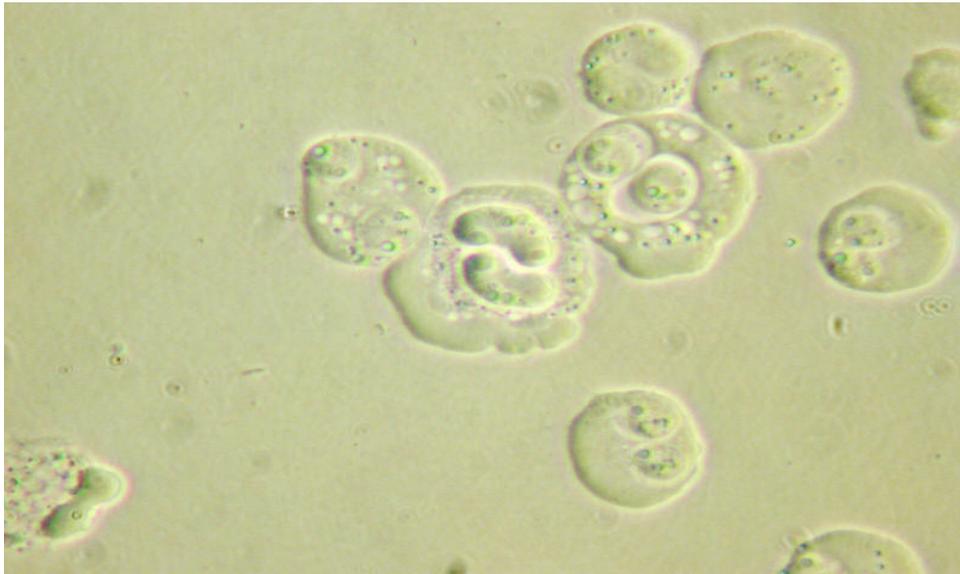




**CERATOMYXA SHASTA EXPOSURE TRIALS AT OXBOW  
FISH HATCHERY**



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## ABSTRACT

The Oxbow Fish Hatchery uses a mixture of well water and river water from the Snake River to culture fall Chinook salmon *Oncorhynchus tshawytscha* subyearlings prior to release into the Snake River below Hells Canyon Dam. The Snake River water used to culture fish at this facility contains the infective stage of *Ceratomyxa shasta*, a lethal parasite to salmonids. The exact role of *C. shasta* in producing mortality in anadromous salmonids in the Snake River is unknown. To maximize the survival of the fall Chinook salmon reared at this facility, release timing to avoid parasite-host contact needs to be developed. To gain insight on the affect of this parasite on fall Chinook salmon reared at Oxbow Fish Hatchery, seven-day exposure trials were conducted from April 2004 through July 2004 to determine the onset of *C. shasta* infectivity in the Snake River at Oxbow Fish Hatchery. Live-boxes containing approximately 50 juvenile rainbow trout *Oncorhynchus mykiss* and a temperature logger were placed in the Snake River at the hatchery intake structure. After exposure, the fish were kept at the Eagle Fish Health Laboratory, where individual mortalities were examined for *C. shasta* spores and survivors were tested for asymptomatic infection using polymerase chain reaction technology.

The initial exposure trial in April did not produce an infection of *C. shasta*. Prevalence of infection in sentinel fish increased during May as Snake River water temperatures warmed, peaking at 91% in mid June. The last two trials in July, had prevalence of infection at 59% and 79% respectively.

We recommend the release of fall Chinook salmon subyearlings from Oxbow Fish Hatchery in early May to reduce exposure to *C. shasta* infective stages in the Snake River. Furthermore, if the fall Chinook salmon program at Oxbow Fish Hatchery is expanded to the 1,000,000 smolt level, an extensive hatchery renovation including expanding well water capacity will be essential.

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## INTRODUCTION

The Idaho Power Company (IPC) as a part of the mitigation for the hydroelectric system of the Hells Canyon Complex constructed the Oxbow Fish Hatchery (OFH) in 1961 (FishPro 2004). Idaho Department of Fish and Game (Department) operates the hatchery through an agreement with IPC as an egg taking station that provides steelhead *Oncorhynchus mykiss* eggs to Niagara Springs Fish Hatchery. This is accomplished by trapping adult steelhead below Hells Canyon Dam, transporting them to OFH, and holding them until spawned. The OFH also provides spring Chinook salmon adults to Rapid River Fish Hatchery (RRFH). These fish are trapped at the Hells Canyon trap, held at OFH and then transported to RRFH to avoid warm water temperatures of the Snake River. All adult spring Chinook salmon trapped below Hells Canyon Dam are spawned at RRFH.

The propagation of fall Chinook salmon has always been a mitigation requirement for IPC as stated in the Hells Canyon Settlement Agreement (HCSA) (1980). The water quality of the Snake River contributed significantly to the failure of the initial fall Chinook salmon program at OFH. Elevated water temperatures during adult holding and spawning contributed to excessive pre-spawning mortality, while cold-water temperatures during the winter hindered egg development and fry growth. The initial attempt to propagate fall Chinook salmon at this facility was terminated in 1973. In 1990, Bonneville fall Chinook salmon were reared at OFH on an experimental basis. These fish were terminated when a permit for release could not be obtained (D. Young IDFG, personal communication).

In December 2000, the Department began a program to evaluate the rearing of sub-yearling fall Chinook salmon using concrete raceways and well water. Early results suggest that a fall Chinook salmon program could be successful by using well water for egg incubation and early rearing. A mixture of well and river water was utilized for final rearing of fry. In May 2001, OFH released approximately 114,000 sub-yearling fall Chinook salmon in the Snake River below Hells Canyon Dam. In the 2002, 161,271 (brood year 2001) fall Chinook salmon were released below Hells Canyon Dam to repeat the evaluation process. The fall Chinook salmon, reared at OFH during 2003, were transported to the Nez Perce Tribal Fishery acclimation site at Pittsburgh Landing (Figure 1) in May, acclimated and then released.

Even though the current fish culture procedure at OFH utilizes a mixture of well and river water to rear fall Chinook salmon, the use of river water and timing of release of the sub-yearling salmon should be evaluated. *Ceratomyxa shasta* (CS) is a myxosporean parasite that is enzootic to this portion of the Snake River (IDFG 2004). This facility uses river water that contains the infective stage of CS. Exposure trials in April, May, June, and July of 1991, at OFH demonstrated that CS was able to infect rainbow trout held in a live-box that was submersed in the cinderblock raceways (Figure 2). *C. shasta* was detected in 55 of the 153 fish sampled (IDFG 2004). A prevalence of 46% was detected during the months of June and July. The May exposure group was lost during the trial, while the April group had a prevalence of 7.5%. Prior to these trials, the parasite had been detected below Hells Canyon Dam.

*Ceratomyxa shasta* is a parasite that infects freshwater salmonids (Bartholomew et al. 1989). It was first observed causing fish mortalities in Crystal Lake Hatchery, Shasta County, California (1948) and its distribution in the Pacific Northwest has expanded to Idaho, Oregon, Washington, Northern California, British Columbia, and Alaska.

The intermediate host of CS is a polychaete worm *Manayunkia speciosa* that was first found attached to the periphyton of freshwater mussels (Bartholomew et al. 1997). The infective stage (actinospore) of the parasite is released from the worm host into the water column where it comes in contact with the fish host, attaches and invades. Transmission of this parasite can occur after ingestion of the infected annelid host by a susceptible salmonid. Neither horizontal, nor vertical transmissions have been documented. Spores are released back into the environment after host mortality. Spores range in size from 14-23 µm long to 6-8 µm wide. Diagnosis is usually achieved by microscopic detection of spores in intestinal scrapings. Recently polymerase chain reaction (PCR) has been developed for detection of this parasite. Other methods of detection include histopathology and the use of monoclonal antibodies.

Research indicates that infection potential of CS is enhanced when temperatures are high, water flows are low, and infective actinospore numbers are high (Pacifcorp 2002). In the Cowlitz, Willamette, and Deschutes infection rates appear to be higher below reservoir environments (Pacifcorp 2002).

At present, there is no treatment for this infection. Hatchery water supplies using a combination of ultraviolet irradiation, ozonation, chlorination, and sand filtration have been successful in decreasing infections in production facilities. Cold water temperatures and salinity may retard progression of disease, but not eliminate infection. Progression of disease and mortality appear to be temperature dependent. Udey et al. (1975) demonstrated that higher water temperatures accelerated disease progression to mortality. Disease resistance of salmonids to this parasite varies and can be compromised by large numbers of CS infective stages (Foott et al. 2004). The parasite has an affinity for the intestinal tract of its host and then spreads to other tissues such as the liver, gall bladder, spleen, gonads, kidney, heart, gills and musculature. This infection results in tissue necrosis and severe inflammatory reaction (Bartholomew et al. 1989). Lethargy, loss of body mass, darkening in color, ascites in the body cavity, exophthalmia and kidney pustules are signs of infection. At present, the fall Chinook salmon reared at OFH are released into the Snake River approximately at the same time as infective stages of CS are beginning to emerge into the river. Because of this, evaluating the impact of CS on the OFH program is difficult. This study was initiated to estimate CS impact on fall Chinook salmon survival at OFH and to give insight on release timing to avoid this parasite. Furthermore, this study provides supporting data for expansion of well water capability on the advent that this program evolves to produce a full term smolt.

## **STUDY SITE**

This study was conducted at OFH, which is located on the Oregon side of the Snake River in Baker County, OR at river mile 270 (602 river miles or 969 km from the Pacific Ocean). The hatchery pump station is located approximately 200 meters downriver of Oxbow Dam Hydroelectric Plant (UTM 11T 511485E 4979901N). Water from the Snake River below Oxbow Reservoir is used to supplement well water in the culture of fall Chinook salmon subyearlings during March, April, and May prior to release. The exposure site selected at OFH (Figure 2) was in the Snake River at the hatchery's pump station, where river water is acquired for fish culture.

## OBJECTIVES

We initiated this study to determine the onset of CS parasitic exposure to the fall Chinook salmon being reared at OFH and to determine the relative prevalence of infection after a 7-day exposure using sentinel fish. If appropriate, recommendations will be made to alter current rearing protocol of fall Chinook salmon to reduce the impacts of CS.

## METHODS

Tripliod rainbow trout *Oncorhynchus mykiss* eggs were obtained from Hayspur Hatchery (Department) and reared at the Eagle Fish Health Laboratory (EFHL) in well water. These trout ranged in size from 0.4 to 4.5 g/fish during the exposure trials (Table 1). Each exposure trial consisted of 50 rainbow trout placed in an aluminum cylinder or experimental unit (EU) that measured 47 cm in length x 30.3 cm in diameter. The sentinel fish were transported to and from OFH in plastic bags with water and oxygen. These fish were exposed for 7 d, returned to the wet laboratory at EFHL, and held in 13°C well water for 60 d, approximately 780 Celsius temperature units (CTUs). Each EU was equipped with a STOWAWAY XTI temperature logger to monitor water temperatures. Mean daily reservoir flow data was acquired through the Idaho Power Company website by subtracting the daily flow from the Pine Creek Gaging Site from the average daily flow from the Hells Canyon Gaging Site. This approximated the mean daily flow past the intake of OFH (Table 1). A YSI meter (model 556 MPS) was used to determine water pH, temperature, dissolved oxygen, percent dissolved oxygen, and conductivity. Turbidity was acquired by the HI 93703 turbidimeter (Hanna Industries). Mortalities were recorded daily and wet mounts of intestinal fluid from these dead fish were examined microscopically for CS spores. These data were used to determine prevalence.

Once the holding period was completed, the fish were euthanized with tricaine methane sulphonate (MS 222) and the last third of the large intestine removed for examination. Initial examination of intestinal wet mounts followed the protocol established by the American Fisheries Society Blue Book, 4<sup>th</sup> edition (Bartholomew 2001). The last one third of the gut before the vent was removed and placed in 95% ethanol for confirmation through polymerase chain reaction (PCR) diagnostic assay (Palenzuela et al. 1998). The data generated by these samples were also included in determining prevalence of infection.

All data analyses were performed using the SAS System 9.1 (SAS 2004). Potential explanatory variables for the prevalence of CS in sentinel fish were examined using bivariate plots for normality and linearity in PROC PLOT. Pearson and Spearman correlation matrices were produced in PROC CORR. Correlations of explanatory variables and prevalence were assessed as well as multicollinearity of potential explanatory water variables. Explanatory variables that were significantly correlated ( $R > 0.5$  and  $P < 0.05$ ) with each other were not used in the same model. Prevalence was arc sine transformed for regression assumptions. Three separate multiple regression analyses were conducted of potential explanatory variables due to missing information and small sample size. Models were fit by restricted maximum likelihood in PROC MIXED. A repeated statement was used to account for serial correlation of prevalence over time period. Accounting for serial correlation is important as disregarding correlation creates artificially small  $p$  values. Model assumptions of constant variance and correct model structure specification were evaluated by assessing bivariate plots of residuals by predicted values and predicted by observed values.

## RESULTS

Results from the first exposure trial conducted from 15 to 22 April 2004 demonstrated that the prevalence of *C. shasta* was below levels of detection. Mortality was not recorded during holding at the EFHL wet laboratory; lethal sampling did not detect CS from intestinal wet mounts or through PCR examination (Table 3). The mean water temperature was 11.6°C during this trial (Table 1). The mean daily reservoir flow at OFH during this exposure trial was 8891 cubic feet per second (cfs). Water chemistry parameters for all exposure trials are presented in Table 2.

Results from the second exposure trial at OFH that was conducted from 26 April 2004 to 2 May 2004 demonstrated the first sentinel trout positive for CS. Prevalence of infection was 6% and the initial mortality attributed to CS occurred 44 days post exposure (Table 3). The mean days to death were 44.5 days. The mean water temperature was 12.5°C during this trial, while the daily reservoir flow averaged 9112 cfs (Table 1).

The third exposure trial at OFH was from 21 to 28 May 2004. Thirty-eight fish were found to be CS positive out of 50 fish examined for a prevalence of infection of 76% (Table 3). The first mortality due to CS in these sentinel fish was 32 days into holding and the Mean Days to Death was 36.8 days. The mean water temperature was 14.6°C and the mean daily flow was 16,927 cfs (Table 1).

Results from the fourth exposure trial at OFH of 9 June 2004 to 16 June 2004 demonstrated the peak of infectivity of CS during these trials. Forty-eight fish were positive for CS of the 53 fish examined, for a prevalence of 91% (Table 3). The onset of mortality was 24 days into holding while the Mean Days to Death decreased to 35.6 days. The mean water temperature was measured at 16.5°C and the mean daily flow was at 16,328 cfs (Table 1).

The fifth exposure trial at OFH took place from 30 June 2004 until 7 July 2004. Thirty-two fish were positive for CS of the 54 fish tested, for a prevalence of 59% (Table 3). The first mortality due to CS was detected 23 days post arrival at the EFHL wet laboratory and the Mean Days to Death was at 29.5 days. The mean water temperature during this trial was 17.8°C and the daily mean flow was 9,573 cfs (Table 1).

Results from the sixth OFH exposure trial of 22 to 29 July 2004 detected 42 positive sentinel fish for CS out of 53 fish examined, for a prevalence of 79% (Table 3). The first CS related mortality was 21 days into post exposure and the Mean Days to Death for these sentinel fish was 31.1 days. The mean water temperature was 20.1°C and the mean daily flow was 10,381 cfs (Table 1) for this last exposure trial.

### **Statistical Comparisons Between Exposure Trials**

No significant correlations were observed with potential explanatory variables and prevalence in Spearman or Pearson correlations (Table 4). Multiple regression analysis performed to examine relationships of Mean Temperature and Mean Discharge resulted in

insufficient evidence for relationships (Table 5). Analysis of potential relationships of pH, Conductivity, and other water quality parameters taken at the beginning and end of each exposure trial did not result in statistically significant relationships (Table 5).

## DISCUSSION

Our exposure trials identified the onset of CS infectivity in the Snake River at the water intake of OFH. The data gathered during these trials demonstrates that the Snake River at OFH produced lethal infections of CS in sentinel rainbow trout during the second exposure in April, and in the following May, June, and July exposures. In the first April exposure trial of 2004, CS was not detected. A previous exposure trial for CS was conducted in 1991 in the head box of the abandoned cinder block raceways at OFH (Figure 2) resulted in a prevalence of 7.5% (IDFG 2004). The trials in May 1991 and May 2004 cannot be compared because the sentinel fish from 1991 did not survive the initial exposure. Both June and July of 1991 had a prevalence of 46%, while the June 2004 had a prevalence of 91% and July 2004 had a prevalence of 59% early in the month and 79% at the end of the July. Differences in rates of infection between 1991 and 2004 can be partially attributed to the exposure site location. Water temperature may have influenced CS emergence in the Snake River during the April 1991 exposure. If the water temperatures were warmer during April of 1991 than April 2004, the infective actinospore stage would have emerged into the Snake River earlier that year. Temperatures and exposure dates were not noted into the database for the 1991 exposure trials, but the second exposure trial in early May 2004, had a prevalence of 6%, which is similar to the April 1991 prevalence of 7.5%. This adds to the observation by Uday et al. 1975, that the water temperatures produced the differences in time of initial infection.

The current management of the fall Chinook salmon program at OFH targets a subyearling size at release of 43 fish per pound (FPP)(10.6 g/fish) by mid-May, while the Nez Perce Tribal Fisheries fall Chinook salmon subyearling program uses 80 FPP (5.7 g/fish) as a target release size. With light infections of CS in the May 2004 trials (Trial II), onset to mortality took 44 days (Table 3). If the current strategy of release is changed to a later date in May or June, mortality from CS still might not be observed before release. The release of the fall Chinook salmon from OFH should be targeted in early May at the latest to avoid the impacts of CS on survival.

As water temperatures increase in the Snake River, so does the prevalence of infection of the sentinel fish in the first four trials and the onset of mortality and mean days to death in these trials decreased. Although mean water temperatures increased from 16.5°C in Trial IV to 17.8°C in Trial V, for yet unexplained reasons the prevalence of infection decreased from 79% to 59%. Onset of mortality was 23 days, the second lowest of all the exposure trials. Trial VI had a prevalence of infection of 79% with mean water temperatures measured at 20.1°C during the exposure trial. This decrease in prevalence followed by a rise in prevalence in a subsequent exposure, has been noticed in the Klamath River and is thought to represent a bimodal emergence of the infective stage of this parasite (R. W. Stocking, Oregon State University, personal communication).

In most cases model fit was problematic in regards to prevalence results from trial II. Removal of this observation as an outlier may result in statistically significant relationships. Without replication it is impossible to determine if this value is anomalous and therefore there is no justification to remove the exposure from analysis. The degree of serial correlation of

prevalence over time in the dataset cannot be adequately addressed with the sample size and lack of replications. Accounting for the correlated response over time is necessary to limit type I error where the null hypothesis is rejected by an artificially low *P* value as a result of correlated responses.

Fall Chinook salmon reared at OFH on Snake River water have not demonstrated CS infection during preliberation sampling (IDFG 2004). This may be due to the water supply delivery system or that rainbow trout are more susceptible to CS infection than fall Chinook salmon. Mechanical injury to the actinospore may occur when the river water is pumped thus reduce the ability of the parasite to invade the host. Water collection from the Snake River may also be from a level in the water column that the infective stage of the parasite is not present. Also the level of infection is probably below detection. If OFH 's fall Chinook salmon program is expanded to a yearling smolt program, treatment of river water supplies using a combination of sand filtration, ultraviolet irradiation, chlorination, and by ozonation could decrease, exposure at this facility. The best and most reliable method of eliminating CS from OFH fall Chinook production is to increase well water supplies to accommodate increased production demands.

## **RECOMMENDATIONS**

The fall Chinook salmon production goals for OFH are presented in the HCSA (1980). This agreement states that IPC is responsible for providing facilities capable of producing 1,000,000 subyearling fall Chinook salmon. The Oxbow Fish Hatchery Expansion Conceptual Design Report (FishPro 2004) details facility expansion plans, including well water enhancement, to culture one million fall Chinook salmon subyearlings to 43 fish per pound. We recommend continuing the release of subyearling fall Chinook salmon during early May. Since target release size has been met and further exposure to CS could be detrimental to survival. If in the future size requirements are not met, eggs from earlier egg takes from Lyons Ferry Hatchery or OFH should be obtained or alternatively manipulations of water temperatures to accelerate growth should be implemented to facilitate recommended release timing. Although evidence for a temperature to prevalence relationship is equivocal in this report, there is evidence in the literature that such a relationship exists (Johnson 1975). Research indicates that the commencement of infection of CS can be expected when the average daily river water temperature reaches 10°C. Hence, reservoir water temperatures could be used to predict onset of infection. If water temperatures are higher than normal in the Snake River during the spring, then the hatchery manager can expect the emergence of the infective stage of CS earlier. The hatchery manager can then propose an earlier release date to minimize infection. If the OFH program is changed to produce a yearling rather than a subyearling, then further hatchery enhancement to provide additional well water or extensive water treatment to remove the infective stage of CS is needed.

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Table 1. Oxbow Hatchery exposure trial data 2004

Exposure Date	Daily Mean Flow (cfs)	Mean Water Temperature	Minimum Temperature	Maximum Temperature	N	Trout Mean Weight (g)
I 4/15/04-4/22/04	8,891	11.6	11.3	12.1	50	1.9
II 4/26/04-5/3/04	9,112	12.5	11.9	13	49	2.1
III 5/21/04-5/28/04	16,927	14.6	13.35	15.22	50	3.5
IV 6/9/04-6/16/04	16,328	16.5	16.01	17.61	53	4.5
V 6/30/04-7/7/04	9,573	17.8	16.97	18.57	54	0.4
VI 7/22/04-7/29/04	10,381	20.1	19.71	21.17	53	0.8

Table 2. Oxbow Hatchery water chemistry parameters during 2004 exposure trials

Trial	Date	Time	Temp. °C	pH	DO mg/l	Turbidity FTU	Conductivity mS/cm
I	4/15/2004	9:55	11.5	8.57	7.33	6.47	0.333
	4/22/2004	13:00	12.1	7.2	6.9	6.72	0.333
II	4/26/2004	14:20	12	ND	ND	ND	ND
	5/3/2004	11:15	12.93	6.6	5.97	5.82	0.303
III	5/21/2004	11:45	14.11	6.21	ND	9.16	0.311
	5/28/2004	12:10	15.03	6.81	7.22	8.36	0.312
IV	6/9/2004	12:10	16.27	7.63	6.06	ND	0.32
	6/16/2004	13:26	17.22	7.68	5.13	ND	0.316
V	6/30/2004	13:00	17.64	6.12	5.98	1.14	0.303
	7/7/2004	11:45	18.31	7.1	6.06	1.22	0.299
VI	7/22/2004	12:45	19.93	6.05	5.29	1.28	0.305
	7/29/2004	12:45	19.84	6.22	4.38	1.53	0.318

Table 3. Oxbow exposure trial infectivity data

Trial	CS+ Wet Mount	CS+ PCR	Total CS+	Prevalence
I	0/50	0/50	0/50	0%
II	3/49	0/46	3/49	6%
III	38/44	0/6	38/50	76%
IV	47/50	1/3	48/53	91%
V	26/42	6/12	32/54	59%
VI	42/48	0/5	42/53	79%
				Mean days to Death
Trial I		ND		ND
Trial II		44 days to onset of mortality		44.5
Trial III		32 days to onset of mortality		36.8
Trial IV		24 days to onset of mortality		35.6
Trial V		23 days to onset of mortality		29.5
Trial VI		21 days to onset of mortality		31.1

ND= No data

Table 4. Spearman and Pearson correlation matrices for prevalence and potential explanatory environmental variables used for data analysis.

	PREV	Mean Dis	Mean Temp	Start pH	Start Do	Start Turb	Start Cond	End pH	End DO	End Turb	End Cond	
PREV	1											
MeanDis	0.77	1										
MeanTemp	0.54	0.49	1									
StartpH	-0.3	-0.2	-0.90*	1								
StartDo	-0.4	-0.4	-1.00*	1*	1							
StartTurb	0	0.4	-0.6	0.6	0.5	1						
StartCond	-0.1	-0.1	-0.8	0.9*	0.8	0.8	1					
EndpH	-0.09	-0.03	-0.31	0.8	0.8	0	0.6	1				
EndDO	-0.6	-0.03	-0.6	0.5	0.8	0.8	0.3	0.26	1			
EndTurb	0	0.1	-0.6	0.6	0.5	1.00*	0.8	0.2	0.7	1		
EndCond	0.09	-0.14	-0.2	0.4	0.4	0.4	0.7	0.14	0.14	0.5	1	
				<b>Spearman</b>								
PREV	1											
MeanDis	0.62	1										
MeanTemp	0.64	0.12	1									
StartpH	-0.64	-0.12	-0.74	1								
StartDo	-0.87	-0.25	-0.99*	0.88	1							
StartTurb	-0.23	0.69	-0.78	0.37	0.94	1						
StartCond	-0.66	-0.04	-0.84	0.97*	0.88	0.55	1					
EndpH	-0.11	0.37	-0.25	0.64	0.53	0.323	0.54	1				
EndDO	-0.54	0.10	-0.74	0.254	0.91	0.824	0.38	0.23	1			
EndTurb	-0.29	0.52	-0.81	0.46	0.93	1.00*	0.62	0.28	0.79	1		
EndCond	-0.52	0.01	-0.27	0.77	0.60	0.390	0.84	0.17	0.09	0.34	1	
				<b>Pearson</b>								

\* denotes  $P < 0.05$

Table 5. Variables tested and results of multiple regression analyses of the prevalence of *C. shasta*.

Variables	N	df	F Value	P
Analysis 1: Mean Temperature, Mean Discharge	6	2	2.42	0.23
Analysis 2: Start pH, Start Conductivity	5	2	0.76	0.56
Analysis 3: End pH, End DO, End Conductivity	6	3	0.74	0.62

Figure 1. Map of Department hatcheries and associated watersheds.

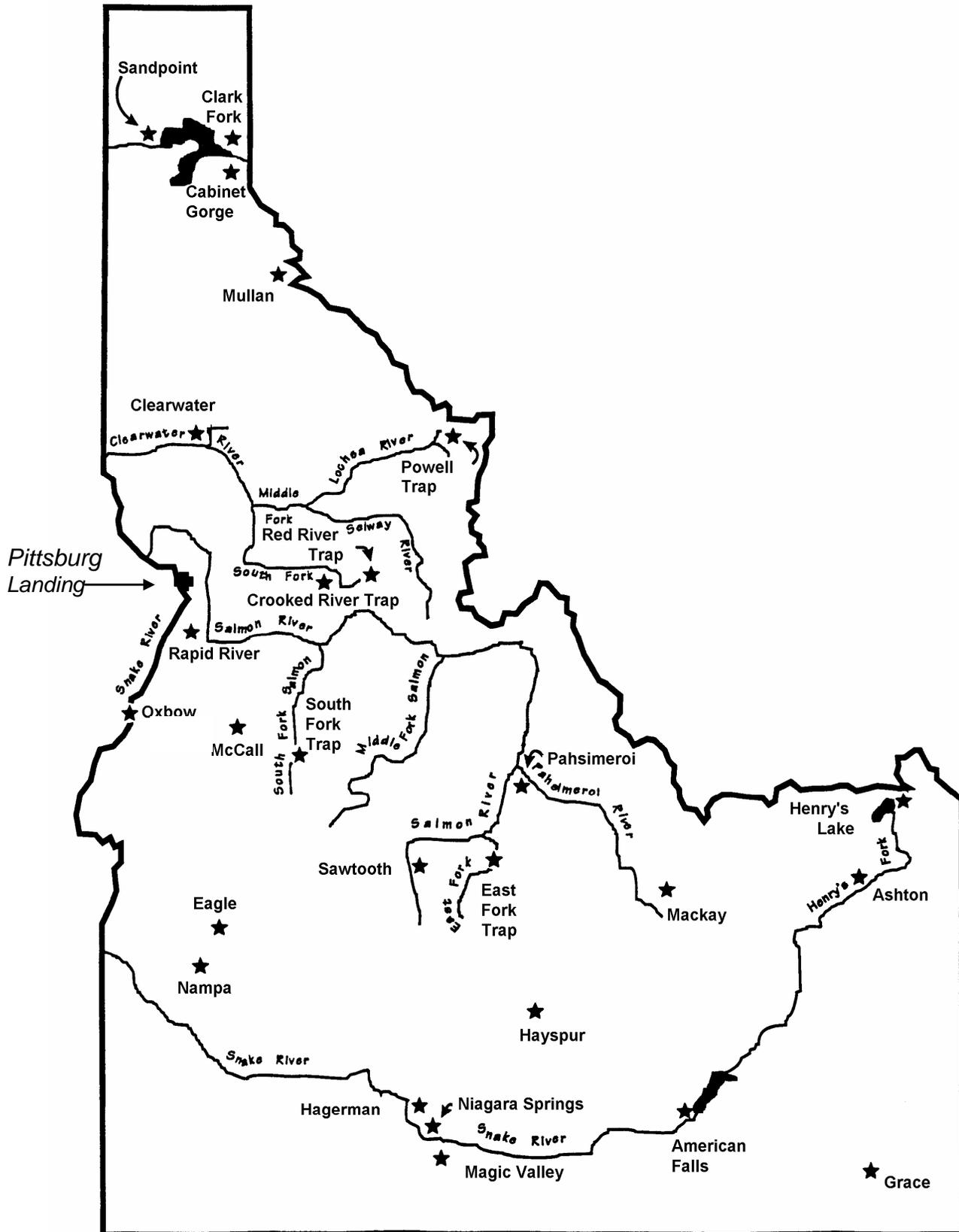
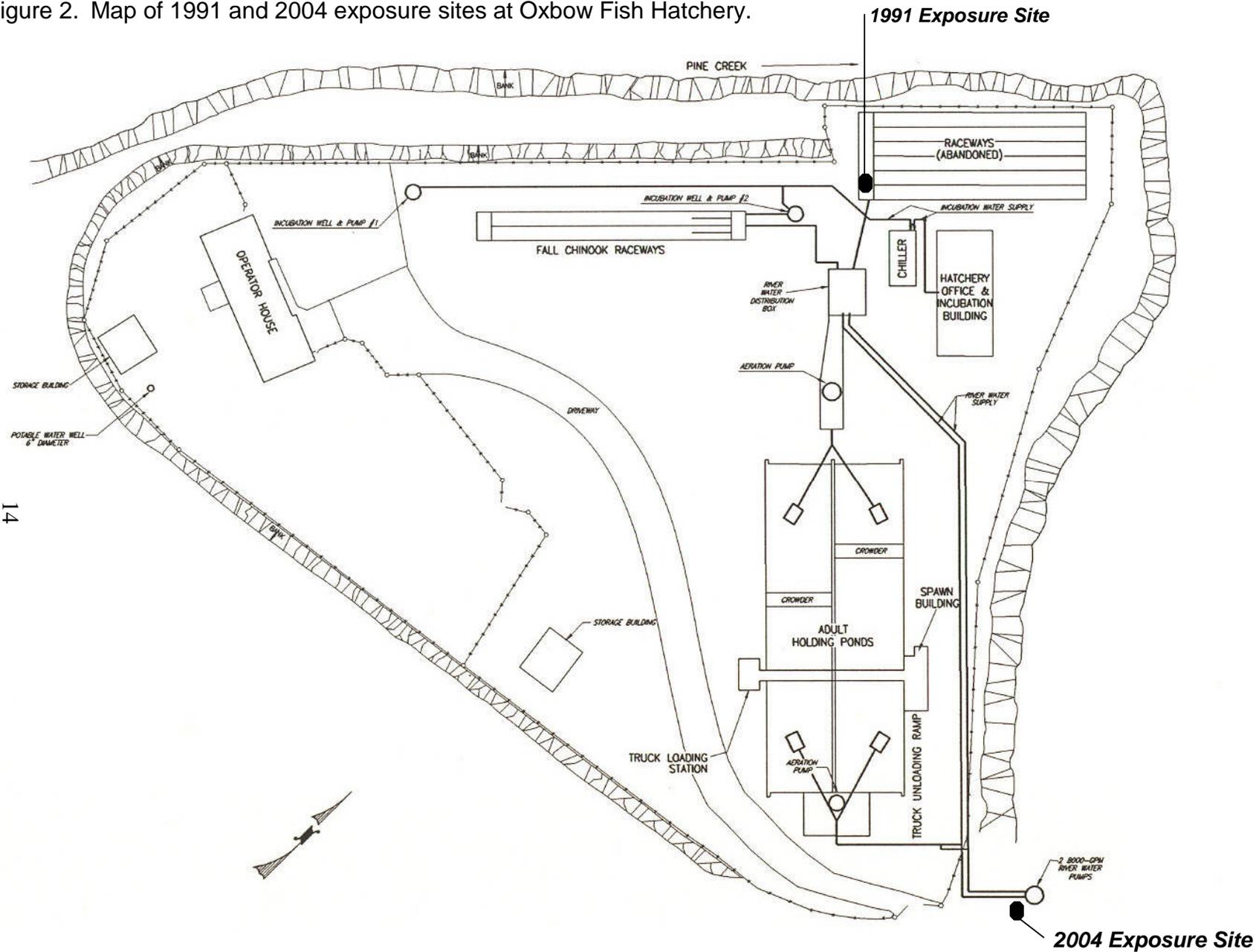


Figure 2. Map of 1991 and 2004 exposure sites at Oxbow Fish Hatchery.



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