

# **KLAMATH RIVER FISH HEALTH WORKSHOP 2013**

River Lodge Conference Center, Fortuna, California

Tuesday, March 12<sup>th</sup>

**AGENDA**

and

**ABSTRACTS**

*Funding for the River Lodge in support of this annual gathering of Klamath Basin fish health experts was provided by the Firedoll Foundation, with assistance from staff of the Klamath Basin Monitoring Program and Salmon River Restoration Council.*

## AGENDA

### 8:30am Welcome

### 8:35am – 10:15am *Ceratomyxa shasta* Monitoring Studies

- 8:35am KLAMATH RIVER FISH HEALTH MONITORING PROGRAM 2012: A SURVEY OF DISEASE PREVALENCE IN JUVENILE CHINOOK SALMON FROM THE KLAMATH RIVER BASIN  
Kimberly True, **Anne Bolick** and Scott Foott, USFWS
- 8:55am KLAMATH RIVER FISH HEALTH MONITORING PROGRAM 2012: A SURVEY OF DISEASE PREVALENCE IN JUVENILE CHINOOK SALMON IN THE TRINITY RIVER AND CODED-WIRE TAGGED TRINITY HATCHERY FALL CHINOOK DURING MIGRATION THROUGH THE LOWER KLAMATH BASIN  
**Kimberly True**, Anne Bolick and Scott Foott, USFWS
- 9:15am SENTINEL FISH STUDIES FOR *CERATOMYXA SHASTA* INFECTION IN 2012  
**Rich Holt**, Adam Ray and Jerri Bartholomew, OSU
- 9:35am ABUNDANCE OF *CERATOMYXA SHASTA* IN RIVER WATER SAMPLES IN 2012  
**Sascha Hallett** on behalf of OSU, Karuk Tribe, Yurok Tribe and The Klamath Tribes
- 9:55am *CERATOMYXA SHASTA* MYXOSPORE SURVEY- FALL 2012: KLAMATH, SHASTA, & TRINITY RIVER ADULT CHINOOK CARCASSES  
**Scott Foott**, Ron Stone, Anne Bolick, Ken Nichols and Kimberly True, USFWS

### 10:15am – 10:30am BREAK

### 10:30am – 11:50am *Ceratomyxa shasta* Monitoring Studies, continued

- 10:30am ASSESSING POTENTIAL RELATIONSHIPS BETWEEN *CERATOMYXA SHASTA* MYXOSPORE ABUNDANCE IN POST-SPAWNED CHINOOK SALMON CARCASSES AND FIVE CARCASS DEMOGRAPHIC PARAMETERS: CARCASS SEX, SIZE, LEVEL OF DECOMPOSITION, AND SITE AND DATE OF CARCASS SAMPLING.  
**Nick Campise** and Gary Hendrickson, HSU
- 10:50am YEAR-ROUND MONITORING OF POLYCHAETE POPULATIONS IN THE HYPER-INFECTIOUS ZONE: DENSITIES, INFECTION LEVELS, AND OBSERVATIONS ON LIFE-CYCLE DYNAMICS  
**Josh Strange** and Luke Walker, Stillwater Sciences and Yurok Tribe
- 11:10am INVERTEBRATE ASSEMBLAGES IN THE LOWER KLAMATH RIVER, WITH REFERENCE TO *MANAYUNKIA SPECIOSA*  
David Malakauskas and **Margaret Wilzbach**, HSU
- 11:30am ASSESSING RISK OF SALMONID CERATOMYXOSIS BY MONITORING POLYCHAETE HOST POPULATIONS  
**Julie Alexander**, Adam Ray and Jerri Bartholomew, OSU

### 11:50am – 1:00pm LUNCH

### **1:00pm – 3:00pm Factors Affecting Infection**

- 1:00pm SUBSTRATE STABILITY INFLUENCES *MANAYUNKIA SPECIOSA* DENSITY  
**Michelle Jordan**, Julie Alexander, Gordon Grant and Jerri Bartholomew, OSU, USDA Forest Service
- 1:20pm PREDICTING THE UNDESIRABLES: NOVEL USE OF HYDRAULIC MODELS TO PREDICT PRESENCE OF THE INVERTEBRATE HOST OF THE SALMONID PARASITE *CERATOMYXA SHASTA*  
**Julie Alexander**, Michelle Jordan, Damon Goodman, Nicholas Hetrick, Nicholas Som, **Katrina Wright** and Jerri Bartholomew, OSU, USFWS
- 1:40pm EPIDEMIOLOGICAL MODEL OF THE CS LIFE CYCLE: DEVELOPMENT AND SENSITIVITY ANALYSIS IDENTIFY DATA GAPS AND POTENTIAL MANAGEMENT OPTIONS  
**R. Adam Ray** and Jerri Bartholomew, OSU
- 2:00pm SIMULATING POPULATION DYNAMICS OF JUVENILE CHINOOK SALMON IN THE CONTEXT OF *C. SHASTA*  
**Russell Perry**, Nick Som and Adam Ray, USGS, USFWS and OSU collaboration
- 2:20pm SPORE ME A RIVER: LESSONS AND HYPOTHESES  
**Nicholas A. Som**, Sascha Hallett, Jerri Bartholomew, Russell Perry, Julie Alexander and Nicholas J. Hetrick, USFWS, OSU, and USGS Collaboration
- 2:40pm  $2\beta R_0 > 2\beta$  : SPEAKING MATH HELPS UNDERSTAND DISEASE DYNAMICS  
**R. Adam Ray**, Nicholas Som, Russell Perry, and Jerri Bartholomew, OSU, USFWS and USGS collaboration

### **3:00pm – 3:15pm BREAK**

### **3:15pm – 4:35pm Other Research**

- 3:15pm PERIPHYTON AND WATER COLUMN PHYTOPLANKTON DISTRIBUTION IN THE KLAMATH RIVER  
**Mike Deas**, Watercourse Engineering Inc.
- 3:35pm 2012 KLAMATH RIVER ADULT CHINOOK DISEASE MONITORING  
**Barry McCovey**, Jamie Holt and Mike Belchik, Yurok Tribe
- 3:55pm KLAMATH FISH HEALTH ASSESSMENT TEAM WEBSITE UPGRADE  
**Nicolas Ramirez**, Klamath Basin Monitoring Program
- 4:15pm Update on Klamath Basin Water Quality Improvement Activities  
**Clayton Creager**, CA North Coast Regional Water Quality Control Board; Maia Singer, Stillwater Sciences, Inc.; Chantell Krider, Klamath Basin Monitoring Program

### **4:35pm – 5:00pm Discussion of critical research questions**

KLAMATH RIVER FISH HEALTH MONITORING PROGRAM 2012: A SURVEY OF DISEASE PREVALENCE IN JUVENILE CHINOOK SALMON FROM THE KLAMATH RIVER BASIN.

Kimberly True, **Anne Bolick** and Scott Foott

USFWS, California-Nevada Fish Health Center  
24411 Coleman Fish Hatchery Rd.  
Anderson, CA 96007

Juvenile Klamath River Chinook salmon (*Oncorhynchus tshawytscha*) were assayed by quantitative polymerase chain reaction (QPCR) and histology for myxosporean parasite infections, *Ceratomyxa shasta* and *Parvicapsula minibicornis*, from April to August in 2012. The prevalence of *C. shasta* by QPCR in Chinook salmon collected above the Trinity River confluence during the peak migration period (May-July) was 30%, an increase from 17% observed in 2011. The prevalence of *C. shasta* below the Trinity River was 54% by QPCR for fish collected later in the season (June-August) in the lower basin.

In coded-wire tagged (CWT) Iron Gate Hatchery (IGH) Chinook salmon screened by QPCR, *C. shasta* was detected in 42% of fish examined. *Ceratomyxa shasta* POI in IGH CWT collected the Trinity River to the Estuary (K1) reach was 79% and 35% in Estuary (K0). The highest *C. shasta* prevalence of infection (72%) occurred in the IGH-CWT Chinook salmon residing 3 Weeks at Large (WAL) post hatchery release.

Prevalence of infection will be presented with emphasis on *C. shasta* by Klamath River reach and fish origin (natural or hatchery origin Chinook).

KLAMATH RIVER FISH HEALTH MONITORING PROGRAM 2012: A SURVEY OF DISEASE PREVALENCE IN JUVENILE CHINOOK SALMON IN THE TRINITY RIVER AND CODED-WIRE TAGGED TRINITY HATCHERY FALL CHINOOK DURING MIGRATION THROUGH THE LOWER KLAMATH BASIN.

**Kimberly True, Anne Bolick and Scott Foott**

USFWS, California-Nevada Fish Health Center  
24411 Coleman Fish Hatchery Rd.  
Anderson, CA 96007

Natural and hatchery origin juvenile Chinook salmon (*Oncorhynchus tshawytscha*) from the Trinity River were assayed by quantitative polymerase chain reaction (QPCR) and histology for myxosporean parasite infections, *Ceratomyxa shasta* and *Parvicapsula minibicornis*. The prevalence of *C. shasta* by QPCR in Chinook salmon collected from April to August, 2012 from an upper and lower site on the Trinity River was 3.8% (9/237, ci = 2-7%). Prevalence was higher (5.8%) in the lower Willow Creek RST (T2 site) compared to the upper Pear Tree RST (T1 site) at 1.7%. *Parvicapsula minibicornis* prevalence of infection in mixed origin Chinook salmon was slightly higher at the upper site (24.8%) but similar to the lower Willow Creek site (23.3%).

Coded wire tagged salmon from Trinity River Hatchery (TRH-CWT) were collected from June 20 through August 3 in the Trinity River. The largest proportion of TRH CWT Chinook salmon were recovered from the Willow Creek rotary screw trap, accounting for 36.1% (69/191) of all TRH CWT tested. In all marked TRH Chinook salmon collected from both the Trinity River and the lower Klamath River, *C. shasta* was detected in 16.8% (32/191, ci = 12-23%) of fish screened by QPCR. *Ceratomyxa shasta* prevalence of infection was higher in TRH CWT captured in the Klamath River in 2012 compared to previous monitoring years, 40% in salmon recovered from the Trinity to Estuary reach and 43% (21/49, ci = 29-58%) in the Klamath Estuary. *Parvicapsula minibicornis* was detected in 43.5% (83/191, ci = 36-51%) of all TRH-CWT Chinook salmon screened by QPCR.

Prevalence of infection, parasite infection levels and relationship to weeks post hatchery release will be presented with emphasis on the higher *C. shasta* prevalence of infection observed TRH CWT recovered from the Klamath Estuary.

## SENTINEL FISH STUDIES FOR *CERATOMYXA SHASTA* INFECTION IN 2012.

**Rich Holt**<sup>1\*</sup>, Adam Ray<sup>2</sup> and Jerri Bartholomew<sup>1</sup>

<sup>1</sup> Department of Microbiology, Oregon State University, Corvallis, OR 97331

<sup>2</sup> Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR 97331

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The myxozoan parasite *C. shasta* has been implicated as a significant source of mortality for salmonid fishes below Iron Gate dam. Fish sentinel studies were conducted to develop a multiyear dataset on *C. shasta* infection prevalence in both Klamath River chinook and coho salmon exposed at selected locations to monitor how changes in flow, water temperature and other variables alter parasite infection rate. In 2012 as in previous years, known *C. shasta*-susceptible rainbow trout stock from Roaring River Hatchery (Oregon Department of Fish and Wildlife) and Klamath River fall Chinook from Iron Gate Hatchery (California Department of Fish and Game) were held at all sites. A limited number of coho salmon juveniles from Iron Gate Hatchery were held near Beaver Creek and Seiad Valley in May and June.

*Ceratomyxa shasta* infections were detected in susceptible rainbow trout in all months tested and at all sentinel sites (except Keno Eddy in May) including the upper and lower Klamath River. Rainbow trout exposed in the lower Williamson River suffered high losses from *C. shasta* despite cessation of the release of this hatchery stock in the watershed in 2011. Compared to sentinel results of 2007-2009, losses of fall Chinook were much lower in 2010, 2011 and 2012. Cooler water temperatures during the spring exposures likely resulted in the decreased loss in Chinook for both May and June. In 2012, Chinook held in sentinel cages near Beaver Creek and Seiad Valley suffered no loss from *C. shasta* in April, May or September. In June Chinook loss was 16% near Beaver Creek and 17.8% at Seiad Valley. At Orleans Chinook exposed in May had 0% *C. shasta* loss and 5% in June. The sentinel coho loss was lower in 2012 compared to 2011. Coho exposed near Beaver Creek had a 10% loss in May and 0% loss in June; at Seiad Valley loss was 13.3% in May and 11.8% in June. Sentinel coho losses in June 2011 were near 60%. Comparison of sentinel study results from 2007-2012 for fish exposed near Beaver Creek shows a shift in the level of mortality between coho and Chinook salmon. In 2007, coho loss in May and June was much higher than for Chinook. In 2008, both species suffered very high losses after exposure. In 2009, the loss of Chinook was higher than coho from *C. shasta*. In June 2010, losses in Chinook were again higher than coho i.e. 20% versus 10%, but mortality for both species was much lower than in previous years. In 2011, coho salmon had much higher loss in June compared to the Chinook salmon. In 2012 *C. shasta* infections in both Chinook and coho were low compared to most previous years.

## ABUNDANCE OF *CERATOMYXA SHASTA* IN KLAMATH RIVER WATER SAMPLES, 2012

**Sascha Hallett**, Gerri Buckles, Charlene Hurst, R. Adam Ray, Peter Wong, Rich Holt, Jerri Bartholomew; Oregon State University

Crystal Bowman, Grant Johnson; Karuk Tribe

Joshua Strange, Barry McCovey, Jr; Yurok Tribe

Craig Spoonemore; Klamath Tribes

Brian Hayes, Eddie Mitchell; USGS Klamath Falls

A major component of the Bartholomew Lab's *Ceratomyxa shasta* monitoring program in the Klamath River is the direct measurement of the parasite in river water samples. One liter samples are filtered to capture and concentrate waterborne material, DNA is extracted and *C. shasta* enumerated using a qPCR assay. Initially, we collected river water samples in conjunction with sentinel fish studies; replicate liter samples were taken by hand at the beginning and end of the fish exposure. The acquisition of ISCO automatic samplers and the assistance of tribal biologists have allowed us to expand our efforts into two types: long term monitoring and longitudinal sampling.

In **long term monitoring**, an ISCO sampler is programmed to collect 1L every 2 h for 24 h; the composite sample is mixed and replicate 1L samples obtained. We have used the ISCOs for year-round sampling at 5 mainstem index sites below Iron Gate Dam since 2006. In 2012, we sampled water also from the Trinity River in the lower Klamath and the Williamson River in the upper Klamath. In the lower Klamath, waterborne stages increased in spring to reach 1 spore/L mid-May (at Kinsman Fish Trap and Beaver Creek); densities were highest at Tully Creek (1-10 spores/L). Trinity River water was sampled weekly July through November, 2012. Parasite densities reached 1 spore/L in September and November.

**Parasite genotypes:** previously, we identified at least 4 ITS1 genotypes of Cs that are associated with different salmonids. As these genotypes are indistinguishable using our primary qPCR assay, we developed a new assay (STYO9) that amplified the parasite for Sanger sequencing, then we genotyped a subset of 278 water samples. For the Beaver Creek (KBC) index site, we sequenced archived 2006-2011 weekly samples. We sequenced all samples available for the other 4 index sites (Klamathon Bridge, KKB; Seiad Valley, KSV; Orleans, KOR; and Tully Creek, KTC) in 2 years of high total parasite density, 2007 and 2009. At KBC, 3/4 genotypes were detected. In all years, genotype I was dominant, followed by genotype II. In September 2008 and 2009, a relatively high amount of genotype II was detected. In 2007, genotypes I and II were detected at all 5 index sites; genotype III at 3/5 sites, most frequently at very low levels at the lowermost index site, KTC; and genotype O was detected only in water samples collected at the uppermost index site, KKB. In 2009, genotypes I and II were lower than in 2007, except at the lowermost site KTC, where levels were higher. Genotype III was detected sporadically at all 5 index sites, whereas genotype O was not detected at any.

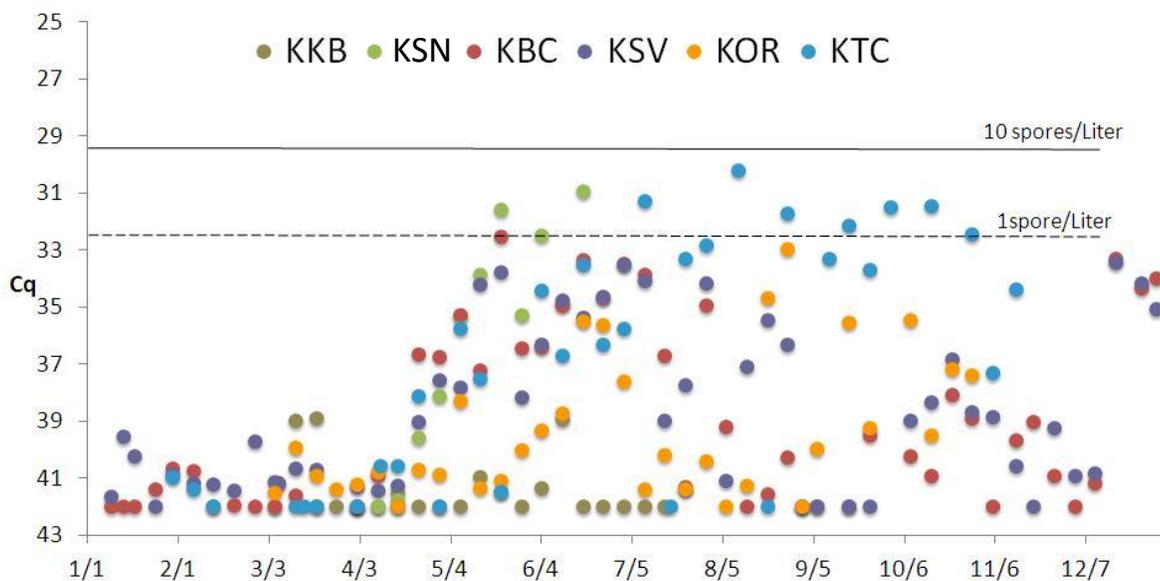
In **longitudinal sampling**, many sites are sampled manually during a day to provide greater spatial resolution of parasite occurrence. In 2012, longitudinal sampling focused around KTC and in the Williamson River (WMR). Long term monitoring had indicated that KBC was a parasite hotspot, until 2010 when levels were surpassed by those at KTC. In July, we collected water upstream and downstream of KTC to ascertain the extent of the high parasite densities: we detected a high parasite stretch encompassing KTC.

In 2012, we repeated longitudinal sampling and initiated long term sampling in the **Williamson River**, in the upper Klamath River basin, to monitor shifts in parasite densities and genotypes associated with

changes in fish stocking practices and fish introduction post-dam removal. Waterborne stages declined from 1 spore/L in late June through early August then suddenly increased to 10 spores/L in mid-August, before declining gradually over the following months. The longitudinal sampling showed that parasite levels were much lower in 2012 than 2009-10, but the spatial pattern of parasite distribution was similar.

Funding: Bureau of Reclamation, Federal Appropriations, PacifiCorp

**2012 *Ceratomyxa shasta* parasite abundance at index sampling sites in the lower Klamath River. Each data point is the average of 3 x 1L water samples.**



## CERATOMYXA SHASTA MYXOSPORE SURVEY- FALL 2012. KLAMATH, SHASTA, & TRINITY RIVER ADULT CHINOOK CARCASSES

**J.S Foott**, R. Stone, A. Bolick, K. Nichols and K. True.

CA-NV Fish Health Center, US Fish and Wildlife Service.

Fall-run Chinook carcass intestines were collected from the Klamath River (Iron Gate Hatchery to Shasta R. mouth) and Shasta R. weir (Rm 1) in October and November 2012. Similar samples were collected from Trinity R. (Lewiston reach) spring and fall –run Chinook carcasses. An estimated 88% or greater of the Klamath and Shasta intestines were infected (DNA positive) with some life stage of *Ceratomyxa shasta*. Myxospores were detected in 22 – 36% of the surveyed carcasses with only 3-9% producing high spore numbers (>500,000). This data is similar to previous surveys in 2008 - 2011. Mean percentage of intact myxospores (excludes methylene blue dye) in Shasta R. carcasses was  $75 \pm 8\%$  and there was an inverse relationship between myxospore quantity and percent intact spores. Percent intact myxospores declined considerably over 32 – 53 days post-collection in refrigerated samples that were < 85% intact at the initial examination. Trinity R. spring -run carcasses contained higher myxospore concentrations than fall-run. This data highlights the influence of time post-infection in cold temperatures on myxospore input from adult salmon carcasses. Quantity of *C. shasta* myxospores in the sampled populations was as follows: Trinity Spring-run > Trinity Fall-run > Shasta Fall-run > Klamath Fall-run. The question of myxospore viability as well as quantity must be better understood in order to inform life cycle models.

### **Report:**

Foott JS, R. Stone, A. Bolick, K. Nichols, and K. True. 2013. FY2012 Technical Report: *Ceratomyxa shasta* myxospore survey of Fall-run Chinook salmon carcasses in the Klamath and Shasta Rivers, and comparison of Trinity River Spring-run to Fall-run carcasses, October-November 2012. U.S. Fish & Wildlife Service California – Nevada Fish Health Center, Anderson, CA.

<http://www.fws.gov/canvfhc/reports.asp>

ASSESSING POTENTIAL RELATIONSHIPS BETWEEN *CERATOMYXA SHASTA* MYXOSPORE ABUNDANCE IN POST-SPAWNED CHINOOK SALMON CARCASSES AND FIVE CARCASS DEMOGRAPHIC PARAMETERS: CARCASS SEX, SIZE, LEVEL OF DECOMPOSITION, AND SITE AND DATE OF CARCASS SAMPLING

**Nick Campise\*** and Gary Hendrickson

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Post-spawned salmon carcasses are regarded as an important reservoir component in the life history of the myxozoan parasite, *Ceratomyxa shasta*. Past effort has been devoted to estimating total myxospore production by salmon carcasses in the Klamath River Basin with results describing highly variable levels of spore production across individual carcasses. Using two models fit to myxospore prevalence and abundance data, we have explained some of this variation in spore production among post-spawned Chinook salmon carcasses. Myxospore abundance was measured in carcasses collected from four sites in the Klamath River Basin. Spore abundance in a carcass was measured using replicate hemocytometer counts on diluted intestinal contents. Spore abundance data, specific to five carcass demographic variables, was fit with two types of models. Binary logistic regression models were fit to myxospore prevalence data (positive / negative). Linear models were fit to log transformed spore abundance data collected from myxospore-positive samples. Akaike's information criterion (AIC) was used to rank varying combinations of carcass variables (models) according to their ability to predict myxospore prevalence and average spore abundance in carcasses. The best combinations determined by the AIC analyses were used to make predictions about expected myxospore abundance in 16 carcass demographic groups to demonstrate how myxospore abundance varied according to carcass size and location in the basin. In 2011, expected myxospore abundance in carcass intestinal contents was positively related to carcass size and level of decomposition and varied according to four spatially distinct sites from which carcasses were sampled. Expected spore abundance was less related to carcass sex and date of sample collection.

## YEAR-ROUND MONITORING OF POLYCHAETE POPULATIONS IN THE HYPER-INFECTIOUS ZONE: DENSITIES, INFECTION LEVELS, AND OBSERVATIONS ON LIFE-CYCLE DYNAMICS

Joshua Strange, Ph.D., Stillwater Sciences  
Luke Walker, Yurok Tribal Fisheries Program

Myxozoan parasites (*Ceratomyxa shasta* and *Parvicapsula minibicornis*) in the Klamath River are dependent on the freshwater polychaete worm *Manyunkia speciosa* in addition to salmonid fishes to complete their life cycle. Determining and evaluating effective management actions to reduce myxozoan disease mortality in juvenile salmonids in the Klamath River is aided by a more complete understanding of the life cycle dynamics, density, and infection prevalence of polychaetes. While monitoring data from the summer months is readily available, data from winter months has been sparse and is needed in order to accurately determine the seasonal dynamics of the polychaete life-cycle and their infection prevalence. This information is especially useful to assist with developing and monitoring potential management actions to disrupt the myxozoan life cycle. The ultimate success of any potential polychaete control action will likely be predicated on the infection rates of polychaetes, which could vary depending on season as well as year and location. Potential management options will be different if relatively few polychaetes are infected as opposed to a large percentage of polychaetes. Current estimates of infection rates in polychaetes within the Klamath River are still being determined with greater confidence and appear to be on the lower side; however, estimates of infection rates during the winter months has remained elusive. If polychaete populations go through a period of low abundance, low infection prevalence, and/or vulnerability, then that information could help guide management actions. Herein we present observations and preliminary results from select months from our year-round study of polychaete populations in 2011 and 2012 at the upper end of the hyper-infectious zone in the mainstem Klamath River below Iron Gate Dam and Hatchery. Specifically, we conducted monthly sampling at two index sites (a run and a pool) in the vicinity of the Shasta River confluence using a boat-mounted, modified suction dredge operated by an air-supplied diver and boat based assistant. This novel sampling methodology has its disadvantages but allowed sampling of a wide variety of substrates, depths, and situations with or without immediate river access and was efficient at thoroughly removing material from sampled substrates. These sampling sites had the advantage of being located at the top of actinospore hyper-production areas in a hydrologically stable reach predominated by Iron Gate Dam releases with minimal chances of wet-season flooding precluding our ability to sample during the winter. Polychaetes were processed primarily by our collaborators at Oregon State University and allowed us to determine polychaete densities, infection prevalence, and life-cycle dynamics.

By focusing on one population at an index site within the “hot spot” for juvenile fish infection genesis between Iron Gate Dam and the Scott River, this project will provide a reproducible means for determining the infection prevalence and density of polychaetes worms over the course of an entire year, thus providing data to evaluate the seasonality of polychaete dynamics. This project is an important step towards being able to evaluate with a high level of confidence, both before and after implementation, the efficacy of potential management actions to control polychaete populations and their infection rates, and will also contribute to the accuracy of efforts to model myxozoan disease dynamics in the Klamath River.

# INVERTEBRATE ASSEMBLAGES IN THE LOWER KLAMATH RIVER, WITH REFERENCE TO *MANAYUNKIA SPECIOSA*

David Malakauskas<sup>1</sup> and **Margaret Wilzbach**<sup>2\*</sup>

<sup>1</sup>Department of Entomology, Michigan State University; <sup>2</sup>U.S.G.S. California Cooperative Fish and Wildlife Research Unit, Humboldt State University. [wilzbach@humboldt.edu](mailto:wilzbach@humboldt.edu); 707-826-5645.

We sampled invertebrate assemblages in the lower Klamath River in the summer and fall of 2005 and 2006 to estimate distribution patterns of the polychaete *Manayunkia speciosa* and to characterize assemblage structure of invertebrates in reaches where the polychaete was both collected and not collected. The polychaete was most often encountered between river kilometers 185-287, in a reach of river extending downstream from the Shasta River, where it occupied a variety of channel geomorphic units, substrates, and micro- flow environments. The reach in which the polychaete was found supported high taxonomic richness of invertebrates and a high abundance of filtering collectors including marine relicts such as sponges, unionid mussels, and bryozoans. We suggest that the large, stable habitat on which these were found represents primary, optimal habitat for *M. speciosa*, which is also believed to be a marine relict. Reaches above and below the zone where polychaetes were most dense showed a general trend of reduced taxonomic richness as distance away from the polychaete zone increased, and exhibited differing relative abundances of non-insect taxa and functional feeding groups. Differences in invertebrate assemblages between years were coincident with large differences in discharge. In the year of higher flows, relative abundances of filter-feeders and scrapers decreased, and all reaches were dominated by the dipteran family Chironomidae. We suggest that flows and food resources play important roles in structuring the spatial pattern of invertebrate assemblages.

## ASSESSING RISK OF SALMONID CERATOMYXOSIS BY MONITORING POLYCHAETE HOST POPULATIONS

**Julie Alexander**, Adam Ray, Jerri Bartholomew, OSU.

Salmonid population declines attributed to ceratomyxosis have generated interest in solutions for managing the causative agent, *Ceratomyxa shasta*. However, phases of the *C. shasta* life cycle that involve the invertebrate host, *Manayunkia speciosa*, are poorly understood. We present long-term data on Klamath River *M. speciosa* including density and size structure of populations and prevalence of *C. shasta* infection, during periods that overlap with peak periods of parasite production (?) in the Klamath River from 2004-2012. We monitored *M. speciosa* populations at three sites on the Klamath River during May, June, and September (periods that overlap with peak parasite transmission to fish hosts) from 2006-2012. We measured density and size structure of populations and assessed the prevalence of *C. shasta* infection. We calculated population growth rates and examined relationships between density during the previous summer and subsequent spring. We also examined relationships between these factors and water year characteristics including discharge and temperature. Polychaete densities were highly variable among months and years, ranging from  $<10\text{m}^{-2}$  to  $>100,000\text{m}^{-2}$ . Median polychaete length varied by month among water years due to variable proportions of progeny present. Prevalence of infection also varied among months and years, ranging from 0-9%. We noted characteristics of polychaete host populations that may have implications for management of *C. shasta*: 1), polychaete population densities were high in September following dynamic water years. When high densities of polychaetes were observed in September and water temperatures were above average the following spring, disease risk to fish was high relative to the previous year. 2) Progeny were detected in May, June and September in all water years. This indicates reproduction is asynchronous and recolonization could be rapid following peak flows. 3) Although differences in infection prevalence among months or water years were not significant, *C. shasta* was detected more frequently in samples collected in May and June during water years having high disease risk to fish. These results should be considered in relation to onset of *M. speciosa* population growth and peak myxospore encounter, thus, we suggest future monitoring studies include sampling that overlaps with these periods.

## SUBSTRATE STABILITY INFLUENCES *MANAYUNKIA SPECIOSA* DENSITY

**Michelle S. Jordan**<sup>1,2</sup>, Julie D. Alexander<sup>1</sup>, Gordon E. Grant<sup>3,4</sup> and Jerri L. Bartholomew<sup>1</sup>

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The freshwater benthic polychaete *Manayunkia speciosa* is the definitive host of *Ceratomyxa shasta*, a myxozoan parasite of salmon and trout. Short-term high water releases from dams have been proposed as a method for reducing *M. speciosa* population densities and thereby decreasing *C. shasta* burden to fish. However, it is not known how successful such strategies might be in reducing high densities of *M. speciosa*, nor when water releases would be most effective. To explore these issues, we sampled pool, run, and eddy features at three locations in the Klamath River over a fifteen-month period, and examined differences in *M. speciosa* densities and prevalence of infection with *C. shasta*. We observed the highest densities in summer (21,244 individuals/m<sup>2</sup>) and very low densities in winter (331 individuals/m<sup>2</sup>). Density was not higher in any one feature class (pool vs run vs eddy), however sites with greater estimated substrate stability had higher observed polychaete densities. Density decreased from the first to the second summer which we suggest was due to disturbance caused by high discharge during the winter and spring. Infection prevalence ranged from 0 to 5.38% and infected polychaetes were detected primarily in summer months in both years (July in 2010; June, August, and September in 2011). Our results suggest that disturbance during low density winter and spring months may influence peak densities in some features the following summer, which is of significance when considering the use of managed flow events as a method to reduce disease in Klamath River salmonids.

PREDICTING THE UNDESIRABLES: NOVEL USE OF HYDRAULIC MODELS TO PREDICT PRESENCE OF THE INVERTEBRATE HOST OF THE SALMONID PARASITE *CERATOMYXA SHASTA*

**Julie Alexander**, Michelle Jordan, Damon Goodman, Nickolas Hetrick, Nickolas Som, Katrina Wright and Jerri Bartholomew

Alteration of the natural flow regime is hypothesized to have increased habitat available to the polychaete host leading to amplification of *C. shasta*, thus actions that target the obligate polychaete host are considered feasible solutions for managing *C. shasta*. The aims of this study were to predict the distribution and density of polychaete hosts in three sections of the Klamath River 'infectious zone,' a section of river characterized by elevated densities of *C. shasta*. Two-dimensional hydraulic models (2DHM) were developed for each of three river sections using topographic survey data, water surface elevation profiles, stage-discharge relationships, and spatial maps of substrate. These models allow us to predict depth, velocity, and shear stress over a range of discharges. We used the 2DHM to describe hydraulic variation and stratify polychaete sampling locations across gradients of depth and velocity within substrate classes. Benthic samples were collected in July 2012 and used to build predictive models of polychaete distribution. Our results show that in summer, the distribution of polychaetes is associated with substrate, as well as depths and velocities predicted from the 2DHM during peak discharge from the previous spring and winter. Development of models to predict polychaete density is in progress. We plan to validate models with polychaete data collected during other water years but our preliminary results suggest that manipulating the hydrograph could influence distribution of polychaete hosts, which in turn may influence prevalence of *C. shasta* and disease in salmonids.

## 2 $\beta\epsilon$ $R_0$ 2 $\beta\epsilon$ : SPEAKING MATH HELPS UNDERSTAND DISEASE DYNAMICS

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We developed a mathematical model of the *Ceratomyxa shasta* life cycle to better understand the host – parasite dynamics. This model consists of eight differential equations that describe the movement of the parasite through its two obligate hosts and two environmental stages. These equations are then solved to define the basic reproduction number ( $R_0$ ). We use data collected from a variety of experiments and observations to estimate  $R_0$ . We conducted a sensitivity analysis on the  $R_0$  equation to determine which parameters may be the most important in the disease transmission and therefore would be targets for interrupting the parasite life cycle.

Symbol	Definition
$\beta$	Transmission rate of spore to host
$\pi$	Parasite induced mortality rate of salmon host
$\delta$	Natural mortality rate of salmon host
$\eta$	Mortality rate of parasite in salmon host
$\lambda$	Production of myxospores from salmon host
$\gamma$	Environmental mortality rate of spore stages
$\mu$	Parasite induced mortality rate of polychaete host
$\epsilon$	Natural mortality rate of polychaete host
$\nu$	Mortality rate of parasite in polychaete host
$\theta$	Production of actinospores from polychaete host

## SIMULATING POPULATION DYNAMICS OF JUVENILE CHINOOK SALMON IN THE CONTEXT OF *CERATOMYXA SHASTA*

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Juvenile fall Chinook salmon, *Oncorhynchus tshawytscha*, in the Klamath River become infected with the myxozoan parasite *Ceratomyxa shasta* when the polychaete worm *Manayunkia speciosa* releases actinospores into the water column. *C. shasta* is thought to cause high mortality rates in juvenile salmon in some years, but the population-level effect of this parasite is poorly understood. Over the past two years, Oregon State University, the US Fish and Wildlife Service, and the US Geological Survey have collaborated on a model for the disease dynamics of *C. shasta*. Specifically, disease-related mortality of juvenile Chinook salmon is modeled as a function of three processes: 1) *C. shasta* spore densities in the water column, 2) infection rates of juvenile salmon with *C. shasta*, and 3) mortality rates of infected juvenile salmon. This disease sub-model is being incorporated into a population model of juvenile salmon, the Stream Salmonid Simulator (S<sup>3</sup>), which simulates growth, movement, and mortality of salmon from spawning through the juvenile life stages. Here, we illustrate how casting disease dynamics in the context of other demographic processes can aid in understanding the population-level effects of *C. shasta* on juvenile Chinook salmon. We simulated population dynamics of juvenile salmon during 2005, a year in which high prevalence of infection (up to 100%) was observed beginning in April, despite low water temperatures. However, field measurements of spore density did not begin until mid-May and never attained levels that might be expected to cause such high prevalence of infection. This led us to ask the question, "What might spore concentrations have been in order to cause such high prevalence of infection at low water temperatures in April 2005?". To answer this question, we hypothesized alternative time-series of spore concentrations during the period when field measurements of spore concentrations were absent. Next, we used the S<sup>3</sup> model to simulate juvenile salmon growth, movement, mortality, and prevalence of infection under alternative hypotheses of spore concentrations. We then assessed which hypothesis of spore concentrations led to a predicted prevalence of infection that was consistent with the observed prevalence of infection during 2005. This application of the S<sup>3</sup> model illustrates its utility for understanding the effects of *C. shasta* on juvenile salmon populations.

## SPORE ME A RIVER: LESSONS AND HYPOTHESES

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The life cycle of *Ceratomyxa shasta*, a myxozoan parasite linked to significant juvenile *Oncorhynchus tshawytscha* mortality in the Klamath River, involves 2 hosts and 2 spore stages. The polychaete host, *Manayunkia speciosa*, releases actinospores into the water leading to ceratomyxosis infections of the other host, *O. tshawytscha* or other salmonid species. Over multiple years of water sampling in the highly infectious zone of the Klamath River, a quadratic relationship has emerged between water temperature and spore concentrations during the outmigrant period of juvenile *O. tshawytscha*. Despite this consistent pattern, the observed difference in spore concentration among years has ranged over several orders of magnitude. It has been hypothesized that these differences might be attributed to current and historic variation in discharge and temperature. We characterize patterns in among-year levels of spore loads, and evaluate the relationship between spore concentrations and the magnitudes and timing of river temperature and discharge. We discuss the potential management implications of our results, and in particular, how they link to related efforts to model the prevalence of ceratomyxosis infection of juvenile salmonids, and their ceratomyxosis induced mortality. In concert, these models inform the mortality subcomponent of a salmonid population dynamics model.

## CURE MODELS A NOVEL SURVIVAL ANALYSIS METHOD TO PREDICT CERATOMYXOSIS IN KLAMATH RIVER CHINOOK AND COHO SALMON

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Parameterizing survival estimates is critical for modeling and predicting variation in populations. However, obtaining accurate estimates of survival for wildlife is difficult, particularly in the context of disease. Consequently, standard survival estimates are typically based on the assumption that all individuals are equally affected by parasite/ pathogen and will eventually succumb to that infection resulting in estimates of 0% survival. We used long term data from sentinel exposures conducted with native Chinook and coho salmon where individuals exhibited a wide range of mortality (0 - ~90%) associated with exposure to and infection with *Ceratomyxa shasta*. The exposures demonstrate that standard survival analysis methods are not appropriate because individuals were not equally affected and did not all succumb to infection. We introduce the novel use of cure models for estimating survival within salmon populations exposed to *C. shasta*. Cure models divide a population into individuals that will succumb to infection and those who will not ("cured"). We used a cure model to estimate the daily mortality rates for Chinook and coho salmon exposed to *C. shasta* in the Klamath River, near the confluence with Beaver Creek from 2006 – 2010. These parasite-induced daily mortality rates can be integrated to improve the accuracy of salmon production models.

## PERIPHYTON AND WATER COLUMN PHYTOPLANKTON DISTRIBUTION IN THE KLAMATH RIVER

**Mike Deas**, Watercourse Engineering Inc.

To better understand polychaete dynamics in the Klamath Basin perhaps a consideration of periphyton and polychaete dynamics – both benthically adapted life forms – may lend insight into future research regarding salmonid disease management in the Klamath Basin. Basic periphyton succession and polychaete life cycle (season minima and maxima, growth and decline, and its colonization mechanisms are points of discussion.

## KLAMATH FISH HEALTH ASSESSMENT TEAM WEBSITE UPGRADE

**Nicolas Ramirez**, Klamath Basin Monitoring Program

The Klamath Basin Monitoring group in collaboration with the Salmon River Restoration Council is currently in the process of upgrading the website of the Klamath Fish Health Assessment Team (KFHAT). An on-line/interactive map will display alert level status and information regarding the potential threat of the fish kill event. The interactive map is currently in the early stages of development. The purpose of this presentation is to solicit feedback from the community regarding the map interface and related information.

## 2012 KLAMATH RIVER ADULT CHINOOK DISEASE MONITORING

**Barry McCovey**, Jamie Holt and Mike Belchik, Yurok Tribe

Since the fall of 2003, the Yurok Tribal Fisheries Program (YTFP) has monitored for the prevalence of *Flavobacterium columnare* (columnaris) and *Ichthyophthirius multifiliis* (Ich) in fall-run Chinook salmon in the lower Klamath River. The YTFP began monitoring Ich and columnaris levels in response to the 2002 Klamath River fish kill, which resulted in the death of 33,000 to 67,000 adult Chinook salmon. The primary reason of the Klamath River fish kill was an epizootic outbreak caused by Ich and columnaris. Factors such as extremely low flows, high fish densities, elevated water temperatures, and long fish residence time are believed to be the main contributing factors to the epizootic outbreak of 2002. The ultimate goal of this project is to establish a long term data set which can be used to relate fish disease incidence to various parameters (e.g., flow, water quality and fish densities), as well as to potentially provide real-time information to managers regarding adult fish health.

In the fall of 2012, the YTFP continued the annual Adult Chinook Pathology monitoring project. The 2012 survey had an elevated level of importance due to extremely large run size prediction and concerns that another fish kill was possible. We were able to sample 212 adult Chinook salmon between August 16<sup>th</sup> and September 27<sup>th</sup>. None of these fish showed visible signs of Ich infection and 25 were observed to be infected with columnaris. This 12% columnaris infection rate matches our 9 year average of 12%. The 2012 adult Chinook fall run showed normal levels of disease and nothing out of the ordinary was observed despite the extremely large run size.

## UPDATE ON KLAMATH BASIN WATER QUALITY IMPROVEMENT ACTIVITIES

**Clayton Creager** – CA North Coast Regional Water Quality Control Board

Maia Singer – Stillwater Sciences, Inc.

Chantell Krider – Klamath Basin Monitoring Program

Improved water quality conditions are critical to the improved health of fish populations in the Klamath Basin and there are several initiatives underway to address the major sources of water quality impacts. In September 2012 the Klamath River Water Quality Workshop was held in Sacramento, CA bringing together over one-hundred experts to conduct evaluations of six large-scale pollutant removal approaches and to develop a strategic project network designed to improve water quality conditions in the Klamath Basin. The projects are primarily focused in the upper basin (upstream of Keno Dam) and address water quality impacts related to the loss of freshwater wetlands and marshes and legacy sources of nutrients generated from sediments in Upper Klamath Lake. The six technologies evaluated included: wetland rehabilitation, wetland treatment systems, diffuse source treatment systems, algal biomass removal, sediment sequestration, and sediment dredging. The purpose of this presentation is to provide background on these project proposals, describe potential project network strategies, and describe the next steps in developing pilot projects for the highest rated proposals. Implementation will rely on an adaptive management framework using existing water quality initiatives including: Klamath Basin Monitoring Program, Klamath Tracking and Accounting Program, and watershed stewardship sub-basin teams.