Lower Klamath River Adult Fall Chinook Salmon Pathology Monitoring, 2006

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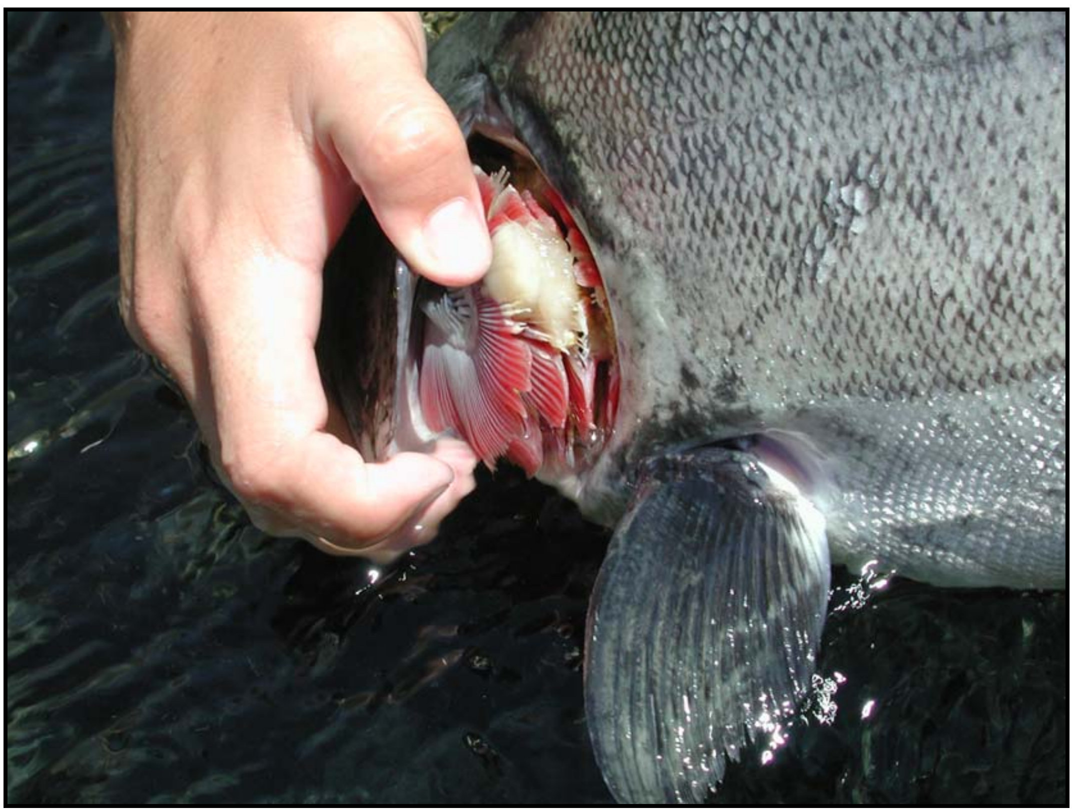

Photo: Severe columnaris infection with secondary fungal growth on gill of adult Chinook salmon in the Klamath River.

INTRODUCTION

The lethal agent in the 2002 lower Klamath River fish kill, which resulted in a minimum of 32,553 dead adult Chinook salmon, was an epizootic outbreak caused by the protozoan parasite *Ichthyophthirius multifiliis* (Ich) and the bacterium *Flavobacterium columnare* (columnaris) (Foott 2002; Guillen 2003; Turek et al. 2004). Columnaris is ubiquitous in the Klamath River and affects the skin and gills of salmonids. In general, healthy fish are resistant to columnaris (Shotts and Starliper 1999); however, infections can develop due to environmental stress, minor injuries to the skin or gills, or the presence of other pathogens such as Ich. Environmental stress can include overcrowding, handling or capture stress, low dissolved oxygen, high temperatures, toxins, and high organic loads (Thune 1993). Columnaris infection is usually secondary to other pathogens, which can include Ich (Plumb 1999). Ich is a ciliated protozoan parasite found throughout the world and is presumed to be native to the Klamath River. Outbreaks of Ich occur when conditions are favorable for rapid multiplication of the parasite, which spreads horizontally from fish to fish. These conditions include, but are not limited to, a suitable environment and susceptible fish. Ich epizootics occur when fishes are stressed, crowded, and often when water temperature is relatively elevated and flows relatively low (Dickerson and Dawe 1995). High water temperatures are not necessary for an Ich outbreak, however, as significant Ich mortality has occurred in British Columbia in low flow spawning channels at 13 to 15ºC (Traxler et al. 1998). High water temperatures do favor outbreaks but alone cannot trigger them. For example, Klamath River water temperatures have been favorable for Columnaris and the Ich outbreaks in past decades, but 2002 was the only year on record to experience an epidemic and was the first documented mortality due to Ich in the Klamath River basin (Belchik et al. 2004). Factors such as low flows, high fish densities, and long fish residence times are believed to be the main contributing factors to the epizootic outbreak of 2002 (Guillen 2003; Belchik et al. 2004; Turek et al. 2004). The importance of flow in controlling Ich outbreaks has been well documented in controlled experimental settings (Bodensteiner et al. 2000).

In 2003 and 2004 the Yurok Tribal Fisheries Program (YTFP), with additional samples collected by the USFWS Arcata Fish and Wildlife Office and the Karuk Department of Natural Resources in those years only, quantified the incidence and severity of Ich and columnaris infections in fall-run Chinook salmon during the late summer and early fall. The purpose was to detect any significant increases in the prevalence or severity of Ich or columnaris infections. If a significant increase was observed, emergency options to prevent or reduce disease mortality would be discussed by river managers and fish biologists. In additional to potential emergency options, a pulse flow was released from Trinity Dam during those years coinciding with peak entry timing of fall-run Chinook salmon in the lower Klamath River in order to reduce the risk of a repeat of the 2002 fish kill. No preventative pulse flows were released in subsequent years. The effects of these pulse flows on migrating adult Chinook salmon as determined by biotelemetry is discussed by Strange (2003, 2006, and 2007), including implications for Ich transmission and disease risk. No epizootic fish kills have occurred among fall Chinook salmon in the lower Klamath River since 2002, and Ich infections have only rarely been documented and usually at low severity (YTFP 2005; YTFP unpublished data).

Beginning in 2005, the focus of YTFP adult Chinook salmon pathology monitoring efforts has been to collect baseline data on background levels of Ich and columnaris (YTFP 2005). Ultimately, we intend to develop a long-term data set, inclusive of different water year types, meteorological conditions, and Chinook salmon run sizes, in order to evaluate the relationship between environmental variables, fish variables, and infection levels. Such information would be especially valuable in the unfortunate event of a future epizootic outbreak among adult salmonids in the Klamath River or its tributaries. This technical report summarizes our findings during the fall Chinook salmon run of 2006.

METHODS

Beginning August 15th, 2006, field personnel began sampling adult fall-run Chinook salmon for pathogens. Sampling was conducted in the mainstem Klamath River, at the Trinity River confluence pool (rkm 69.5). We set and drifted monofilament gillnets, which were 50’ by 75’, 12’ deep, with 7 ¼” mesh size. Drift sets were conducted by setting a net perpendicular to the thalweg of the river that was allowed to float downstream with the current. Samplers drifted next to the net in a jet boat to ensure it was positioned correctly or did not get tangled. Nets were drifted in the current for 450’-500’ in length. Stationary sets were typically deployed in the upstream terminus of eddies. The float line was secured to the bank and the net was stretched at an angle to the flow of the river. Stationary sets were left for two to seven hours per day. Field crews attended nets for the entire duration of the set, checking them every 30 to 60 minutes, or whenever a salmon appeared to be entangled. For the first two weeks of sampling, stationary sets were deployed at dusk and removed early in the morning. Later stationary sets were initiated in the early morning hours, which seemed to result in a higher catch per unit effort.

Upon capture, live or recently expired adult Chinook salmon were examined externally with the unaided eye for evidence of columnaris infection and general body condition. Samplers then removed the outside gill arch from the left and right sides and placed them in plastic bags for examination. Gill arch samples were examined immediately or stored on ice for examination within one hour of removal. Each gill arch was examined using a dissecting scope (10x lens) and with a consistent search pattern. Any Ich trophozoites observed on the gill tissue samples were enumerated and recorded. Ich trophozites are distinguishable from other similar looking benign parasites (e.g. *Nanophytes*) by their characteristic spinning motion resulting from their cilia.

We calculated the mean daily river discharge for the study period based on actual measurement data records from the U.S. Geological Survey (USGS). Records were obtained from gauges on the Klamath River near Klamath, CA (USGS 11530500), below Iron Gate Dam (USGS 11516530), and on the Trinity River just below Lewiston Dam

(USGS 11525500). Klamath River temperatures were measured just downstream of the Klamath and Trinity River confluence (rkm 69). Temperatures were recorded at this site by the U.S. Forest Service Orleans Office.

RESULTS

From August 15th to October 7th, 2006, YTFP personnel fished a total of 99 set net hours and 20 drifts. The number of adult Chinook salmon sampled was 102. Weekly samples ranged from 0 to 32 adults per week. Sampling efforts were reduced during the last week due to fishery closures by the Yurok Tribe and an increase in coho salmon (*Oncorhynchus kisutch*) by-catch. During this study there were 15 fish infected with columnaris but not a single incidence of Ich (Table 1). The first appearance of columnaris occurred during the fifth week of the survey. The incidence of columnaris increased during the last few weeks of sampling. Generally, adult Chinook salmon and their gills appeared very healthy.

Mean daily flows during sampling months are presented in Figure 1 for the Klamath River below Iron Gate Dam (IGD) and near the Klamath estuary at rkm 13 and for the Trinity River below Lewiston Dam. Flows in the lower Klamath River increased briefly in September due to a four day pulse flow from IGD for the Yurok ceremonial boat dance that peaked at 3,490 cfs on September 11th. For the purpose of comparison to conditions leading up to the 2002 fish kill, mean daily flows in the lower Klamath River are presented in Figure 2 for years 2000 through 2006. Hourly river temperatures at the sampling site during this study ranged from a high of 23.4ºC on August 13th, to a low of 15.0ºC on October 7th and were comparable to 2002 temperatures (Figure 3).

DISCUSSION

Conditions in the lower Klamath River during the fall of 2006 were substantially different than in 2002, with 2006 having a smaller run of salmon and notably higher flows, in particular from IGD. Adult fall-run Chinook salmon escapement from the ocean to the Klamath River in 2002 was estimated at 160,788 fish (CDFG 2007). In comparison, the provisional estimated ocean escapement for 2006 was 61,629, which was also far below the average ocean escapement since 1978 of 104,504 fish (Figure 4). Due to the time delay between infection and death from Ich, the appropriate period for calculating relevant flows was the preceding month prior to 2002 fish kill, which began on Sept 19th. Average flow below IGD in 2002 during this period was 727 cfs, whereas average flow in 2006 for the same period was 1,025 cfs. Average flow during this period near Klamath (rkm 11) in 2002 was 2,019 cfs, substantially lower than 2006 average (rkm 13) of 3,086 cfs. River flows have been substantially higher in the lower Klamath River in all years since 2002, with 2,500 cfs appearing to be an important threshold for extreme disease risk. Finally, unlike run-size and river discharge, river temperatures for 2002 versus 2006 during this period were generally equivalent. This is not a surprising result since high water temperatures alone do not cause Ich outbreaks.

The exact level of Ich incidence and severity over the course of the fall Chinook salmon run in 2002 was not measured. However, based on observed mortality in relation to overall escapement, approximately 19 to 38% of adult fall-run Chinook salmon in 2002 were infected with sufficient severity to cause death. In contrast, the YTFP has observed almost no Ich infections in gill monitoring conducted every year since from 2004 to 2007, with the exception of 2003, which had low incidence and moderate severity. The general absence of Ich infections since the 2002 fish kill is a critically important finding and suggests that a threshold effect is occurring due to the all or nothing character of Ich infections in the Klamath River. Since a larger fall Chinook salmon run occurred in 2003 than in 2002, and high water temperatures in the summer and fall are an annual occurrence, such a threshold effect is not due to run-size or water temperature. Additionally, biotelemetry research has documented that fall-run Chinook salmon have congregated, held extensively, and migrated slowly through the lower Klamath River every study year from 2003 to 2007 (Strange 2003, 2006, and 2007; unpublished data). By process of elimination, river discharge is the remaining factor that could be responsible for this threshold effect. It is highly likely that flows above the apparent threshold lead to low mortality risk and an almost complete absence of infection whereas flows below the threshold lead to high mortality risk and can produce fish kills of the magnitude observed in 2002. Currently, 2002 provides the only affirmative data point for flows below the threshold.

Logical deduction of the importance of river discharge in controlling Ich infections among fall-run Chinook salmon in the lower Klamath River as discussed above is also supported by the life-history of Ich and the best available peer-reviewed experimental information. Bodensteiner et al. (2000) conducted research in a controlled fish culture environment using channel catfish as the test organism to determine the most effective means for controlling Ich infections. Their research results led to the conclusion that increasing turnover rates and water velocities are the most effective measures to prevent and stop Ich outbreaks. Interestingly, Bodensteiner et al. (2000) found that a wide range of fish densities did not affect Ich infection or mortality rates, which suggests that fish density has an on-or-off threshold relationship (e.g. necessary condition) and not a linear relationship with Ich infections. Thus once the fish density threshold is crossed for a given setting, which could be produced by relatively small numbers of fish, river discharge via turnover rates and water velocities are the primary determinants of Ich infection and mortality rates (e.g. controlling factors). This is not surprising given that Ich is a ciliated protozoan that must swim from fish to fish (horizontal transmission) in order to spread within a window of several days depending on temperature. Since these relationships are not field testable in a controlled experimental manner, it is incumbent on river mangers to take risk averse actions in the face of uncertainty of the turnover rate, water velocity, and fish density thresholds for the lower Klamath River for which there is only one affirmative data point – 2002.

In the case of columnaris infections, incidence increased as the season progressed, which was the opposite of what would be expected based on water temperatures. While water temperature certainly influences whether a given fish becomes infected with columnaris as has been observed during the summer for spring-run Chinook salmon, it does not explain the observed increase in columnaris infections among fall-run Chinook salmon as the season progresses. A more fitting explanation is the decreasing immune system function that occurs as salmon approach senescence.

ACKNOWLEDGEMENTS

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Table 1. Results of adult fall-run Chinook salmon pathology monitoring on the lower Klamath River, California, rkm 69.5 in 2006.

Sample Week	Sample Size	Samples with Ich	Samples with Columnaris	Effort net hours	Effort drifts
13 Aug - 19 Aug	4	0	0	17.5	0
20 Aug - 26 Aug	5	0	0	19.5	0
27 Aug - 2 Sept	32	0	0	17.5	0
3 Sept - 9 Sept	12	0	0	7.0	0
10 Sept -16 Sept	7	0	1	4.0	20
17 Sept - 23 Sept	18	0	4	15.5	0
24 Sept - 30 Sept	24	0	10	14.0	0
1 Oct - 7 Oct	0	0	0	4.0	0

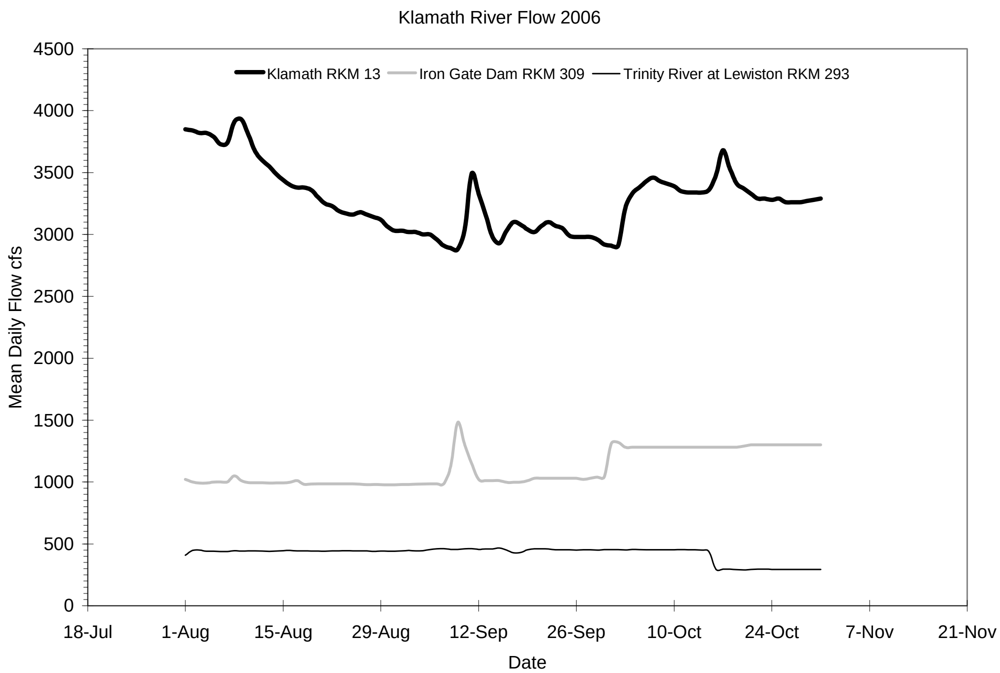

Figure 1. Mean daily discharge (cfs) of the Klamath and Trinity rivers during the adult fall-run Chinook salmon pathology monitoring sampling months, August to October, 2006. Discharge was measured by the USGS on the Klamath River near Iron Gate Dam and near the estuary at Klamath, and on the Trinity River just below Lewiston Dam (USGS final data).

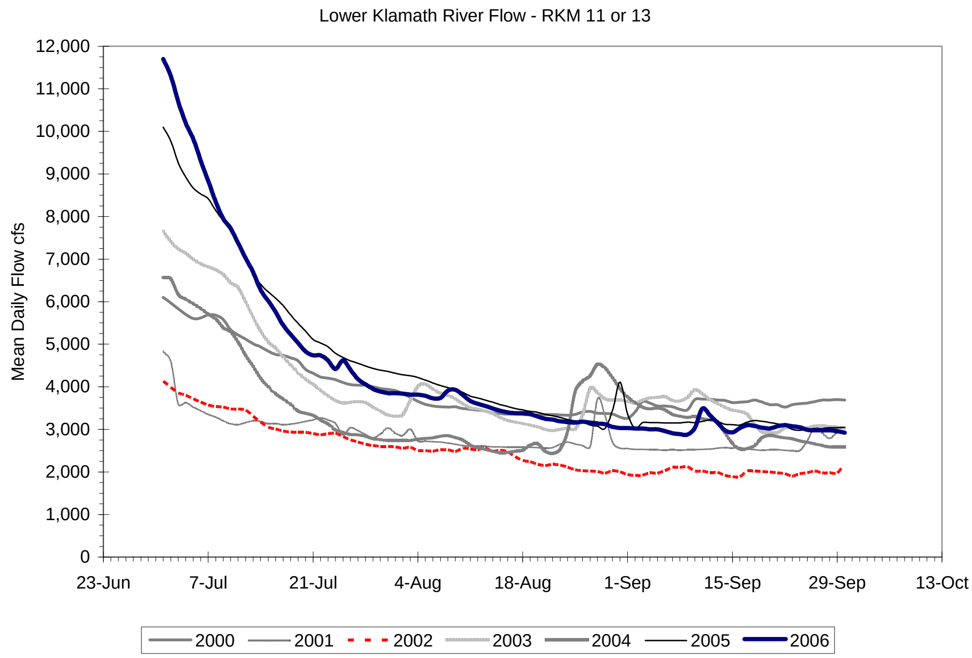

Figure 2. Summer and fall flows for the lower Klamath River from 2000 to 2006 (USGS final data).

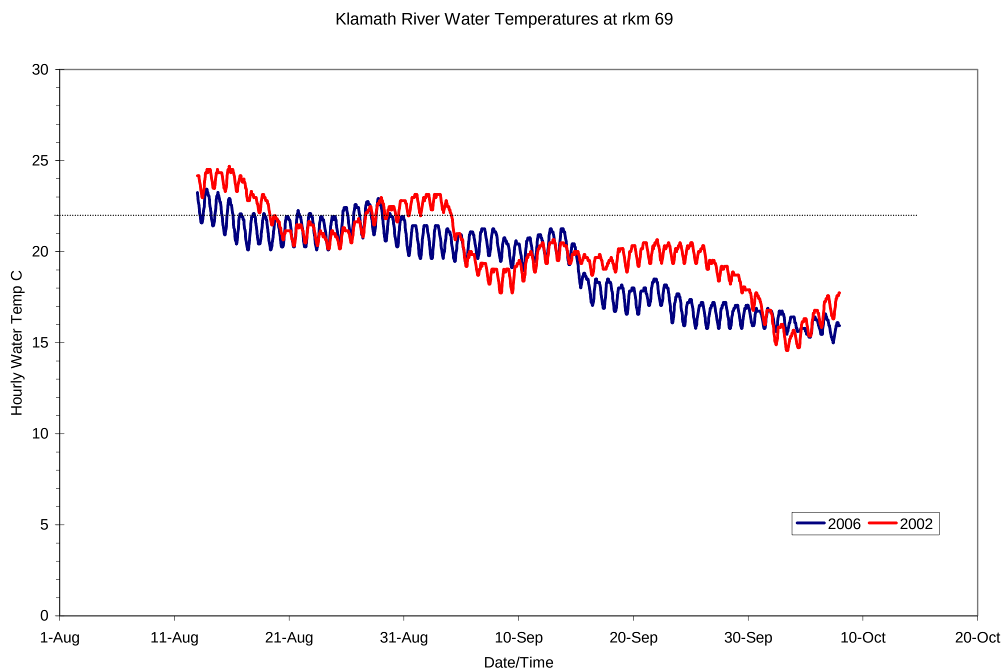

Figure 3. Klamath River temperatures at rkm 69, which is just downstream from the sampling location, during the sampling period for 2006 with 2002 shown for comparison. The dashed line marks the approximate threshold for migration inhibition due to high temperature for adult Chinook salmon as determined by biotelemetry studies.

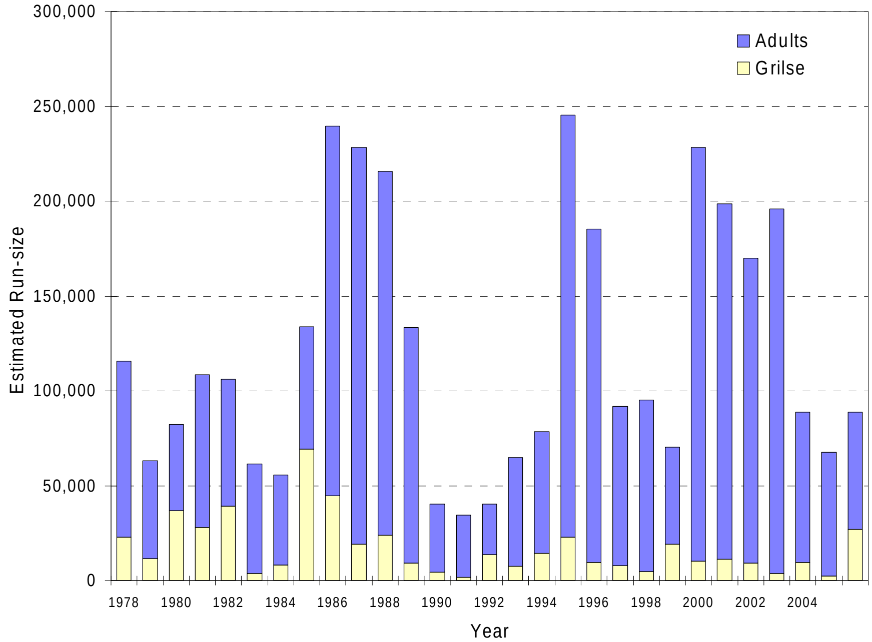

Figure 4. Klamath River basin fall-run Chinook salmon escapement from 1978 to 2006 (source CDFG 2007 "megatable"; 2005 and 2006 are provisional data).

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