present in September 2001 than 2002 but is not reflective of the densities of fish because flows in 2001 were significantly higher. Air temperatures were higher in both the upper and lower Klamath River basin in September 2001 compared to 2002. Maximum water temperatures actually reached higher levels in 2001 than 2002. Channel morphology changes from the 1997 and 1998 floods would be similar in 2001 and 2002, since both years were quite dry. Therefore, with the exception of the flow management regime, conditions were more favorable for a disease outbreak and fish kill in 2001 than 2002. There was a much larger run of fish, air, and water temperatures were actually warmer, channel morphology was similar, and pathogens were also present in 2001. Yet, with flows managed at a higher level in 2001, passage problems were not observed, over-crowding and high densities of fish were not observed and no fish kill took place.

4.5 Summary comparison of 1988, 1991, 1992, 1994, and 2001 with 2002

September 2002 was unique compared to other low flow years when adult fish kills did not occur in the Klamath River basin. September flow releases from Iron Gate Dam in 2002 (provisional data) were the lowest on record when the numbers of returning fall Chinook salmon were at an average or above average level. In addition, September 2002 flows (provisional data) in the Klamath River were the lowest since the major storm events in 1997 and 1998 when channel conditions in the river could have changed. The year 2002 is the only year after the 1997 and 1998 floods where we found a combination of very low flows, warm atmospheric, and water temperatures, and a moderate sized run of fall Chinook salmon entering the river. It appears that this moderate sized run of fish (132,600) in 2002 peaked a week or two earlier than in other low flow years. However, relatively high CPUEs, when compared to other low flow years, were still observed from September 2 to 15, 2002, indicating the presence of a large number of fish prior to the kill. It also appears that in years with moderate to high numbers of returning fall Chinook salmon, the runs tend to peak earlier (i.e., 1988, 2001, and 2002) compared to low return years (i.e., 1991, 1992, and 1994) (Figure 8). The year 2002 represents the lowest flow conditions in the Klamath River since major storm events in 1997 and 1998. The large influx of sediment, as would be expected during such high flow events, may have led to substantial changes in channel morphology, such that the flows which occurred in 2002 were not adequate to allow unimpeded fish passage over shallow riffle areas. USFWS biologists conducting fishery surveys on the lower river during 2002 had difficulty in navigating their jet boat over certain shallow riffle areas (where they had no difficulty in past higher flow years) and expressed concerns that two riffles appeared shallow enough to impede adult fish passage. Minimum depth criteria recommendations for fish passage are 0.8 feet (9.6 inches) for adult Chinook salmon and 0.6 feet (7.2 inches) for steelhead and coho salmon (Thompson 1972 and Lauman 1976). The September 2002 fish kill was likely caused by a combination of high densities of adult fish in the lower Klamath River (due to low flows and possibly inadequate fish passage) and warm water temperature conditions which are typical for this time of year. These conditions were favorable for a disease outbreak by ICH and columnaris which are commonly present in the aquatic environment.

Flow management under the 2002 Biological Opinion (BO) compared to the 2001 BO is the only major factor DFG can identify over the past two years that differs substantially enough to have caused the 2002 fish kill. The BO flow prescriptions for September 2002 were significantly lower than in 2001 and lower than those recommended in the Hardy Phase II Flow Study (Figure 27). Other conditions that could lead to a disease outbreak and fish kill were actually the same or worse in 2001, yet no disease or mortality was observed. DFG concludes that low flows and other flow related factors (e.g. fish passage and fish density) caused the 2002 fish kill on the lower Klamath River. Furthermore, of the conditions that can cause or exacerbate a fish kill, flow is the only factor that can be controlled to any degree. There is a distinct potential for future fish kills considering that pathogens are always present, temperatures are normally at levels that can cause disease and, under the 2002 BO flow prescription, a moderate sized run of salmon and steelhead can generate high enough fish densities in the lower Klamath River to result in a major fish kill.

Figure 27. Comparison of September flows from Iron Gate Dam, Siskiyou County for the 2001 BO requirements, 2002 BO requirements, Hardy Phase II recommendations and the mean for the period of record since 1961.



5.0 Conclusions

- The DFG concludes that low flows and other flow related factors (e.g., fish passage and fish density) caused of the 2002 fish kill on the lower Klamath River. Furthermore, of the conditions that can cause or exacerbate a fish kill, flow is the only factor that can be controlled to any degree. Flow is regulated by upstream reservoirs operated by the USBR on both the Klamath and Trinity rivers.

- September 2002 was unique compared to other low flow years when adult fish kills did not occur in the Klamath River basin. September flow releases from Iron Gate Dam in 2002 (provisional data) were the lowest on record when returning numbers of fall Chinook salmon were at average or above average levels. In addition, September 2002 flows in the Klamath River were the lowest since the major storm events in 1997 and 1998 when channel conditions in the river could have changed dramatically.

- During late September of 2002, a minimum of 33,000 adult salmon, steelhead trout and other fish species were killed in the lower 36 miles of the Klamath River.

- Of the dead fish collected by DFG downstream of the mouth of Blue Creek on September 27, 2002, 95.2% were fall Chinook salmon, 0.5% were coho salmon and 4.3% were steelhead trout. These percentages differ slightly from the preliminary USFWS estimates which covered the entire fish kill survey area from Coon Creek Falls to the mouth of the Klamath River. Out of the 33,000 anadromous fish that were killed, USFWS found that 96% were fall Chinook salmon, 1.5% were coho salmon and 2.0% were steelhead trout. Carcasses of sculpin, Klamath River smallscale sucker, speckled dace, coastal cutthroat trout and green sturgeon were also identified during the fish kill.

- Of the Chinook salmon killed, DFG estimates that 68% were naturally spawned fish while only 32% were fish produced in one of the two mitigation hatcheries (Iron Gate or Trinity River hatcheries) in the Klamath River system.

- Of the Steelhead killed, DFG estimates that 53% were naturally spawned fish and 47% were fish produced in one of the two mitigation hatcheries (Iron Gate or Trinity River hatcheries) in the Klamath River system.

- Only 13 coho salmon carcasses were directly examined by DFG, of which three were naturally spawned fish and ten were fish produced in one of the two mitigation hatcheries (Iron Gate or Trinity River hatcheries) in the Klamath River system.

- The cause of death for adult Chinook and coho salmon and steelhead during September 2002 was disease from the ciliated protozoan *Ichthyopthirius multifilis* (ICH) and the bacterial pathogen *Flavobacter columnare* (columnaris). Both pathogens commonly occur naturally worldwide and are always present in the Klamath River and other aquatic systems.

- Similar or lower average flows than during the September 2002 fish kill (2002 flow is provisional) have occurred in the lower Klamath River at Klamath during September 1988, 1991, 1992, and 1994. Most of these low flow years occurred during a prolonged drought in the early 1990s and are unusual conditions. When looking at the longer period of record since 1951, higher average September flows than in 2002 occurred in 92% of the years. Without looking at the long term flow records, it is inappropriate to use the drought years of the early 1990s to characterize "normal" flow conditions in the Klamath River.

- The Scott and Shasta rivers contribute less than six percent of the average annual unimpaired flows in the Klamath River. A solution to flow related fisheries problems in the Klamath System (Klamath and Trinity river systems and major tributaries) must be addressed at a basinwide level. Important considerations include sources of water and regulation of releases from reservoirs.

- Average September flow records for the Klamath River below Iron Gate Dam (KIG) were lower in 1973, 1991, and 1992 than those observed in 2002 (2002 flow is provisional). Similar to flow records from the lower Klamath River, KIG records show that in 93% of the years since 1961, flow releases from Iron Gate Dam were higher than the flows during the September 2002 fish kill. Two of the years where lower flows were recorded during September at KIG occurred during the drought of the early 1990s. Without looking at the long term flow records, it is inappropriate to use these years to characterize "normal" flow conditions in the Klamath River.

- The 2002 projection for the numbers of in-river fall-run Chinook salmon (132,600 fish) represents a slightly above-average run. The mean run-size for the twenty-four-year period since 1978 is 120,983 fish. Runs have varied in size from a low of 34,353 fish in 1991 to a high of 239,366 fish in 1986.

- Of the six low flow years (1988, 1991, 1992, 1994, 2001, and 2002) analyzed in this report, the projected numbers of in-river fall-run Chinook salmon for 2002 (132,600 fish) is of medium size with two years of significantly larger runs (1988 = 215,322 fish and 2001 = 200,579 fish) and three years of significantly smaller runs (1991 = 34,353 fish, 1992 = 40,346 fish and 1994 =75,936 fish). The years of 1991 and 1992 represent the lowest returns of fall Chinook salmon to the Klamath River basin for the period of record beginning in 1978.

- There was nothing unusual with the timing of Chinook salmon entering the Klamath River during 2002 with the peak occurring in the last week of August. Past records indicate that Chinook salmon runs entering the Klamath River peak from mid-August to mid-September and the average run peaks in early to mid-September. Of the six low flow years (1988, 1991, 1992, 1994, 2001, and 2002) analyzed in this report, runs during years with larger returning numbers of salmon (1988, 2001, and 2002) tended to peak earlier (in late August and early September) than years when fish returns were low (1991, 1992, and 1994). Some years exhibited two peaks with one peak in mid-August likely representing spring-run Chinook salmon and one in mid-September likely representing fall-run fish.

- Atmospheric temperatures were nearly average in September 2002 and lower than have been observed during other low flow years. The average North Coast Division of California air temperature for September 2002 was 63.6˚F and is almost equal to the 25-year September average of 63.7˚F. Average September 2002 air temperature for the South Central Division of Oregon was 57.8˚F and was slightly higher than the 25 year average of 57.4˚F.

- Water temperatures in the Klamath River were not unusually high during September 2002 when compared to historic data. Temperatures in the Klamath River Estuary typically approach a maximum of 70˚F or higher during September.

- Sampling of the lower Klamath River in September 2002 confirmed that no toxic substances were present at concentrations to have caused the fish kill.

- Fish passage in the lower Klamath River under the low flows occurring in the summer and September of 2002 may have been restricted to an unknown degree. Biologists conducting fishery surveys on the lower river reported difficulty in navigating their boat over shallow riffles (where they have had no difficulty in the past) and observed that these riffles appeared shallow enough to impede passage of adult salmon.

- The September 2002 fish kill was caused by a combination of high densities of adult fish in the lower Klamath River (due to low flows and possibly inadequate fish passage) and warm water temperature conditions which are typical for this time of year. These conditions were favorable for a disease outbreak by ICH and columnaris which are commonly present in the aquatic environment.

- There is a substantial risk for future fish kills on the Klamath River considering that pathogens are always present, temperatures are normally at levels that can cause disease, and under the 2002 BO flow prescription, a moderate sized run of salmon and steelhead can generate high enough densities in the lower Klamath River to result in a major fish kill.

- Preliminary data from the Shasta River Fish Counting Facility, the Willow Creek Weir on the Trinity River, Iron Gate Hatchery, and Trinity River Hatchery, suggests that the 2002 fish kill has impacted fall Chinook salmon returns to up-river areas. The DFG will address these basinwide impacts at a later date after additional data is collected and analyzed.

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Attachment 1

State of California
Department of Fish and Game

FISH PATHOLOGIST REPORT

Location	**Date**
Klamath River	26 & 27 September 2002
Species and Size	**Sample Area**
Chinook, steelhead, and coho returning adults	Blake's Riffle and confluence with Blue Creek

Observations and Fish Sampling:
Sept 26 - Twenty relatively fresh Chinook salmon of the 100 or more mortalities (including four coho and one steelhead which were all too decomposed for evaluation) located along an approximately half-mile section of shore near Blake's Riffle were observed for external lesions and signs of internal pathology. Best guess, these fish had all been dead for 12-24 hours. None of the fish had color left in the gills, but 12 of 20 had signs of erosion of the lamellae – the filaments appearing to be intact. No other external lesions were observed. Internally, 4 of the 20 fish had signs of mild to moderate inflammation of the lower intestine, and one of those also had mild hemorrhaging of the intestine with no other apparent tissue involvement. Tissue samples of the inflamed intestines were taken, as well as samples of the kidneys of these fish to ascertain degree of decomposition by presence/absence of bacteria. Observations were made using phase-contrast microscopy of wet mounts. No *Ceratomyxa shasta* trophozoites were observed in any of the intestinal scrapes, possibly due to degradation of the organism, and bacteria were observed in only one of the scrapes (from the hemorrhagic sample). No bacteria were observed in the kidney wet mounts, suggesting overall pathology was not due to decomposition.

Since none of the fish were in good enough condition to evaluate gill pathology, fishermen along the Riffle were asked to donate anything they caught to the analysis. Talking with fishermen I was told that most of the fish seemed unwilling to put up a fight and the gills of the fish they were catching seemed to be covered in excess mucous, and looked as if they had been "sprinkled with salt". One steelhead, two Chinook, and one coho were evaluated. One of the Chinook and the coho appeared to have just entered the river, having no signs of disease, corroborated by statements from the fishermen to the effect that the fish had given them a good fight, compared to the others. The gills of the other fish did, indeed look as if they had been sprinkled with salt, and wet mounts revealed heavy infestations of *Ichthyophthirius multifilis* trophonts – approximately 30 per scrape. Ich was also present on the skin in fewer numbers. No typical columnaris lesions were observed, and no *F.columnare* was seen in wet mounts. Internally, the steelhead had moderate inflammation of the lower intestine, with some mixed bacteria present, but no *C. shasta* trophs were observed. No internal pathology was observed in the listless Chinook.

Sept. 27 – A USFW boat was taken Friday morning to the confluence of the Klamath River and Blue Creek, approximately 13 river miles from the mouth. Gill and skin scrapes, and lower intestine samples were taken from 4 moribund and 2 fresh dead Chinook, and one fresh-dead coho. Other dead coho were observed (10 or more), but none fresh enough to evaluate, other than noting the presence of typical dark yellow "scooped out" columnaris lesions on the gills of two of the fish, and erosion of the lamellae of three others. Samples were kept on ice in separate zip-loc bags for approximately two hours before being evaluated using phase-contrast microscopy of wet-mounts. Heavy infestations of Ich were present on all but two gill samples, which had large amounts of *F.columnare* and some motile rod bacteria. No other external pathogens were observed. *C. shasta* trophs were observed in the intestinal scrape of one fish. Scrapes were also taken from one fish that had an external lesion (*F.columnare*) and cloudy cornea (Ich). Summary of results follows.

Blake's Riffle - 26 September 2002

Dead Fish

# fish/species	# lamellae erosion	# columnaris lesions	# inflamed lower intestines	*C.shasta* observed
20/Chinook	12	0	4	0

Fish Obtained from Fishermen

species	lamellae erosion	columnaris observed	Ich observed	inflamed lower intestines	*C.shasta* observed
steelhead	-	-	+	+	-
coho	-	-	-	-	-
chinook	-	-	+	-	-
chinook	-	-	-	-	-

Blue Creek - 27 September 2002

species	lamellae erosion	columnaris observed	Ich observed	inflamed lower intestines	*C.shasta* observed
coho – fresh dead	+	+	-	-	-
Chinook – fresh dead	+	+	-	+	-
Chinook– fresh dead	+	+	+	-	-
Chinook- moribund	+	+	+	-	-
Chinook - moribund	+	+	+	+	+
Chinook - moribund	+	+	+	-	-
Chinook - moribund	-	-	+	-	-

Comments:

Water temps.

Blake's Riffle – 5 PM in 12" of water: 69°F

Blue Creek – 11AM in 3 ft of water: 59°F

Submitted by

Tresa Veek, Associate Fish Pathologist, CDFG

Attachment 2

PATHOLOGY REPORT

US Fish & Wildlife Service **phone 530-365-4271**
CA-NV Fish Health Center **fax 530-365-7150**
24411 Coleman Hatchery Rd
Anderson, CA 96007

FHC Case No. : 2002-139 Submittal date: 09/27/02
Sample Collector: S Foott Sample Site(s): Blue creek mouth, Klamath R. (16rm)
Histological specimen examiner: J. Scott Foott
Species: Morubund Chinook salmon and intestine from 1 dead coho Age: Adult

Tissues: Gill , liver, kidney, spleen, and lower intestine
Fixative: Davidson (X) , PREFER-ETOH ( ), 10%BF ( ), ZFIX ( ), Bouins ( )
Stains: Hematoxylin & eosin (X), PAS ( ), Iron ( )
Block No. 4182 - 4189 Block / slide deposition: FHC

Blood Smear (Number): 4 Bloodsmear Stain: Leishman-Giemsa ( ), DiffQuick(xx)
General leukopenia in 2 of 4 smears, neutrophilia in 3 of 4 (see attached table)
No erythrocyte inclusions or blood parasites seen in smears

Clinical chemistry: 4 serum samples= osmolarity, chloride, and total protein
Hypochloremia detected in 2 of 3 samples with reduced osmolarity values (< 280 mmol/kg), one sample (male 3) cannot be evaluated due to fibrin clot. Serum protein levels were slightly elevated but within the broad “normal” range for adults (2 – 6 g/dL). See attach table.

<u>Summary</u>
Tissues were collected from 4 moribund adult Chinook and one hatchery coho (right maxillary clip = Trinity R. hatchery) adult that had recently died. Ich (*Ichthyophthirius multifiliis*) was observed in all 4 Chinook gill specimens and was associated with epithelial hyperplasia. While histological processing would remove the heavy mucus layer observed on the gills at the time of collection, large numbers of globlet (mucus) cells were associated with the parasites. The combination of hyperplastic epithelium and excessive mucus would act to reduce respiratory and ion control functions of the gill. Skin lesions associated with the severe Ich infection would cause ion loss as demonstrated by the low serum chloride levels (hypochloremia). One gill section showed necrotic changes consistent with the gross Columnaris (*Flavobacterium columnare)* disease signs observed at the time of collection.

Liver, kidney, and spleen specimens were normal. Three of 4 kidney sections contained 1 to 2 metacercaria (presumptive *Nanophyetus salmincola*). Little to no host response was associated with these trematodes and the infection is considered benign. Three of 5 lower intestine sections contained *Ceratomyxa shasta* trophozoites however there was only minor inflammation associated with the parasites. These infections were not deemed significant to the health of the fish *<u>at the time of collection</u>*. Ceratomyxosis can advance into a debilitating hemolytic condition.

While *Aeromonas hydrophilia* was isolated from 2 of 4 kidney samples, it is unlikely that an internal bacterial infection was the cause of the epizootic. Examination of gram-stained spleen imprints did not detect bacteria as would be expected in a serious bacterial infection.

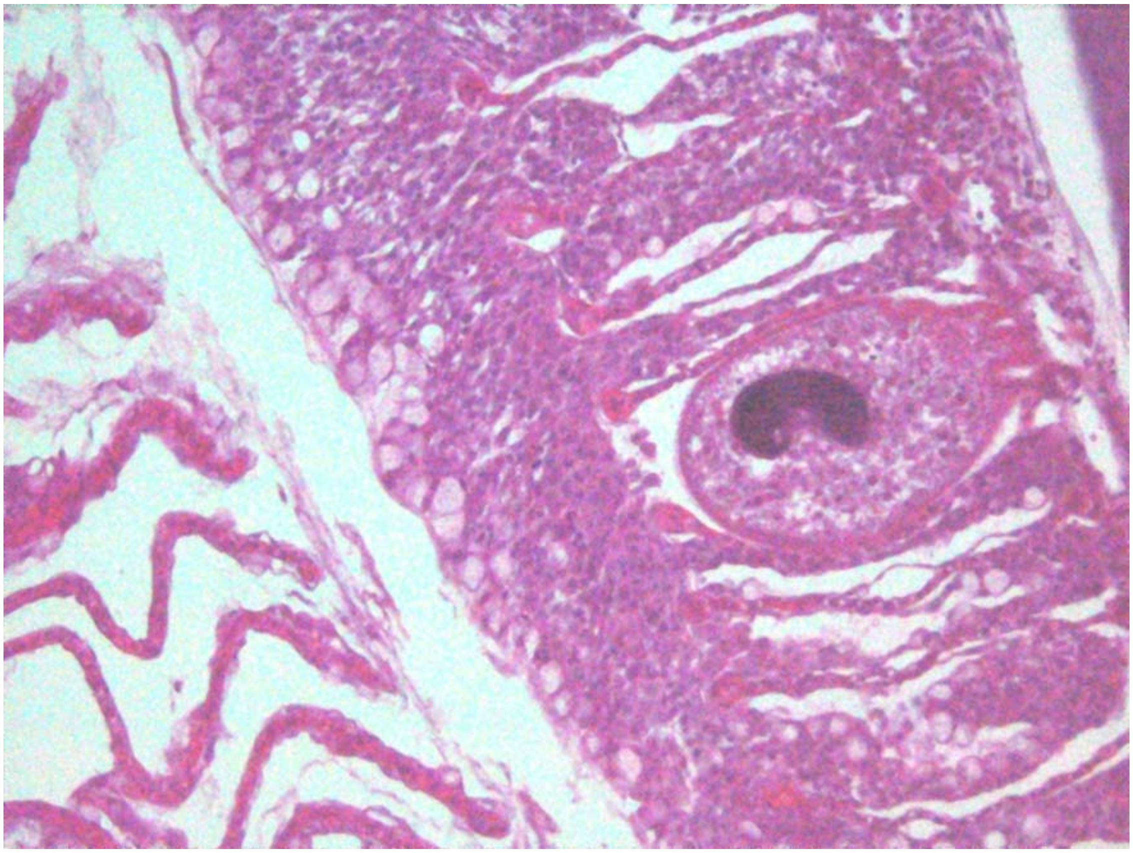
The gross clinical signs of swollen gills containing Ich and the high incidence of gill rot (columanris) provide strong evidence that the disease, induced by these two contagious pathogens, was the immediate cause of the fish kill.

Blue Creek / blue hole seep region (16 river mile) Klamath R. 9/27/02

Fish (m=male, f= female)	m1	m3	f7	m8
Swollen gill / excess mucus	y	y	y	y
Fc gill lesion	n	n	y	y
Bacteria detected in spleen imprint	n	n	n	n
Bacteria isolated from kidney (BHIA)	Ah	Ah	none	none
Ah = *Aeromonas hydrophilia*				
BLOOD				
Serum protein (g/dL)	4.6	1.5**	5.3	3.9
Serum Chloride (meq/L)	79	88**	66	86
Serum Osmolarity (mmol/ kg)	299	261**	253	272
Serum notes		**fibrin clot	hemolysis	

Normal ranges
serum chloride 120 – 130 meq/L
osmolarity 280 – 320 mmol/kg
protein 2 – 6 g/dL

Leukocyte counts / 100 WBCs	m1	m3	f7	m8
Lymphocyte	24	38	39 (55%)	46
Thrombocyte	38	61	4 (6%)	1
Neutrophil	33	1	23 (33%)	53
Monocyte	5	0	4 (6%)	0
Leukopenia	y	n	y	n
L:G ratio	0.72	38	1.7	0.86
Neutrophilia	y	n	y	y
Erythrocyte inclusion / parasite	none	none	none	none



Ich trophont (large arrow) within hyperplastic gill epithelium of Klamath R. Adult Chinook Salmon (50x mag., H & E stain). Note the contrast between normal gill lamella (arrow head) and thicken epithelium surrounding the parasite (region between small arrows).