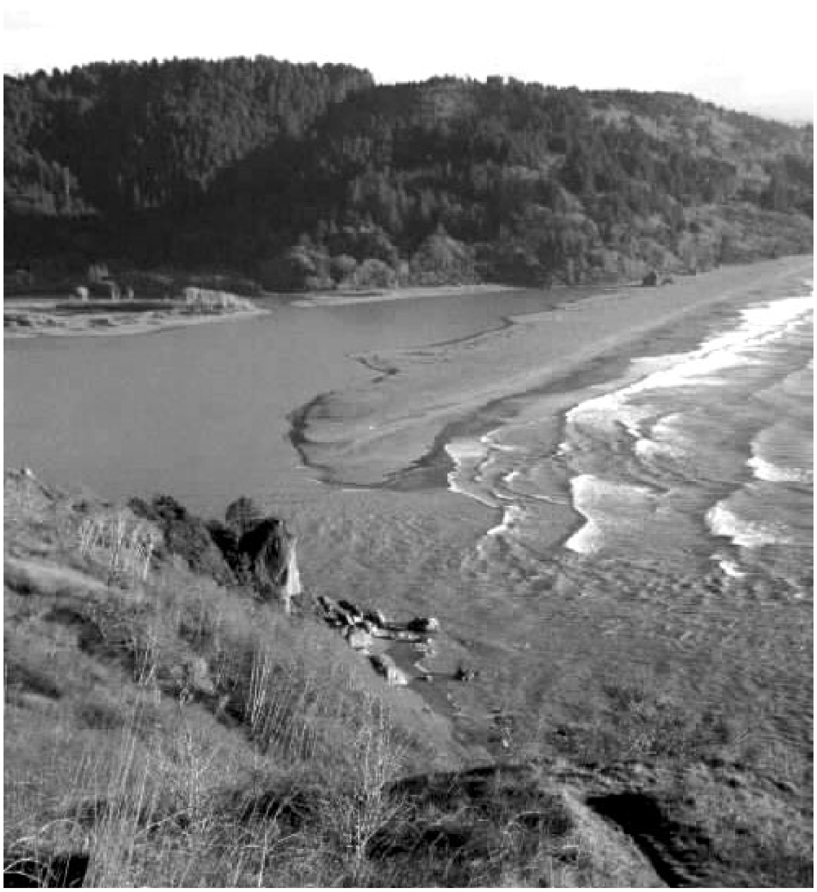
Agenda Item D.3.b
KRFC Stock Assessment
March 2008

ASSESSMENT OF FACTORS AFFECTING NATURAL AREA ESCAPEMENT SHORTFALL OF KLAMATH RIVER FALL CHINOOK SALMON IN 2004-2006



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EXECUTIVE SUMMARY

Klamath River fall Chinook (KRFC) failed to meet the Pacific Fishery Management Council's (Council's) conservation objective of at least 35,000 adult natural spawners in 2004, 2005, and 2006. In accordance with the Fishery Management Plan (FMP), the Council convened a workgroup consisting of members of the Salmon Technical Team (STT), with assistance from members of the Habitat Committee (HC), and the tribes and resource management agencies involved with management of the Klamath River and its salmon fisheries. The charge to this workgroup was to investigate the causes of this failure, and to determine if overfishing of KRFC occurred.

The workgroup reviewed as many factors as possible that could have played a role in the decline of the Klamath Fall Chinook during the years leading up to, and contributing to, the Overfishing Concern. The Council's HC draft report provided much of the background related to factors potentially affecting the production of juvenile out migrants from the river system in the contributing brood years. These sections of the report identify problems in the basin that limit production and adversely affect juvenile survival, as well as information gaps about juvenile production and survival, and the factors affecting them. The STT provided analysis of the fishery management context for the three consecutive years in which the stock failed to meet its conservation objective, including modifications to the Klamath Ocean Harvest Model (KOHM), implemented to reduce apparent biases in 2003—2005, which resulted in reduced harvest impacts in 2006.

The habitat sections in the report present discussion of river flows, temperatures, competition, predation, and disease that affected the survival of out migrant juvenile fish. In all of these cases it was not possible to quantify a relationship between the causal factor and juvenile production that resulted in stock depression during the overfishing assessment (OA) period. The work group was unable to find any studies that confirmed the causal factors of the population decline. However there were factors identified such as incidence of disease that likely contributed to reduced survival. Another example of these likely causal factors was the unknown effect of predation by a steelhead population that was increasing during the years of Chinook decline. All of these considerations could only be speculative because of the lack of data or specific studies to demonstrate the effects. A freshwater survival index was calculated, using hatchery fingerling releases as indicators of the natural stock. Survival rates were calculated as the reconstructed abundance of hatchery cohorts age-2 September 1 in the ocean, divided by the number released. These calculated survival rates included mortality in the latter phase of river, estuary and early ocean life. The results of this analysis showed that of the affected broods only the 2001 brood and probably the upcoming 2003 brood showed depressed survival rates, but not the 2000 or 2002 broods. These sections demonstrate that early life history survival is complex, and the factors that influence it are difficult to quantify and likely vary from year to year.

The sections of the report that consider the role of fishery management in the Overfishing Concern clearly demonstrate where variability in abundance forecasts and predictions in ocean fishery impacts resulted in natural adult spawning escapements that were lower than anticipated in 2004, and 2005, and though higher than anticipated in 2006, were still below the floor of 35,000 natural adult spawners. In 2004, fishery management measures were adopted to target the escapement floor. Ocean abundance of KRFC was slightly higher than forecasted, but impacts in ocean fisheries were substantially higher than the model predicted, resulting in a reduced terminal run and failure to meet the floor. In 2005, fishery management measures were again adopted that were intended to target the escapement floor. Ocean abundance was lower than forecast, and ocean harvest impacts again exceeded expectations resulting in failure to meet the floor for a second year. In 2006, modifications were made in the modeling of ocean fisheries to address apparent bias in some model components the forecast; however, the preseason forecast abundance was insufficient to meet the escapement floor in the absence of fishing. Through an Emergency Rule, management measures were adopted to allow summer fisheries that resulted in an expected escapement of 21,100 natural adult spawners. Ocean abundance was higher than the preseason forecast, and ocean fishery impacts were as anticipated, producing a natural adult spawning escapement greater than predicted, but still below the floor. In each of these years, fall fisheries in the preceding year had reduced ocean abundance, limiting management flexibility for summer fisheries. However, ocean abundance of KRFC was still sufficient to meet the escapement floor in the absence of fishing, though after the impacts of fall fisheries, this would have required severely restricting ocean fisheries in 2005 and 2006.

In any one year, the maximum fishery mortality rate allowable under the Council's Pacific Coast Salmon FMP, as amended through Amendment 14, is the maximum rate that would allow the stock in question to meet its conservation objective (PFMC 2003 § 3.1); or zero if the stock could not meet its conservation objective even in the absence of fishing (PFMC 2003 § 3.2.2.2). Conservation objectives may be expressed in terms of escapements, exploitation rates, or both. In the case of KRFC, the maximum allowable fishery mortality rate is implicitly defined by its ocean abundance and the minimum spawner requirement, not to exceed a spawner reduction rate of 2/3. In any one year, *overfishing* is said to have occurred if the realized fishery mortality rate exceeded the maximum allowable rate under the FMP. Thus, if a stock's ocean abundance was sufficient to meet the conservation objective in the absence of fishing, but the objective was in fact not met in the presence of fishing, then overfishing occurred and the fishery management process may generally be faulted. On the other hand, if the stock's ocean abundance was insufficient to meet the conservation objective in the absence of fishing, overfishing, if it occurred, may not have been the sole factor responsible for the stock not meeting its conservation objective. Other factors such as especially poor stock production and/or survival at earlier life stages may have been largely responsible for the stock not meeting its conservation objective.

The ocean abundance of KRFC during the period of the Overfishing Concern was high enough to have met the FMP conservation objective for this stock in each of these three years had the fisheries been sufficiently limited. The workgroup thus concludes that overfishing of KRFC occurred in 2004, 2005, and 2006. The primary cause for overfishing in 2004 and 2005 was a substantial under-forecast of the ocean commercial fishery mortality. In 2006 the primary cause was a policy decision to allow fisheries to proceed under emergency rule. Meeting the escapement floor in any one of these three years would have averted this Overfishing Concern.

The aggregate natural spawning escapement levels observed during the OAP were below the best estimate of spawning stock size at maximum sustainable yield (S_{MSY}), however they were not unprecedented. Between 1990 and 1994 there were much lower natural spawning escapements, and for a more extended period than in 2004 through 2006, and yet the aggregate population abundance recovered. In fact some of the larger broods on record, including the parent broods of the OAP natural spawners, occurred subsequent to the 1990-1994 period. If the aggregate abundance were all that mattered, there would probably be little concern for the potential of the current shortfall to affect long-term productivity of KRFC. However, the sequential low spawning escapements in the Salmon and Scott rivers during the OAP are unprecedented. The current depression of these key natural sub-stocks does raise concerns regarding the long-term genetic integrity of KRFC that were not present during the 1990 to 1994 period. The loss of genetic integrity raises concerns for the ability of KRFC to produce MSY on a continuing basis.

The workgroup's recommendations are:

1. Consider the Overfishing Concern of KRFC ended when a natural spawning escapement of at least 35,000 adults is achieved in three out of four consecutive years with a natural spawning escapement of 40,700 adult KRFC (SMSY) or more in at least one of those three years.

2. Target a natural spawning escapement of 40,700 adult KRFC until the Overfishing Concern is ended (the rebuilding period).

3. When implementing *de minimis* fisheries during the rebuilding period, provide for an age-4 ocean impact rate of no more than 10 percent when preseason stock abundance forecasts result in pre-fishing spawning escapement projections of less than about 54,000, plus an additional requirement of introducing a sliding scale, which would reduce the allowable rate linearly from no more than 10 percent at a projected natural spawning level of 30,000 to 0 percent at a projected natural spawning level of 22,000.

4. No further modifications in parameterizing the KOHM components are recommended at this time.

5. During periods of stock rebuilding, fall fishing opportunity in areas impacting KRFC abundance should be restricted.

6. The practice of reopening the upper Klamath and Trinity rivers to recreational fishing once hatchery egg take goals are met should be suspended during rebuilding periods or when an Overfishing Concern is imminent.

7. All river fishery strata should be sampled at a minimum sampling rate of 20 percent for catch and biological information, including coded-wire tags (CWTs) used to estimate impact on natural area spawners and returns of hatchery fish.

8. No change to the current FMP conservation objective for KRFC.

9. Encourage implementation of a 25 percent constant fractional marking program at Iron Gate Hatchery.

10. Encourage further research on disease issues in the Klamath Basin as they relate to population dynamics and fishery management.

11. Encourage expanded studies of tributary and mainstem production and survival rates of KRFC. Encourage studies of early-life marine survival rates for KRFC.

12. Continued Council involvement in the FERC relicensing process, and consideration of Council recommendations by FERC.

1.0 INTRODUCTION

Amendment 9 to the Council's FMP specified the conservation objective for Klamath River fall Chinook (KRFC) was to preserve 33 percent to 34 percent of potential adult natural spawners, but no less than 35,000, in any one year. The preseason projected adult spawning escapement was 35,000 in both 2004 and 2005; however, the post season estimates were 24,100 and 26,800, respectively. In 2006 the preseason projection was 21,100, and the postseason estimate was 30,400.

KRFC failed to meet the Council's conservation objective of at least 35,000 adult natural spawners in 2004, 2005, and 2006. When a stock fails to meet its conservation objective for three consecutive years an Overfishing Concern is triggered under the terms of the Pacific Coast Salmon Plan (FMP) (PFMC 2003). An Overfishing Concern requires specific actions of the Council and its advisory bodies, and may result in a declaration by the National Marine Fisheries Service (NMFS) that the stock is overfished, and subsequent development of a rebuilding plan.

Specific actions required by the FMP when an Overfishing Concern is triggered include developing an assessment of the stock and the pertinent factors causing the stock depression, and a review of essential fish habitat (EFH) status affecting the stock. After review of the stock and EFH assessments, the Council will recommend actions to: 1) end any excessive fishing mortality; 2) specify criteria for determining the end of the Overfishing Concern; 3) achieve the conservation objective of the stock; and 4) specify actions necessary to rebuild the stock.

1.1 Purpose and Need

The purpose of this report is to satisfy the requirements of the FMP when an Overfishing Concern occurs, specifically to review the current status of KRFC, determine the level and source of fishing mortality, identify pertinent factors leading to the Overfishing Concern, and assess the overall significance of the stock depression with regard to achieving maximum sustainable yield (MSY) on a continuing basis.

The Salmon Technical Team (STT) was directed by the Council to coordinate with relevant state, tribal, and Federal agencies, and the Council's Habitat Committee (HC), to complete the stock assessment. The STT has primary responsibility for determining the status of KRFC and developing recommendations for any management changes that may be necessary to rebuild the stock for application beginning in 2008, and for determining the end of the Overfishing Concern.

During the 2006 preseason salmon management process, the Council was aware that KRFC had failed to meet the conservation objective for two consecutive years and was projected to not meet the conservation objective in 2006, even if all Council managed fishing that would impact KRFC were prohibited. These circumstances triggered a Conservation Alert according to the FMP, and required the Council to request relevant state and tribal managers to complete an assessment of the primary factors leading to the escapement shortfall. The Council assigned the HC to assess the EFH related factors associated with the Conservation Alert. The HC completed a draft report, which was the basis for part of this assessment.

This report is needed to fulfill the requirements of the FMP and the Magnuson-Stevens Reauthorization Act (MSRA) to prevent overfishing, and rebuild depressed stocks to sustainable levels. This report is the first step in a process designed to identify the cause of their depressed status and rebuild KRFC, which have triggered an Overfishing Concern, and therefore may be at risk of long term decline in MSY. KRFC are a primary constraint to ocean fisheries between Cape Falcon, Oregon and Point Sur, California, and an important contributor to catch in ocean fisheries between Humbug Mt., Oregon and Horse Mt., California, an area known as the Klamath Management Zone (KMZ). KRFC are the primary contributor to Klamath River recreational and tribal fisheries. When KRFC are depressed, fishing interests and communities in the entire area suffer hardship, as was the case in 2006 when a fishery failure was declared, and commercial ocean fisheries in southern Oregon and northern California, and the Klamath River recreational fishery were closed. Without an abundant, harvestable stock of KRFC, fisheries cannot proceed and tribal needs cannot be met, which affect the cultural, economic, and religious fabric of Klamath River tribes. An abundant KRFC stock also contributes to the ecosystem function of the marine and freshwater environment by providing food for predators, scavengers, and decomposers and nutrient transport for forest ecosystems.

1.2 Assessment Objectives

The objectives for this stock assessment were to:

- Identify potential factors affecting KRFC natural area recruitment;
- Compare the status of these factors during the overfishing assessment period (OAP) to appropriate benchmarks (e.g., long term average);
- Identify potential factors affecting KRFC natural area escapement;
- Assess the performance of the fishery management forecast model during the OAP;
- Review the fishery management decisions made during the OAP;
- Determine if excessive fishing mortality resulted in overfishing;
- Determine if the current stock depression resulted in loss of the stock's ability to achieve MSY on a continuing basis, and;
- Recommend actions to prevent future natural area escapement shortfalls.

1.3 Background

A harvest rate based management plan for KRFC was developed by the Klamath River Technical Team (KRTT) and approved by the Klamath River Salmon Management Group (KRSMG) in 1986. The plan called for a 35 percent escapement rate (later changed to 33-34 percent) for each brood of naturally spawning fish except that 35,000 naturally spawning adults would be protected in all years (35,000 escapement floor; KRTT 1986). The KRTT report is the original source for the 35,000 fish escapement floor, which together with the escapement rate at higher abundance levels, remains a key feature of the conservation objective for KRFC in the current salmon FMP. The KRTT concluded that the escapement floor of 35,000 was needed to protect the production potential of the resource in the event of several consecutive years of adverse environmental conditions. At that time, the KRTT concluded that the escapement floor represented approximately 50 percent of the adults required to achieve the best available estimate of MSY.

The harvest rate based management plan recommended by the KRTT was subsequently adopted as part of Salmon Plan Amendment 9, which was first implemented in ocean fishery regulations beginning May 1, 1989. Amendment 9 incorporated the 35,000 fish escapement floor as part of the management objective for KRFC. The Council concluded that inclusion of the floor protected the stock by reducing the risk of prolonged depressed production, provided greater long term yield, and resulted in a high probability of attaining sufficient escapement for hatchery production.

Failure to meet the 35,000 natural adult escapement goal in 1990, 1991, and 1992 led to a stock assessment by the Council and the Klamath Fishery Management Council (KFMC) (PFMC 1994). One primary recommendation adopted from that assessment was to reduce the bias in projecting ocean abundance of the stock by forcing the sibling regression relationships through the origin.

As part of its ongoing commitment to periodic review of management objectives, the Council asked the KFMC to conduct a modeling study of stock, recruitment, and yield of KRFC. The objective of the study was to evaluate the present management policy and, particularly, the 35,000 fish escapement floor. The task was assigned to the Klamath River Technical Advisory Team (KRTAT). The KRTAT updated data and analysis done originally by the KRTT (1986), and explored new areas including the effects of environmental variability on recruitment. The KRTAT (1999) concluded that use of the 35,000 fish escapement floor remained a prudent choice and "near optimal" for the purpose of optimizing long-term average yield.

Ocean fishery management to protect Endangered Species Act (ESA) listed California Coastal Chinook (CCC) salmon began in 2000. The NMFS ESA consultation standard resulted in a requirement that ocean fisheries be limited to a pre-season projected age-4 ocean harvest rate on KRFC of no more than 17.0 percent (equates to no more than 16.0 percent based on new estimation methodology adopted in 2002). This rate was the maximum observed for the three-year period[1] prior to the CCC consultation and was used to curb further declines in abundance of CCC salmon stemming from ocean fishery impacts. The consultation standard takes precedence over the Council's 33 percent to 34 percent spawner escapement rate policy as it applies to ocean fisheries, but does not affect Klamath Basin inriver fisheries.

In 2005, the Council asked for a review of the technical basis of the 35,000 escapement floor (STT 2005a), and for a review of the relationship between spawning escapement and recruitment for KRFC (STT 2005b). The STT (2005b) updated information, explored several alternative spawner-recruit models, and also considered the effects of environmental factors on recruitment. The STT did not comment specifically on the 35,000 fish escapement floor, but did provide a range of MSY escapement values that depend on the assumptions and models used. The Model 2 stock/recruitment relationship from STT (2005b) included a juvenile survival index term and was considered to represent the best available science by the STT and the Scientific and Statistical Committee (SSC). The Model 2 estimate of MSY escapement was 40,700. Although

[1] The three year period chosen to determine an appropriate harvest rate began in 1996, the year in which ESA requirements to protect Sacramento River winter Chinook salmon were first implemented.

this estimate of MSY escapement is somewhat lower than the estimate provided by the KRTT (1986) 21 years ago, the Council remained committed to reliance on the escapement floor as part of the conservation objective for KRFC. When the escapement floor was adopted into the Salmon FMP through Amendment 9, the Council required that modification of the floor could only occur by FMP amendment.

In 2006 the Council adopted Amendment 15 to the FMP, which allows *de minimis* impacts to KRFC in ocean salmon fisheries during years that might otherwise be closed because of a projected escapement shortfall of KRFC relative to the conservation objective of no fewer than 35,000 naturally spawning adults. The intent of Amendment 15 was to provide some low level of economic relief for fisheries dependent communities without significantly impacting the long term productivity of KRFC. However, the Council specifically excluded modifying the floor itself, thus demonstrating a continued commitment to the 35,000 spawner floor as a conservation objective.

1.4 Factors Potentially Affecting Natural Area Recruitment and Escapement

A number of factors could have played a role in the decline of KRFC during the years leading up to, and contributing to, the Overfishing Concern. Some of these factors could have affected recruitment of the critical broods, which may have influenced certain fishery management decisions, whereas the fishery management decisions themselves had a more direct impact on the spawning escapement in 2004, 2005, and 2006.

Factors potentially affecting natural area recruitment include:

1. Insufficient parent stock size or high adult prespawning mortality
2. Skewed or unbalanced parent distribution
3. Low egg to fry survival
    a. redd scour
4. Low juvenile freshwater or early marine survival rate
    a. Water quality, quantity, disease, etc.
5. Hatchery/wild interaction
    a. Juvenile competition, predation, genetic diversity, etc.
6. Depensatory mechanisms that limit or depress cohort survival

Factors potentially affecting natural area escapement include:

7. Unanticipated fishing effort
    a. Entry of latent effort, shifts among areas or times, etc.
8. Increased efficiency in fisheries
    a. High catch per unit of effort or contact rates, stock distribution changes, etc.
9. Population forecast errors
    a. Preseason ocean abundance, natural/hatchery components, natural mortality, maturation rates, etc.
10. Policy considerations
    a. Needs of fishing communities, allocation, management objectives, etc.

Many of these potential factors were difficult to assess because of inadequate information, but an attempt was made to at least note these potential factors and identify data shortfalls.

Factors one through six could affect recruitment of the stock, and hence the harvestable surplus available to the fisheries in a given year. Factors seven through ten fall under the umbrella of the fishery management process, the success of which determines whether the harvestable surplus in a given year is exceeded and thus whether or not the spawning escapement goal is realized. Recruitment is important to the fishery since it determines the harvestable surplus. However, given the realized recruitment in any given year, it is the responsibility of fishery management to ensure adequate escapement occurs to achieve the conservation objective in that year (assuming there is a harvestable surplus and fisheries take place). If the management target for any one year is a specified spawner escapement number (e.g., the 35,000 natural spawner floor), recruitment can affect annual spawning escapement only if it is sufficient to exceed the capacity of fisheries to achieve their allocations or sufficient to reach another constraint (e.g., KRFC 66 percent spawner reduction rate (SRR), Snake River fall Chinook index, etc.).

Sections 3 and 4 provide an assessment of the factors potentially affecting natural area recruitment and escapement, respectively.

2.0 STOCK/ECOSYSTEM DESCRIPTION

2.1 Location and Geography

The Klamath Basin lies in Northern California and Southern Oregon and encompasses 40,632 km^2 (Figure 2-1). More than half of the watershed (20,875 km^2) lies in the Upper Klamath Basin. Anadromy in the upper basin was cut off by the construction of Copco Dam #1 in 1917, and was further limited by construction of Iron Gate Dam in 1962, built to re-regulate the discharge of Copco Dam. Access to the upper Trinity Basin was cut off by the construction of Trinity Dam in 1962 and its re-regulation dam (Lewiston) in 1963, which together blocked access to the upper 459,264 acres (1,859 km^2) of the Trinity Basin, leaving an accessible watershed area of 17,898 km^2. There are various other smaller dams and water diversions in the basin (Appendix 9.3).

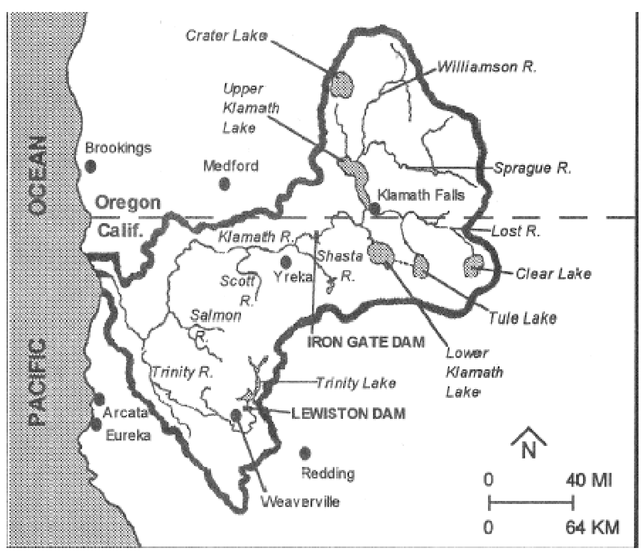

Figure 2-1. Map of the Klamath Basin.

All remaining habitat accessible to anadromous fish lies in California, though portions of the lower Klamath Basin Watershed extend into Oregon. Major tributaries to the Klamath River within the lower basin include the Trinity, Salmon, Scott, and Shasta Rivers, and Bogus Creek, which support spawning populations of KRFC.

Fall run is the predominant natural Chinook salmon run type throughout the basin. Hatchery fall Chinook production occurs at Iron Gate Hatchery (IGH) located at the base of Iron Gate Dam at the upper limit of anadromous migration in the Klamath River and at Trinity River Hatchery (TRH) located at the base of Lewiston Dam at the upper limit of anadromous migration in the Trinity River. Both facilities were constructed to mitigate for habitat loss resulting from construction of the major dams on the mainstems of the Klamath and Trinity rivers, respectively. The remaining natural populations of spring Chinook salmon occur in the South Fork Trinity and Salmon rivers. There is a hatchery program for spring Chinook salmon at TRH and for coho salmon (*O. kisutch*) and steelhead (*O. mykiss*) at both hatcheries. Other anadromous species in the basin include coastal cutthroat (*O. clarkii*), Pacific lamprey (*Lampetra tridentata*), and green sturgeon (*Acipenser medirostris*). Coho salmon in the Klamath Basin are part of the ESA-listed Southern Oregon-Northern California Coastal (SONCC) coho evolutionarily significant unit (ESU).

2.2 Life History

2.2.1 Natural Stock

Naturally spawning KRFC enter freshwater to spawn during August-September and deposit their eggs during October-December. The eggs incubate in the gravel during October-January and young fish emerge in February-March. Downstream migration begins soon after emergence (Figure 2-2). Juveniles that are ready to enter the ocean reach the estuary during June-August and ocean entrance is generally complete by the end of September. In August-September of the following year a small proportion (range 2 percent to 11 percent, 4 percent average) of each cohort, mostly males (jacks), returns to the river to spawn. The first major contribution to adult spawning escapement takes place during August-September of the following year as age-3 fish. The age-3 return is about equal proportions of males and females. The age-3 maturation rate has averaged 39 percent with a range of from 19 percent to 66 percent since the 1979 brood (Grover 2007, pers. comm.). The majority of the adult fish in each cohort are destined to spawn at age-4, although the actual number of fish that survive to spawn may be less than the age-3 return due to ocean and river fishing impacts. The age-4 maturation rate has averaged 89 percent with a range of from 61 percent to 99 percent and has been comprised of about equal numbers of males and females. The very few remaining fish of each cohort mature at age-5 or very rarely at age-6. All KRFC die soon after spawning.

Natural mortality of naturally produced fish is very high during early life history stages. Small changes in ecological conditions, whether physical or biological, can substantially decrease the chances that a cohort of fish will replace itself much less support a satisfactory level of fishery harvest. Cohorts of fish transition during their life from one of passive existence, totally dependent for their survival on surrounding physical and biological conditions, to one of active existence, wherein the fish actively seek out and compete with one another and other animals for their survival.

Recently emerged fry are totally dependent on a ready supply of high quality food items in their immediate vicinity. Their ability to seek out suitable food items and food streams increases as they grow, but their geographic range continues to be very limited until well into their first summer in the ocean due to their small size and inability to move laterally or in opposition to stream flow or ocean current conditions. Flood events or receding stream levels can strand fish in side pools that may never again reconnect with the main river flow. Low stream flow conditions increase feeding opportunities for predatory animals and decrease the amount of living space available for hiding and feeding. Predatory birds and fish likewise can have a major impact on stream rearing fish and recent ocean entrants, particularly when they are massed in large schools. Disease and parasitic infections are exacerbated or have increased effect during warm water events and/or low stream flow periods.

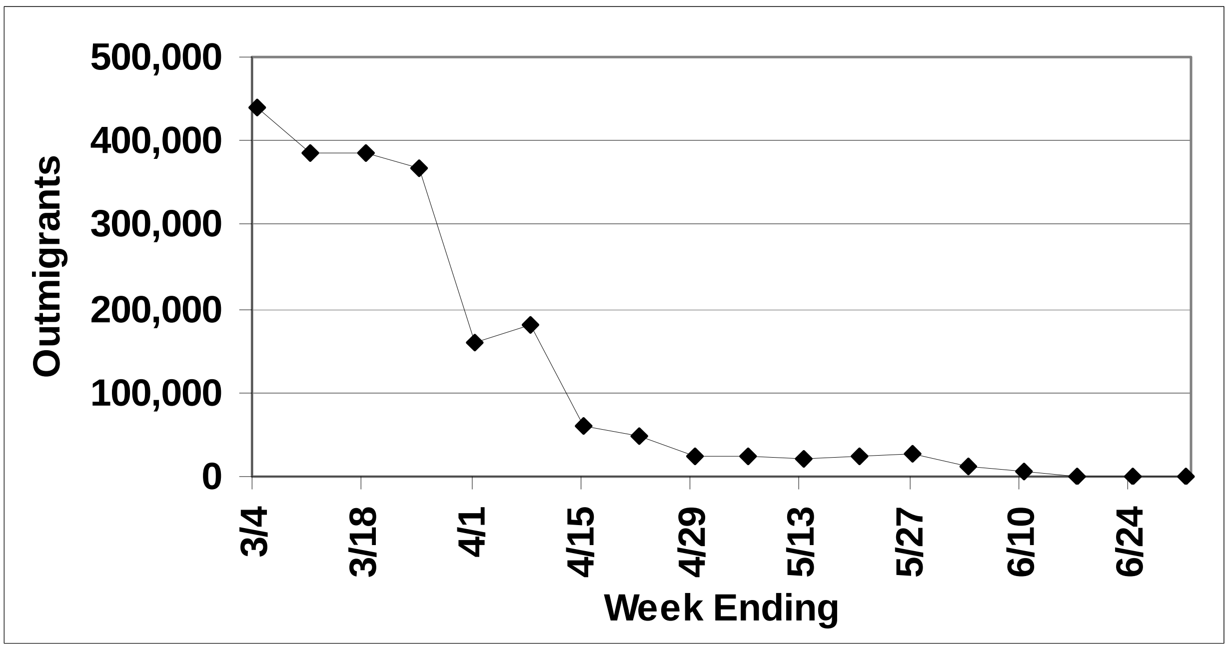

Figure 2-2. Estimated average number of juvenile Chinook salmon emigrating from the Shasta River by week, 2001-2005.

In their later years of life KRFC can make ocean migrations sometimes ranging over hundreds of miles away from the Klamath River mouth. El Niño events can adversely affect ocean salmon prey items both in terms of biomass and nutritional value. Such events can also redirect feeding habits of hungry marine mammals to prey on salmon in confined or restricted areas such as the Klamath River mouth and estuary.   El Niño events can also cause the fish themselves to change migration patterns.

The relative magnitude of the survival rates experienced by stream and ocean rearing fish can be approximated based on available age-specific life history data for the stock. Table 2-1, Appendix 8.2). This example is based on an age-2 September 1 population of 380,000 fish (approximate 1979-1998 brood year average); an ocean and river fishery adult SRR of 66 percent; an assumed average of 1,250 eggs per adult spawner; the natural mortality rates used in

California Department of Fish and Game (CDFG) cohort reconstructions; average maturity rates resulting from those calculations; and CDFG Scott and Shasta rivers outmigrant estimates.

Table 2-1. Approximate KRFC life stage-specific survival rates absent fisheries.

Life history stage	Period of time: w/o fishing survival rate	Source
Egg deposition to mainstem entrance	5-8 months: 17%	Appendix 9.2
Mainstem entrance to ocean entrance	4-7 months: 5.5%	Appendix 9.2
Age-2 (Sept. 1-Aug. 31)	12 months: 50%	Goldwasser et al. 2001
Age-3 (Sept. 1-Aug. 31)	12 months: 61%	Goldwasser et al. 2001
Age-4 (Sept. 1-Aug. 31)	12 months:80%	Goldwasser et al. 2001
Age-5 (Sept. 1-Aug. 31)	12 months:80%	Goldwasser et al. 2001

This example shows that, on average, less than 6 percent of the fish that enter the mainstem areas from tributary spawning areas during February-May survive to January 1 of the following year as age-2 fish. During this time the fish are dependent for their survival on the quality and quantity of available habitat, the availability of suitable food items and food streams, and also on the ability to avoid predators. Year class strength is believed to be determined largely in the early life history stages because small changes in the survival rate during this period can have a major impact on the number of surviving fish.

2.2.2 Hatchery Stock

All fish that return to receiving facilities at the two basin hatcheries have been allowed access to the facilities for spawning since 1996. Before that year, surplus fish were sometimes denied access when egg-take goals were met. At both hatcheries the majority of juvenile fish are released directly into the river as fingerlings at or near the respective facilities when they reach an average length of about 3 inches and average weight of about 90 fish per pound. This generally occurs during May and June of the year following spawning, although release timing can be advanced if river water temperatures are projected to be less than optimal during the downstream migration period. Currently, about 18 percent of IGH and 31 percent of TRH production goals are released as yearlings in October and November (Table 2-2). CDFG policy prohibits release of surplus eggs or fry into natural rearing areas of the basin. Surplus eggs or fry may be used in inland fishery programs where the chance of escape to anadromous waters is minimal.

The two hatcheries have specific production goals for fall-run Chinook salmon which total 8.9 million fish, 6 million at IGH and 2.9 million at TRH (Table 2-2).

Table 2-2. Fall Chinook salmon production goals for Iron Gate and Trinity River hatcheries.

	Release Type[a/]		
Hatchery	Fingerling	Yearling	Total
Iron Gate Hatchery	4,920,000	1,080,000	6,000,000
Trinity River Hatchery	2,000,000	900,000	2,900,000
Total	6,920,000	1,980,000	8,900,000

a/ Fingerlings are released May – June at about 90/lb, yearlings are released October – November 15.

The maturation schedule for fingerling releases is believed to be similar to that of naturally produced fish. The maturation schedule of yearling releases is delayed because of their smaller ocean size at age due to extended hatchery rearing compared to fingerling releases (Hankin 1990) and the importance of size at age to the onset of sexual maturity in Pacific salmon (Hankin et al. 1993). The delayed maturation schedule and extended period of ocean residence of yearling releases results in increased vulnerability to harvest in ocean and river fisheries (Hankin et al 1993; CDFG/NMFS 2001).

Hatchery fish by their confinement are able to avoid the natural perils that naturally produced fish face during their first six to eight months of life. Artificial techniques virtually ensure that every egg is fertilized and the resulting fry have a high chance for release into the stream to migrate to the ocean. The eggs and fish are protected in the hatchery by the use of chemicals that prevent or remedy diseases and parasites and the fish are fed special high protein diets that promote fast growth at this stage and result in fish that are probably larger than their naturally produced counterparts at release. Note however that yearlings, while released at a larger size than fingerlings, are likely smaller at that date than the surviving natural and fingerling-released fish of that brood year that have resided in the ocean for the past several months. Screens or other deterrents may be used to minimize predation by birds. The survival probabilities for age-2 and older hatchery fish are assumed to be the same as reported above (Table 2-1) because those estimates are based on hatchery fish data. One major difference between hatchery and natural stocks is that the egg to mainstem entrance survival estimate for hatchery fish is closer to 90 percent than the 17 percent estimated for wild fish, although their survival in the mainstem following release is probably lower because of their naivety.

IGH release policy to delay fingerling releases until May and June when the fish are ready to migrate to the sea is intended to minimize competition (interaction) with the naturally produced stream rearing fish. To the extent possible, stream environmental conditions are closely monitored at the hatcheries to ensure the fish are released when environmental conditions are suitable and the fish are ready to migrate to the sea. Following release, the hatchery fish must survive and compete with naturally produced fish and other aquatic species.

2.3 Production

2.3.1 Harvest

Prior to 1990, the average harvest of age-3 and age-4 KRFC was 234,753 in ocean fisheries and 60,900 in river fisheries (Table 2-3). Since 1990, the average harvest level has declined by 88 percent in the ocean fisheries, and by 58 percent in the river fisheries (Table 2-3). Additional historical harvest information for the river recreational and river tribal fisheries are provided in Table 2-4 and Table 2-5, respectively. Analysis of the expected and realized harvest for these fisheries during the OAP and whether this contributed to the escapement shortfall in 2004, 2005, and 2006 is presented in Section 4.

Table 2-3. KRFC ocean fishery harvest, age-3 plus age-4, 1986-2006 seasons.

	KMZ			Outside KMZ			Ocean	Inriver		
Year	Troll	Sport	Total	South	North	Total	Total	Tribal	Sport	Total
1986	43,474	6,002	49,476	97,527	155,192	252,719	302,195	25,100	21,000	46,100
1987	39,035	9,527	48,562	114,225	105,366	219,591	268,153	52,400	19,900	72,300
1988	27,928	8,778	36,706	51,379	158,613	209,992	246,698	51,100	21,800	72,900
1989	12,486	21,469	33,955	47,787	40,224	88,011	121,966	43,700	8,600	52,300
1990	4,051	7,264	11,315	76,144	21,568	97,712	109,027	7,300	3,600	10,900
1991	0	2,028	2,028	1,862	4,959	6,821	8,849	9,716	3,293	13,009
1992	171	55	226	2,760	12	2,772	2,998	5,330	974	6,304
1993	0	823	823	1,687	8,058	9,745	10,568	9,212	3,160	12,372
1994	43	1,732	1,775	1,170	4,900	6,070	7,845	11,209	1,783	12,992
1995	0	1,242	1,242	14,091	16,579	30,670	31,912	14,797	6,016	20,813
1996	774	3,468	4,242	10,349	30,007	40,356	44,598	56,322	12,741	69,063
1997	3	406	409	1,086	4,220	5,306	5,715	10,900	5,322	16,222
1998	0	111	111	4,372	466	4,838	4,949	9,395	7,603	16,998
1999	78	558	636	2,921	1,125	4,046	4,682	13,770	2,242	16,012
2000	523	4,185	4,708	11,235	26,328	37,563	42,271	29,191	5,649	34,840
2001	1,429	1,714	3,143	8,618	10,039	18,657	21,800	38,644	12,113	50,757
2002	2,164	1,615	3,779	4,903	19,372	24,275	28,054	23,663	10,321	33,984
2003	1,007	1,595	2,602	10,186	57,208	67,394	69,996	29,750	9,653	39,403
2004	**1,824**	**2,187**	**4,011**	**21,582**	**29,285**	**50,867**	**54,878**	**22,302**	**3,802**	**26,104**
2005	**248**	**952**	**1,200**	**6,342**	**4,769**	**11,111**	**12,311**	**7,442**	**1,945**	**9,387**
2006[a/]	**271**	**1,241**	**1,512**	**5,475**	**1,258**	**6,733**	**8,245**	**9,960**	**55**	**10,015**
avg 86-89	30,731	11,444	42,175	77,730	114,849	192,578	234,753	43,075	17,825	60,900
avg 90-03	732	1,914	2,646	10,813	14,632	25,445	28,090	19,229	6,034	25,262
avg 04-06	**781**	**1,460**	**2,241**	**11,133**	**11,771**	**22,904**	**25,145**	**13,235**	**1,934**	**15,169**
avg 86-06	6,453	3,664	10,117	23,605	33,312	56,917	67,034	22,914	7,694	30,608

a/ Preliminary.

Table 2-4. KRFC river recreational adult harvest and impacts, 1986-2006.

Year or Avg	Total Adult Run-Size	Quota	Landed Catch	Catch as Percent of Quota	Incidental Harvest Impacts[a/]	Total Harvest Impacts	Harvest Impact Rate (harvest/run)
1986	195,019	7,800	21,027	270%	429	21,456	0.110
1987	209,134	17,900	20,169	113%	412	20,581	0.098
1988	191,642	15,575	22,203	143%	453	22,656	0.118
1989	124,340	15,600	8,775	56%	179	8,954	0.072
1990	35,882	6,500	3,553	55%	73	3,626	0.101
1991	32,670	2,600	3,383	130%	69	3,452	0.106
1992	26,698	800	1,002	125%	20	1,022	0.038
1993	57,212	2,700	3,172	117%	65	3,237	0.057
1994	63,983	1,400	1,832	131%	37	1,869	0.029
1995	222,768	1,800	6,081	338%	124	6,205	0.028
1996	175,773	15,700	12,766	81%	261	13,027	0.074
1997	83,736	3,500	5,676	162%	116	5,792	0.069
1998	90,647	1,800	7,710	428%	157	7,867	0.087
1999	51,048	2,900	2,282	79%	47	2,329	0.046
2000	218,077	4,200	5,650	135%	115	5,765	0.026
2001	187,333	29,800	12,134	41%	248	12,382	0.066
2002	160,788	20,500	10,495	51%	214	10,709	0.067
2003	191,948	10,800	2,358	22%	48	2,406	0.013
2004	**78,943**	**4,796**	**4,003**	**83%**	**82**	**4,085**	**0.052**
2005	**65,125**	**1,244**	**1,985**	**160%**	**41**	**2,026**	**0.031**
2006	**61,629**	**300** [b/]	**62**	**169%**	**444**	**506**	**0.008**
1986-2003	128,817	8,993	8,348	93%	170	8,519	0.066
2004-2006	**68,566**	**2,113**	**2,017**	**95%**	**189**	**2,205**	**0.032**

a/ Landed catch multiplied by 0.020408.

b/ In 2006 the adult KRFC quota was zero, however 300 impacts were assumed for non retention mortality in the steelhead/jack Chinook recreational fishery.

Table 2-5. KRFC river tribal adult harvest and impacts, 1986-2006.

Year or Avg	Total Adult Run-Size	Quota	Landed Catch	Catch as Percent of Quota	Incidental Harvest Impacts[a/]	Total Harvest Impacts	Harvest Impact Rate (harvest/run)
1986	195,019	28,250	25,127	89%	2,186	27,313	0.140
1987	209,134	59,000	53,096	90%	4,619	57,715	0.276
1988	191,642	51,725	51,651	100%	4,494	56,145	0.293
1989	124,340	52,000	45,565	88%	3,964	49,529	0.398
1990	35,882	24,500	7,906	32%	688	8,594	0.240
1991	32,670	10,300	10,198	99%	887	11,085	0.339
1992	26,698	4,920	5,785	118%	503	6,288	0.236
1993	57,212	18,500	9,636	52%	838	10,474	0.183
1994	63,983	11,800	11,692	99%	1,017	12,709	0.199
1995	222,768	15,300	15,557	102%	1,353	16,910	0.076
1996	175,773	104,100	56,476	54%	4,913	61,389	0.349
1997	83,736	21,600	12,087	56%	1,052	13,139	0.157
1998	90,647	12,000	10,187	85%	886	11,073	0.122
1999	51,048	15,300	14,660	96%	1,275	15,935	0.312
2000	218,077	28,200	29,415	104%	2,559	31,974	0.147
2001	187,333	75,500	38,645	51%	3,362	42,007	0.224
2002	160,788	50,400	24,574	49%	2,138	26,712	0.166
2003	191,948	41,400	30,034	73%	2,613	32,647	0.170
2004	**78,943**	**33,806**	**25,803**	**76%**	**2,245**	**28,048**	**0.355**
2005	**65,125**	**9,022**	**8,016**	**89%**	**697**	**8,713**	**0.134**
2006	**61,629**	**10,870**	**10,285**	**95%**	**895**	**11,180**	**0.181**
1986-2003	128,817	34,711	25,127	72%	2,186	27,313	0.212
2004-2006	**68,566**	**17,899**	**14,701**	**82%**	**1,279**	**15,980**	**0.233**

a/ Landed catch multiplied by 0.087.

2.3.2 Escapement

Most (65 percent average from 1978—2003) of the natural escapement of KRFC occurs in the Trinity River and Bogus Creek, a tributary of the Klamath (Table 2-6; Figure 2-3). A large portion of these sub-populations are near hatcheries and hatchery strays contribute substantially to natural spawning. Other major spawning populations include: the mainstem Klamath, Scott, Shasta, and Salmon rivers. These other sub-populations are relatively free of hatchery influence in most years, except for the Shasta River, which ranged from an estimated 1.2 percent to 38.7 percent and averaged 15.4 percent hatchery fish between 2002 and 2006. Other miscellaneous tributaries of the Klamath and Trinity Rivers collectively generally account for less than 10 percent of the natural spawners. Additional information on this subject is presented in Section 3.4.

Table 2-6. KRFC adult spawner escapement estimates by spawning unit, 1978-2006.

	Upper	Salmon	Scott	Shasta	Bogus	Mainstem	Other	Total	Hatchery		Total	Grand
Year	Trinity[a/]	River	River	River	Creek	Klamath	Tributaries	Natural	Iron Gate	Trinity	Hatchery	Total
1978	31,052	2,600	3,423	12,024	4,928	1,700	2,765	58,492	6,945	6,034	12,979	71,471
1979	8,028	1,000	3,396	7,111	5,444	4,190	1,468	30,637	2,301	1,335	3,636	34,273
1980	7,700	800	2,032	3,762	3,321	2,468	1,400	21,483	2,412	4,099	6,511	27,994
1981	15,340	750	3,147	7,890	2,730	3,000	1,000	33,857	2,055	2,370	4,425	38,282
1982	9,274	1,000	5,826	6,533	4,818	3,000	1,500	31,951	8,353	2,058	10,411	42,362
1983	17,284	1,200	3,398	3,119	2,713	1,800	1,270	30,784	8,371	5,494	13,865	44,649
1984	5,654	1,226	1,443	2,362	3,039	1,350	990	16,064	5,330	2,166	7,496	23,560
1985	9,217	2,259	3,051	2,897	3,491	468	4,294	25,677	19,951	2,583	22,534	48,211
1986	92,548	2,716	3,176	3,274	6,124	603	4,919	113,360	17,096	15,795	32,891	146,251
1987	71,920	3,832	7,769	4,299	9,748	863	3,286	101,717	15,189	13,934	29,123	130,840
1988	44,616	3,273	4,727	2,586	16,215	2,982	4,987	79,386	16,106	17,352	33,458	112,844
1989	29,445	2,915	3,000	1,440	2,218	1,011	3,839	43,868	10,859	11,132	21,991	65,859
1990	7,682	4,071	1,379	415	732	505	812	15,596	6,719	1,348	8,067	23,663
1991	4,867	1,337	2,019	716	1,261	572	877	11,649	4,002	2,482	6,484	18,133
1992	7,139	778	1,873	520	598	366	754	12,028	3,581	3,779	7,360	19,388
1993	5,905	3,077	5,035	1,341	3,285	647	2,568	21,858	20,828	815	21,643	43,501
1994	10,906	3,216	2,358	3,363	7,817	3,249	1,424	32,333	13,808	3,264	17,072	49,405
1995	77,876	4,140	11,198	12,816	45,225	6,472	4,067	161,794	22,681	15,178	37,859	199,653
1996	42,646	5,189	11,952	1,404	10,420	2,790	6,925	81,326	13,622	6,411	20,033	101,359
1997	11,507	5,783	8,284	1,667	9,809	3,472	5,622	46,144	13,275	5,387	18,662	64,806
1998	24,460	1,337	3,061	2,466	6,630	2,913	1,621	42,488	14,923	14,296	29,219	71,707
1999	6,753	670	3,021	1,296	3,537	1,978	1,202	18,457	9,290	5,037	14,327	32,784
2000[b/]	***23,468***	***1,544***	***5,729***	***11,025***	***34,678***	***3,271***	***3,013***	***82,728***	***71,635***	***25,976***	***97,611***	***180,339***
2001[b/]	***35,991***	***2,607***	***5,398***	***8,452***	***11,927***	***9,832***	***3,627***	***77,834***	***37,204***	***17,908***	***55,112***	***132,946***
2002[b/]	***10,880***	***2,669***	***4,261***	***6,432***	***17,530***	***21,650***	***2,213***	***65,635***	***23,667***	***3,516***	***27,183***	***92,818***
2003[c/]	***31,173***	***3,302***	***11,988***	***4,134***	***15,422***	***17,722***	***3,901***	***87,642***	***31,970***	***29,812***	***61,782***	***149,424***
2004[c/]	**12,718**	**282**	**445**	**833**	**3,493**	**5,037**	**1,023**	**23,831**	**10,582**	**12,399**	**22,981**	**46,812**
2005[c/]	**12,987**	**401**	**698**	**2,018**	**5,341**	**4,622**	**722**	**26,789**	**13,955**	**13,744**	**27,699**	**54,488**
2006[c/]	**15,634**	**1,278**	**3,007**	**789**	**3,368**	**4,538**	**1,808**	**30,422**	**11,604**	**7,918**	**19,522**	**49,944**
78-03 avg	24,744	2,434	4,690	4,359	8,987	3,803	2,706	51,723	15,468	8,445	23,913	75,635
00-03 avg[b/]	***25,378***	***2,531***	***6,844***	***7,511***	***19,889***	***13,119***	***3,189***	***78,460***	***41,119***	***19,303***	***60,422***	***138,882***
04-06 avg[c/]	**13,780**	**654**	**1,383**	**1,213**	**4,067**	**4,732**	**1,184**	**27,014**	**12,047**	**11,354**	**23,401**	**50,415**
78-06 avg	23,609	2,250	4,348	4,034	8,478	3,899	2,548	49,167	15,114	8,746	23,860	73,026

a/ Trinity River upstream from the Willow Creek weir.

b/ Parent broods associated with returns comprising the overfishing assessment period.

c/ Return years comprising the overfishing assessment period.

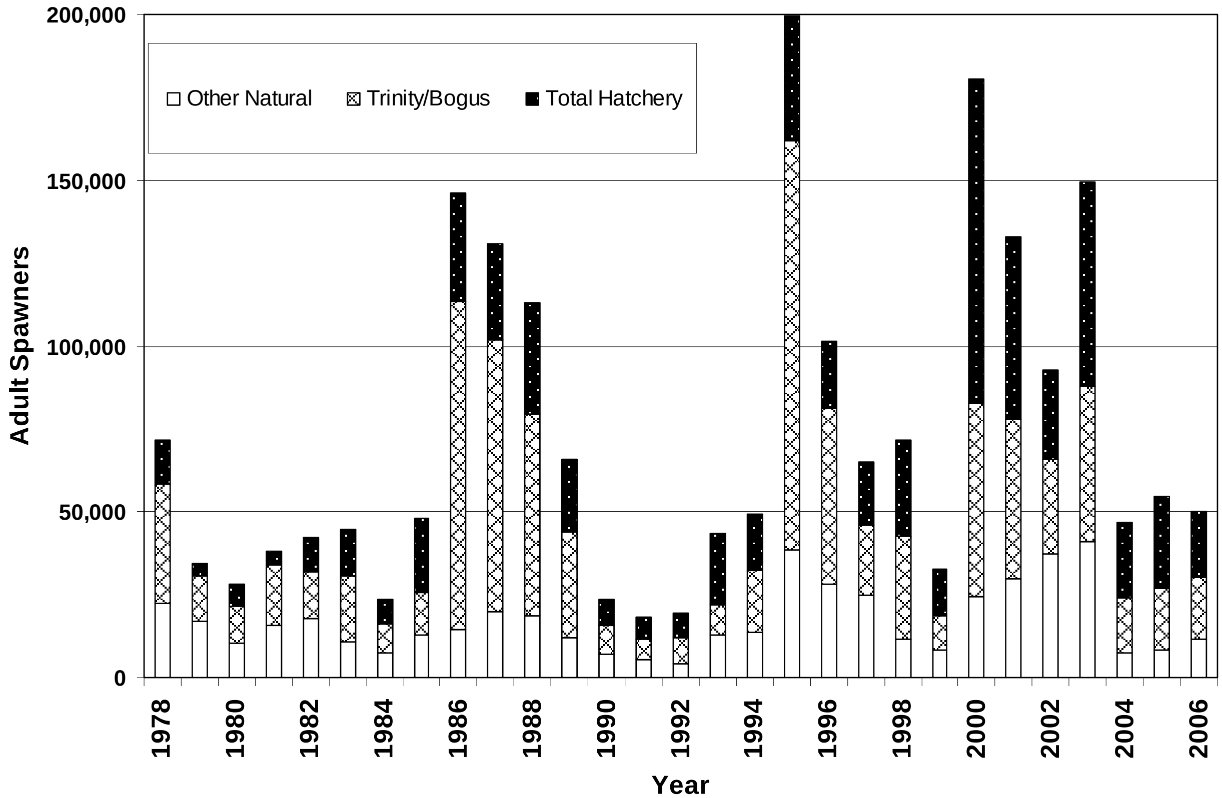

Figure 2-3. Annual spawning escapement in Klamath Basin tributaries and hatcheries, 1978-2006.

2.3.3 Natural Stock Productivity

The stock/recruitment relationship for KRFC helps to explain the effect that depressed stock status has on fisheries and spawning runs. Stock and recruitment data were analyzed by the STT (2005b) for natural spawners of the 1979—2000 broods to determine the following reference points: spawning stock size at sustainable equilibrium production (S_{UEQ}), spawning stock size at maximum sustainable production (S_{MAX}) and spawning stock size at MSY (S_{MSY}). Several models of stock and recruitment were evaluated for this analysis, and the STT (2005b) and SSC (2005) concluded that "Model 2," which included a juvenile survival index term, represented the best available science.

The Model 2 estimated reference points were S_{UEQ} = 112,300, S_{MAX} = 56,900, and S_{MSY} = 40,700. The 35,000 escapement floor thus represents 86 percent of S_{MSY} and 62 percent of $S_{MAX.}$ The latter value means that natural escapements less than 35,000 adults would result, on average, in reduced recruits (harvestable surplus) compared to higher escapements, and that escapements greater than 35,000 up to S_{MAX} (56,900) would be expected to result in more recruits. Thus failure to meet the escapement floor for KRFC would be expected to result in reduced production of natural recruits. Above S_{MAX}, further increases in spawning escapement would be expected to result in fewer natural recruits. However, expected recruitment is still greater than that produced by S_{MSY} until natural adult spawning escapement exceeds 76,900, and is greater than recruitment expected at the escapement floor for natural adult spawning escapement up to 86,500.

2.4 Stock Status

Representative marking, using CWTs, of KRFC hatchery fish have made it possible to reconstruct the life histories of hatchery and natural fish starting with the 1979 brood, 24 broods total. These "cohort reconstructions" are estimated on a monthly basis using fishery and spawning ground CWT expansions in combination with assumed fixed natural and fishery-related non-catch mortality rates. The methodology has been reviewed by Hankin and Mohr (1993) and found to be in error in some years based on "band recovery" analysis of CWTs, but no further progress has been made in the development and implementation of this alternative approach. The available reconstruction estimates show that the average hatchery age-2 ocean population size (recruitment) of the critical broods (285,307) was 100 percent of the previous 21-year average (285,186) and all of the individual broods were within the range of recruitment observed during the previous 21 years (Table 2-7; Figure 2-4). The average age-2 ocean population size (recruitment) of naturally produced fish for the critical broods (237,552) was 45 percent of the previous 21-year average (522,895). The 2001 and 2002 brood year recruits from natural spawners were very small in a historical context, representing the third and seventh lowest, respectively, on record. The 2000 brood natural recruits (405,951) were about 78 percent of average, but well within the range of natural recruits observed during the previous 21 year period. The 2003 brood natural recruitment cannot yet be estimated (Table 2-8), but the forecast age-3 ocean abundance was the third lowest on record, and the forecast age-4 ocean abundance was the lowest on record.

Age-2 recruitment data are not available for basin sub-populations, but post-spawning data are available to show the final distribution of individual cohorts. Post-spawn data during 2004—2006 indicated below average escapement levels in all natural spawning areas of the basin, including those most heavily influenced by hatchery production, Trinity River and Bogus Creek (Table 2-4).

Population modeling work by Mohr and Fujiwara (2007) concluded that natural origin adult run sizes to the Salmon, Scott, and Shasta rivers of less than 720 adults in any year pose a threat to the long-term viability of those sub-basin populations, and the genetic integrity of the aggregate KRFC stock lies in maintaining an adequate diversity of subpopulations (particularly these). Spawning escapement was less than 720 adults in the Salmon and Scott rivers in 2004 and 2005 (Table 2-6, Figure 2-5). If the subsequent returns produced from those broods continue to be depressed there may indeed be long-term negative genetic implications as described above, and indications are that the 2005 brood year juvenile outmigrant production from at least the Scott River was very low (Table 3-1). Shasta River spawning escapement was above the 720 fish threshold level in all three years, although those values include stray hatchery fish. Excluding hatchery adults and jacks, only an estimated 492 and 708 natural origin adult spawners returned to the Shasta River in 2004 and 2006, respectively. Indications are that the 2004 and 2005 brood year juvenile outmigrant production from the Shasta River was very low (Table 3-2), particularly for brood year 2005 (the 2006 outmigrant production was unavailable at the time of this report).

Table 2-7. KRFC September 1 age-2 cohort reconstruction recruitment for hatchery and naturally produced fish from 1979-2002 brood years.

	Age-2 Recruitment		
Brood Year	Hatchery	Natural	Total
1979	283,013	906,521	1,189,534
1980	193,723	524,793	718,516
1981	104,158	217,854	322,012
1982	199,932	567,179	767,111
1983	1,156,457	1,609,472	2,765,930
1984	566,372	1,089,565	1,655,936
1985	762,771	794,089	1,556,861
1986	256,778	527,568	784,347
1987	60,327	311,514	371,841
1988	68,694	80,382	149,076
1989	13,975	68,783	82,759
1990	176,457	188,924	365,381
1991	59,668	196,444	256,112
1992	527,776	1,068,999	1,596,776
1993	26,955	400,559	427,513
1994	84,756	215,880	300,636
1995	167,653	157,675	325,328
1996	110,625	158,004	268,628
1997	601,770	674,091	1,275,861
1998	213,312	523,004	736,316
1999	353,724	699,486	1,053,210
2000	**410,816**	**405,951**	**816,767**
2001	**231,507**	**97,477**	**328,984**
2002[a/]	**213,597**	**209,228**	**422,825**
79-99 avg	285,186	522,895	808,080
cv	1.01	0.77	0.83
00-02 avg	**285,307**	**237,552**	**522,859**
cv	**0.38**	**0.66**	**0.50**
79-02 avg	285,201	487,227	772,428
cv	0.95	0.80	0.82

a/ Brood incomplete for age-5; average maturation rate used.

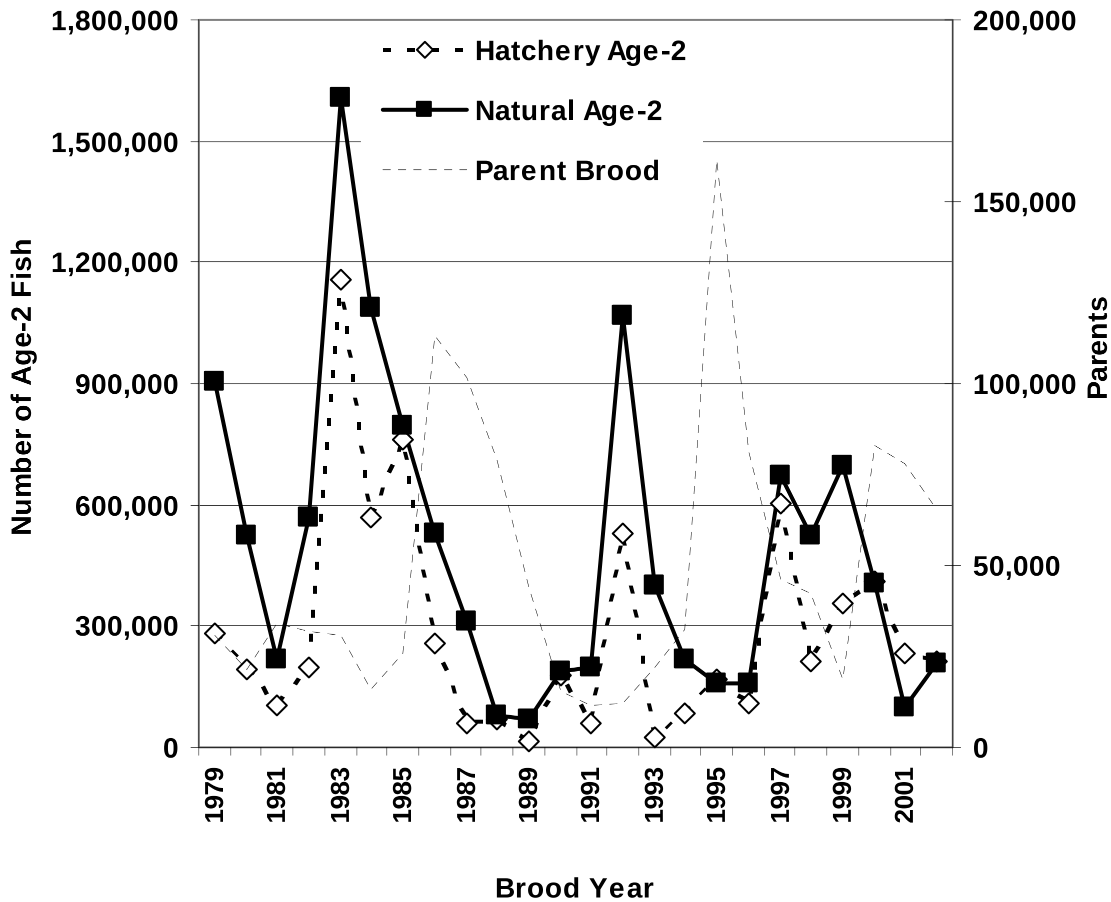

Figure 2-4. Reconstructed run size to January age-2 and natural parental brood size for KRFC, brood years 1979-2002.

Table 2-8. KRFC river run age composition, brood years 1979-2004.

Brood year	Klamath Basin Return (thousands)				
	Age-2	Age-3	Age-4	Age-5	Total
1979	28.2	30.1	20.7	1.1	80.1
1980	39.4	35.9	24.4	5.8	105.5
1981	3.8	21.7	25.7	2.3	53.5
1982	8.3	32.9	29.8	6.8	77.8
1983	69.4	162.9	112.6	3.9	348.8
1984	44.6	89.7	86.5	4.3	225.1
1985	19.1	101.2	69.6	1.3	191.2
1986	24.1	50.4	22.9	1.1	98.5
1987	9.1	11.6	21.6	1.0	43.3
1988	4.4	10.0	18.8	0.7	33.9
1989	1.8	6.9	8.2	1.0	17.9
1990	13.7	48.3	26.0	2.6	90.6
1991	7.6	37.0	18.3	0.3	63.2
1992	14.4	201.9	136.7	4.6	357.6
1993	22.8	38.8	44.2	1.7	107.5
1994	9.5	35.0	29.7	1.3	75.5
1995	8.0	59.2	20.5	0.5	88.2
1996	4.6	29.2	30.5	0.2	64.5
1997	19.2	187.1	88.2	3.7	298.2
1998	10.2	99.1	62.5	0.9	172.7
1999	11.3	94.6	96.8	5.3	208.0
2000	**9.2**	**94.3**	**40.7**	**3.9**	**148.1**
2001	**3.8**	**33.2**	**17.5**	**1.3**	**55.8**
2002[a/]	**9.7**	**43.8**	**41.8**		
2003[a/]	**2.3**	**18.6**			
2004[a/]	27.1				
Average	16.4	62.9	45.6	2.4	130.7

a/ These brood years are not yet complete.

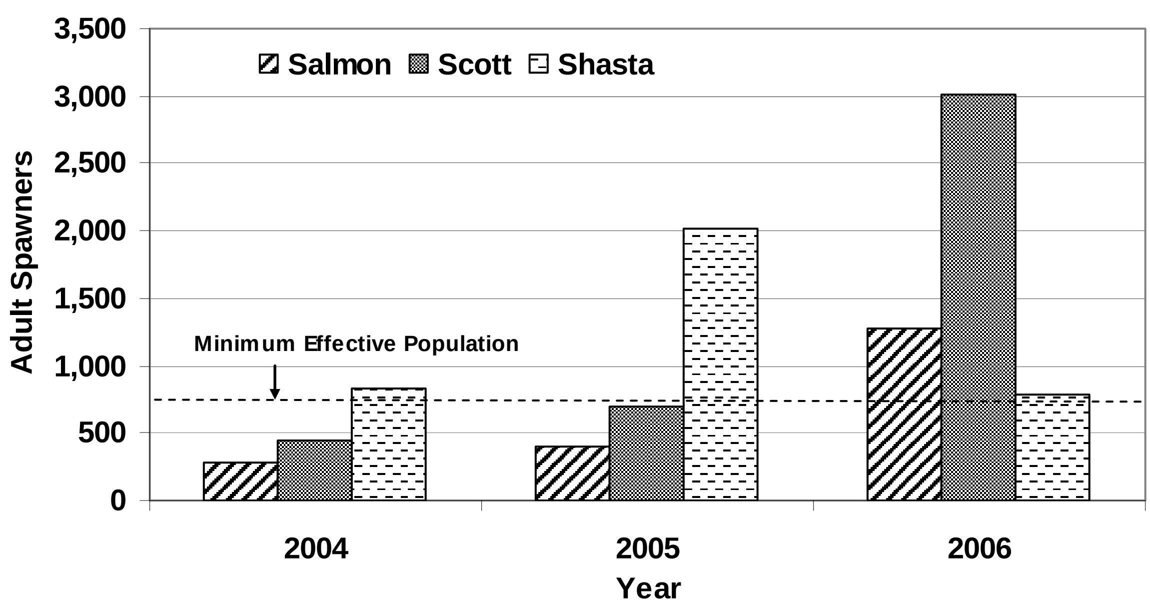

Figure 2-5. Spawning escapement in the Salmon, Scott and Shasta rivers, including hatchery strays, compared to the critical threshold escapement of 720 natural origin adult spawners (Mohr and Fujiwara 2007).

3.0 ASSESSMENT OF FACTORS AFFECTING NATURAL AREA RECRUITMENT

3.1 Parent Stock Size and Distribution

Natural spawning parental stock for the critical broods of 2000-2003 were near average or above average compared to the previous 22-year averages (Table 2-6; Figure 3-1).

The fish kill in the lower Klamath River in September 2002 was estimated to have killed between 30,500 and 68,000 adult fall Chinook salmon (CDFG 2004a), many of which were destined for the Trinity River. It was a very large run that year compared to historical levels, therefore the impact did not substantially reduce the natural escapements to below average levels for any streams in the basin except the Trinity River, which was 44 percent (10,900) of the 1978—1999 average (Table 2-4). Hatchery personnel reported no discernible impact to returning hatchery fish and hatchery fish fecundity was comparable to recent years (CDFG 2004a). It appears that low egg deposition and distribution of naturally spawning adults in 2000, 2001, 2002, and 2003 were likely not contributing factors to low recruitment of those broods.

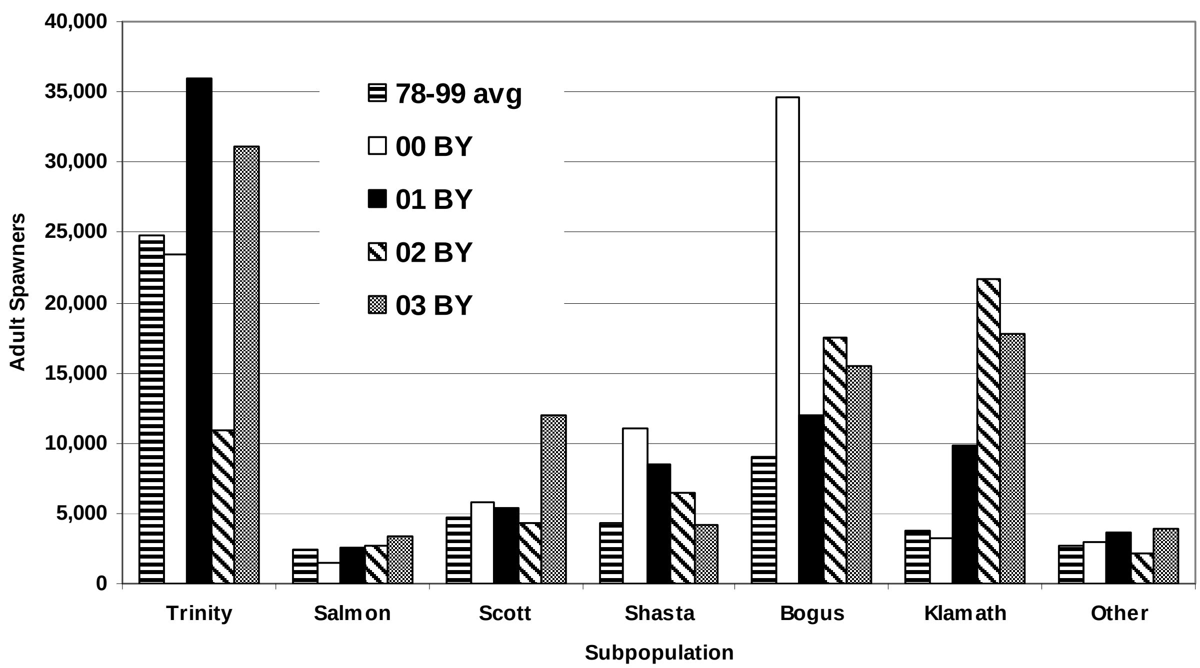

Figure 3-1. Spawning escapements to natural areas, of 2000- 2003 brood years (BY) compared with 1978-1999 averages.

3.2 Juvenile Production

The CDFG has monitored Chinook salmon juvenile production in the Scott and Shasta rivers using portable screw traps annually since 2000 and 2001 (migration years for 1999 and 2000 broods), respectively. The data show a positive relationship between emigrants and parental spawners for both rivers with a higher number of emigrants produced per adult in the Shasta River (325) compared to the Scott River (102) (Tables 3-1 and 3-2) (CDFG 2007). The emigrant production levels of the critical 2000—2003 broods ranged from about 126,000-1.0 million fish in the Scott River and 1.0 million to 4.2 million fish in the Shasta River.

Historical production data are not available for either of these rivers with which to compare production data for the critical broods. Data collected for Scott and Shasta River Chinook salmon emigrants of the 2004 and 2005 broods indicated much lower production levels for those broods compared with the critical 2000—2003 broods. With the few years of data available, no conclusions can be drawn relative to the effects on recruitment to the critical broods.

Table 3-1. Scott River emigrant Chinook salmon estimates for 1999-2005 broods.

Brood Year or avg.[a/]	Emigrants	Lower Confidence Limit	Upper Confidence Limit	Parents	Emigrant/Parent
1999	160,906	52,719	269,093	3,021	53
2000	**457,800**	**398,422**	**517,177**	**5729**	**80**
2001	**239,483**	**140,620**	**338,346**	**5398**	**44**
2002	**125,909**	**78,709**	**173,109**	**4,261**	**30**
2003	**1,029,696**	**870,359**	**1,189,033**	**11988**	**86**
2004	178,863	154,908	202,818	445	402
2005[b/]	10,890	6,982	14,797	698	16
1999-2005 avg.	314,792	243,246	386,339	4,506	102
2000-2004 avg.	406,350	328,604	484,097	5,564	128

a/ Emigrant year is brood year plus one.
b/ Redd scour in December 2005 appeared to reduce emigrant production in 2006.

Table 3-2. Shasta River emigrant Chinook salmon estimates for 2000-2005 broods.

Brood Year or avg.[a/]	Emigrants	Parents	Emigrants/Parent
2000	**4,203,764**	**11,025**	**381**
2001	**3,509,388**	**8,452**	**415**
2002	**1,020,905**	**6,432**	**159**
2003	**2,486,076**	**4,134**	**601**
2004	295,699	833	355
2005[b/]	83,348	2,018	41
2000-2005 avg.	1,933,197	5,482	325
2000-2004 avg.	2,303,167	6,175	382

a/ Emigrant year is brood year plus one.
b/ Redd scour in December 2005 appeared to reduce emigrant production in 2006.

3.3 Spawner Success Rate

A major storm event in December of 2005 was believed to have scoured redds and incubating eggs in both the Scott and Shasta rivers (CDFG 2007). Stream flows measured in the Shasta River near the mouth reached nearly 10,000 cfs. The scour impact resulted in very low emigrant production levels in both streams and substantially delayed outmigration timing the following winter and spring (Tables 3-1 and 3-2; CDFG 2007). Based on CDFG reports and available sample data, redd scouring did not appear to be a problem for the critical 2000—2003 broods.

Age-2 recruitment estimates (R) for the critical broods were compared with previous broods in Section 2.4 (Stock Status). Those estimates, when linked to parent stock size (S) estimates, provide estimates of number of recruits per spawning adult (R/S), which is an index of pre-fishing cohort survival rate. The analysis showed that the R/S values for the critical 2000—2002 broods, for which data are sufficiently complete, were each well below the previous 21-yr brood average, and that the 2001 brood value was the third lowest on record (Table 3-3). The expectation is that final data for the 2003 brood will show a below average R/S value based on the very low number of age-3 fish that returned to the river in 2006 (Table 2-8).

Table 3-3. KRFC natural area stock-recruitment data, 1979-2002 brood years.

Brood Year	Parents	Age-2 Recruits	Recruits/Parent
1979	30,637	906,521	29.59
1980	21,483	524,793	24.43
1981	33,857	217,854	6.43
1982	31,951	567,179	17.75
1983	30,784	1,609,472	52.28
1984	16,064	1,089,565	67.83
1985	25,677	794,089	30.93
1986	113,360	527,568	4.65
1987	101,717	311,514	3.06
1988	79,386	80,382	1.01
1989	43,868	68,783	1.57
1990	15,596	188,924	12.11
1991	11,649	196,444	16.86
1992	12,028	1,068,999	88.88
1993	21,858	400,559	18.33
1994	32,333	215,880	6.68
1995	161,794	157,675	0.97
1996	81,326	158,004	1.94
1997	46,144	674,091	14.61
1998	42,488	523,004	12.31
1999	18,457	699,486	37.90
2000	**82,728**	**405,951**	**4.91**
2001	**77,834**	**97,477**	**1.25**
2002[a/]	**65,635**	**209,228**	**3.19**
2003[b/]	**87,642**	**unkn**	**unkn**
79-99 avg	46,307	522,895	21.43
<50k avg[c/]	27,180	609,103	27.40
>50k avg[c/]	95,473	243,475	2.62

a/ Uses assumed age-4 maturation rate.
b/ Incomplete for age-4.
c/ Parent run <50,000, 1979-2002 broods.
d/ Parent run 50,000 or more, 1979-2002 broods.

The effect of parent spawning stock size on age-2 recruits was analyzed by plotting R/S values on 1979—2002 parent spawning stock sizes. This analysis indicated that the low R/S values for the critical broods were consistent with previous data for parent stock sizes above about 50,000 parents (Figure 3-2). Data for all broods in the data series showed an average R/S value of 27.4 for parent stock sizes below 50,000 fish and an average R/S value of 2.62 for parent stock sizes above 50,000 fish. The 50,000 fish value is close to the STT's estimate of S_{MAX} for the stock of 56,900 adults.

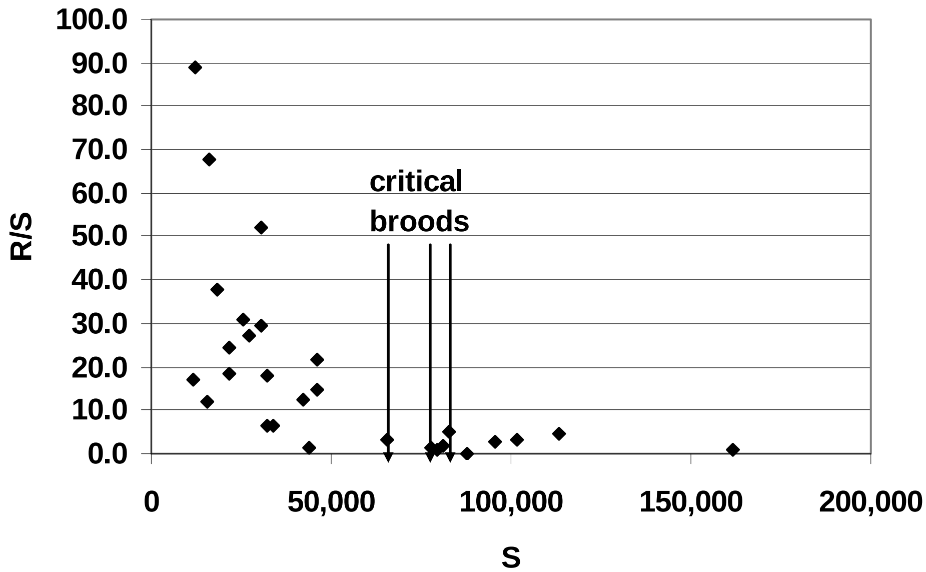

Figure 3-2. Plot of recruits per parent (R/S) on parent stock size (S); brood years 1979-2002.

Over-escapement of spawners can result in reduced realized production due to depensatory factors such as redd superposition, juvenile competition, predator attraction, and disease transmission. Low water discharge levels years could exacerbate the situation by further restricting available rearing habitat and increasing temperatures. Natural spawning escapement in 2000—2003 was above average, and above estimates of S_{MSY} and S_{MAX}, which could have resulted in reduced realized production from those broods. However, natural spawning escapement in all of these critical brood years was near the upper end of the range of spawner abundance that should produce more recruits than escapement at the floor of 35,000. The expected production of recruits from the observed spawning escapements in 2000—2003 ranged from 90 percent to 99 percent of the recruitment expected at S_{MAX}. Thus over-escapement, by itself, does not appear to have been a problem.

It seems unlikely that available spawning area is a limiting factor in the basin other than in the mainstem Trinity River near TRH and in Bogus Creek adjacent to IGH, where redd superimposition is commonly observed even in low run-size years. As discussed in Section 3.7, increased disease transmission from adult spawners was considered a possible result of the high natural spawner escapement in 2000—2003. Predation in the freshwater rearing and migration phase is also possibly a contributing factor.

3.4 River Flows

3.4.1 Klamath River Flows

This analysis compares flow conditions faced by juveniles of the critical broods of the OAP relative to the historical record by time and area. We reviewed flows from March 1 to July 31 to assess conditions faced by the OAP broods when juveniles were rearing or emigrating in the Klamath River. Flows were assessed from different areas of the Klamath River, including the Lower Klamath River (sum of flows at Orleans in the Klamath and at Hoopa in the Trinity), the middle Klamath (at Orleans, RM 60) and the Upper Klamath (Iron Gate Dam releases). Given that low flows are thought to be the primary limiting factor during this time period, the upper ends of the hydrographs were truncated in Figures 3-3, 3-4, and 3-5 to provide more resolution during periods of low flow.

Figures 3-3 and 3-4 show similar trends in discharge between the lower and middle Klamath River locations (respectively). Flow during 2001 was extremely low, well below the 25 percentile of the period of record during most of the spring/early summer. Flow during 2002 was also relatively low at both of these locations, hovering near the 25 percentile of the period of record beginning in late April through the end of July. Flow was above the median for the period of record during most of the spring/early summer during 2003. During 2004 flow was near the median for most of the time period in the Lower Klamath River (Figure 3-3), above or near the median through mid-May in the middle Klamath River, and between the median and the 25 percentile for the rest of the spring/early summer. Therefore, it is possible that low river discharge during the spring/early summer, as illustrated by the lower and middle Klamath River hydrographs, contributed to low recruitment of the 2000 and 2001 broods, but not for the 2000 and 2002 broods.

The period of record for Iron Gate Dam flow began after the dam was constructed in the early 1960's, therefore it is not reflective of natural conditions, but of managed flow releases that are affected by agricultural diversions in the Upper Basin as well as hydroelectric operations. Beginning in 2001, these flows have largely been dictated by ESA constraints regarding Klamath Irrigation Project operations in the Upper Klamath Basin. Figures 3-5 shows that flows at Iron Gate Dam during the spring/early summer were typically above the 25 percentile of the period of record and often above the median. Therefore, flow releases at Iron Gate Dam during the spring/early summer were not considerably lower than those portrayed in the historic record, so they likely did not contribute to the low recruitment of the critical broods.

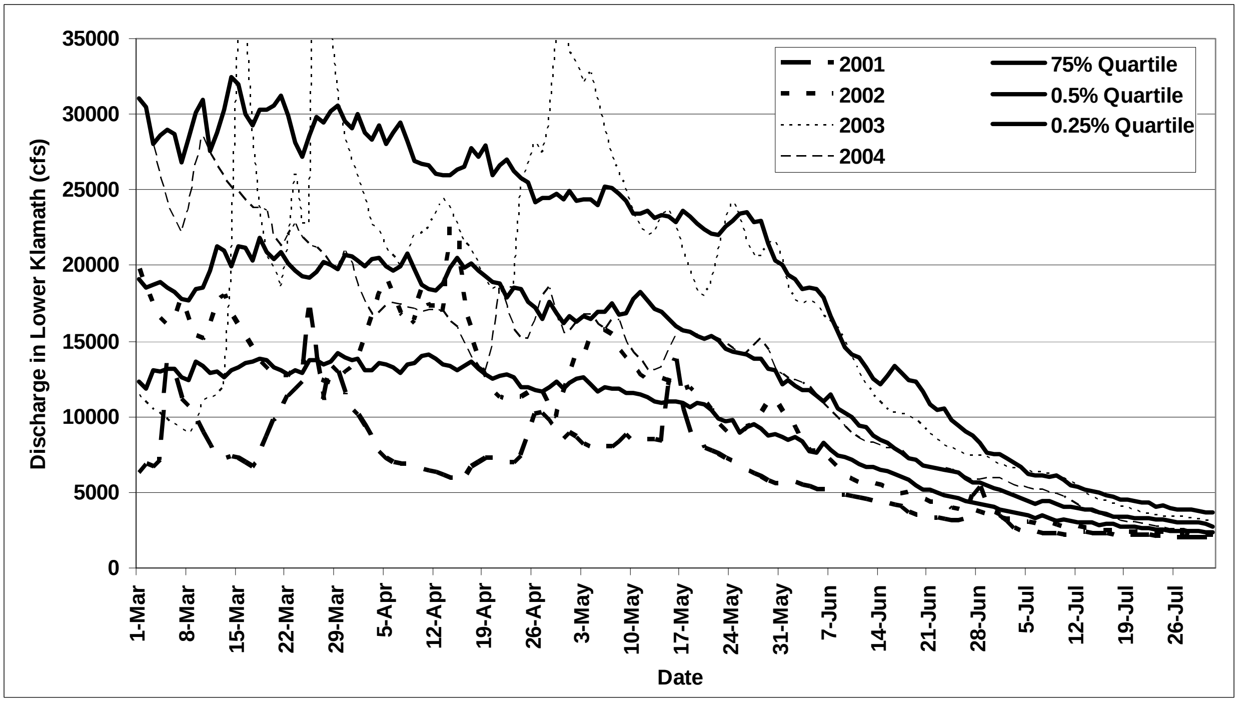

Figure. 3-3. Mean monthly flows in lower Klamath (sum of discharge from Trinity River at Hoopa and Klamath River at Orleans), March through July, relative to the historical record.

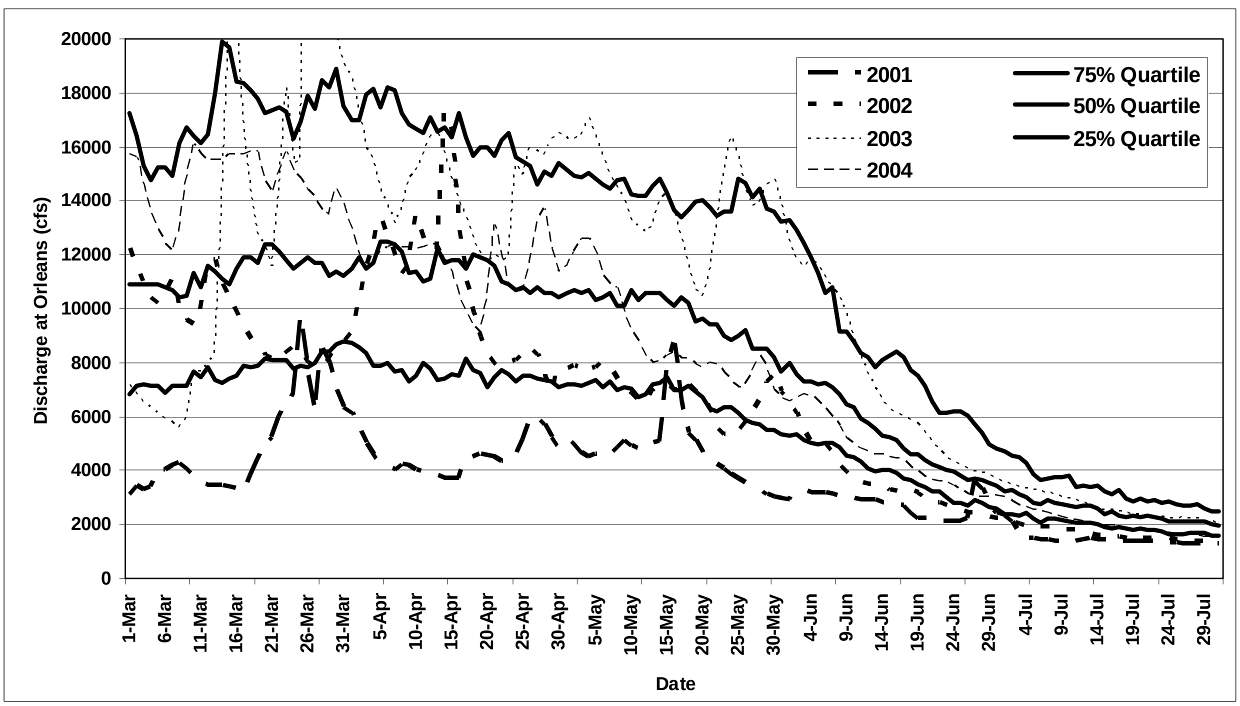

Figure 3-4. Mean monthly flows in the middle Klamath, near Orleans (RM 60), March through July, relative to the historical record.

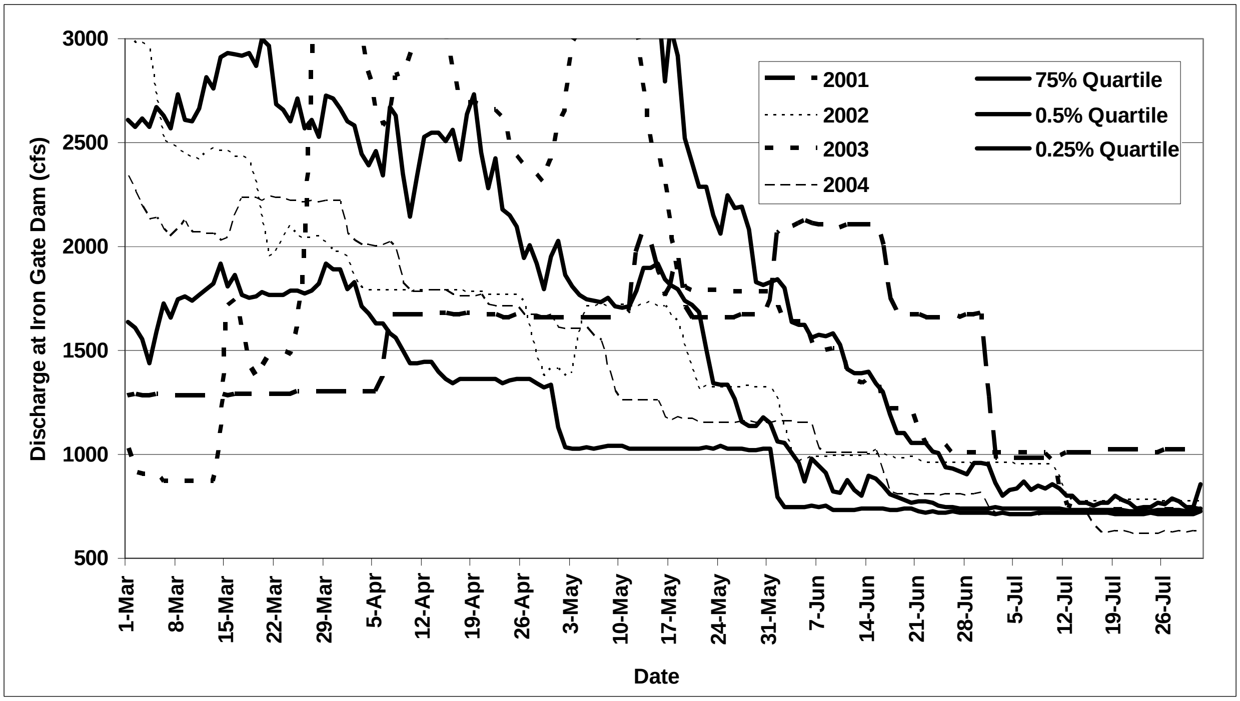

Figure 3-5. Mean monthly flows at Iron Gate Dam (RM 190), March through July, relative to the historical record.

We did not conduct an assessment of flow during the adult migration time of the parent stock for the critical broods; instead we focused on factors that could affect recruitment, not parent stock size. However it should be noted that the adult fish kill of 2002 was determined to be partially related to low flow (CDFG 2004a). The effect of 2002 adult fish kill on recruitment of the critical OAP broods is discussed in section 3.5.1.

Low flows during the time of spawning (generally from early October to mid-December) can affect recruitment by reducing the amount of available spawning habitat, thereby reducing egg survival from events such as superimposition, redd scour, and/or redd de-watering. Low or high flows during the time of egg incubation (generally October through February) can reduce egg survival from events such as redd scouring or redd dewatering.

Figure 3-6 shows that flows in the Middle Klamath during the time of incubation hovered around the mean for the period of record with some peak events (up to 50,000 cfs), but flows never neared the maximum of 240,000 cfs for the period of record.

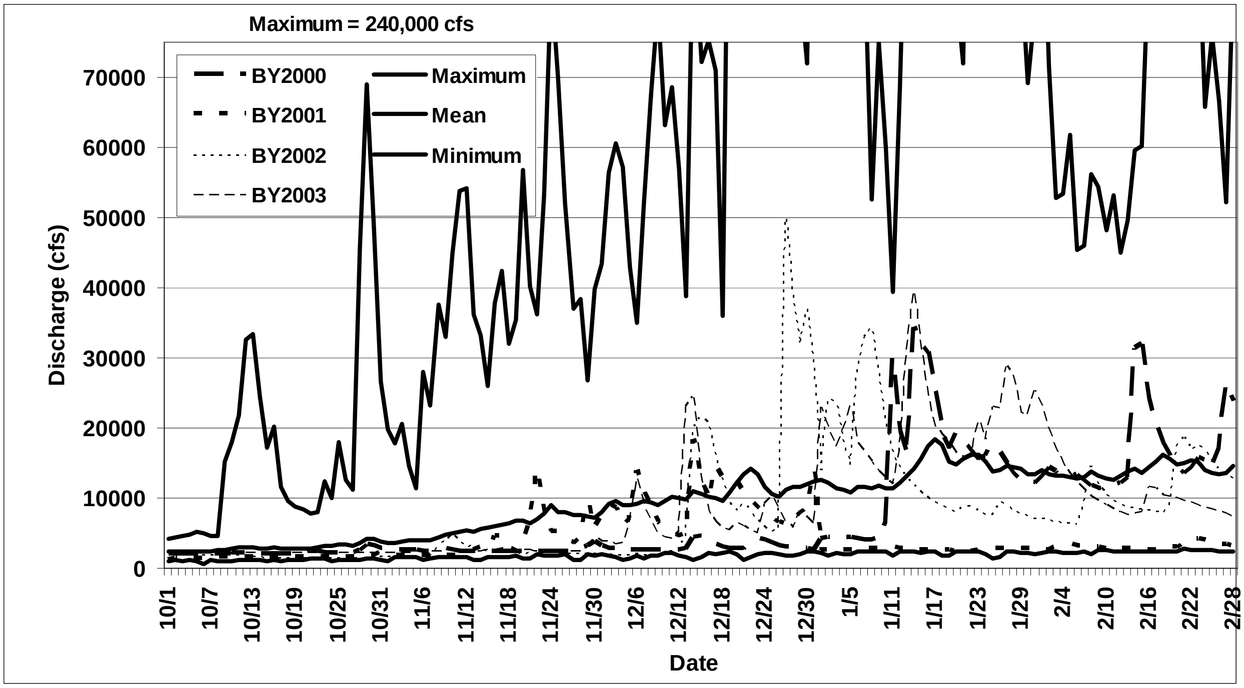

Figure 3-6. Mean monthly flows in the middle Klamath, near Orleans (RM 60) October through February, relative to the historical record.

3.4.2 Trinity River Flows

During water years 2001—2004 (brood years 2000–2003), discharge from Lewiston Dam to provide spawning and rearing habitat were similar to previous years (Figure 3-7) with the exception of safety-of-dams (SOD) releases which were sometimes required to meet operational criteria. In 2004, a month-long SOD release occurred from mid-February to mid-March but the potential impact of this on rearing Chinook salmon is unknown. The flow released was sufficient to overtop the riparian berms, which currently constrain habitat availability at moderate flow levels (generally between 300 cfs to 2,000 cfs); however, it is unknown if this increase in flow caused a premature emigration of fry and juvenile Chinook salmon or the subsequent reduction in flow led to significant stranding behind the riparian berms. During controlled high flow releases in May-June 2002, an estimated 27,000 Chinook salmon fry and juveniles were stranded in the upper Trinity River, with 97 percent of these occurring in riparian berm areas. While there was no monitoring for stranding during the 2004 SOD release, it is possible that greater numbers of fry Chinook salmon were stranded because this occurred during the peak of their emergence and rearing period. SOD releases of varying magnitude and duration have occurred in 8 of the 14 years from 1991 to 2004, including 1995 through 2000, which affected broods with relatively strong and weak returns. While the 2004 SOD release probably has an impact on naturally produced Chinook (NPC) salmon at an early life stage, because of the relative common occurrence of these events, it is unlikely the 2004 SOD had a substantial effect on 2003 brood survival.

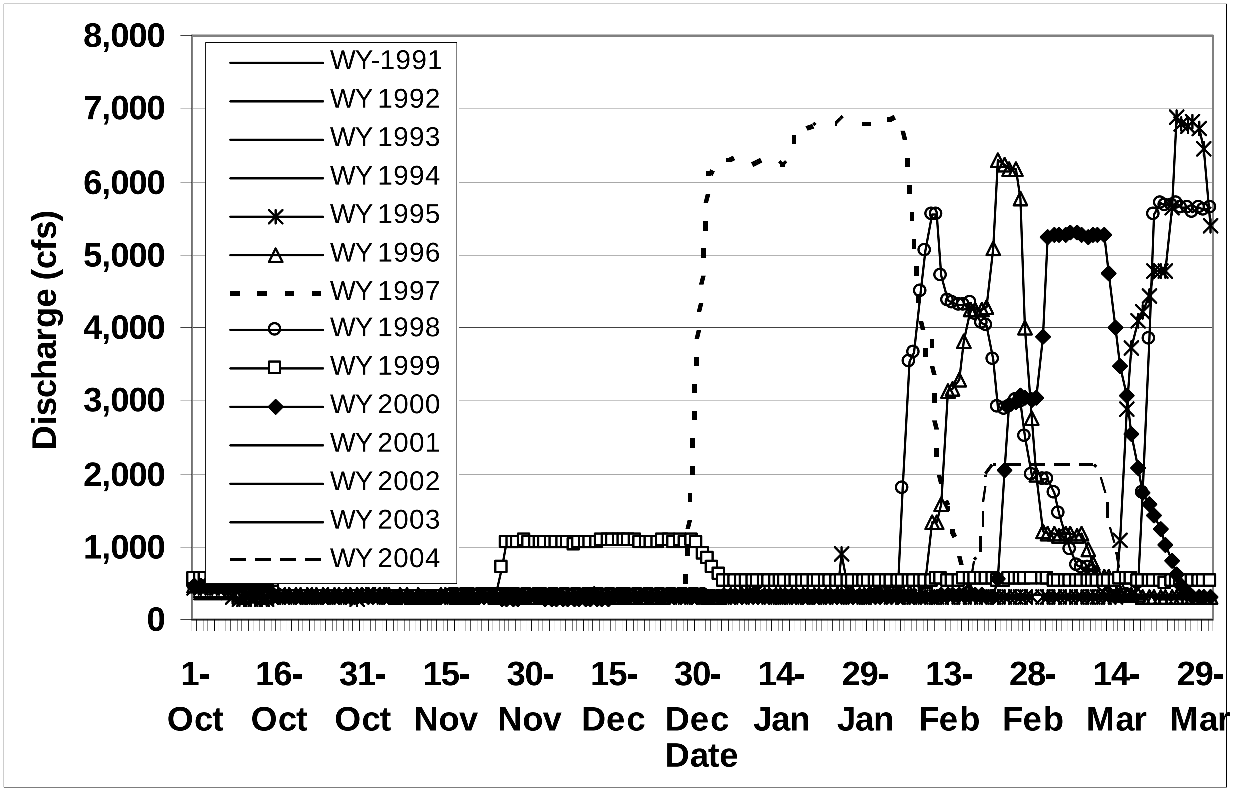

Figure 3-7. Discharge into the Trinity River from Lewiston Dam during the spawning and rearing period, 1991—2004 (brood years 1990 – 2003).

3.5 *Water Quality*

3.5.1 Klamath River

Fall Chinook abundance during 2004—2006 may have been affected by water quality conditions that juveniles experienced during their freshwater rearing and emigration life-stages during 2001-2004. Unfortunately, long-term data sets regarding Klamath River water quality parameters are limited. The longest-term data set regarding Klamath River water quality conditions available for this review for comparison to conditions during 2001—2004 was water temperatures measured from the U.S. Fish and Wildlife Service (USFWS) Big Bar trap (RM 50), which is located near Orleans, CA. The period of the year that juvenile fall Chinook are present, and therefore most vulnerable to Klamath Basin water quality conditions, is February-July (USFWS, 1997). Studies by Brett (1952) and Marine and Cech (2004) show that as temperatures rise above 19°C, Chinook growth, smoltification, and/or predator avoidance decline.

To assess whether juvenile Chinook rearing and emigrating in the river during 2001—2004 experienced relatively warm water temperatures, the maximum daily water temperature from May 1-July 22 (period for which consistent data was available) in 2001 – 2004 was compared to the 25 percent, median, and 75 percent quartiles for the period of record (1991 – 2004). During 2001, water temperatures were extremely warm relative to the period of record (Figure 3-8) throughout most of the time period. During 2002, temperatures were typically above the median and above the 75 percent quartile during much of late June and July. During 2003 water temperatures typically hovered around the median. During the latter half of June 2004 through the first week of July 2004 temperatures were relatively warm (usually above the 75 percent quartile). Given that water temperatures were exceptionally warm during 2001 and 2002 (and part of 2004), when juvenile Chinook rear/emigrate in the mainstem Klamath River, it is possible that warm water temperatures contributed to low survival of the 2000, 2001, and 2003 broods of fall Chinook, thereby contributing to low stock abundance during 2004-2006.

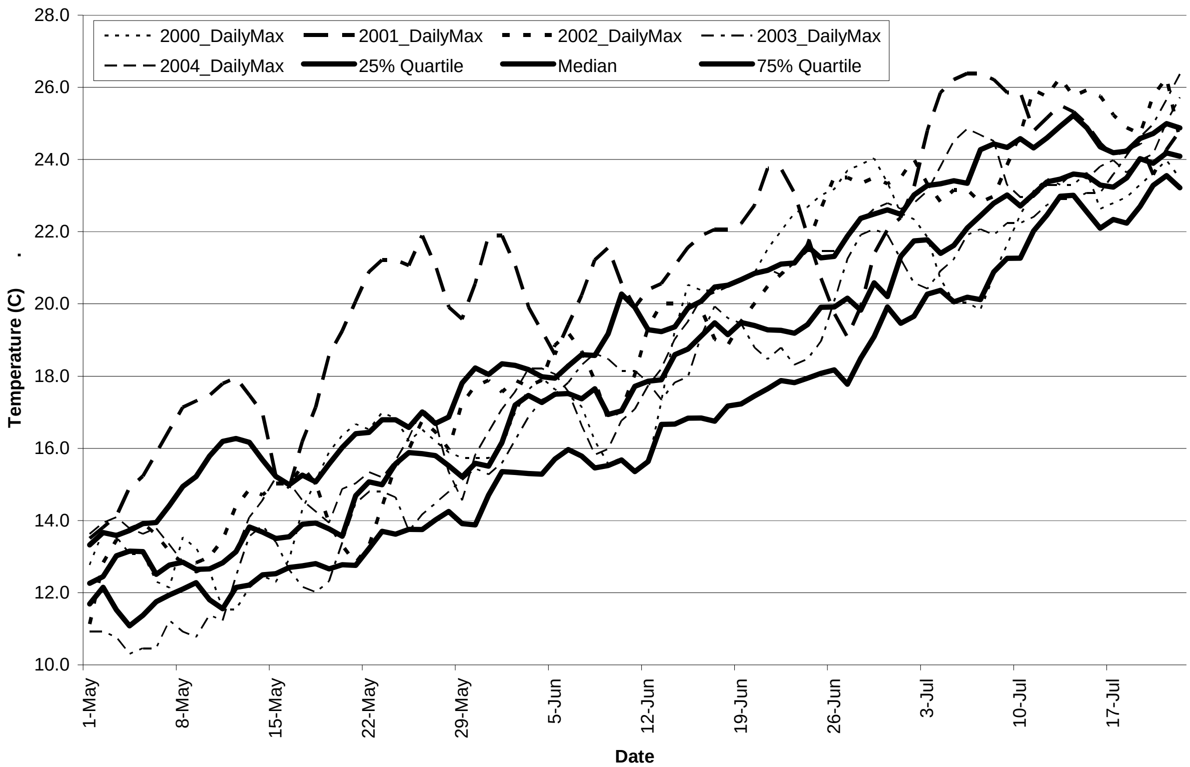

Figure 3-8. Daily maximum water temperatures at Big Bar trap (RM 50) from May 1-July 22, 2001—2004 relative to the 1st, 2nd, and 3rd quartiles from 1991 – 2004.

3.5.2 Trinity River

Portions of the recommended hydrographs were developed to provide better thermal conditions during salmonid outmigration periods during the spring/early summer, based on water year type (USFWS and HVT 1999). During normal and wetter water years, flows are scheduled to provide greater periods of optimum thermal regimes (<63ºF, 17ºC) for outmigrating salmonids while during dry and critically dry water years flows were anticipated to provide at least marginal thermal regimes (<68ºF, 20ºC). Although temperature objectives were established in developing the recommended flow schedules, flows are not managed on a real time basis to achieve the objectives. Part of the expectation of establishing a fixed schedule once the water year is established (early April) is to allow the downstream hydro-meteorological conditions to influence dam releases to restore some semblance of natural and variable thermal regime.

Discharge from Lewiston Dam is managed to meet adult holding and spawning temperature criteria (USFWS and HVT 1999). Generally releases ranging from 300 cfs (later in the year) to 450 cfs (during the summer) are necessary to meet the criteria, and during occasions when criteria are not met flows are increased (Figure 3-9). For 2000 to 2003, water temperature objectives were generally met during fall Chinook salmon holding and spawning period (late September through November) except for minor exceedences (<1ºC) in early October during 2000, 2001, and 2003, which appear to be an artifact of shifting the compliance monitoring point (Figure 3-10). It does not appear that these relatively minor and short duration exceedences compromised the survival and spawning success of spawning fall Chinook during 2000—2004. Additional flows were released in the fall of 2003 and 2004 to assist in preventing unfavorable conditions that contributed to the adult fish die-off in the lower Klamath River in the fall of 2002 (Table 3-4, Figure 3-9). While no adult fish die-off occurred in either 2003 or 2004, the effectiveness of these flow releases from the Trinity in preventing this event is uncertain. Some of the possible negative reactions resulting from these atypical (primarily in duration) fall flows were fall Chinook salmon moving into the upper river up to two weeks early, increasing the probability of hybridizing with spring Chinook salmon.

Prior to May 20 temperatures at Weitchpec (RM 40) were in the optimum range during all years of interest (2001 to 2004) (Figure 3-11). The most favorable thermal regime through the lower Trinity River was observed for the period from May 20 through July 9, 2004 where optimal temperatures prevailed through mid-June and at least marginal temperatures through July 9. July 9 is the transition date when temperature targets shift from providing outmigration temperatures to those necessary to support upriver migrating adult salmonids in normal or wetter years.

Comparison of the percentage of days (from May 1 to July 9) that exceeded the marginal and optimal Chinook salmon outmigration temperature indicates that the 2001, 2002, and 2003 outmigrants (brood years 2000, 2001, and 2002, respectively) experienced the least favorable thermal conditions (Figures 3-12 and 3-13). During these years, optimal temperatures were exceeded 49 percent to 69 percent of the time and marginal temperatures 21 percent to 34 percent of the time. During 2004, outmigrants (brood year 2003) exceeded marginal temperatures 0 percent of the time and exceeded optimal temperatures 36 percent of the time. Similar percentages of exceeding marginal temperatures (>20 percent) occurred in 1992 (41 percent) and 1994 (29 percent) and exceeding optimal temperatures (>50 percent) occurred in 1991 (56 percent), 1992 (74 percent), 1994 (63 percent), and 1997 (50 percent). All of the broods affected by those rearing temperatures (1990, 1991, 1993, and 1996) had below average age-2 natural populations (Table 2-8). In contrast, percentages of exceeding optimal water temperatures were less than 50 percent in 1995 (24 percent), 1996 (43 percent) and 1999 (24 percent) but these broods also had below-average or average age-2 natural populations. While the desired benefit for better thermal regimes in the Trinity River with increased releases was not fully realized, the increased releases likely provided better thermal regimes than if they had not been released. Data to evaluate the relationship between thermal regimes of experienced by outmigrants in the Trinity River and Trinity specific age-2 natural populations were not available for this analysis.

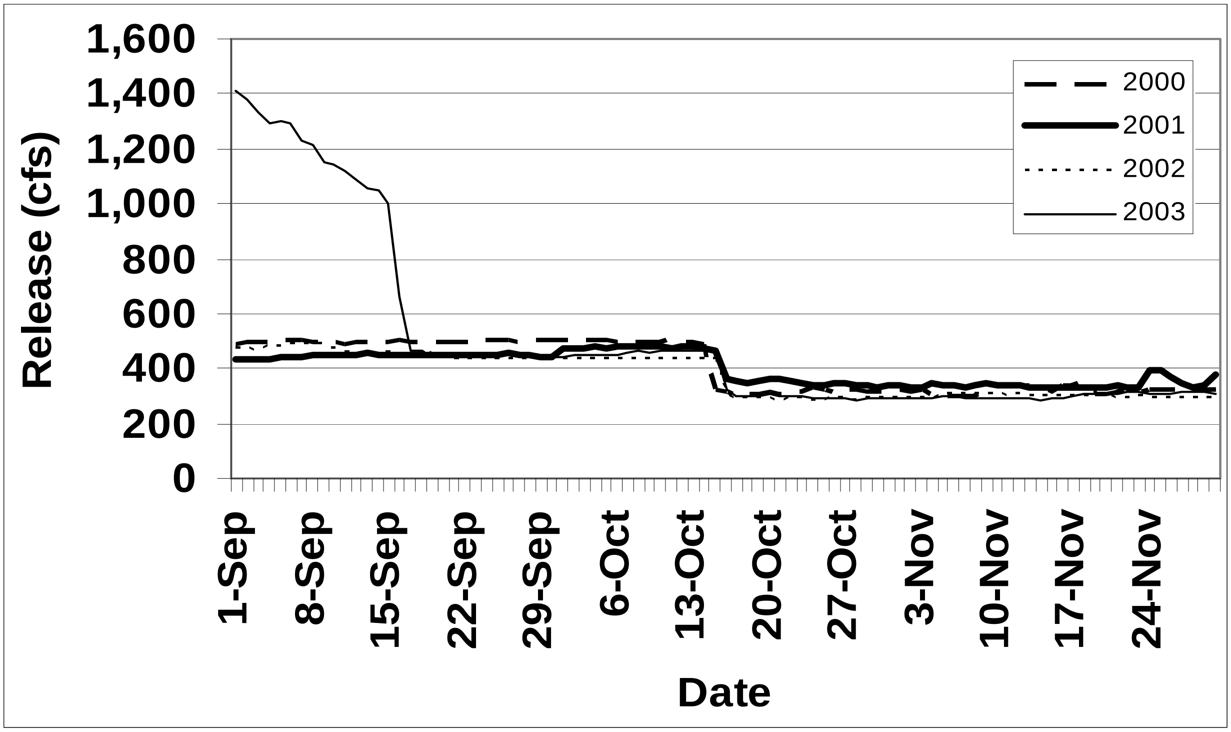

Figure 3-9. Mainstem Trinity River flow releases from Lewiston Dam from September through November, 2000—2003. Large release in 2003 through mid-September was managed release to improve water conditions in the lower Klamath River, not made to meet the holding/spawning temperature criteria for the upper mainstem Trinity River.

Table 3-4. Trinity River Record of Decision (ROD) flow requirements and compliance.

Water Year[a/]	Annual Release Volumes (acre-feet)			Channel Rehabilitation Sites Constructed[d/]
	Actual Volume Released	Volume Necessary to meet ROD Objectives	Other Fishery Flows[c/]	
2001[b/]	368,000	453,000		
2002[b/]	468,000	647,000		
2003[b/]	453,000	671,300	34,000	
2004[b/]	647,000	671,300	36,300	
2005	647,000	647,000		1
2006	815,000	815,000		4

a/ Water year begins in October of previous year (i-1) and ends in September (year i).

b/ Flow volumes were limited due to court order and ongoing litigation over the implementation of the ROD. During WY2005 full releases recommended in the ROD were able to be released.

c/ During the fall of 2003 and 2004 releases from the Lewiston Dam above ROD volumes to improve conditions in the lower Klamath River.

d/ Mechanical rehabilitation activities recommended in the ROD include 44 channel rehabilitation sites and 3 side channels.

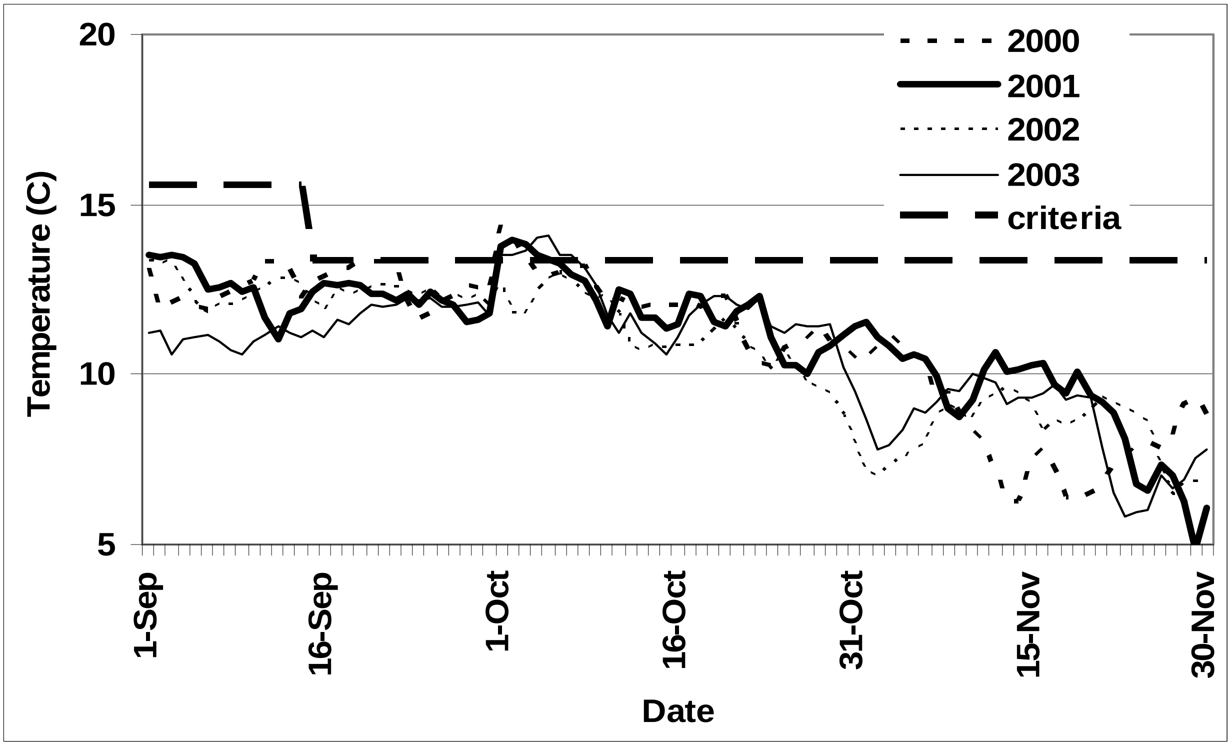

Figure 3-10. Mainstem Trinity River water temperature from September through November, 2000 – 2003.

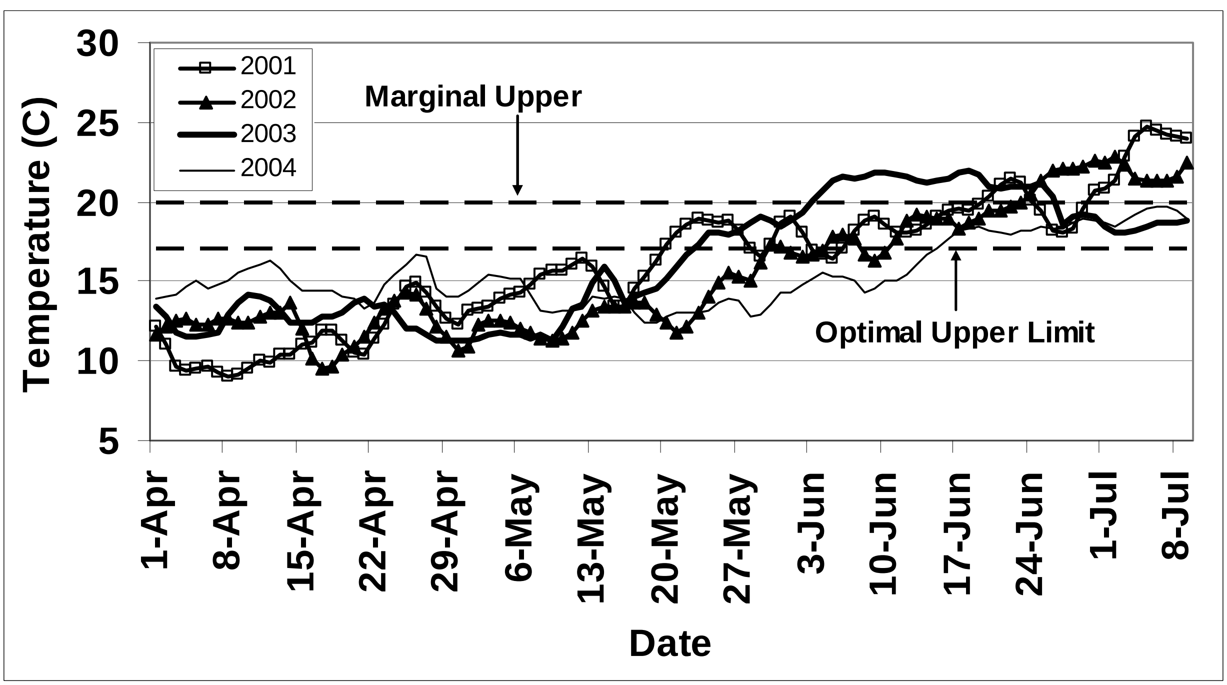

Figure 3-11. Mean daily water temperature on the Trinity River at Weitchpec, April 1 to July 9, 2001—2004. Dashed lines are upper level of optimal Chinook salmon smolt criteria (63ºF) and upper level of marginal Chinook salmon smolt criteria (68ºF).

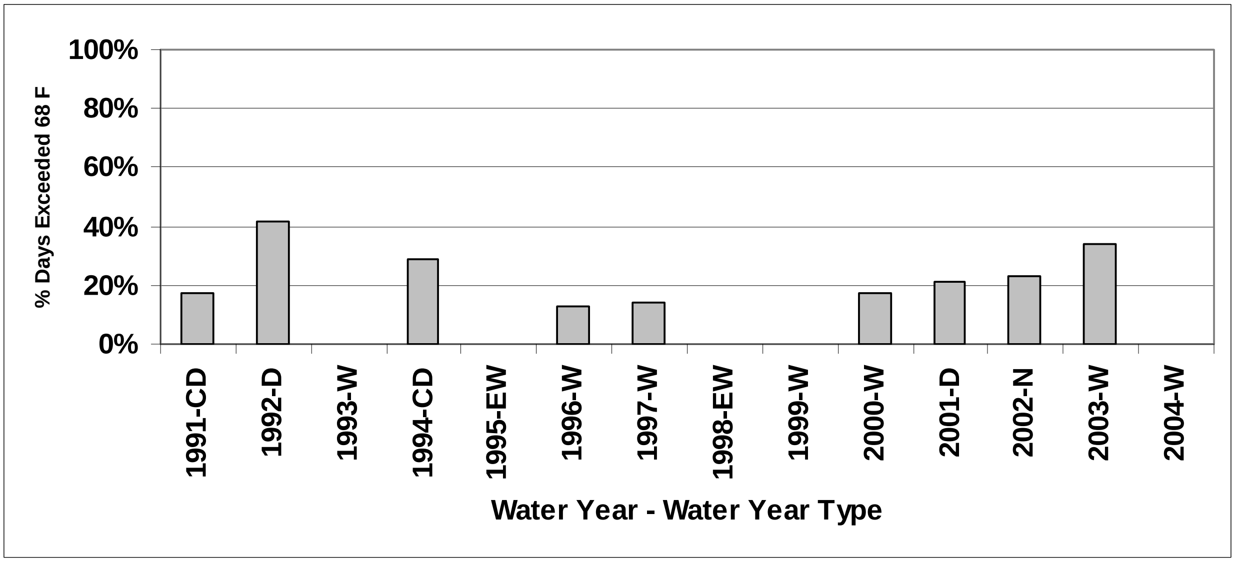

Figure 3-12. Percentage of days marginal (>68ºF) Chinook outmigrant temperature objective was exceeded on the Trinity River between May 1 - July 9 at Weitchpec. Water year is October 1 (year-1) to September 30 (year); water year 2001 affected outmigrants from brood year 2000. Water year types are actual classifications, not forecasts: CD= Critically Dry; D= Dry; N= Normal; W=Wet; EW= Extremely Wet.

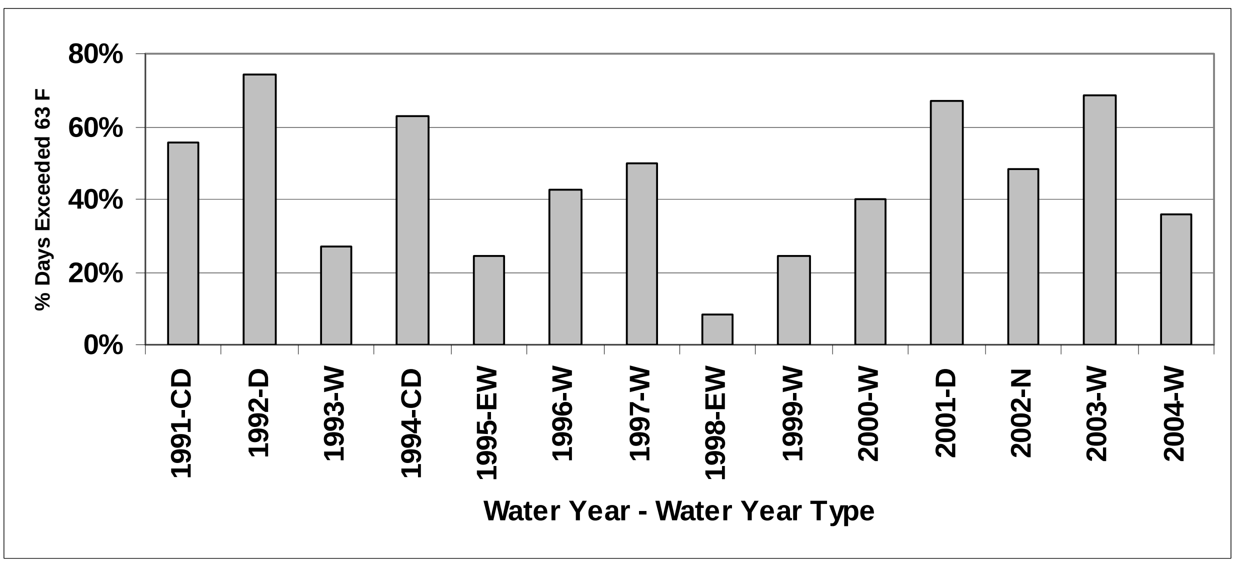

Figure 3-13. Percentage of days optimal (>63ºF) Chinook outmigrant temperature objective was exceeded on the Trinity River between May 1 - July 9 at Weitchpec. Water year is October 1 (year-1) to September 30 (year); water year 2001 affected outmigrants from brood year 2000. Water year types are actual classifications, not forecasts: CD= Critically Dry; D= Dry; N= Normal; W=Wet; EW= Extremely Wet.

3.6 Hatchery/Wild Interactions

Concern over the interaction of natural and hatchery produced fish in the Klamath Basin may extend to all the species and races propagated at the two hatcheries. These include fall-run Chinook salmon, coho salmon and steelhead trout. At TRH, the hatching and rearing program also includes spring-run Chinook salmon. In terms of pounds of fish produced, steelhead is the most abundant of the three species propagated at TRH, followed by Chinook salmon and coho salmon. The IGH program has been almost entirely fall-run Chinook salmon in recent years.

There are many potentially negative consequences of interactions between hatchery and naturally produced fish. The short-term concerns include: 1) predation of steelhead yearlings and adults on salmon fingerlings, 2) competition for food and space between juvenile hatchery fish and naturally produced fish of all three species, 3) competition for natural spawning areas between hatchery and naturally produced adults, particularly in the immediate area of the two hatcheries, 4) alteration of the natural gene pool from hybridization of natural and hatchery fish, and 5) disease transmission to natural fish. The long-term consequences and concerns over the interaction of natural and hatchery produced salmon and trout were discussed in a CDFG and NMFS (2001) report on the subject.

3.6.1 Adults

Interactions of hatchery and naturally produced Chinook salmon adults occur on the spawning grounds in both the Klamath and Trinity basins as a result of straying by hatchery fish into natural spawning areas and naturally produced fish into the hatcheries. Straying of hatchery fish is most notable on the Trinity River where a large fraction of the natural spawners in the upper mainstem Trinity (upper 101 kms) are composed of hatchery fish. The estimated contribution of hatchery fish from 2002 through 2006 ranged from 13.5 percent to 42.8 percent and averaged 31.3 percent (Table 3-6). During the OAP the contribution of hatchery fish observed during carcass surveys averaged 37 percent. In particular, the first several miles below TRH are heavily utilized by spawning Chinook salmon, both spring-run and fall-run. Up to 85 percent of the total natural spawning Chinook carcasses recovered in the Trinity Basin are found in the first several miles below Lewiston Dam, which leads to redd superposition, matings between hatchery and natural fish, and racial mixing (Knechtle and Currier 2006).

On the Klamath River the incidence of straying appears to be greatest in Bogus Creek, a small tributary located adjacent to IGH, and in some years in the Shasta River, located approximately 10 miles downstream of IGH. In Bogus Creek the estimated incidence (as a proportion of the total Bogus Creek return) of hatchery strays ranged from 7.5 percent to 61.6 percent and averaged 34.4 percent between 1999 and 2006 (Table 3-5) During those years between 1,019 and 13,025 hatchery KRFC spawned in Bogus Creek (Table 3-5). The incidence of hatchery strays on the Shasta River ranged between 1.2 percent and 38.7 percent with an average of 15.4 percent between 2002 and 2006 (Table 3-5). In those years between 79 and 469 hatchery KRFC (adult and jacks) spawned in the Shasta River (Table 3-5). In the mainstem Klamath the percentage of hatchery adults and jacks in natural spawning populations ranged from 3.5 percent to 28.6 percent and averaged 9.7 percent during 2001 to 2005. The incidence of IGH strays in other areas of the Klamath is minimal (Sinnen 2007, pers. comm.).

As noted above, a high incidence of redd superposition occurs in the immediate vicinity of TRH in part due to a large number of hatchery strays, however this does not appear to be the case on the Klamath River (KRTAT 2007). It is likely, however, that redd superposition occurs in Bogus Creek. Other potential negative consequences of hatchery straying that may occur are the loss of genetic integrity, lowered productivity potential, lowered spawning success, and crowding in holding areas, which could lead to higher disease transmission. None of these issues have been thoroughly investigated to date, and data are not available to compare the critical broods to historical periods.

Table 3-5. Number of adipose-clipped fish (adults and jacks) observed through the counting flumes at Bogus Creek, and observed on the upper Trinity River spawning grounds, with coded-wire-tag (CWT) expanded hatchery contributions. Data from Hampton (2007) and Walsh and Hampton (2007).

Year	Total Escapement/ Carcasses Observed	Adipose Clips Observed	CWTs Recovered	Expanded Hatchery Contribution	Hatchery Chinook as Percent of Run
			Shasta River		
2002	6,820	3	1	79	1.2%
2003	4,195	25	0	436	10.4%
2004	962	23	0	372	38.7%
2005	2,129	32	11	469	22.0%
2006	2,163	6	1	106	4.9%
Average	3,254	18	3	292	15.4%
			Bogus Creek		
1999	6,165	93	83	2,915	47.3%
2000	35,051	212	186	13,025	37.2%
2001	12,575	66	40	7,747	61.6%
2002	17,835	40	40	1,330	7.5%
2003	15,610	85	59	2,722	17.4%
2004	3,788	75	58	1,019	27.0%
2005	5,397	131	96	1,931	35.8%
2006	4,133	93	50	1,724	41.7%
Average	12,569	99	77	4,052	34.4%
			Trinity River		
2002	1,486	62	42	200	13.5%
2003	10,321	804	719	2904	28.1%
2004	3638	451	377	1539	42.3%
2005	2,096	236	214	898	42.8%
2006	3,462	247	222	899	26.0%
Average	5,595	317	275	1,749	31.3%

Adult steelhead are present in the Klamath Basin during September-March. Adult steelhead likely prey on juvenile KRFC during February and March when juvenile Chinook are emerging from the gravel. Steelhead returns have been increasing at TRH in recent years, particularly in 2003 and 2004 (Table 3-7). These fish potentially affected juvenile Chinook salmon production of the 2002 and 2003 broods. The amount of impact is not possible to estimate but should be considered a possible contributing factor to the depressed recruitment of the critical brood years of KRFC.

3.6.2 Juveniles

The degree of interaction between hatchery steelhead and Chinook salmon in the Klamath Basin is not well understood. Studies have been conducted of migration timing of IGH and TRH Chinook salmon between the hatcheries and the estuary. These findings have been important in terms of assessing the amount of time that hatchery and naturally produced fish co-exist in the mainstems and compete with one another for food and space and potentially prey upon one another.

The previous stock assessment workgroup (PFMC 1994) reviewed available field sampling data on interactions of hatchery and naturally produced Chinook salmon in the Klamath Basin. They reached the following conclusions:

1. Migration rate for hatchery fingerling releases is related to size of fish with the larger fish moving out faster than the smaller fish.
2. Small average size at release of the 1987—1989 broods coupled with larger numbers released may have had an adverse impact on the natural populations (taking up to 80 days to reach the estuary).
3. Fingerlings released at 90/lb take from 10—40 days to reach the estuary
4. Yearling releases move through the system rapidly (<10 days between hatchery and estuary) and do not pose a significant threat to naturally produced fish.

3.6.2.1 Inter- and Intra-specific Competition

Hatchery releases of fall Chinook fingerlings and coho yearlings during the outmigration period for 2000—2003 brood natural KRFC averaged slightly more than the previous 8 year (two brood cycle) average, but were within the observed range (Table 3-6). Spring Chinook releases were slightly lower. Steelhead yearling releases during the same period were substantially greater, averaging 30 percent greater from TRH and 100 percent greater from IGH than the previous 8 year average. The discharge in the Klamath Basin was particularly low during 2001 (Figure 3-4), which would have increased the effects of competition that year. It is likely that 2000 brood KRFC were negatively affected by competition from hatchery reared steelhead compared to earlier broods, and possible that 2001—2003 broods were also negatively impacted.

CDFG's recently implemented IGH "Early Release Strategy," provides additional information on the migration timing of KRFC hatchery fingerlings. The study results which are available for 2001—2003 coincide with the outmigration years of the depressed 2004—2006 runs of KRFC (Hampton 2001, 2002, 2006). Study results for subsequent years including CWT expansions for adult fish catches and escapements are not yet available. Study groups were generally released in May at IGH at an average size of about 90/lb. Dry weather conditions and low stream flows were experienced in all three study years. Stream and estuary sampling showed the fish typically migrated at a rate of about 5 miles per day (range 3 miles to 14 miles/day), which equates to an average river residency period of about 38 days. This meant that fish released on or about June 1 typically reached the estuary in early to mid July. Compared to the river residency period noted in the 1994 report, the 38 day period average for the 2001-2003 was at the high end of the range, which may have contributed to increased competition with natural fish and the high incidence of parasitic disease infestation found in trapped hatchery and natural fish during the study years.

3.6.2.2 Predation

Yearling steelhead, Chinook salmon and coho salmon have the potential to prey upon fingerling Chinook salmon during the period of time following planting to when the fish enter the ocean (Riley et al. 2004). Yearling releases of Chinook salmon take place in the fall (October at TRH and November at IGH), several months prior to when fingerling Chinook salmon begin to emerge and migrate downstream (February-August) or are released from the two hatcheries (May or June). Yearling steelhead and coho salmon are released in March, approximately 2 months prior to when fingerling Chinook salmon are released from the hatcheries, but overlapping the presence of stream rearing and migrating naturally produced Chinook salmon fingerlings. It likely takes 1-2 weeks for yearling steelhead and coho salmon (based on yearling Chinook salmon migration timing data) to reach the ocean following hatchery release, thus the potential is high that these fish may consume a substantial number of fingerling Chinook salmon based on the numbers of fish released from the two basin hatcheries (Table 3-6). Hatchery steelhead are also known to residulize in the river and may never migrate to sea, and steelhead adults are present when naturally spawned Chinook salmon are emerging and migrating to sea, further increasing the likelihood of predation. The steelhead residualization problem below TRH may be compounded by brown trout predation. These resident sources of predatory fish further exacerbate the potential for predation on fingerling Chinook salmon.

In addition to the increased numbers of steelhead released during the outmigration of the critical KRFC broods, the size at release was also about 24 percent greater (by weight) for TRH steelhead (Table 3-6). Size at release was about 33 percent smaller (by weight) for IGH steel head releases, but almost 90 percent of steelhead releases were from TRH. The increased number and larger average size of steelhead yearling releases in the Klamath Basin during 2001—2004 may have increased the predation on critical KRFC brood juveniles in comparison to historical averages.

The Yurok Tribe (in preparation, 2008) conducted a study in the Upper Trinity River (within the first 3.2 kilometers downstream of TRH) during 2005 and 2007 to assess predation rates of residualized steelhead and recently released steelhead smolts from TRH. High predation rates were observed relative to other predation studies (Table 3-7). These relatively high predation rates, combined with the increased releases and size at release during the time the KRFC brood juveniles were in the river may have contributed to reduced recruitment during the OAP years.

Yearling Chinook salmon have also been known to prey upon fingerling Chinook salmon in the Central Valley (Sholes and Hallock 1979). However, in the Klamath Basin, Chinook salmon yearlings are released in the fall, well after the time of year natural fish are rearing and emigrating in the river and well after the time hatchery fingerlings are released in the spring, and there have been no indications of overwintering or residualization of yearling Chinook. Thus, the potential appears low for significant impact of yearling Chinook salmon on the current or following year fingerling Chinook salmon production.

Coho salmon release timing poses more of a potential problem for fingerling Chinook salmon than yearling Chinook salmon releases. Coho salmon are planted in the spring of the year following the year in which the adults were spawned. Coho salmon yearlings of the 1999—2002 broods (planted in 2001—2004) had the potential to impact fingerling Chinook salmon of the 2000—2003 broods. However, TRH yearling coho salmon releases during 2001—2004 were all within the range of nearly all previous year releases, while the IGH coho releases were generally below the number of fish released from that facility in previous years (Table 3-6). Thus, no increased impact of coho salmon on the 2000—2003 broods of KRFC seems likely based on IGH and TRH yearling coho salmon production data.

Table 3-6. Klamath Basin salmon and steelhead hatchery releases and adult steelhead returns to hatcheries with potential for interaction with natural KRFC juveniles during outmigrant years 1993 through 2005.

Outmigrant Year	Spring Chinook Fingerlings	Fall Chinook Fingerlings	Coho Yearlings	Steelhead Yearlings	Steelhead Size at Release (fish/lb)	Steelhead Adult Returns
			Trinity River Hatchery			
1993	488,219	2,342,037	384,555	337,589	4.1	551
1994	1,498,015	202,275	480,790	323,791	4.7	882
1995	1,458,984	2,153,982	549,983	879,841	4.7	376
1996	1,057,037	2,038,461	71,993	614,828	6.2	744
1997	1,034,825	2,101,306	584,970	784,844	6.6	4,046
1998	1,294,518	2,403,407	516,192	811,513	4.1	419
1999	1,148,984	2,050,636	519,273	611,443	5.7	438
2000	959,019	1,991,693	493,727	382,903	4.4	1,584
2001	**1,093,525**	**2,113,804**	**513,400**	**822,505**	**3.5**	**842**
2002	**1,032,548**	**2,084,069**	**530,285**	**624,650**	**3.9**	**2,371**
2003	**1,005,179**	**2,078,192**	**418,139**	**877,268**	**5.1**	**6,163**
2004	**1,062,912**	**2,105,708**	**517,774**	**798,449**	**3.8**	**10,283**
2005	1,115,927	2,006,066	520,563	792,861	4.2	5,691
1993-2000 avg.	1,117,450	1,910,475	450,185	593,344	5.1	1,130
2001-2004 avg.	**1,048,541**	**2,095,443**	**494,900**	**780,718**	**4.1**	**4,915**
			Iron Gate Hatchery			
1993		3,300,312	144,998	63,000	5.8	126
1994		4,962,344	76,999	74,000	10.0	163
1995		4,913,457	79,506	74,000	10.0	271
1996		5,626,408	74,250	163,000	8.0	12
1997		5,286,641	81,498	10,702	7.8	97
1998		5,103,476	79,607	35,802	10.2	127
1999		4,962,229	75,156	37,080	12.0	91
2000		5,028,070	77,147	51,324	14.0	112
2001[a/]		**4,938,000**	**46,250**	**31,897**	**18.0**	**529**
2002[a/]		**4,966,640**	**67,933**	**141,362**	**14.0**	**617**
2003[b/]		**5,116,165**	**74,271**	**192,770**	**12.0**	**481**
2004[b/]		**5,182,092**	**109,374**	**148,991**	**13.0**	**554**
2005[b/]		5,369,792	74,716	195,698	14.0	281
93-00 avg.		4,897,867	86,145	63,614	9.7	125
01-04 avg.		**5,050,724**	**74,457**	**128,755**	**14.3**	**545**
			Total			
1993	488,219	5,642,349	529,553	400,589	4.3	677
1994	1,498,015	5,164,619	557,789	397,791	5.2	1,045
1995	1,458,984	7,067,439	629,489	953,841	4.9	647
1996	1,057,037	7,664,869	146,243	777,828	6.5	756
1997	1,034,825	7,387,947	666,468	795,546	6.7	4,143
1998	1,294,518	7,506,883	595,799	847,315	4.2	546
1999	1,148,984	7,012,865	594,429	648,523	5.8	529
2000	959,019	7,019,763	570,874	434,227	4.8	1,696
2001	**1,093,525**	**7,051,804**	**559,650**	**854,402**	**3.6**	**1,371**
2002	**1,032,548**	**7,050,709**	**598,218**	**766,012**	**4.5**	**2,988**
2003	**1,005,179**	**7,194,357**	**492,410**	**1,070,038**	**5.7**	**6,644**
2004	**1,062,912**	**7,287,800**	**627,148**	**947,440**	**4.3**	**10,837**
2005	1,115,927	7,375,858	595,279	988,559	4.9	5,972
93-00 avg.	1,117,450	6,808,342	536,331	656,958	5.3	1,255
01-04 avg.	**1,062,018**	**7,192,106**	**574,541**	**925,290**	**4.6**	**5,562**

a/ Fingerling fall Chinook were released in May rather than June.

b/ Fingerling fall Chinook released in May and early June rather than all in June.

Table 3-7. Summary of hatchery steelhead predation studies.

Citation	Year(s)	River System	Methods	Sample size	Fry ingested (*n*)	Fry/ Stomach
Whitesel et al. 1993	1992-1993	Imnaha/Grande Rhonde	RST/Electro	611	8	0.01
Jonasson et al. 1994	1993-1994	Imnaha/Grande Rhonde	H&L /Electro	358	1	0
Jonasson et al. 1995	1994-1995	Imnaha/Grande Rhonde	Electro	175	2	0.01
Canamella et al.	1992	Upper Salmon River	H&L /Electro	6,762	10	0
Martin et al.	1993	Lower Snake (Tucannon)	H&L	1,713	3	0
Pearsons et al. 1994	1992	North Fork Teanaway and Jack Creek	Electro	55	0	0
Harper 1999	1993	North Fork Teanaway	RST/ H&L	59	0	0
Hawkins and Tipping; WDFW unpublished	1995-1996	Lewis	Seine	74	1	0.01
Hawkins and Tipping; WDFW unpublished	1997	Lewis	Seine	110	2	0.02
Hawkins and Tipping; WDFW unpublished	1998	Lewis	Seine	48	52	1.08
Fuss et al. 1999	1999	Elochoman	H&L	221	1	0
Fuss et al. 1999	2000	Elochoman	H&L	45	1	0.02
Wash. Dept. of Fish and Wildlife (WDFW) unpublished	2002	Kalama	RST	266	0	0
WDFW unpublished	2002	Deschutes	RST	29	0	0
WDFW unpublished	2003	Deschutes	RST	3,673	5	0
WDFW unpublished	2002	Green	RST	398	0	0
WDFW unpublished	2003	Green	RST	210	0	0
WDFW unpublished	2002	Chehalis	RST	35	0	0
WDFW unpublished	2002	Skagit	RST	6	0	0
Beachamp 1995	1983-1985	Cedar	Electro	18	0	0
Yurok Tribal Fisheries Program (YTFP)	2005	Trinity (smolts)	H&L/Frame net	2,507	155	0.06
YTFP unpublished	2005	Trinity (residuals)	H&L	216	145	0.67
YTFP unpublished	2007	Trinity (smolts)	H&L/Electro	1,636	882	0.54
YTFP unpublished	2007	Trinity (residuals)	H&L	316	435	1.38

3.6.2.3 Estuary Studies

CDFG sampled juvenile fish in the Klamath River estuary during June and July in years 1998—2003. Captured Chinook salmon were examined to determine the presence of adipose fin clips. Adipose-fin-clipped fish were sacrificed for CWT extraction and determination of race and hatchery of origin. Overlap of hatchery and NPC occurs in the Klamath River estuary after release of hatchery fish in May and June of each year (CDFG 2004b). Of interest for this analysis were relative abundance and degree of temporal overlap for hatchery and natural KRFC in the summer period of 2001 through 2004 coincident with the presence of 2000—2003 critical brood years. However, data on the overlap of hatchery and naturally produced fish are limited to the 1997—2001 brood years. There were four unique categories of Chinook juveniles found in the estuary: IGH fall Chinook; TRH fall Chinook; TRH spring Chinook; and naturally produced Chinook.

Generally, hatchery origin Chinook were most abundant in late June thorough early July of 1998 through 2002 (Wallace 2003) and comprised 24 percent to 79 percent of total juvenile Chinook captured (Table 3-8). The arrival and co-occurrence of hatchery produced fish is consistent with their release timing and rapid migration to the estuary (Table 2-2). As summer progressed, the presence of hatchery fish relative to naturally produced Chinook decreased (Wallace 2003). Meanwhile, naturally produced Chinook appeared to utilize the estuary over a much more protracted period and were detectable in seine samples as early as March and as late as September.

Table 3-8. Number of Chinook smolts recovered in the lower Klamath River estuary during June and July seining in 1998 through 2002. Hatchery values represent expanded CWT recoveries from Iron Gate Hatchery (IGH) and Trinity River Hatchery (TRH). Year is year of sampling, which relates to fish of the previous brood year.

Year	Total Chinook	IGH	TRH Fall	TRH Spring	Total Hatchery	Percent Hatchery
1998	942	608	22	117	747	79%
1999	223	79	22	26	127	57%
2000	1,835	880	54	45	979	53%
2001	1,407	185	144	4	333	24%
2002	719	125	248	41	414	58%

The duration of estuary residency by both hatchery and naturally produced juvenile Chinook reflects the significance of this habitat to pre-marine adaptation by smolts (March through September for natural fish, June through July for hatchery produced fish). Distributional overlap of hatchery and naturally produced Chinook in the estuary during June-July suggests that in years of limited habitat and/or forage base, hatchery releases may represent a significant source of additional competition for naturally produced fish. The percent of hatchery produced Chinook for the 1999 and 2001 brood years (contributing to fisheries in 2002 through 2005), relative to hatchery and natural Chinook combined occupying the estuary in the June-July period, was at or below the low end of the observed range seen for the 1997 and 1998 broods (sampled broods that contributed to fisheries in years immediately prior to the OAP. However, the 2000 brood hatchery representation (24 percent) was well below that observed in adjacent years. Based on the limited data available, it is likely the critical broods experienced average to less than average intra-specific competition from hatchery releases, unless resources, such as food or space, were unusually limiting, which may have been the case for the 2003 brood due to record low flows in 2004.

3.7 Disease

3.7.1 Adults

The 2002 fish kill included at least 34,000 adult salmonids (primarily fall Chinook) in the lower Klamath River, mature hatchery and natural area fish that had returned to the river for spawning (CDFG 2004a). The progeny of fish that died would have contributed to age-3 adults in 2005 and age-4 adults in 2006. Approximately 65,600 adult Chinook survived the fish kill to spawn in natural areas, substantially above the average escapement of adult fall Chinook to natural areas (51,700) from 1978—2003 (Table 2-6) and above the number of spawners estimated to produce maximum recruits (S_{MAX}). No other evidence of unusual disease occurred in the adult population, although a disproportionate mortality of Trinity River fish likely reduced natural spawners in that system.

Overall, the natural age-2 recruits for the 2002 brood were lower than the long-term average (Table 2-8); however, the recruits per spawner for 2002 parents was slightly above average for larger parent broods (Table 3-3). Because of the density dependence inherent in the stock-recruitment relationship (escapement exceeded S_{MAX}), from a basin wide perspective it is unlikely that the 2002 adult fish kill contributed to low recruitment of the 2002 brood. However, because several independent natural populations exist, it is also possible that the disproportionate mortality of Trinity River natural spawners may have resulted in decreased recruitment from that area.

3.7.2 Juveniles

Increasing concerns over water quality, habitat conditions, and fish health have led to increasing efforts in assessing the incidence of pathogens in outmigrating juvenile Chinook salmon. Observations of large numbers of dead juvenile Chinook salmon along the Klamath River in 2000 (Pisano 2000), high incidence of juvenile disease during recent years, and the adult fish-kill that occurred during the fall of 2002, led to heightened awareness of the salmonid fish health issues in the Klamath Basin. Following the 2002 adult fish-kill, the Klamath fish health assessment team was formed to coordinate information and facilitate cooperative monitoring efforts in the event that fish health concerns were imminent due to water quality conditions or fish health observations from field studies.

The primary pathogens implicated in the elevated disease-related mortality of juvenile Chinook salmon are the myxozoan parasites *Ceratomyxa shasta* and *Parvicapsula minibicornis* (Nichols and Foott 2005). Juvenile disease monitoring was conducted in the Klamath Basin in 2001, 2002, and 2004 (Foott et al. 2002; Nichols et al. 2003; Nichols and Foott 2006). No assessments were conducted in 2003. Monitoring has generally been divided into three areas: 1) the mainstem Klamath River above the confluence with the Trinity River, 2) the mainstem Trinity River above the confluence with the Klamath River, and 3) the Klamath River Estuary. Complete monitoring of the three areas was only conducted in 2001 and 2002.

Juvenile KRFC sampled in the Trinity River, 21 river miles above the confluence with the Klamath River, showed little incidence of infection with either pathogen (Table 3-9). In the 2002 samples from the estuary, TRH Chinook showed infection rates of 19 percent and 14 percent for *C. shasta* and *P. minibicornis*, respectively (Table 3-9), while the samples collected from the Trinity River indicated no infection (although the sample size was small), suggesting that the primary area for infection of these fish is the lower Klamath River.

Contrary to the Trinity River, disease incidence of juvenile KRFC sampled in the Klamath River was relatively high for *C. shasta* (34 percent to 50 percent) and *P. minibicornis* (77 percent to 95 percent) (Table 3-9). Samples collected in the estuary also indicated high incidences of infection by these pathogens, although the sample size of IGH Chinook was very small. Infection rates for juvenile Chinook sampled on the Klamath River in 1995 were somewhat similar for *C. shasta* (44 percent in 1995) but were much lower for *P. minibicornis* (47 percent in 1995).

To be clear, no definitive fish disease information exists to link the incidence of fish pathogens in juveniles to poor recruitment of the critical broods 2000—2003. However, infection rates for *C. shasta* in Columbia and Fraser River Chinook are typically about 10 percent compared to KRFC infection rates of about 30 percent above the Klamath-Trinity confluence (Foott 2008 pers. comm.). Also, almost every fish that was infected with *C. shasta* was also infected with *P. minibicornis,* which causes severe anemia and osmoregulatory problems (Foott 2007 pers. comm.) and compromises the ability of infected fish to fight the *C. Shasta* infection. While there are no data on the physiological effect of infections of juvenile KRFC, it is assumed that renal impairment reduces survival. For *C. shasta* and possibly *P. minibicornis*, a polychaete worm (*Manayunkia speciosa*) is the intermediate host (Bartholomew et al. 1997). Research is currently being conducted to assess the habitat conditions for the polychaete, especially the establishment of extensive algal beds, in the Klamath River below Iron Gate Dam. McKinney et al. (1999) suggested that reductions in the magnitude and duration of peak flows due to hydroelectric operations likely have increased the amount of polychaete habitat. Returning adults acquire the disease upon entering the river or during their upstream migration, and spores are released from carcasses on the spawning grounds, which in turn infect the intermediate host. Based on the high incidence of disease detected in the Klamath River, it seems likely that juvenile incidence of disease contributed to low survival (recruitment) of OAP broods, although there is no data available to compare infection or mortality rates for the critical broods with rates for other broods.

Table 3-9 Klamath Basin juvenile Chinook pathogen infection rates. (Sample size in parentheses)

Pathogen	Brood Year	Klamath	Trinity	Estuary Iron Gate CWT	Estuary Trinity CWT	Estuary Unmarked
Ceratomyxa shasta	2000	50% (34)	0% (38)	NA	NA	29% (42)
Parvicapsula minibircornis	2000	88% (25)	6% (31)	NA	NA	84% (43)
Ceratomyxa shasta	2001	37% (38)	0% (14)	60% (5)	19% (68)	26% (47)
Parvicapsula minibircornis	2001	95% (39)	0% (19)	100% (5)	14% (64)	60% (47)
Ceratomyxa shasta	2003	34% (735)	Not Sampled	Not Sampled	Not Sampled	Not Sampled
Parvicapsula minibircornis	2003	77% (732)	Not Sampled	Not Sampled	Not Sampled	Not Sampled

3.8 Other Habitat Degradation

Habitat for Chinook salmon in the Klamath River Basin has been seriously impacted over the past century and a half, beginning with gold dredging in the 1800s. Subsequent impacts from dam building and operation, grazing, agriculture, mining, wildfires, water diversion, timber harvest, floods, urbanization, and road construction have diminished the productive capacity of the stream and river habitat. As a result, the fisheries resources of the Klamath River have undergone a major decline during the past century.

It is unlikely that activities such as mining, timber harvest, agriculture, or urbanization were substantially greater during the OAP or rearing of the critical broods. However, the cumulative effects of such activities would be expected to have long term effects that reach a critical threshold for KRFC eventually. Because of the dispersed nature of these effects, it would also be very difficult to identify a particular event that would result in crossing that threshold. It is important to recognize that chronic habitat degradation from multiple sources can combine with other factors to result in an unstable ecosystem. Such cumulative effects undoubtedly result in years of low production and survival of KRFC.

3.9 Marine Survival

3.9.1 Hatchery Fish Survival

The effects of marine survival on year-class strength are believed to be most variable in the early marine life history of the fish. The best measure of marine survival would be to calculate survival rates between smolts leaving the river and ocean abundance of the cohort at some later point in time. We can reconstruct the marine abundance of cohorts, using spawning runs, exploitation rates, and constant assumed adult natural mortality rates, back to September of the year they migrate to sea. However, because very few age-2 fish are recovered in ocean fisheries, reconstructed ocean abundance is more indicative of the cohort abundance when age-2 jacks leave the ocean to spawn. No time series of emigration estimates for naturally produced KRFC exist to compare this with; the nearest approximation is KRFC fingerling releases from the two hatcheries in the basin (STT 2005b). Use of fingerling releases as a proxy for natural smolt emigration includes mortality in the period of riverine residence and migration in the estimate of early life-history survival. Therefore, the estimate of early life history survival reflects the period from the spring, when fingerlings are released, until the following year when age-2 jacks return to spawn.

The pattern of survival between the two hatcheries for which comparative data are available is highly correlated (Figures 3-14 and 3-15), which suggests that variation in these survival rates may be primarily driven by variation in ocean conditions. Least squares trend analysis indicates IGH survival rate, when forced through zero, has been about 52 percent that of comparative TRH survival rate data (Figure 3-15). Survival of IGH and TRH fingerlings was more comparable in years when survival rate at both hatcheries was less than 0.03 (Figure 3-16). The higher survival of TRH fish is consistent with pathogens (e.g., *C. Shasta)* in the mainstem Klamath being a significant source of mortality, and having a lesser impact on fish from TRH by virtue of their shorter migration pathway in the mainstem Klamath River below the Trinity River confluence with the Klamath River at Weitchpec (RM 42). However, the overall shorter migration distance for TRH fish (RM 145) compared to IGH fish (RM 192 miles) probably contributes to the higher survival rate of TRH fish regardless of disease conditions in the mainstem Klamath River.

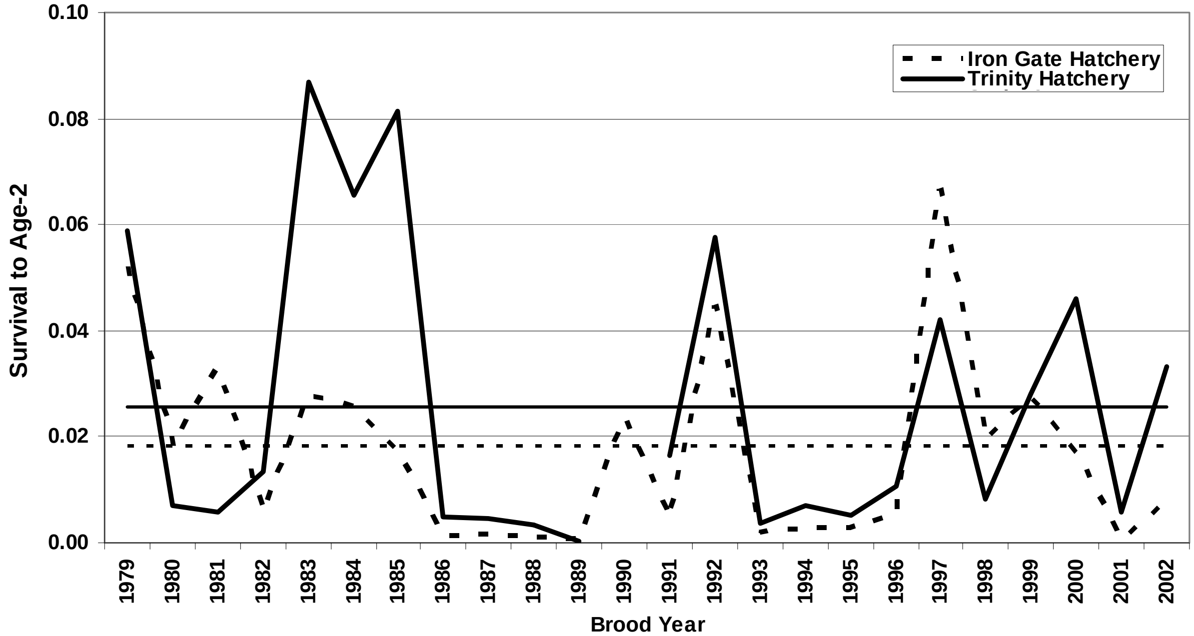

Figure 3-14. Survival of hatchery fingerling releases to age-2, September 1 and long-term averages.

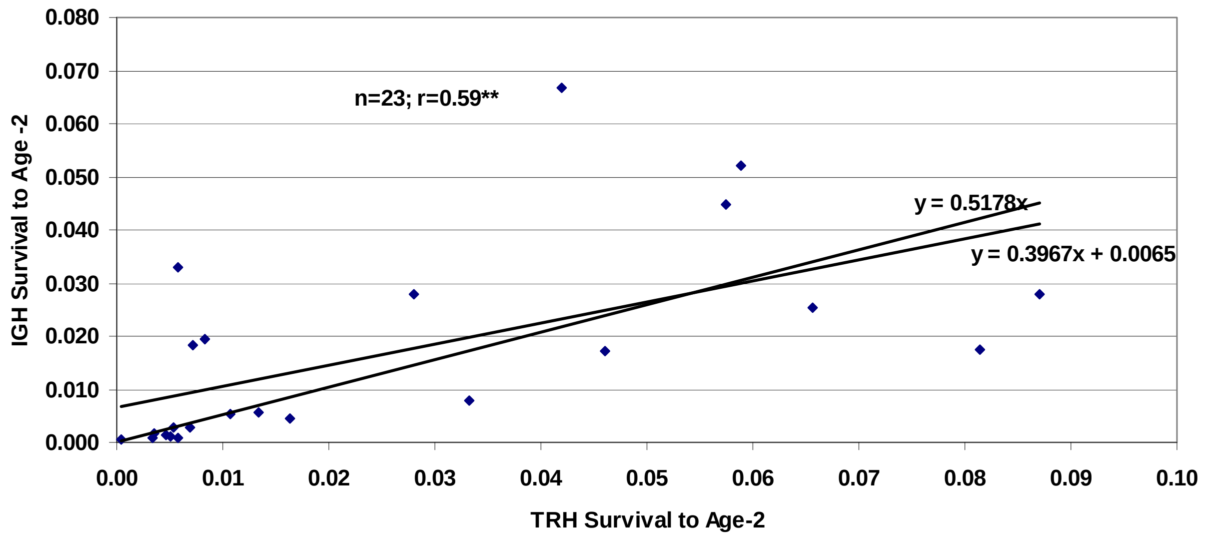

Figure 3-15. IGH and TRH fingerling release to age-2 September 1 survival rates, 1979—89 and 1991—2002 broods.

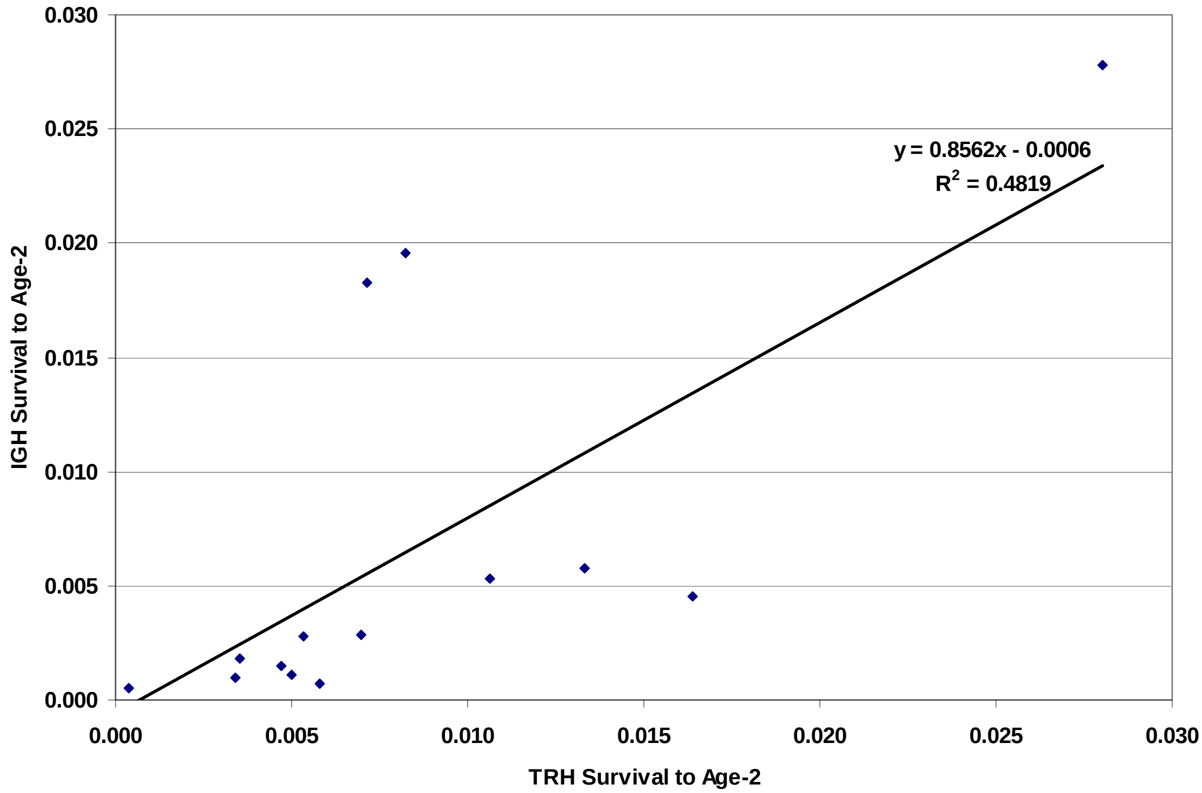

Figure 3-16. IGH and TRH fingerling release to age-2 September 1 survival rates, with high rates (>0.03) removed.

Of the 2000—2002 brood years, all exhibited the pattern of lower survival of Iron Gate fingerlings than that of Trinity River fingerlings. Actual survival rates of IGH and TRH fish of these broods was similar to or above the previous 21-year averages for the respective facilities except for hatchery fish of the 2001 brood year. The IGH 2001 brood survival rate (0.0007) was the second lowest on record and the TRH (0.0058) rate was the seventh lowest for that facility. The low survival of the IGH fish of the 2002 brood was considerably below the long-term average but there were 10 other years in the previous 21 year record with lower survival rates. The 2003 brood year was only represented by age-3 spawners, therefore the brood was too incomplete to calculate an early life-history survival rate. However, the terminal run of age-3 fish in 2006 was 18,600, the smallest run of age-3 Chinook since 1992 (Table 2-9), which suggests that the survival rate of the 2003 brood year may be even less than that of the 2001 brood year. The available data indicate depressed survival of KRFC hatchery fingerlings of the 2001 brood and probably the 2003 brood, but not of the 2000 or 2002 broods. We assume there were similar trends in the survival rates of naturally produced fish of the 2000-2003 broods.

3.9.2 Marine Mammal Predation

The Marine Mammal Protection Act of 1972 dramatically reduced the harvest or taking of seals and sea lions by man. With this protection, California sea lion (*Zalophus californianus*) and Pacific harbor seal (*Phoca vitulina richardsi*) populations have increased along the coast of California, Oregon, and Washington by an average annual rate of 5 to 9 percent (NMFS 1999). In

1997, Lowe (as cited in NMFS 1999) noted that California sea lion populations may now be larger than any historical level.

Anecdotal information from Yurok Tribal members has indicated an increase in pinniped predation upon salmonids in the Klamath River estuary during recent years. During 1998 and 1999, the Yurok Tribe, with assistance from NMFS, conducted research to estimate the magnitude of pinniped predation upon KRFC in the estuary of the Klamath River. During this study period, pinniped predation rates upon adult fall Chinook ranged from 2.3 percent (1,630 KRFC in 1999) to 2.6 percent (2,559 KRFC in 1998) (Williamson, 2001a; Williamson 2001b). Based upon the 1998—1999 study results, it seems unlikely that predation rates increased to the level that pinniped predation would have been a primary contributor to the natural spawning escapement shortfall of 2004—2006. It is also worth noting that salmonids of the Klamath Basin have coexisted with pinnipeds within the West Coast and Klamath River ecosystems for thousands of years.

4.0 ASSESSMENT OF FACTORS AFFECTING NATURAL AREA ESCAPEMENT

4.1 Fishery Management

Harvest impacts occur in ocean commercial and recreational, river recreational, and river tribal fisheries. Impacts result from retention of fish as well as incidental sources such as release of sublegal fish and drop-off/drop-out mortality. Harvest impacts are predicted prior to each fishing season using the Klamath Ocean Harvest Model (KOHM) (see section 4.1.5). Management authorities, including the Council, CDFG, and the tribes, determine annual levels of impacts to meet the conservation and allocation objectives for the stock. This combination of stock prediction and management responsibility we refer to as the fishery management process, and includes both science and policy components. The management process is collectively responsible for ensuring harvest impacts are maintained at such a level that statutory requirements are met and that the long-term productivity of stocks is preserved.

4.1.1 FMP Conservation Objective

The Salmon FMP establishes conservation and allocation guidelines for annual management of ocean salmon fisheries. This framework plan allows the Council to develop management measures responsive to annual circumstances such as relative stock abundance in the mixed stock ocean salmon fisheries.

The Council has authority to manage ocean fisheries but not inland fisheries or habitat issues; however those factors must be taken into account when setting management measures, establishing conservation and management objectives, and ensuring those objectives are met. For KRFC this means including annual forecasts of inriver fishery impacts when planning ocean fisheries to ensure the conservation objectives are met, and analyzing the effects of those fisheries if the conservation objectives are not met. It also means periodic review of conservation objectives to determine if they are appropriate for the current productive capacity of the Basin.

The FMP conservation objectives are based on achieving MSY, or an MSY proxy, for all Salmon Fishery Management Unit (FMU) stocks. The Council structures its salmon fisheries to achieve these objectives for each stock annually. If postseason estimates confirm that a stock conservation objective was not met, a rebuilding program for the following year is implicit in the conservation objective since it is based on annually meeting MSY. In addition, the Council reviews stock status annually and, where needed, identifies actions required to improve estimation procedures and correct biases. Such improvements provide greater assurance that objectives will be achieved in future seasons. Consequently, a remedial response is built into the preseason planning process to address excessive fishing mortality levels relative to the conservation objective of a stock. Because conservation objectives are generally based on MSY rather than a minimum stock size threshold, the Council's management approach is more conservative than recommended by the National Standard Guidelines.

The remedial response to stock depression acts as a default rebuilding plan, but only in terms of the biological needs of the stock, and not with regard to the socio-economic needs of fishing communities. The intent of Amendment 15 was to allow consideration of both of those needs within the short time frame necessary to complete the preseason planning process. Salmon abundance is highly variable from year to year because broods that contribute to fisheries only do so for one or two years. Therefore, developing a formal rebuilding plan to address both biological and socio-economic needs often takes longer than recovery to MSY levels. The intent of Amendment 15 was to allow management flexibility to provide some relief to fishing communities without significantly affecting the long-term productivity of KRFC, and without additional process delays. However there were concerns that the Amendment 15 analysis may not adequately account for substock viability.

4.1.2 Management Objectives

Section 5 of the FMP describes the overall objectives for the fisheries, including meeting biological objectives for the FMU stocks, meeting tribal trust responsibilities, maintaining continued participation of recreational and commercial fishing sectors, achieving optimal yield, minimizing bycatch, promoting safety at sea, etc. Section 3 of the Salmon FMP describes the conservation objectives for FMU stocks necessary to meet the dual MSA objectives of obtaining optimum yield from a fishery while preventing overfishing. Each stock within the Salmon FMU has a specific objective, generally designed to achieve MSY, MSP, or in some cases, an exploitation rate to serve as an MSY proxy.

Amendment 9 to the FMP, implemented in May 1989, established the Council's conservation objective for KRFC as a minimum natural adult brood year spawner escapement rate of 33 percent to 34 percent, but with no less than 35,000 natural adult spawners in any one year. A review of the KRFC conservation objective by the STT resulted in clarifying the minimum spawner escapement rate as a long-term annual average, which could be exceeded for a given brood in order to achieve tribal/non-tribal allocation requirements. The review was necessary because of a 1993 opinion issued by the Solicitor of the Department of Interior recognizing the rights of the Hoopa Valley and Yurok tribes to 50 percent of the available harvest of Klamath/Trinity salmon. Combined tribal and non-tribal fisheries in 2001 were limited to achieve an annual spawner escapement rate of 34 percent, the only year the spawner escapement rate has been a management constraint.

The ESA consultation standard for CCC uses KRFC as an indicator stock and limits ocean fisheries to a pre-season projected age-4 ocean harvest rate of no more than 16.0 percent.

Amendment 15 to the FMP provided flexibility to allow limited harvest of KRFC in ocean salmon fisheries during years that might otherwise be closed because of a projected shortfall in the KRFC conservation objective of 35,000 naturally spawning adults. Amendment 15 allows an age-4 KRFC ocean impact rate of no more than 10 percent, although additional inriver tribal and recreational fisheries that occur must be accounted for. Because of these additional fisheries and associated impacts with age-3 and age-5 adults, an age-4 ocean impact rate of 10 percent is roughly equivalent to a SRR of about 25 percent, or a spawner escapement rate of 75 percent. Prior to Amendment 15, if the projected escapement of natural spawners was below 35,000, all ocean salmon fisheries affecting KRFC would be closed, unless authorized by Emergency Rule as was done in 2006. While Amendment 15 does allow fishing to occur even though the 35,000 spawner conservation objective is projected not to be met, it does not change the FMP requirements relating to an Overfishing Concern. Therefore, if the 35,000 spawner escapement objective is in fact not met for three consecutive years, an Overfishing Concern would still be triggered. These impact rates associated with Amendment 15 were determined not likely to jeopardize the long term productive capacity of the stock (PFMC and NMFS 2006).

Amendment 15 has not yet been implemented, and therefore is relevant to this report primarily in the context of stock rebuilding and the implications for achieving MSY on a continuing basis.

4.1.3 Management Description

The Secretary of Commerce (Secretary) establishes annual commercial and sport ocean salmon fishing regulations for the Federal Exclusive Economic Zone (3-200 nautical miles offshore) based on recommendations of the Council. The Oregon and Washington Fish and Wildlife Commissions adopt regulations annually for the Oregon and Washington ocean recreational and commercial salmon fisheries in their respective state waters. The California Fish and Game Commission (CFGC) sets the recreational fishing regulations in state marine waters. The CDFG Director is authorized to conform commercial salmon fishing regulations in state waters to the management plans of the Council.

West Coast ocean salmon fisheries operate on mixed stocks of Chinook and coho from which the river of origin cannot be determined visually, although conservation objectives for the FMU stocks are based on river of origin or finer stratifications (PFMC 2003). To manage ocean fisheries, impacts are projected using models based on stock-specific historical timing and distribution estimated from CWT recoveries. Fisheries are managed on a weak stock basis, where harvest is allowed only to the point that the weakest stock is projected to meet its conservation and allocation objectives (PFMC 2007a); available harvest of other stocks is foregone or transferred to inland fisheries. To meet these conservation and allocation objectives, the fisheries impacting KRFC are managed through specification of time-area-specific fishing seasons (ocean commercial and recreational fisheries), or time-area-specific Chinook harvest quotas (ocean commercial fisheries), and anticipated KRFC harvest levels in river tribal and recreational fisheries (PFMC 2007b).

Ocean fisheries are limited almost every year south of Cape Falcon, Oregon, either because of the FMP KRFC minimum spawner requirement (35,000 natural area adults) or because of the ESA consultation standard for CCC (no more than 16.0 percent age-4 ocean harvest rate on KRFC).

In any one year, the maximum fishery mortality rate allowable under the Council's Pacific Coast Salmon FMP, as amended through Amendment 14, is the maximum rate that would allow the stock in question to meet its conservation objective (PFMC 2003 § 3.1); or zero if the stock could not meet its conservation objective even in the absence of fishing (PFMC 2003 § 3.2.2.2). Conservation objectives may be expressed in terms of escapements, exploitation rates, or both. In the case of KRFC, the maximum allowable fishery mortality rate is implicitly defined by its ocean abundance and the minimum spawner requirement, not to exceed a spawner reduction rate of 2/3. In any one year, *overfishing* is said to have occurred if the realized fishery mortality rate exceeded the maximum allowable rate under the FMP. Thus, if a stock's ocean abundance was sufficient to meet the conservation objective in the absence of fishing, but the objective was in fact not met in the presence of fishing, then overfishing occurred and the fishery management process may generally be faulted. On the other hand, if the stock's ocean abundance was insufficient to meet the conservation objective in the absence of fishing, overfishing, if it occurred, may not have been the sole factor responsible for the stock not meeting its conservation objective. Other factors such as especially poor stock production and/or survival at earlier life stages may have been largely responsible for the stock not meeting its conservation objective.

In years that the CCC consultation standard has not been the limiting factor, the Council has generally set the 35,000 KRFC natural adult spawning escapement floor as its management target. This was the case in 2004 and 2005. In 2006 the preseason projected spawning escapement was 25,400 absent summer ocean fisheries between Cape Falcon and Point Sur, and 21,100 given the Council adopted management measures intended to provide *de minimis* opportunity, which necessitated the Secretary promulgating an emergency rule in approving these management measures.

Non-tribal river recreational salmon fishing takes place throughout the Klamath Basin and is regulated by the CFGC, typically in the form of a quota. The river sport fishery quota has typically been allocated based on sub-area quotas as follows: 1) the river mouth area closes when 15 percent of overall quota is taken below 101 Bridge, 2) Klamath River between the river mouth and Weitchpec (RM 40) closes when 50 percent of overall quota is reached, and 3) Klamath and Trinity rivers above Weitchpec close when 100 percent of the quota is projected to have been met; however, in an effort to utilize excess hatchery produced fish, the upper Klamath and Trinity rivers are frequently reopened to take of adult Chinook once the two hatcheries have reached their adult take goals.

In 1993, the Interior Department Solicitor issued a legal opinion that concluded the Yurok and Hoopa Valley Tribes of the Klamath Basin had a Federally protected reserved right to 50 percent of the available harvest of Klamath Basin salmon. Under the Council annual salmon management process, half of the annual allowable catch of KRFC has been reserved for these tribal fisheries since 1994.

Tribal fisheries with recognized Federal fishing rights occur on the Yurok and Hoopa Valley Indian reservations located on the Lower Klamath and Trinity Rivers, respectively. The Yurok and Hoopa Valley tribal authorities adopt annual tribal fishing regulations for their respective reservations.

The Yurok Tribal Council regulates the fall Chinook fishery via annual Fall Harvest Management Plans, which are based upon the tribal allocation and subsequent regulations regarding sub-area quotas, conservation measures, and potential commercial fisheries. When the Tribal Council allows a portion of the allocation to go to commercial fishing, then most harvest is taken in the estuary where commercial fisheries are implemented. Subsistence fisheries are spread throughout the reservation.

The Hoopa Tribal Fishery is conducted in accordance with the Hoopa Valley Tribe's Fishing Ordinance. Fishing by tribal members occurs within the exterior boundaries of the Hoopa Valley Indian Reservation. The Hoopa Valley Tribal Council is the sole authority responsible for the conduct of the tribe's fishery, enforces the fishing ordinance, and ensures collection of harvest statistics through its Fisheries Department. Summary catch data for spring and fall Chinook harvested in the tribe's fishery are provided annually to co-managers and published by the Council.

The tribal fisheries normally set aside a small (unquantified) number of fish for ceremonial purposes. Subsistence needs are the next highest priority use of KRFC by the Tribes. The subsistence catch has been as high as 32,000 fish since 1987 when separate tribal use accounting was implemented. Generally, commercial fishing has been allowed when the total allowable tribal catch was over 11,000 –16,000 adult KRFC.

Allocations among non-tribal fisheries are based on annual negotiations and preseason Council recommendations. Prior to 2006, the pre-season allocations of the non-tribal catch of KRFC were typically as follows: 15 percent (7.5 percent of total) to the Klamath River recreational fishery and 85 percent (42.5 percent of total) to the combined ocean troll and recreational fisheries. Within the ocean fishery allocation, the KMZ (Humbug Mt., Oregon to Horse Mt., California; KMZ) recreational fishery was typically allocated up to 17 percent of the ocean KRFC catch (7.23 percent of total), and outside of the KMZ was not limited by KRFC impacts. The Oregon and California troll fisheries generally shared the remaining KRFC catch as equally as practical, depending on annual circumstances.

In 2006, some of the preseason fishery allocations did not follow the typical pattern in response to the depressed condition of KRFC. Impacts to KRFC in areas of high concentration were constrained to allow limited access to more abundant stocks elsewhere; the KMZ sport fishery share was 8.8 percent and the Klamath River recreational allocation for directed harvest was 0 percent. In 2007, the Klamath River recreational share was 26 percent and the California/Oregon troll shares were 63 percent/37 percent. The increased river allocation was in response to a relatively high projection of KRFC abundance and constraints on other stocks such as ESA listed CCC and Lower Columbia River natural tule Chinook, which precluded taking a larger share of the allowable KRFC harvest in ocean fisheries.

4.1.4 Fisheries Description

Ocean fisheries affecting KRFC occur primarily between Cape Falcon, Oregon and Point Sur, California. The major management areas include northern Oregon (Cape Falcon to Florence) central Oregon (Florence to Humbug Mt.), the KMZ (Humbug Mt. to Horse Mt.), Fort Bragg (Horse Mt. to Point Arena), San Francisco (Point Arena to Pigeon Point), and Monterey (Pigeon Point to Point Sur). Commercial and recreational fisheries traditionally occur in all areas; however, the season dates are more restrictive for commercial fisheries due to the greater fishing power of the commercial fleet and the high social value placed on the recreational fishery. Fisheries restrictions to limit impacts on KRFC are also more stringent near the Klamath River than in more distant management areas as KRFC are more highly concentrated there. The KRFC contribution rate in the commercial harvest is typically higher than in the recreational harvest in the same management area and time. The Council has also placed a higher value on recreational opportunity than on commercial opportunity. As a result, restrictions on the commercial sector have been proportionally greater during periods of stock depression, including 2005 and 2006.

4.1.4.1 Ocean Commercial

Commercial fisheries in the northern Oregon area are typically open from mid-March/early April through October, with some closures in the summer period to reduce KRFC or other limiting stock impacts. In the central Oregon area fisheries are similar to the northern Oregon area, but may be more restrictive when KRFC impacts are severely limiting, as in 2005 and 2006. The KMZ fisheries in Oregon typically open in mid-March/early April and continue through May without restriction, followed by small monthly quota fisheries run through September. In KRFC restricted years the summer fisheries are eliminated first, then the spring fisheries, with the September fishery usually the last to be eliminated. In the California KMZ, fisheries outside of a September quota fishery are now rare. Fort Bragg area fisheries are typically closed in the spring and summer, with some opportunity provided in September. Fisheries in the San Francisco area are constrained to May through mid-October by Sacramento winter Chinook ESA consultation standards; KRFC restrictions result in periodic closures in the summer months, especially in June when KRFC impacts are highest. Fisheries in the Monterey area are similar in scope to the San Francisco area fisheries, but are usually less constrained by KRFC due to the lower KRFC contact rates in this area.

4.1.4.2 Ocean Recreational

Recreational fisheries occur in the same management areas as commercial fisheries, but the season dates are generally more expansive due to lower impacts on KRFC. Season dates are frequently restricted to reduce impacts on stocks of concern such as Sacramento winter Chinook. The KMZ fishery is generally open from May/June through early September, although some closed periods may be necessary in June, July, or August to reduce KRFC impacts. Seasons outside the KMZ are generally less restrictive because of relatively lower impacts on KRFC.

4.1.4.3 River Recreational

Recreational fisheries for KRFC occur from August through December. Angler effort is highest in the lower Klamath River, peaking in September (50 percent of the total fall Chinook allocation is reserved for the lower Klamath River). From October through early December fishing effort is more dispersed throughout the upper Klamath and Trinity Rivers. During this time angling effort somewhat follows the upstream migration of Chinook as they migrate towards the two basin hatcheries and natural spawning areas. By mid to late December Chinook fisheries have generally ceased due to quota attainment or by the diminished quality and quantity of the remaining Chinook. All tributary streams, with the exception of the mainstem Trinity River, are closed to the take of Chinook salmon.

Recreational fisheries are managed using a quota system; sub quotas have been established for all open areas of the Klamath system. As mentioned previously, recreational fisheries are managed by the CFGC. Annual regulations are generally responsive to the adult fall Chinook quota allocations for each particular year. In years of low quota allocations, daily and weekly bag limits are reduced so that all sub quota area fisheries can participate. In high abundance years bag limits are increased, however the maximum daily bag for adult Chinook has not been higher than two fish for many years.

4.1.4.4 Tribal Fisheries

The Yurok Tribal fishery occurs within the lower 44 miles of the Klamath River. The Hoopa Tribal fishery occurs in the Trinity River from near the confluence with the Klamath River upstream to the boundary of the Hoopa Valley Indian Reservation, approximately 12 river miles. The primary gear type used is gill nets; however, a small portion of the fall Chinook harvest is taken by dip nets and hook and line. Fall Chinook are typically harvested from early August through November, with peak harvest in the estuary occurring in late August through mid September and in the Trinity River from mid-August through mid-December, with peak harvest typically occurring in late-September to early-October.

4.1.5 Fishery Management Forecast Model

The Council uses the KOHM to forecast whether or not a proposed set of annual fishery management measures are expected to result in a KRFC spawning escapement that meets the FMP conservation objective. A description of the KOHM and an evaluation of its forecast performance during the OAP follows in the next two sections, respectively.

4.1.5.1 Description

The KOHM is an age-specific cohort projection model for KRFC that the Council uses to forecast the number of natural spawning adults that are expected to result from a set of fishery control measures given the current year's forecast KRFC ocean abundance. The projection of the ocean abundance through to river spawning escapement covers a one-year time period from September 1, year *t-1* through August 31, year *t*, and is used to set the fishery control measures for the May 1, year *t* through April 30, year *t+1* period. The KOHM consists of several submodel components: 1) September 1 ocean abundance, 2) ocean fishery and natural mortality, 3) maturation, 4) out-of-basin straying, 5) river fishery mortality, and 6) proportion of spawners in natural areas versus hatcheries. For a detailed specification of the KOHM and its submodel components see Mohr (2006a).

The expected number of naturally spawning age-*a* adults, E_a, is modeled by the KOHM as

$$E_a = N_a o_a m_a (1 - w_a) r_a g_a, \qquad (1)$$

where all the quantities on the right-hand-side of the equation are age-*a* specific: N_a is the September 1, year *t-1* ocean abundance, o_a is the ocean survival rate from September 1, year *t-1* through August 31, year *t* (includes fishery-related and natural mortality), m_a is the maturation rate, w_a is the out-of-basin stray rate, r_a is the river survival rate (includes fishery-related mortality), and g_a is the proportion of spawners using natural areas (includes prespawning mortality). The sum, $E = E_3 + E_4 + E_5$, is the expected total number of naturally spawning adults, and may be expressed in the form above as

$$E = N\,\overline{o}\,\overline{m}(1-\overline{w})\overline{r}\,\overline{g}, \qquad (2)$$

where $N = N_3 + N_4 + N_5$, and the "bar" above each of the remaining quantities denotes the average of the respective age-specific rates weighted by the age-specific abundance immediately preceding that stage. The expected number of potential (absent fishing) adult natural spawners, E^0, may be determined from equations (1) and (2) above by assuming no fishery-related mortality. The conservation objective specifies 1) that $E/E^0 \geq 1/3$ or, equivalently, that the SRR due to fishing, *SRR*, not exceed 2/3:

$$SRR = 1-(E/E^0) \leq 2/3, \qquad (3)$$

and 2) that $E^o \geq 35{,}000$.

The KOHM is used annually by the Council to develop fishery control measures by substituting into equations (1), (2), and (3) that year's preseason forecast values of the right-hand-side components and determining whether the resulting *E* and *SRR* satisfy the conservation objectives. Mohr (2006a, 2006b) provides a description of the forecasting methods used for the KOHM submodel components.

4.1.5.2 Performance

The performance of the KOHM in 2004, 2005, and 2006, may be directly examined by comparing the preseason forecasts of the equation (1), (2), and (3) quantities with their postseason realized values (Table 4-1). Because of the multiplicative structure of equations (1) and (2), the postseason value of *E* is equal to the preseason value of *E* times the postseason/preseason ratios of the submodel components. Therefore, the degree to which a component postseason/preseason ratio is less than or greater than one has a comparable scaling effect on the postseason value of *E* relative to its preseason forecast value. This allows one to isolate which of these forecast components were primarily responsible for the observed difference between the postseason and preseason value of *E*.

The "absent fishing" postseason value of *E* in 2004 (71,949), 2005 (36,551), and 2006 (44,299), exceeded the FMP conservation objective of 35,000, while the realized (with fishing) postseason value of *E* in 2004 (24,079), 2005 (26,790), and 2006 (30,421) failed to meet this objective (Table 4-1). Thus, overfishing occurred in each of these three years and the fishery management process may generally be faulted (Section 4.1.3) for having not met the KRFC conservation objective in 2004, 2005, and 2006, but the reasons for this in each of these years differ as described below.

For 2004, the postseason value of E (24,079) was less than its preseason forecast (35,011) (Table 4-1). While the preseason age-specific ocean abundance forecasts all differed from their postseason values, the direction of these errors largely compensated each other, such that the preseason and postseason values of E^0 differed by only 388 fish (72,337 versus 71,949, respectively). Thus, in this case, the difference in the preseason and postseason value of E is entirely due to the under-forecast of the fishery SRR (0.516 versus its postseason value of 0.665), which in turn is primarily attributable to the under-forecast of the ocean fishery mortality rate ($\bar{o}$ post/pre ratio of 0.73); more specifically, the ocean commercial fishery mortality rate (Appendix 9-1; PFMC 2006a; Mohr 2006c). The river fishery mortality rate was well forecast ($\bar{r}$ post/pre ratio of 0.99).

For 2005, the preliminary postseason value of E (26,790) was less than its preseason forecast (35,023) (Table 4-1). Here, the age-3 and age-5 ocean abundance was well forecast, and the difference between the preseason value of E and its postseason value (8,233) is due entirely to forecast error associated with the age-4 cohort (the preseason and postseason value of E_4 differ by 8,194). In this case, the N_4 forecast error (post/pre ratio of 0.79) was compounded by optimistic forecasts of m_4 (post/pre ratio of 0.87) and g_4 (post/pre ratio of 0.75), and further compounded by the under-forecast of the age-4 ocean fishery mortality rate (o_4 post/pre ratio of 0.83); again, primarily the ocean commercial fishery mortality rate ((Appendix 9-1; PFMC 2006a; Mohr 2006c). The age-4 river fishery mortality rate was adequately forecast (r_4 post/pre ratio of 0.96).

For 2006, the postseason value of E (30,421) was greater than its preseason forecast of 21,089[2] (Table 4-1). In this year, N_4 was well forecast (63,710 preseason versus 68,913 postseason). The difference between the postseason and preseason value of E is accounted for by the N_3 post/pre ratio of 2, and the compounding of the slightly higher than forecast values of N_4, r_4, and g_4. The ocean fishery mortality rate was well forecast ($\bar{o}$ post/pre ratio of 0.99).

[2]The preseason forecast of E assuming: (a) the previous fall ocean fishing mortality, (b) an equal harvest allocation for the river tribal fishery, but (c) no additional fishery mortality was 25,400; less than the minimum spawner requirement of 35,000. An emergency rule was issued by the DOC Secretary which allowed for additional fishery mortality subject to a preseason E forecast of at least 21,000.

Table 4-1. Klamath Ocean Harvest Model (KOHM) submodel component forecasts compared with postseason estimates. N = preseason ocean abundance, o = ocean survival rate, (including fishery and natural mortality), m = maturation rate; w = out of basin stray rate; r = river survival rate (including tribal and recreational fisheries and prespawning mortality), g = proportion of naturally spawning fish, E = number of naturally spawning fish, and SRR = spawner reduction rate due to fishing mortality.

			With Fishing								Without Fishing					
Year	Age	Type	N	o	m	1-w	r	g	E	SRR	N	o	m	1-w	g	E
2004	3	Pre	72,100	0.54	0.38	0.99	0.76	0.55	6,132	0.302	72,100	0.58	0.38	0.99	0.55	8,780
		Post	160,628	0.45	0.46	1.00	0.78	0.44	11,469	0.401	160,628	0.58	0.46	1.00	0.44	19,162
		Post/Pre	2.23	0.83	1.22	1.00	1.03	0.80	1.87	1.33	2.23	1.00	1.22	1.00	0.80	2.18
	4	Pre	134,500	0.65	0.89	1.00	0.59	0.61	27,683	0.523	134,500	0.80	0.89	1.00	0.61	58,094
		Post	105,227	0.45	0.86	0.99	0.49	0.59	11,567	0.724	105,227	0.80	0.86	0.99	0.59	41,879
		Post/Pre	0.78	0.70	0.96	1.00	0.83	0.96	0.42	1.38	0.78	1.00	0.96	1.00	0.96	0.72
	5	Pre	9,700	0.49	1.00	0.99	0.36	0.71	1,197	0.781	9,700	0.80	1.00	0.99	0.71	5,463
		Post	17,247	0.31	1.00	1.00	0.25	0.79	1,043	0.904	17,247	0.80	1.00	1.00	0.79	10,908
		Post/Pre	1.78	0.63	1.00	1.00	0.69	1.12	0.87	1.16	1.78	1.00	1.00	1.00	1.12	2.00
	3+4+5	Pre	216,300	0.61	0.74	1.00	0.60	0.60	35,011	0.516	216,300	0.73	0.76	1.00	0.61	72,337
		Post	283,102	0.44	0.64	1.00	0.59	0.51	24,079	0.665	283,102	0.68	0.67	1.00	0.56	71,949
		Post/Pre	1.31	0.73	0.86	1.00	0.99	0.85	0.69	1.29	1.31	0.93	0.89	1.00	0.92	0.99
2005	3	Pre	185,653	0.57	0.38	0.99	0.90	0.54	19,278	0.123	185,653	0.58	0.38	0.99	0.54	21,983
		Post	201,518	0.56	0.39	1.00	0.85	0.50	18,778	0.183	201,518	0.58	0.39	1.00	0.50	22,991
		Post/Pre	1.09	0.99	1.03	1.00	0.94	0.93	0.97	1.49	1.09	1.00	1.03	1.00	0.93	1.05
	4	Pre	48,863	0.72	0.88	1.00	0.82	0.55	13,899	0.257	48,863	0.80	0.88	1.00	0.55	18,712
		Post	38,424	0.60	0.77	1.00	0.79	0.41	5,705	0.410	38,424	0.80	0.77	1.00	0.41	9,663
		Post/Pre	0.79	0.83	0.87	1.00	0.96	0.75	0.41	1.59	0.79	1.00	0.87	1.00	0.75	0.52
	5	Pre	5,171	0.69	1.00	0.99	0.72	0.72	1,846	0.372	5,171	0.80	1.00	0.99	0.72	2,942
		Post	6,915	0.57	0.99	1.00	0.83	0.71	2,307	0.408	6,915	0.80	0.99	1.00	0.71	3,896
		Post/Pre	1.34	0.82	0.99	1.01	1.15	0.99	1.25	1.10	1.34	1.00	0.99	1.01	0.99	1.32
	3+4+5	Pre	239,687	0.60	0.52	1.00	0.86	0.55	35,023	0.197	239,687	0.63	0.52	1.00	0.55	43,637
		Post	246,858	0.57	0.47	1.00	0.84	0.49	26,790	0.267	246,858	0.62	0.49	1.00	0.49	36,551
		Post/Pre	1.03	0.94	0.91	1.00	0.97	0.90	0.76	1.35	1.03	0.99	0.93	1.00	0.89	0.84
2006	3	Pre	44,105	0.56	0.38	0.99	0.87	0.67	5,479	0.166	44,105	0.58	0.38	0.99	0.67	6,571
		Post	87,677	0.58	0.37	1.00	0.85	0.57	9,025	0.157	87,677	0.58	0.37	1.00	0.57	10,711
		Post/Pre	1.99	1.03	0.96	1.00	0.98	0.85	1.65	0.95	1.99	1.00	0.96	1.00	0.85	1.63
	4	Pre	63,710	0.68	0.88	1.00	0.74	0.55	15,546	0.370	63,710	0.80	0.88	1.00	0.55	24,678
		Post	68,913	0.69	0.89	1.00	0.79	0.62	20,725	0.319	68,913	0.80	0.89	1.00	0.62	30,445
		Post/Pre	1.08	1.01	1.01	1.00	1.08	1.13	1.33	0.86	1.08	1.00	1.01	1.00	1.13	1.23
	5	Pre	2,228	0.07	1.00	0.99	0.59	0.72	63	0.950	2,228	0.80	1.00	0.99	0.72	1,277
		Post	5,321	0.24	1.00	1.00	0.71	0.74	671	0.787	5,321	0.80	1.00	1.00	0.74	3,143
		Post/Pre	2.39	3.60	1.00	1.01	1.19	1.02	10.57	0.83	2.39	1.00	1.00	1.01	1.02	2.46
	3+4+5	Pre	110,043	0.62	0.70	1.00	0.76	0.58	21,089	0.352	110,043	0.71	0.72	0.99	0.58	32,526
		Post	161,911	0.61	0.62	1.00	0.81	0.61	30,421	0.313	161,911	0.68	0.65	1.00	0.62	44,299
		Post/Pre	1.47	0.99	0.89	1.00	1.06	1.05	1.44	0.89	1.47	0.96	0.90	1.00	1.07	1.36

4.2 Hatchery Strays

The natural spawning population consists of both natural and hatchery origin KRFC. The degree to which hatchery origin fish spawn in the wild affects the compliance with the spawner floor, and can therefore mask the true status of wild populations. Large numbers of hatchery produced fall Chinook spawners are routinely observed near the two basin hatcheries in the upper mainstem Trinity River, Bogus Creek and to a lesser degree the Shasta River. The average hatchery composition in these areas for the period of record are 30.5 percent, 34.4 percent and 15.4 percent respectively (Table 3-6). These three areas contribute more than half of the adult spawner escapement annually to the basin total. The definition of "natural spawners" for KFRC is "adult fish which spawn outside of the hatchery facilities in natural areas." Therefore, hatchery produced fish constitute a portion of each year's spawner escapement under the current definition and in years where the conservation objective of 35,000 naturally spawning adult KRFC is barely achieved, hatchery strays may be the only reason the floor was met.

Hatchery returns of KRFC averaged 23,401 during the OAP, about the same as the long-term average prior to the OAP of 23,913 (Table 4-2). In contrast, returns of KRFC to natural areas averaged 27,014 during the OAP, about 52 percent of the long term average prior to the OAP of 51,722. Assuming the hatchery stray rate is constant across years, this suggests that hatchery strays may have constituted a significantly larger percentage of the natural area spawners during the OAP than is normally the case. This finding is broadly consistent with the trends exhibited in the (limited) time series of percentages of hatchery-origin strays reported in Table 3-5 for the Trinity River, Bogus Creek, and the Shasta River, and is concerning for the reasons described in Section 3.4.

Table 4-2. Proportion of Hatchery fall Chinook in Klamath Basin returns.

Year	Hatchery	Total	Percent Hatchery
1978	12,979	71,471	18%
1979	3,636	34,273	11%
1980	6,511	27,994	23%
1981	4,425	38,282	12%
1982	10,411	42,362	25%
1983	13,865	44,649	31%
1984	7,496	23,560	32%
1985	22,534	48,211	47%
1986	32,891	146,251	22%
1987	29,123	130,840	22%
1988	33,458	112,844	30%
1989	21,991	65,859	33%
1990	8,067	23,663	34%
1991	6,484	18,133	36%
1992	7,360	19,388	38%
1993	21,643	43,501	50%
1994	17,072	49,405	35%
1995	37,859	199,653	19%
1996	20,033	101,359	20%
1997	18,662	64,806	29%
1998	29,219	71,707	41%
1999	14,327	32,784	44%
2000	**97,611**	**180,339**	**54%**
2001	**55,112**	**132,946**	**41%**
2002	**27,183**	**92,818**	**29%**
2003	**61,782**	**149,424**	**41%**
2004	**22,981**	**46,812**	**49%**
2005	**27,699**	**54,488**	**51%**
2006	**19,522**	**49,944**	**39%**
78-03 avg	23,913	75,635	32%
00-03 avg [1]	**60,422**	**138,882**	**44%**
04-06 avg	**23,401**	**50,415**	**46%**
78-06 avg	23,860	73,026	33%

5.0 CONCLUSIONS

5.1 Factors Affecting Recruitment

1. Low parent stock size was not a limiting factor in the production of the critical 2000—2003 brood years.

2. Over-escapement (>S_{MAX}) of parent stock seems unlikely to have contributed to low recruitment of the 2000—2003 broods by itself, but low flows, high temperatures, and other adverse environmental conditions may have exacerbated density dependent effects.

3. Emigration success data for juvenile Chinook salmon were inconclusive for tributary streams in 2001—2004 due to lack of previous years' estimates, but redd scour did not appear to be a problem for incubating eggs of the critical broods.

4. Contemporary hatchery practices have helped to minimize interaction of hatchery and naturally produced Chinook in the juvenile freshwater phase, but have not eliminated it. Sampling continues to show considerable timing overlap of hatchery and natural fingerlings in mainstem migration corridors and the estuary.

5. Steelhead predation and competition impacts possibly increased for the critical 2000—2003 broods due to increased hatchery production and river returns of these fish, particularly in the Trinity River.

6. Drought and low flow conditions throughout the basin during 2001—2004 limited the amount of salmonid rearing area, and caused reduced stream flow velocities and early water temperature warming. 2001 had the lowest annual flows since at least 1979. Such conditions resulted in reduced stream rearing habitat, slowed water velocities, increased competition, and increased predation opportunities for avian and fish predators, and may have exacerbated conditions for disease infection of juvenile KRFC.

7. Temperatures in the Trinity River during 2000—2002 were in the range expected to result in lower than average recruitment.

8. The common occurrence of diseased fish, particularly *C. shasta* infections, is cause for concern and may indicate disease is a factor limiting recruitment of KRFC.

5.2 Factors Affecting Escapement

9. Overfishing of KRFC occurred in 2004, 2005, and 2006. The ocean abundance of KRFC during this period was high enough to have met the FMP conservation objective in each of these three years had the fisheries been sufficiently limited. The primary cause for overfishing in 2004 and 2005 was a substantial under-forecast of the ocean commercial fishery mortality. In 2006 the primary cause was a policy decision to allow fisheries to proceed under emergency rule.

10. The Klamath River tribal fishery, Klamath River recreational fishery, and ocean recreational fishery KRFC harvest impacts were adequately forecast in 2004, 2005, and 2006. The errors in these forecasts did not contribute significantly to the spawning escapement shortfalls in 2004, 2005, or 2006.

11. The KOHM biological components (abundance forecasts) were for the most part adequately forecast in 2004, 2005, and 2006. For a particular year and age, forecast errors in several of these components, particularly when compounded, lead to a significant forecast error in age-specific escapement (e.g., age-4 in 2005 and 2006). This error tended to be compensated for, to some extent, by opposing errors for the other age classes.

12. The principal reasons for the under-forecast of the ocean commercial fishery mortality rate in 2004 and 2005 was (a) unexpectedly high levels of fishing effort per day open in the sub-areas between Cape Falcon and Humbug Mountain, and (b) much higher than expected KRFC contact rates per unit of effort for the area south of Horse Mountain (Appendix 8.1; PFMC 2006a; Mohr 2006c). These factors did not appear to be the results of stochastic variation, but due to a shift in these underlying processes resulting in model bias. In response, the STT (a) modified the KOHM commercial fishery effort per day open submodel to account for effort transfer from closed to open sub-areas between Cape Falcon and Humbug Mountain, and (b) adjusted the KOHM commercial fishery contact rate per unit of effort submodel for the area south of Horse Mountain to reflect the higher rates observed in the 2003—2005 period (Appendix 9.1; PFMC 2006a; Mohr 2006c). Together, these adjustments resulted in an adequate KOHM forecast of the 2006 ocean commercial fishery mortality rate.

13. Small errors in the KOHM component forecasts have the potential to determine whether the KRFC conservation objective is met in a given year, particularly if the adopted fishery control measures target the escapement floor. It is conceivable, for example, that every component could be well forecast with the exception of one, and that error alone could result in the objective not being achieved.

14. If the fishery management forecast model is unbiased with respect to forecasting KRFC natural spawning escapement, and harvest control measures are adopted annually which are expected to result in a KRFC spawning escapement of no more and no less than 35,000 adults, the chances of meeting the conservation objective in any one year are 50:50. This would result in the triggering of an Overfishing Concern (failing to meet the objective in three consecutive years) on average once in every eight years (a probability of 12.5 percent). If, in addition, FMP Amendment 15 or Emergency Rules are used in some years to target spawning escapements lower than 35,000 adults, the average amount of time before an Overfishing Concern was triggered would be something less than eight years. Conversely the likelihood would be less than once in every eight years if the target was more than 35,000, as in 2001. In that year the preseason ocean abundance forecast included 247,000 age-4 KRFC, ocean fisheries were constrained by the CCC ESA consultation standard, and river recreational and tribal allocations targeted the 66 percent SRR, which resulted in an expected natural spawning escapement of 47,000 adults.

15. Ecological factors played a role in determining KRFC ocean abundance (recruitment), and fishery management responded by setting target escapement levels at or below the escapement floor. The policy choice in 2006 to target below the escapement floor and subsequent adoption of FMP 15 illustrate that providing *de minimis* fishing opportunity to sustain a viable fishery has the potential to compromise short-term attainment of conservation objectives.

16. Hatchery-origin strays may have constituted a significantly larger percentage of the natural area spawners during the OAP than is normally the case, increasing the potential for negative interactions between hatchery and naturally produced fish during this period.

5.3 Significance to Achieving MSY on a Continuing Basis

The aggregate natural spawning escapement levels observed during the OAP were below the best estimate of spawning stock size at maximum sustainable yield (S_{MSY}), however they were not unprecedented. Between 1990 and 1994 there were much lower natural spawning escapements, and for a more extended period than in 2004 through 2006, and yet the aggregate population abundance recovered. In fact some of the larger broods on record, including the parent broods of the OAP natural spawners, occurred subsequent to the 1990-1994 period. If the aggregate abundance were all that mattered, there would probably be little concern for the potential of the current shortfall to affect long-term productivity of KRFC. However, the sequential low spawning escapements in the Salmon and Scott rivers during the OAP are unprecedented. The current depression of these key natural sub-stocks does raise concerns regarding the long-term genetic integrity of KRFC that were not present during the 1990 to 1994 period. The loss of genetic integrity raises concerns for the ability of KRFC to produce MSY on a continuing basis.

6.0 RECOMMENDATIONS

6.1 Criteria for Identifying Stock Recovery and the End of the Overfishing Concern

Meeting the spawning escapement floor of 35,000 adult natural spawners in any one of the OAP years could have prevented triggering of an Overfishing Concern, and similarly, the current Overfishing Concern cannot end until the 35,000 floor is achieved. The FMP notes that when an Overfishing Concern is triggered, there may be concern that a downward trend is occurring. Therefore, the recommendations for criteria to determine the end of the current Overfishing Concern include more than just achieving the conservation objective once following the OAP. Therefore the workgroup recommends the following as one necessary criterion for ending the current Overfishing Concern:

Recommendation 1: Consider the Overfishing Concern of KRFC ended when a natural spawning escapement of at least 35,000 adults is achieved in three out of four consecutive years with a natural spawning escapement of 40,700 adult KRFC (S_{MSY}) or more in at least one of those three years.

Achieving 35,000 natural adult spawners in three years will help ensure that recovery represents more than one strong brood.

The current National Standard 1 Guideline requires rebuilding of an overfished stock to S_{MSY}. The 35,000 natural adult spawner floor in combination with the 33 to 34 percent spawner escapement rate limit was accepted as a proxy for S_{MSY} to meet administrative requirements when Amendment 14 to the Salmon FMP was approved. Therefore, a precedent exists for setting one criterion as an escapement of at least 35,000 natural spawners. However, when FMP Amendment 9 was adopted the dual nature of the conservation objective was intended to allow a range of spawning escapements, which would allow an MSY objective to be developed while protecting the stock during prolonged periods of reduced productivity. In 2005, after compiling spawner-escapement data on 22 complete broods, the STT recommended 40,700 as the best estimate of B_{MSY} (S_{MSY}) for the aggregate KRFC stock (STT 2005b). This estimate was based on a stock-recruitment model that accounts for variation in both parental spawners and early life history survival, and the SSC concurred that the estimate of 40,700 represented the best available science. Achieving a natural spawning escapement of 40,700 would satisfy the National Standard 1 Guideline requirement using the best scientific information available to estimate S_{MSY}, as determined by the STT (2005b) and SSC (2005).

Mohr and Fujiwara (2006) in FMP Amendment 15 note that natural spawning escapements of less than 720 adults in mid-Klamath tributary populations substantially increase the risk of loss of genetic diversity, which could negatively affect the ability of the aggregate KRFC stock to produce MSY in the long term. A natural spawning escapement of 40,700 would achieve a probability of less than 20 percent that a spawning escapement in one of the three mid-Klamath tributaries less than 720 adults would occur in any one year, and should provide additional surplus production to benefit fisheries and ecosystem functions.

6.2 Stock Recovery Measures

In order to meet the criterion for ending the Overfishing Concern, a rebuilding strategy should be adopted to facilitate that process.

6.2.1 Management Measures

The probability of certain events, or combination of events, with negative consequences occurring may not change as stock size decreases, but the probability of crossing critical thresholds affecting the long-term productivity of the stock is high at low abundance levels. Therefore, a more precautionary management approach is warranted during periods of stock depression and rebuilding.

Recommendation 2: Target a natural spawning escapement of 40,700 adult KRFC until the Overfishing Concern is ended (the rebuilding period).

If preseason stock abundance projections are sufficient to allow for at least *de minimis* fisheries, targeting for the S_{MSY} level of 40,700 (as opposed to 35,000) will increase the likelihood that the 35,000 spawner floor will be achieved, and that the Overfishing Concern would end. As noted above, it will also decrease the risk to subpopulations and should provide additional surplus production in future years to the benefit of fisheries and ecosystems.

Amendment 15 to the Salmon FMP was intended to provide management flexibility to allow KRFC spawning escapement to fall below 35,000 in order to accommodate *de minimis* harvest levels while preventing collapse of the salmon fishing industry and infrastructure. Amendment 15 was intended to be implemented primarily when temporary depression of KRFC occurred, and did not supersede the Overfishing Concern criteria listed in the FMP. A similar approach could be used to allow KRFC to recover from an Overfishing Concern while accommodating some of the needs of fishing communities. However, if 40,700 becomes the management target as recommended above, the threshold for implementing the Amendment 15 approach would require adjustment to prevent a discontinuity in allowable harvest between the management targets. The implementation threshold for a 10 percent age-4 ocean impact rate resulting in a natural spawning escapement of 35,000 adults is a pre-fishing spawning escapement of about 47,000; for a spawning escapement of 40,700, the implementation threshold would be a pre-fishing spawning escapement of about 54,000.

Recognizing the increased risk associated with an Overfishing Concern as opposed to a Conservation Alert, rebuilding measures should be more conservative, particularly when abundance is on the lower end of the *de minimis* fishing scale. However, the needs of the fishing communities are also heightened during prolonged stock depression. Therefore, recognizing the importance that some opportunity be preserved, the workgroup makes the following recommendation:

Recommendation 3: When implementing *de minimis* fisheries during the rebuilding period, provide for an age-4 ocean impact rate of no more than 10 percent when preseason stock abundance forecasts result in pre-fishing spawning escapement projections of less than about 54,000, plus an additional requirement of introducing a sliding scale, which would reduce the allowable rate linearly from no more than 10 percent at a projected natural spawning level of 30,000 to 0 percent at a projected natural spawning level of 22,000.

The value of 30,000 spawners was chosen to be consistent with the NMFS proposed rule for Amendment 15, noting the need to substantially reduce the impact rate at spawning escapements below that level. The value of 22,000 was chosen to reflect the level at which the Council's preferred option for Amendment 15 required reduction of the impact rate, combined with the increased risk associated with an Overfishing Concern. The sliding scale feature is intended to provide a structured implementation of the rebuilding measure, which allows for a predictable and consistent process in adopting management options for public review and final action.

The implementation threshold of 54,000 is an approximate value, and the specific value in a given year would be determined preseason by the STT, and would be based on year specific age composition, size limits, and fishing strategies.

Recommendation 4: No further modifications in parameterizing the KOHM components are recommended at this time.

One primary cause of the KRFC spawning escapement shortfall in 2004 and 2005 was that the forecast of the commercial fishery mortality during spring/summer fisheries was biased low, and significantly so. The STT observed this bias and responded with appropriate modifications to the KOHM and the data used to parameterize the KOHM in 2006.

The modifications made to the KOHM were effective in 2006; however, the STT will continue to verify model results with postseason information, and react as necessary to ensure the KOHM performs adequately.

Impacts to KRFC in ocean fisheries occurring in the September-November period (fall fisheries) are assessed against escapement in the following calendar year, although there is currently no forecast of impacts available for these fisheries. Fall fisheries provide significant opportunity for some ocean fishery strata, particularly in the KMZ commercial fisheries. However, fall fisheries also pose a risk in that fall impacts may substantially reduce the KRFC impacts available, and hence the opportunity available in spring/summer fisheries the following year. During periods of stock depression, this can result in hardship to fishing communities and pressure to exceed the conservation objective through use of an Emergency Rule, as was the case when fall 2005 fisheries affected spring/summer 2006 fishery planning.

Recommendation 5: During periods of stock rebuilding, fall fishing opportunity in areas impacting KRFC abundance should be restricted.

This will reduce the likelihood of severe restrictions in subsequent spring/summer fisheries, pressure to increase harvest impacts during times of low abundance, future spawning escapement shortfalls, and prolonged rebuilding periods.

Recommendation 6: The practice of reopening the upper Klamath and Trinity rivers to recreational fishing once hatchery egg take goals are met should be suspended during rebuilding periods or when an Overfishing Concern is imminent.

The KOHM assumes that river recreational fisheries stay within the preseason allocation. Fisheries that reopen after quotas are met are not accounted for. Lack of accountability could compromise achieving natural area spawning escapement objectives.

Recommendation 7: All river fishery strata should be sampled at a minimum sampling rate of 20 percent for catch and biological information, including CWTs used to estimate impact on natural area spawners and returns of hatchery fish.

The proportion of hatchery fish in the upper mainstem Klamath natural spawning areas is relatively low, and increased escapement to those areas should benefit stock recovery. In the Trinity River, hatchery fish generally make up the majority of natural spawners, and increased escapement probably has relatively less benefit to stock recovery. In addition, the proportion of hatchery spawners increases with proximity to TRH, so there may be a gradient of benefits to natural spawning populations in the Trinity.

6.2.2 Conservation Objective

The combined objectives for KRFC of a minimum spawning escapement floor and a maximum SRR comport with the basis for salmon conservation objectives identified in the FMP, that is to approximate or approach MSY. Therefore, the workgroup recommends:

Recommendation 8: No change to the current FMP conservation objective for KRFC.

The workgroup does not believe the current analysis reveals any compelling evidence of problems with the current FMP conservation objective for KRFC. However, the natural spawning escapement floor of 35,000 adults is below the best estimate of S_{MSY} (STT 2005b). Unless recruitment is sufficient for the SRR to limit fisheries (rather than the spawner floor), it is unlikely that S_{MSY} will be achieved on a long-term basis. Therefore, as an annual management target, the 35,000 floor may not be appropriate if the objective is to meet the intent of the FMP and achieve S_{MSY} on an average basis.

As noted above, regularly targeting for the minimum escapement acceptable under the conservation objective is also likely to result in occasional triggering of an Overfishing Concern due purely to stochastic variation. In any given year, the probability of an escapement shortfall could be reduced by setting a target that is greater than the minimum acceptable under the conservation objective. This strategy could be particularly useful if previous shortfalls have occurred and an Overfishing Concern is imminent or if rebuilding from an Overfishing Concern is underway.

6.3 Hatchery Practices

Recommendation 9: Encourage implementation of a 25 percent CFM program at IGH.

Currently there is a constant fraction marking program at TRH but not at IGH. The TRH program, which marks 25 percent of all production, provides for substantially increased precision of estimated ocean fishery contact rates and harvest of Trinity River fall Chinook, as well as estimated proportions of TRH-origin fall Chinook in natural spawning areas. Coupling this with a 25 percent constant fractional marking program at IGH would extend these benefits to the entire KRFC stock.

Fingerling tags are desirable as an indicator stock for naturally produced stock because of similar life history characteristics. Unfortunately the low survival rate for fingerlings frequently provides too few recoveries for adequate estimates of exploitation. Increasing the tag rate to 25 percent would reduce reliance on using yearling tag groups for impact assessment and would better meet management needs (CDFG and NMFS 2001).

6.4 Research

Additional research is necessary to identify the relationship between disease occurrence, prevalence, and recruitment success and their effects on the population dynamics of KRFC. This research should consider juvenile fish interactions as well as parent to offspring interactions.

Recommendation 10: Encourage further research on disease issues in the Klamath Basin as they relate to population dynamics and fishery management.

Instream mortality studies of naturally produced juvenile fish need to be conducted on an annual basis. Expanded juvenile fish trapping and efficiency sampling might be considered along with controlled releases of tagged hatchery fish in the estuary for comparison with counterpart tagged hatchery fish releases. If results indicate a significant population effect, additional research should be directed at further assessing the mechanisms and solutions to the problem.

Recommendation 11: Encourage expanded studies of tributary and mainstem production and survival rates of KRFC.

Expanded study areas, including the key tributaries and lower Klamath mainstem, would provide better estimates of stream specific outmigrant population sizes. These data when used in conjunction with river survival estimates could be used in forecasting brood strength and assessing factors related to stock status.

Recommendation 12: Encourage studies of early-life marine survival rates for KRFC.

The current efforts being conducted by NMFS Northwest Fisheries Science Center on ocean ecosystem indicators of salmon marine survival in the northern California current should be extended southward to include areas potentially important to KRFC.

6.5 Restoration and Enhancement Measures

Ongoing and planned habitat restoration and enhancement efforts should increase the capacity and productivity of KRFC in the basin, which will address some of the recruitment issues observed during the OAP. Increased and properly timed water releases from the two mainstem dams in combination with improved water quality conditions in the Klamath River have the potential to increase survival of outmigrant smolts in the Klamath and Trinity mainstems. Habitat restoration efforts currently underway in the Trinity River are also expected to expand spawning area for adult fish and increase the number of natural spawners that can utilize that system. The Federal Energy Regulatory Commission (FERC) relicensing process for the Klamath mainstem dams has the potential to increase available habitat and improve water quality as well. All of these actions are expected to increase basin productivity, resulting in enhanced future fishing opportunities and additional spawning fish to the Klamath/Trinity ecosystem.

A number of recommendations for improving and increasing habitat in the Klamath Basin have been made by the Council through the FERC process. These improvements would enhance productivity in the basin and address recruitment issues. The workgroup recommends:

Recommendation 13: Continued Council involvement in the FERC relicensing process, and consideration of Council recommendations by FERC.

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8.0 APPENDICES

Appendix 8.1 KOHM Adjustments for 2006 Fisheries

The material presented in this Appendix was written in March 2006 (PFMC 2006a) and is reprinted here because of its importance, both in describing the details underlying the under-forecast of the ocean fishery mortality rate in 2004 and 2005, and in demonstrating the responsiveness of the Council's STT to remedy the situation when these facts became clear. No attempt has been made to revise the tense of the reprinted text.

The age-4 ocean harvest rate on KRFC has been significantly under-predicted for three consecutive years. Table 8-1 lists the preseason and postseason estimates for these years, stratified by sector (commercial, recreational) and time period (September-December, January-August).

The recreational sector preseason estimates have not been particularly problematic (Table 8-1). The commercial sector preseason estimates for the previous September-December period have been somewhat more problematic, but it is not yet clear whether the estimator is positively biased versus generally uncertain (September-December 2002 was over-estimated, Table 8-1). The preseason estimates for the September-December period are actually preliminary "postseason" estimates based on CWT recoveries in these fisheries (these fisheries are prosecuted prior to the preseason planning process) coupled with the current ocean abundance forecasts. These preliminary "postseason" estimates for the September-December period are inputs to the KOHM—not outputs. The primary source for the substantial under-prediction of the age-4 ocean harvest rate in 2003, 2004, and 2005 has been the commercial sector preseason prediction for the January-August period (as highlighted in Table 8-1). The preseason predictions for this time period are outputs of the KOHM, and the STT therefore reviewed the KOHM harvest rate predictors for the commercial sector during the January-August period, and adjusted these predictors for the recent observed patterns in the postseason estimates as described below.

The KOHM January-August period age-4 ocean harvest rate predictors are a function of the sector-area-month-specific expected contact rate per unit of effort and the expected level of effort per day open. For the expected contact rate per unit of effort, the KOHM default predictor is a ratio estimator fit to all available data (postseason estimates from 1983–2005). Figure 8-1 displays these area-month-specific postseason estimates and contact rate predictors for the commercial sector. The small dots are 1983–2002 postseason values; the large dots are the postseason values of the last three years (2003–2005). The thin predictor line is the ratio estimator fit to the entire dataset (KOHM default); the thick predictor line is the ratio estimator fit to the 2003–2005 data. For the northern Oregon (NO) and central Oregon (CO) areas in March and April, the high contact rates per unit effort in 2003–2005 were initially unanticipated by the KOHM, but the 2006 predictors have now adapted to the recent accumulation of these data and do not appear in need of any adjustment (Figure 8-1). During the May-August period in the NO and CO areas there are a few outlying points from the last three years, but for the most part the recent data is consistent with the historical data pattern, indicating no adjustment is necessary for these months (Figure 8-1). Adjustment of the Oregon KMZ (KO) and California

KMZ (KC) predictors is also judged to be unnecessary (Figure 9-1). For the Fort Bragg (FB), San Francisco (SF), and Monterey (MO) areas however, there has been a fairly consistent under-prediction of the contact rate per unit of effort across the May-August period (Figure 9-1). The consistency of this recent upward shift in the data across this broad geographic area and time period (years, and months within years) argues for restricting the database for these areas to the 2003–2005 period, and this adjustment was made. In summary, for the commercial sector, the 2006 KOHM contact rate per unit of effort predictors for the NO, CO, KO, and KC areas will be the ratio estimator based on all available data (thin line), and for the FB, SF, MO areas will be the ratio estimator based on the 2003–2005 data (thick line).

For the expected level of effort per day open, the KOHM default predictor for the commercial sector is a ratio estimator fit to all available data since 1991 (postseason estimates from 1991–2005). There are two exceptions to this. First, if there is insufficient pre-existing data for a given area in a particular month (e.g., early season fisheries), the effort predictor for the following month in the same area is used (for early season fisheries this predictor will probably be conservative). Second, in the FB, SF, and MO areas the predictors account for effort shift expected under partial closure of the overall area (effort from the closed areas is assumed to move into the open areas). The FB, SF, and MO effort predictors have worked reasonably well in recent years and do not appear in need of adjustment. The KO and KC effort predictors also appear to be satisfactory. For the NO and CO areas however, there has been relatively high levels of effort in the last few years, particularly in 2005. While the 2005 NO and CO commercial fisheries were substantially restricted in time and area, the observed levels of effort in those areas and months that were open were unexpectedly high (near record highs in several months), with the result that overall effort across these areas within a month and for the season as a whole was not dampened. In other words, there was considerable effort shift within months, and a concentration of effort across months, in the NO and CO areas in 2005. The effort predictors for the NO and CO areas were thus adjusted to account for effort shift between these two areas within a month (as is presently done for the FB, SF, and MO areas): within a particular month, if NO is closed, all of the NO effort is assumed to move into the CO area, and vice-versa. In summary, for the commercial sector, the 2006 KOHM effort per day open predictors for all areas will be the ratio estimator based on the 1991–2005 data. Effort transfer has now been incorporated into the NO and CO area predictors, as it is for the FB, SF, MO area predictors.

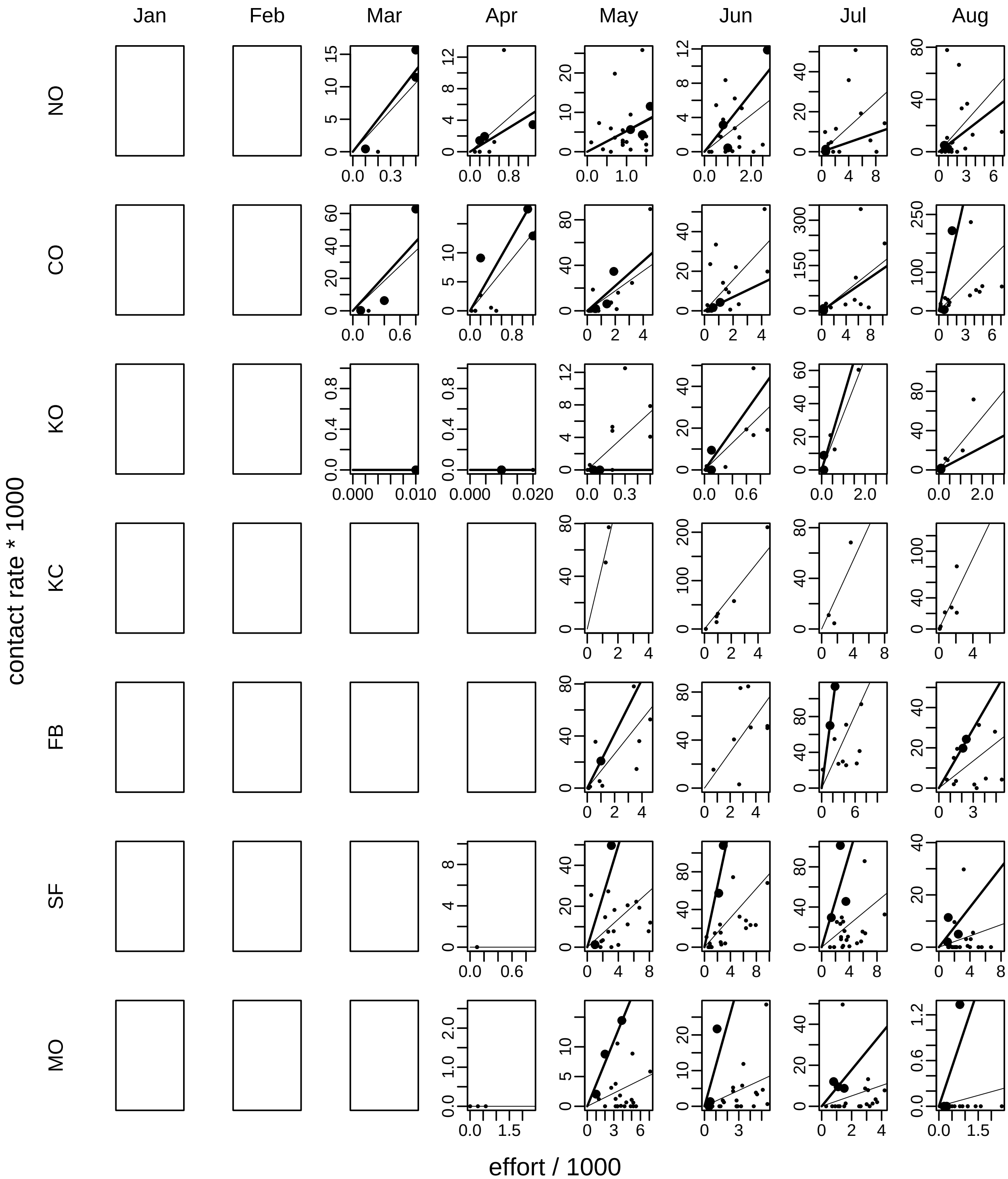
To gauge the net effect of these adjustments on the age-4 ocean harvest rate forecast, Table 8-2 compares the 2005 preseason prediction versus that which would have resulted had the adjusted KOHM been used for preseason prediction in 2005. In this example, the adjusted KOHM forecasts closely track the January-August postseason results, with the largest unaccounted for errors arising from the September-December preliminary “postseason” estimated values (Table 8-2).

Table 8-1. 2003-2005 preseason, postseason estimates of Klamath River fall Chinook age-4 ocean harvest rates (percent).

		Commercial			Recreational			Combined		
	Year (t)	Sep-Dec(t-1)	Jan-Aug(t)	Sep(t-1)-Aug(t)	Sep-Dec(t-1)	Jan-Aug(t)	Sep(t-1)-Aug(t)	Sep-Dec(t-1)	Jan-Aug(t)	Sep(t-1)-Aug(t)
Pre	2003	3.6	9.9	13.6	0.2	2.3	2.5	3.8	12.2	16.0
Post	2003	2.0	19.8	21.8	0.1	1.2	1.3	2.1	20.9	23.0
Post-Pre	2003	-1.6	9.8	8.2	-0.1	-1.1	-1.2	-1.7	8.7	7.0
Pre	2004	3.4	9.0	12.4	0.5	2.1	2.6	3.9	11.1	15.0
Post	2004	7.5	40.8	48.2	1.0	3.2	4.2	8.5	44.0	52.4
Post-Pre	2004	4.1	31.8	35.9	0.5	1.1	1.6	4.6	32.8	37.4
Pre	2005	2.9	3.0	5.9	0.3	1.4	1.7	3.3	4.4	7.7
Post	2005	8.0	13.6	21.6	0.8	1.6	2.3	8.8	15.2	23.9
Post-Pre	2005	5.1	10.5	15.6	0.4	0.2	0.6	5.5	10.7	16.3

Table 8-2. 2005 preseason, adjusted KOHM, and postseason estimates of Klamath River fall Chinook age-4 ocean harvest rates (percent).

		Commercial			Recreational			Combined		
	Year (t)	Sep-Dec(t-1)	Jan-Aug(t)	Sep(t-1)-Aug(t)	Sep-Dec(t-1)	Jan-Aug(t)	Sep(t-1)-Aug(t)	Sep-Dec(t-1)	Jan-Aug(t)	Sep(t-1)-Aug(t)
Pre	2005	2.9	3.0	5.9	0.3	1.4	1.7	3.3	4.4	7.7
Post	2005	8.0	13.6	21.6	0.8	1.6	2.3	8.8	15.2	23.9
Post-Pre	2005	5.1	10.5	15.6	0.4	0.2	0.6	5.5	10.7	16.3
KOHM adj	2005	2.9	13.4	16.3	0.3	1.3	1.6	3.3	14.7	18.0
Post	2005	8.0	13.6	21.6	0.8	1.6	2.3	8.8	15.2	23.9
Post-Pre	2005	5.1	0.1	5.2	0.4	0.3	0.7	5.5	0.4	6.0



Appendix 8-1 Figure 1. Klamath River fall Chinook commercial age-4 contact rate versus effort for KOHM management areas by month, January through August. Large dots are 2003-2005 postseason values; small dots are 1983-2002 postseason values; thick lines are predictors based on the 2003-2005 data; thin lines are the KOHM default predictors based on all data (1983-2005). See Appendix 8.1 text for further details.

Appendix 8.2 Mortality Rate Calculations

Appendix 8-2 Table 1. Data and assumptions used to estimate survival rate from stream migrant stage to age-2 September 1.

	Age 2	3 1/	4	5	Total	Source
Monthly survival rate=	0.944	0.982	0.982	0.982		Goldwasser et al. 2001
Maturity rate=	0.047	0.387	0.879	1.000		CDFG cohort reconstruction
Eggs/spawner=					1,250.00	PFMC A-15 statistic
Sept 1 age 2 pop size (ocean entrants)=					477.00	Computed age 2 Sept 1 ocean pop. for MSY
Potential adults in age 2 pop=					0.25	Computed assuming no ocean fishing (see below)
Combined fishry impact=					0.66	PFMC harvest rate policy
Egg to migrant rate=					0.17	This report: 214 migrants/adult, 1250 eggs/adult
Calculations:						
Potential adults=		119.64				
Harvest=		78.96				
Spawners=		40.68				
Eggs=		50,845.31				
Stream migrants=		8,643.70				
Age 2 stream migrant survival=		**0.055**				

1/ May 1 ocean birthday for rate change

Survival calculations: no fishing scenario

	Age 2			**Age 3**			**Age 4**			**Age 5**		
Month	**ocean**	**river**	**Oc surv**	**ocean**	**river**	**Oc surv**	**ocean**	**river**	**Oc surv**	**ocean**	**river**	**Oc surv**
9	477.000			227.281			84.754			8.184		
10	450.228			214.524			83.193			8.033		
11	424.959			202.484			81.660			7.885		
12	401.108			191.119			80.155			7.740		
1	378.595			180.393			78.679			7.597		
2	357.346			170.268			77.229			7.457		
3	337.290			160.712			75.806			7.320		
4	318.359			151.692			74.410			7.185		
5	300.491			148.897			73.039			7.052		
6	283.626			146.154			71.693			6.922		
7	267.707			143.461			70.372			6.795		
8	252.682	11.219	0.500	140.818	53.469	0.608	69.076	59.620	0.800	6.670	6.547	0.800
										Adults	**119.636**	

Appendix 8.3 Dams and Water Diversions

Flows

There are several major diversions of water within the Klamath-Trinity Basin. Although estimates vary, there are approximately 500,000 acres of irrigated agricultural land in the Upper Klamath Basin (above Iron Gate Dam). Approximately 190,000 – 220,000 of these acres are within the Klamath Irrigation Project, which is operated by the Bureau of Reclamation (BOR 2001[3]; Gannett et al, 2007[4]); the remaining diversions in the Upper Klamath Basin consist of private water diversions that have been undergoing adjudication for more than 20 years.

There is also substantial irrigation within the Scott and Shasta Rivers, as well as the diversion of more than half the water from the Upper Trinity River to the Central Valley.

Klamath Irrigation Project

The Federal Klamath Irrigation Project (Project), operated by the U.S. Bureau of Reclamation (BOR), supplies irrigation water to over 190,000 acres of farm land in south-central Oregon and north-central California and regulates flows to the Klamath River downstream.

The Project is divided into two delivery areas: the Upper Klamath Lake (UKL) delivery area which provides water from Upper Klamath Lake and the Klamath River to both agriculture and two national wildlife refuges, and the East Side delivery area, which provides water from Clear Lake Reservoir, Gerber Reservoir and the Lost River to lands on the east side of the Project area.

In allocating water the BOR must maintain minimum elevation levels in Upper Klamath Lake in accordance with the USFWS Biological Opinion (May 2002) to manage for ESA listed Klamath Shortnose and Lost River suckers. The NMFS Biological Opinion (May 2002) provided minimum flows at Iron Gate Dam for maintenance of critical habitat for ESA listed SONCC coho salmon. These Biological Opinions (BOs) were challenged in a 2003 lawsuit filed against the BOR and NMFS by the Pacific Coast Federation of Fishermen’s Associations. In 2006 a 9th Circuit Court of Appeals judge remanded the NMFS BO, ruling that it was in violation of the ESA, and requested a re-consultation, now in progress. In the interim, the judge ordered immediate implementation of the “long-term” flows which the NMFS BO had prescribed to be implemented during years nine and ten of the 10-year BO and that require flows at Iron Gate Dam be maintained at a minimum of 1,000 cfs during the summer months to protect SONCC coho.

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[3] Bureau of Reclamation, 2001. Biological assessment of the Klamath Projects continuing operations on Southern Oregon/Northern California ESU coho salmon and critical habitat for Southern Oregon/Northern California ESU coho salmon. U.S. Bureau of Reclamation, Mid-Pacific Region, Klamath Area Office, Klamath Falls, Oregon.

[4] Gannett, M.W., Lite, K.E. Jr., La Marche, J.L., Fisher, B.J., and Polette, D.J., 2007, Ground-water hydrology of the upper Klamath Basin, Oregon and California: U.S. Geological Survey Scientific Investigations Report 2007-5050, 84 p.

Shasta River

The Shasta River provides irrigation water to approximately 46,400 acres of irrigated crop area (primarily pasture) in the Shasta River basin. Shasta River water rights have been adjudicated since 1932, with full appropriation from May 1 through October 31 (North Coast Regional Water Quality Control Board [NCRWQB] 2006[5]).

The California Department of Water Resourced (CDWR) data from 1945 to 1994 show a steady increase in consumptive impairment from the Shasta River ranging from 42,500 acre-feet (af) in 1945 to 109,500 af in 1994 (CDWR 1964[6]). During the irrigation season from March through September, flows decline markedly (NRC 2004[7]). Reduced flows, elevated temperatures, and low dissolved oxygen levels were identified as the water quality parameters having the most adverse impacts to cold water fish in the Shasta River (NCRWQCB 2006).

Scott River

Water from the Scott River is used to irrigate approximately 34,000 acres of pasture, alfalfa and grain in the Scott Valley, using about 98,100 af of applied water per year. Water rights were adjudicated in 1980, but do not include adjudication rights for fish upstream of the U.S. Geological Survey gage at Fort Jones. Below the gage, the U.S. Forest Service (a junior appropriator) was allotted a minimum flow for fish of 30 cfs during August and September, 40 cfs during October and 200 cfs from November through March. However, there is no watermaster service on the mainstem, and the U.S. Forest Service adjudication is often not met (National Research Council [NRC] 2004). Irrigation withdrawals are supposed to cease on October 15, however, this is sometimes violated, minimizing migration flows for adult salmonids.

Historically, the Scott River has provided optimum coho salmon spawning and rearing habitat, with beaver dams throughout the valley. The hydrology of the Scott River watershed is not well documented, and a water budget is currently underway (CSWRCB 1995[8]).

Trinity River

The Trinity River is impounded by Trinity and Lewiston Dams which were completed in 1963 as part of the 1955 Central Valley Project Act. An average of 1.1 million af flowed past Lewiston prior to the dam construction. In some years up to 90 percent of this inflow was diverted to the

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[5] NCRWCB (North Coast Regional Water Quality Control Board). 2006. Action plan for the Shasta River watershed temperature and dissolved oxygen total maximum daily loads (online). Available at: http://www.swrcb.ca.gov/rwqcbl/programs/tmdl/Shasta/060707/FinalShastaTMDLActionPlan.pdf

[6] California Department of Water Resources. 1964. Shasta Valley Investigation, Bulletin no. 87.

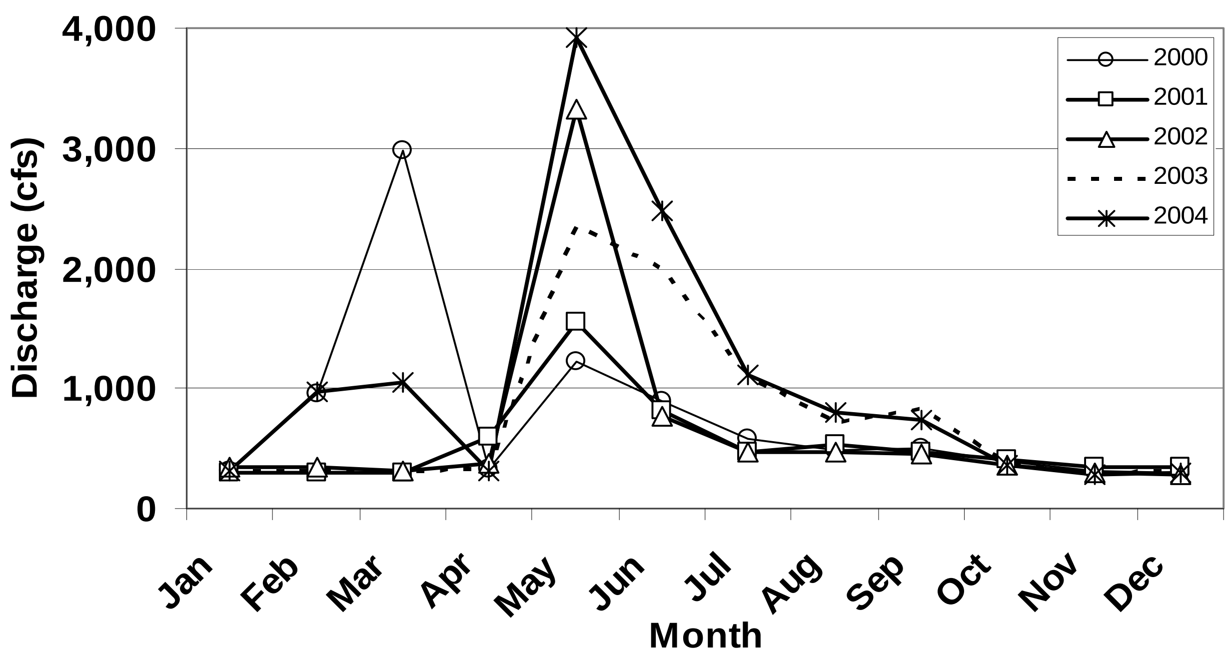
[7] NRC (National Research Council). 2004.Endangered and Threatened Fishes in the Klamath River Basin. Washington, D.C. National Academy Press.

[8] California State Water Resources Control Board. 1995. Proposal for a Water Budget of the Scott River Watershed (online). Available at: http://www.krisweb.com/biblio/scott_xxxx_siskrcd_xxxx_waterbudget/205.htm

Sacramento River as part of the 1955 Act. Subsequent decline of the fisheries led to a series of administrative and congressional actions (1981 Interior Secretarial Decision for the Flow Evaluation Study; 1984 Trinity River Basin Fish and Wildlife Management Act; 1992 Central Valley Project Improvement Act), which culminated in the 2000 Record of Decision (ROD) co-signed by then Interior Secretary Bruce Babbitt and the Chairman of the Hoopa Valley Tribe (USDOI 2000). The ROD specified in-river flows based on five water year types that range from critically dry to extremely wet, with annual volumes of 369,000 af to 815,000 af. The goal of the Trinity River Restoration Program, which implements the ROD, is to restore populations of naturally produced anadromous fish to those levels observed prior to construction of the Trinity Division of the Central Valley Project.

Smaller diversions occur throughout the Trinity River Basin mostly for domestic water use; however, several small scale operations pump water for crop and pasture irrigation on the mainstem Trinity and in the South Fork Trinity Basins. Any potential direct fish losses as a result of pump/diversion entrainment are un-quantified at this time, but are believed to be minor.

Increased river flows, primarily in the spring to promote fluvial process and to provide more favorable thermal regimes for outmigrating juvenile salmonids, have been implemented since the signing of the ROD in 2000 (**Figure A-2**). Additional flows were released in the fall of 2003 and 2004 to assist in preventing unfavorable conditions that contributed to the adult fish die-off in the lower Klamath River in the fall of 2002. While no adult fish die-off occurred in either 2003 or 2004, the effectiveness of these flow releases from the Trinity in preventing this event is uncertain. Some of the possible negative reactions resulting from these atypical (primarily in duration) fall flows were fall Chinook salmon moving into the upper river up to two weeks early, increasing the probability of hybridizing with spring Chinook salmon.



Appendix 8-3 Figure 1. Mean monthly discharge in cubic feet per second (cfs) at Lewiston Dam, 2000-2004.

Another major component of the Trinity ROD is the construction of channel rehabilitation sites where lack of flow variation over four decades has led to channel simplification. As originally envisioned in the ROD, 47 sites were to be completed by 2005. However, as a result of inadequate funding and poor strategic planning, the implementation schedule has been significantly delayed with completion now anticipated by 2012. Efforts are under way to improve overall program efficiency and budget adequacy.

The major change in fish habitat that has been implemented since the signing of the ROD was increased flows during the spring/summer outmigration period (USFWS and HVT 1999). Due to litigation over implementation of the ROD recommendations, full instream release volumes were not available until 2005; however, beginning in 2001, volumes were increased above that previously available (340,000 af), which allowed for meeting some of the flow based objectives recommended in the Trinity River Flow Evaluation (USFWS and HVT 1999) (**Table 3-4**).