OROVILLE FERC RELICENSING
(PROJECT NO. 2100)

DRAFT REPORT
SP-F2, Task 1 & 2

EVALUATION OF PROJECT EFFECTS ON FISH DISEASE

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TABLE OF CONTENTS

LIST OF FIGURES / TABLES

1.0 INTRODUCTION TO FISH DISEASE

Disease is a deviation from normal health and may result from infectious agents, nutritional deficiencies, toxicants, environmental factors, or may be genetically based (Plumb 2002). There is a difference between "infection" and "disease". Infection is the presence of a pathogen in a host that may or may not be diseased. Infected fish that are not diseased can serve as a natural reservoir for pathogens (Coutant 1998). This is often a normal state. Disease is the condition in which a pathogen is present in sufficient numbers and under the right environmental conditions to affect the animal's well being (Plumb 2002). Many fish disease organisms are normally present in the aquatic environment, co-existing with the host species and natural population without causing regular or significant outbreaks, and/or wide spread mortality (Plumb 2002). However, if environmental conditions become unfavorable for the host and some stressor(s) compromises individual immune systems or natural resistance, disease outbreaks may result.

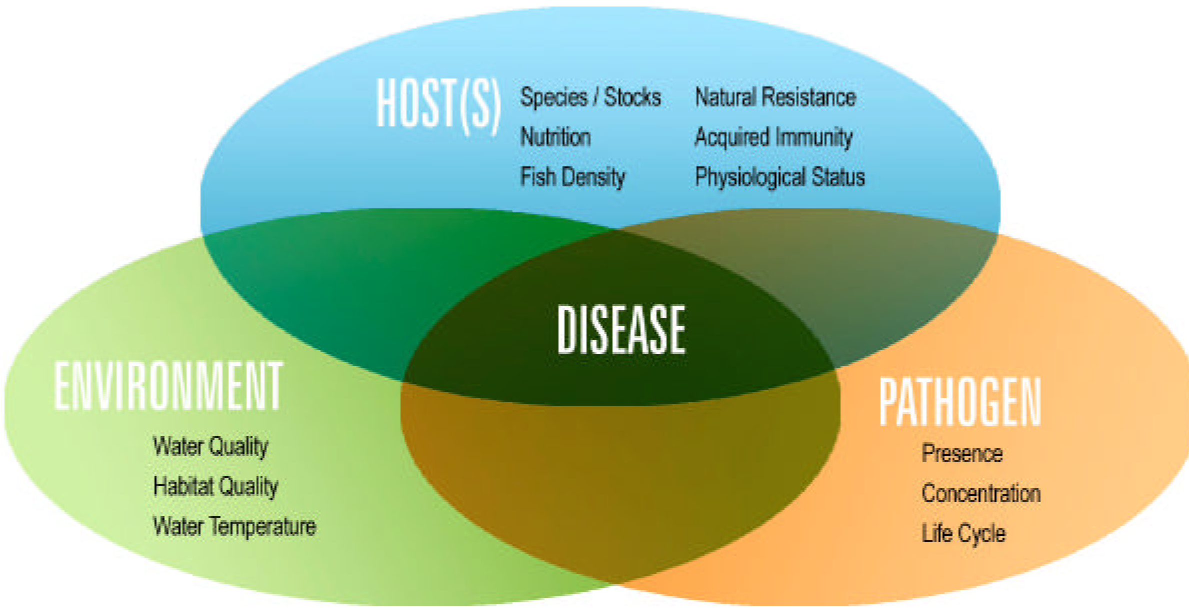
An important relationship exists between environmental quality and fish disease. Changes in environmental conditions affect the incidence and severity of infectious disease (Plumb 2002). Fish are constantly adapting to changing environmental conditions that may result in stress to an individual fish (Plumb 2002). Stress is generally defined as a reaction of an animal to physical, physiological, or chemical insult (Barton 1997). Stress can manifest itself in many ways including reduced weight gain, reduced immune response, higher disease incidence, and increased mortalities (Plumb 2002). Some stressors for fish include organic pollution (nitrates and nitrites), low oxygen levels, high concentrations of carbon dioxide, water temperature (based on specific species requirements), fish density, heavy metals, pesticides, high turbidity, and pH extremes (Plumb 2002). Snieszko (1973) theorized that a host/pathogen/environment relationship exists, such that if a host and pathogen are both present in combination with an unfavorable environmental condition, disease may result. For example, fisheries management actions such as artificial propagation can be associated with density dependant stress during rearing, which when combined with natural occurrence of pathogens in raceway water can lead to disease outbreaks in the culture environment. However, it is important to note that the presence of pathogen and host infection do not necessarily indicate that a disease outbreak has or will occur.

Fish health management should consider potential interactions among a broad set of parameters such as hatchery practices, environmental quality, nutritional factors, physiological status of the fish, and specific pathogen attributes (Plumb 2002). Figure 1 (adapted from Plumb 2002) represents a schematic of several important factors that can influence the overall health status of a fish population. The factors in Figure 1 can interact individually and collectively affecting the health status of an entire fish population. The various segments of the diagram are not autonomous; they can interact and affect one anther.

Theoretically the ideal approach to preventing infectious fish diseases, in culture or in the wild, is to avoid exposure to pathogenic agents whenever possible (Plumb 2002). However, it is impossible to prevent fish exposure to all potential pathogens in the open aquatic environment. Many fish pathogens naturally occur in most waters and are opportunistic, facultative organisms that remain viable under a variety of environmental conditions (Plumb 2002). Some parasites have complex life cycles that involve fish-eating birds, snails, worms, or copepods. To control infestations by these parasites the life cycle of the non-fish vector must be broken, a nearly impossible task. Another alternative is to limit environmental stressors; however, environmental stressors such as unfavorable water temperatures and water quality are often out of control of fisheries managers. In addition, water temperature affects various diseases in different ways. For example, although low water temperature may inhibit the onset of ceratomyxosis in salmonids, it is favorable for infection by

Infectious Haematopoietic Necrosis Virus (IHN).

Figure 1. Factors that influence fish disease outbreaks.



2.0 PURPOSE OF STUDY AND BACKGROUND INFORMATION

The purpose of this study was to obtain and review existing information and to evaluate the Project's effects on the establishment, transmission and control of fish diseases in Project waters, and to evaluate the potential for significant fish diseases to move downstream of the Project waters.

As mitigation for the loss of salmonid habitat due to construction of the Oroville Facilities, California Department of Water Resources (DWR) constructed the Feather River Hatchery (FRH). Millions of spring-run and fall-run Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*) have been released from FRH, providing contribution to commercial and recreational fisheries, both inland and ocean (DWR 2001).

Several endemic salmonid pathogens (disease in parenthesis) occur in the Feather River basin, including *Ceratomyxa shasta* (salmonid ceratomyxosis), *Flavobacterium columnare* (columnaris), infectious haematopoietic necrosis virus (infectious haematopoietic necrosis, IHN), *Renibacterium salmoninarum* (bacterial kidney disease, BKD), and *Flavobacterium psychrophilum* (cold water disease). While these pathogens occur naturally, the Oroville Facilities, as well as other reservoirs, water withdrawals, agriculture and silviculture, may have produced environmental conditions that are more, or less, favorable to these pathogens as compared to historic conditions. Impediments to migration may have altered the timing and the duration of exposure of anadromous salmonids to certain pathogens. Fish management practices, such as introductions of exotic fish species, hatchery production, and out-of-basin transplants, also have inadvertently introduced foreign diseases (such as whirling disease). However, while whirling disease does exist in the upper Feather River drainage, it is not found in Lake Oroville or in the river below the dam (Pers. comm. Dr. Bill Cox, CDFG 2003). Water management activities such as transfers, pumpback operations, and flow manipulation can result in water temperature changes and/or increased fish density, and thereby increased risk of disease.

Conversely, Project facilities and their operations may also have reduced the transmission and extent of some fish diseases. For example, during the late spring and summer, the Project releases cooler water into the Feather River low flow channel than existed historically. This may have suppressed outbreaks of ceratomyxosis in the steelhead populations residing in the river, as cool water temperatures suppress the onset of ceratomyxosis. However, cool water temperatures can be favorable for other diseases such as IHN.

Little is known about diseases and pathogens of non-captive fish in the Feather River basin. Extensive records of hatchery-reared salmonids exist, and inferences for wild fish diseases are appropriate. Of the fish diseases occurring in the Feather River basin, those that are main contributors to fish mortality at the FRH (IHN and ceratomyxosis) are of highest concern for fisheries management in the region. Although other pathogens associated with disease may occur in Feather River fish, they do not necessarily lead to significant fish mortality or threaten fish populations. Thus, they may be considered less important for the management of the Feather River fisheries. Hereinafter, the use of the adjective "significant" will be restricted to those diseases or vectors that are important for the management of the FRH and fisheries because of their contribution to Feather River fish mortality and diseases that are directly or indirectly managed in Project waters.

IHN resulted in significant mortality at the Feather River Hatchery. In 1998, 2000, 2001, and 2002 several million juvenile Chinook salmon died as a result of IHN (DWR 2001). IHN causes significant disease in Chinook salmon, kokanee, steelhead, and rainbow trout. IHN disease outbreaks are rare above 59°F, but can be severe at 50°F (Moeller 2001). Since 2000, IHN issues have caused the stocking of Chinook salmon and brown trout in Lake Oroville to be halted until further notice in order to protect the water supply to the FRH and the Feather River below the fish barrier dam. An experimental program using coho salmon (*Oncorhynchus kisutch)* to stock Lake Oroville is currently being implemented and evaluated; coho salmon appear to be more resistant to IHN than other salmonids.

Ceratomyxa shasta, an endemic myxosporean parasite that causes ceratomyxosis (lethal to many strains of rainbow trout and steelhead) is prevalent in Lake Oroville (DWR 2001). Ceratomyxosis was first observed in 1948 in fall spawning rainbow trout from the Crystal Lake Hatchery in Shasta County, California. The poor success of California Department of Fish and Game (CDFG) efforts at stocking non-native stocks of rainbow trout in Lake Oroville in the 1970s and 1980s are thought to be due, in part, to the prevalence of the infective stage of *C. shasta* in the lake. Salmonids that are native to rivers where *C. shasta* naturally occurs have developed varying degrees of resistance to the disease through natural selection (examples are Pit River rainbow trout and Deschutes River steelhead). Likewise, salmonid populations that have not evolved with the parasite are highly susceptible to the disease (such as Alsea River steelhead). Resistance to the disease is heritable; offspring of a resistant parent and a susceptible parent have been found to have intermediate resistance to the disease. The progression of ceratomyxosis is influenced by water temperature. Mortality generally occurs when water temperatures exceed 50°F; however, fish can become infected at temperatures as low as 39°F (Bartholomew 2001).

Another potential disease of concern for Oroville Project waters is cold-water disease (*Flavobacterium psychrophilum*). This disease exists at temperature of 65°F or less. More serious losses occur near the bacterium's growth optimum of approximately 60°F. This disease does however exist at all temperatures under 65°F in contrast to a similar bacterium, *Flavobacterium columnare*, which causes disease in warmer waters. *F. psychrophilum* is a bacterium known to affect wild and hatchery populations of virtually all salmonid species. This bacterium can cause mortality of up to 50 percent among young salmonids. Outbreaks of cold-water disease generally occur at temperatures below 61°F.

BKD is a typically chronic disease caused by the bacterium *Renibacterium salmoninarum.* BKD is economically significant to salmonid hatcheries, especially with regard to Pacific salmon (*Oncorhynchus* sp.), because of its widespread distribution both in freshwater and marine environments, its chronic nature, which does not allow the disease to be diagnosed before late clinical or debilitating manifestations, its vertical transmission through sexual products, and the inefficacy of the main therapeutic compounds used in treating infected fish.

Whirling disease, a European disease introduced into North America in the late 1950s, is caused by the metazoan parasite, *Myxobolus cerebralis*. To date, whirling disease has caused severe damage primarily to wild rainbow trout populations in Montana and Colorado, but it impacts hatchery salmonids as well. *M. cerebralis* was first detected in California in 1966, and is now found in many Central Valley drainages, including the Feather River. Although present in several watersheds in California, no adverse effects on salmon or trout populations have been observed in California (Modin 1998). Native North American salmonids are more susceptible than European salmonids to the disease. Brown trout, which originated in Europe, have developed some resistance and may carry the parasite without succumbing to the disease.

Lake Oroville also supports a warmwater fishery. There is little information on the warmwater diseases present and their impacts on the fishery. However, many warmwater diseases could be of concern for Oroville Facilities waters, especially when water temperature increases above 50°F. Some potentially significant warmwater diseases include columnaris and epistylis (red sore disease). Epistylis was observed with black bass in Lake Oroville during the fall and winter of 2000/2001, though no mortality was actually seen (Pers. comm. Dr. Bill Cox, CDFG 2003).

3.0 RELATIONSHIP TO RELICENSING AND NEED FOR THE STUDY

The purpose of the study was to obtain and review existing information and to evaluate the Project's effects on the establishment, transmission and control of fish diseases. This information is useful for evaluating direct, indirect and cumulative effects of the Oroville Facilities required to comply with the Federal Energy Regulatory Commission's (FERC) environmental review process under the National Environmental Policy Act (NEPA) and Endangered Species Act (ESA) consultation information requirements. This study was initiated to collect and compile the baseline information regarding fish diseases in waters influenced by Project operations in order to evaluate potential Project effects and to provide a foundation for development of future protection, mitigation, and enhancement measures (PM&Es), if needed.

Fish health and disease occurrence are related to a variety of factors, as previously listed and presented in Figure 1. The Project operations have the potential to affect all of these factors in the FERC Project waters, FRH, and the Feather River downstream of the Oroville Facilities. Of significance to disease issues are potential Project impacts to water temperature and Project operations that include actions that might introduce diseases, such as out-of-basin fish transfers.

Section 4.51(f)(3) of 18 CFR requires reporting of certain types of information in the FERC application for license of major hydropower projects, including a discussion of the fish, wildlife and botanical resources in the vicinity of the Project. The discussion needs to identify the potential impacts of the project on these resources, including a description of any anticipated continuing impact for ongoing and future operations. This study fulfills these requirements by evaluating potential Project effects on the establishment, transmission, extent and control of significant coldwater and warmwater fish diseases in the Feather River and reservoir waters within the Project boundary.

4.0 STUDY OBJECTIVES

The overall objective of this study was to evaluate the effects of ongoing and future Project operations (pumpback operations, hatchery production, etc.) on the establishment, transmission, extent and control of IHN, BKD, and other significant coldwater and warmwater fish diseases. Significant diseases are (as defined earlier) those diseases that can cause serious losses to Feather River basin fish populations through increased direct, or indirect mortality, or are managed in the Feather River basin.

Specific disease study objectives detailed in the SP-F2 study plan for Task 1 include the following:

? Determine the occurrence and distribution of significant diseases in Project waters, including IHN, ceratomyxosis, BKD, cold water disease, and whirling disease.

? Catalog historical and current fish species found within the study area and evaluate their susceptibility to diseases.

? Document the life history characteristics of the causative agents of the significant diseases and the mechanisms of disease transmission.

? Document methods of controlling significant diseases.

? For each significant disease, identify salient environmental conditions that impact disease transmission, e.g. high water temperatures.

? Evaluate the effect of hatchery operations on disease transmission within the study area.

? Evaluate the prevalence and potential for disease outbreak in the study area from current Project operations.

? Review environmental characteristics of Project waters (i.e., from SP-F3.1, SP-F3.2, and SP-F10) to identify areas of management concern that have significant potential for disease outbreaks or disease transmission.

? Evaluate the potential for diseases to spread downstream in the Feather River.

? Evaluate whether disease outbreaks in the study area may result from pumpback operations because of fluctuating environmental characteristics.

5.0 DISTRIBUTION OF FISH SPECIES IN PROJECT WATERS AND SUSCEPTIBILITY OF FISH TO DISEASE

Forty-four fish species are known to currently exist throughout Project waters (IIP 2001, SWRI 2003) and are listed in Table 1. Approximately 16 native species would have been found here historically. The remaining 28 exotic species were either introduced by fisheries managers to create recreational fishery opportunities or to provide a forage base for game fish, or were illegally introduced.

Within the Project waters the highest diversity of fish species occurs in the Lower Feather River (40 species) followed by Lake Oroville (28 species). A majority of the species overlap between these two water bodies, with a larger number of riverine and anadromous species in the Lower Feather River (i.e. steelhead, shad) and mostly introduced game species in Lake Oroville (i.e. lake trout, brown trout, bass). The Thermalito complex has lower fish diversity with 18 species in the Afterbay, 12 species in the Forebay, and 12 species in the Diversion Pool. This low number may reflect limited sampling efforts (IIP 2001, SWRI 2003).

All fish in Project Waters are subject to modified environmental conditions associated with Lake Oroville, change in the natural flow regime in the Feather River, historic stocking of exotic and game species including predators and species with low resistance to endemic pathogens, and potential amplification of disease due to hatchery rearing. These four management actions affect the host/pathogen/environment relationship and can affect the susceptibility of fish to disease. Based on review of hatchery records and discussions with local disease experts the most significant diseases in the Project Waters are IHN and ceratomyxosis.

The two most significant diseases (ceratomyxosis and IHN) only affect salmonids. In general, species of salmonids that can be significantly affected by IHN include Chinook salmon, rainbow trout, sockeye salmon and kokanee. Rainbow trout and steelhead are normally highly susceptible to ceratomyxosis, while Chinook and coho salmon are more resistant to the disease. Ceratomyxosis and minor incidence of IHN have been reported from the Thermalito Annex Fish Facility. However, it is believed that the higher water temperature in the facility has slowed the spread of IHN since the disease is more problematic at lower water temperatures.

Table 1. Fish species known to be present in Project waters (IIP 2001, SWRI 2003).

Common Name	Scientific Name	Lake Oroville	Thermalito Diversion Pool	Thermalito Forebay	Thermalito Afterbay	Lower Feather R.
American shad	*Alosa sapidissima*					x
Bigscale Logperch	*Percina macrolepida*					x
Black bullhead	*Ameiurus melas*					x
Black Crappie	*Pomoxis nigromaculatus*	x			x	x
Bluegill	*Lepomis macrochirus*	x	x	x	x	x
Brook Trout	*Salvelinus fontinalis*		x	x	x	x
Brown bullhead	*Ameiurus nebulosus*					x
Brown Trout	*Salmo trutta*	x	x	x	x	x
Carp	*Cyprinus carpio*	x	x	x	x	x
Channel Catfish	*Ictalurus punctatus*	x			x	
Chinook Salmon	*Onchoryhnchus tshawytscha*	x	x	x		x
Golden Shiner	*Notemigonus crysoleucas*	x	x	x	x	x
Goldfish	*Carassius auratus*	x	x	x	x	x
Green Sturgeon	*Acipenser medirostris*					x
Green Sunfish	*Lepomis cyanellus*	x			x	x
Hardhead	*Mylopharodon conocephalus*	x				x
Hitch	*Lavinia exilicauda*					x
Lake Trout	*Salvelinus namaycush*	x				
Largemouth Bass	*Micropterus salmoides*	x	x	x	x	x
Pacific Lamprey	*Lamptera tridentate*					x
Prickly Sculpin	*Cottus asper*					x
Pumkinseed	*Lepomis gibbosus*					x
Rainbow Trout	*Onchoryhnchus mykiss*	x	x	x	x	x
Redear Sunfish	*Lepomis microlophus*	x			x	x
Redeye Bass	*Micropterus coosae*	x				x
Riffle Sculpin	*Cottus gulosus*					x
River Lamprey	*Lamptera ayresi*					x
Sacramento Pike Minnow	*Ptychocheilus grandis*	x				x
Sacramento Sucker	*Catostomus occidentalis*	x	x	x	x	x
Sculpin*	*Cottus sp.*	x	x	x	x	
Smallmouth Bass	*Micropterus dolomieu*	x			x	x
Speckled Dace	*Rhinichthys osculus*					x
Splittail	*Pogonychthys macrolepisdotus*					x
Spotted Bass	*Micropterus punctulatus*	x				x
Steelhead	*Onchoryhnchus mykiss*					x
Threadfin Shad	*Dorosoma petenense*	x				x
Threespine Stickleback	*Gasterosteus aculeatus*	x				
Tule Perch	*Hysterocarpus traski*				x	x
Wakasagi	*Hypomesus nipponensis*	x	x	x	x	x
Warmouth	*Lepomis gulosus*	x				x
Western mosquitofish	*Gambusia affinis*	x			x	x
White Catfish	*Ameiurus catus*	x				x
White Crappie	*Pomoxis annularis*	x				x
White Sturgeon	*Acipenser transmontanus*	x				x

Note: *Sculpins were not identified to species

? Warmwater fish species found in Lake Oroville are believed to exist in low number in the forebay.

? Afterbay fish presence was based on limited sampling. Other Lake Oroville fish likely occur in the Thermalito waters to some degree.

? Lower Feather River fish presence was based primarily on fish species captured in rotary screw traps on the Lower Feather River.

6.0 OCCURRENCE AND DISTRIBUTION OF SIGNIFICANT DISEASES IN PROJECT WATERS

For purposes of identifying disease presence and prevalence, the primary study area downstream of the Project was defined to encompass the Feather River upstream of the confluence of the Feather and Yuba rivers. Upstream of the Project, the geographic scope of the study area was limited by fish passage barriers above Lake Oroville. These barriers represent the greatest upstream extent that diseased fish could travel. Study plans approved by the Environmental Work Group defined the limits of the study area. Table 2 presents significant diseases requiring management action that are present in Project waters and are considered in this study. These diseases were identified in consultation with local fish pathology experts Dr. Scott Foott of the United States Fish and Wildlife Service (USFWS) and Dr. Bill Cox of California Department of Fish and Game (CDFG). In addition, Table 3 summarizes diseases detected at Sacramento River basin fish hatcheries from 1991 to 2000. Figure 2 shows fish hatchery locations in the Sacramento River basin.

Review of the Feather River Hatchery records revealed that several endemic salmonid pathogens occur in the Feather River basin. The two most significant diseases of concern are salmonid ceratomyxosis (*C. shasta*) and infectious haematopoietic necrosis (also known as Sacramento River Chinook disease or IHN). Cold water disease (also known as rainbow trout fry syndrome) is also present in the area, but never caused a significant disease outbreak. Other significant diseases, such as BKD exist in the Project waters. Whirling disease has been found in the North and South forks of the Feather River, California, but has never been detected in Project waters.

Coho salmon with symptomatic BKD were reported at cage culture facilities in Lake Oroville in 1988 after infected juvenile Chinook and coho salmon from out-of state parent stock were released in Lake Oroville in 1985 and 1987 (California Fish and Game, notes to outside agencies, 1989). The cage culture program has since been terminated and no further incidence of the disease has been reported. The only incidence of IHN in Lake Oroville was observed in 2000 in inland sexually mature Chinook salmon captured by electrofishing. This finding resulted in an immediate cessation of planting of Chinook salmon and other susceptible salmonids into the lake.

The majority of current information on disease occurrence in the Project waters is from the Feather River Hatchery records. CDFG fish health personnel have detected pathogens in wild fish (Pers. comm. Dr. Bill Cox, CDFG 2003). However, no evidence of a disease outbreak in the wild is available. Although in 2000, DWR fisheries biologists observed a few Chinook salmon that were symptomatic of IHN while conducting a snorkeling survey between the Feather River Hatchery and Live Oak. These fish were collected and tested positive for FR Type II, IHN. It was suspected that either this strain of IHN was extremely virulent or that heavy stocking of Chinook salmon in Lake Oroville was resulting in conditions that allowed for amplification of the virus.

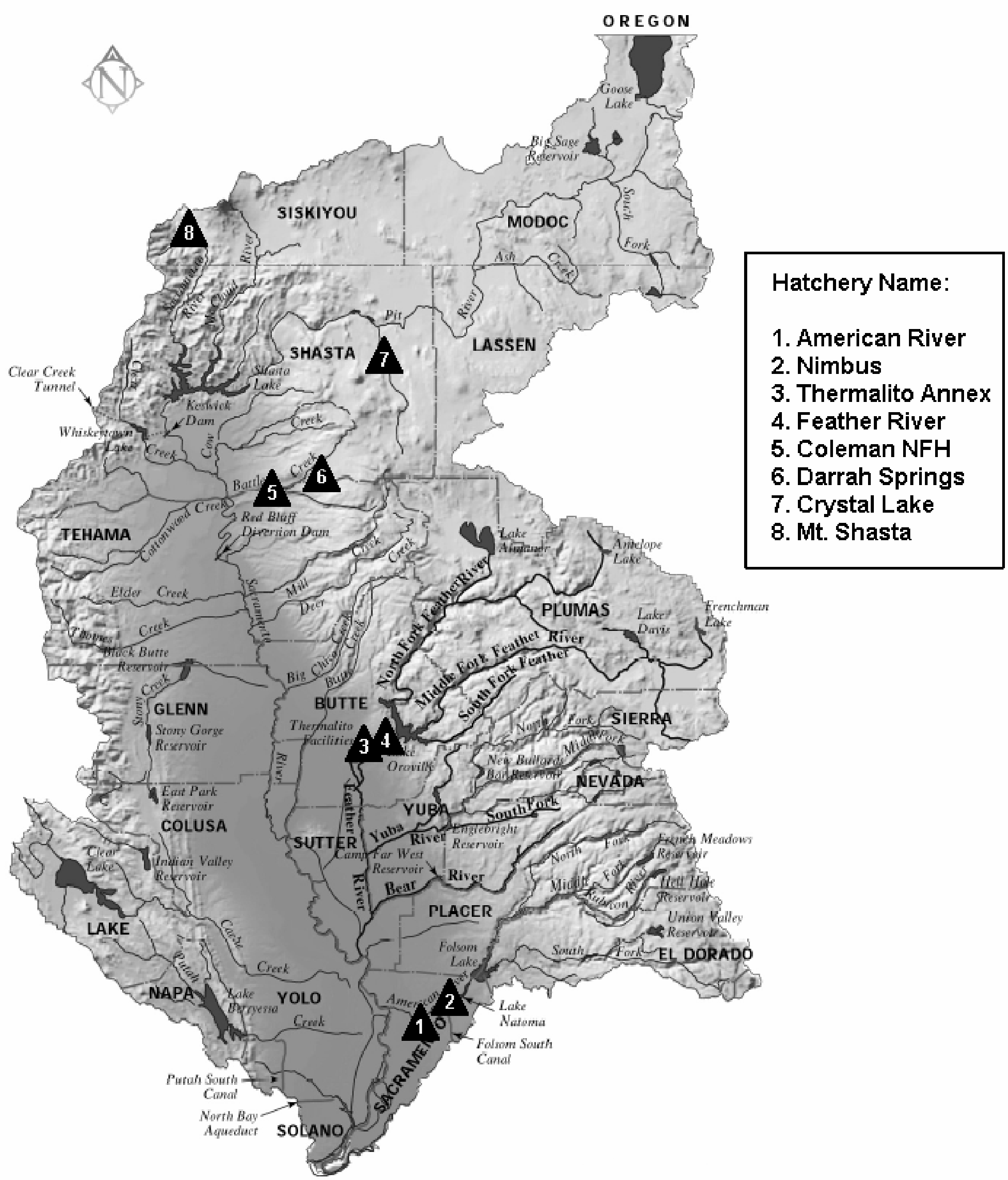
Table 2. Significant fish diseases requiring management action that are known to be present in the study area.

Disease	Pathogen
Infectious Haematopoietic Necrosis (IHN)	Infectious Haematopoietic Necrosis Virus
Salmonid Ceratomyxosis	*Ceratomyxa shasta*
Bacterial Kidney Disease (BKD)	*Renibacterium salmoninarum*
Whirling Disease	*Myxobulis cerebralis*
Cold Water Disease	*Flavobacterium psychrophilum*
Enteric Red Mouth (ERM)	*Yersinia ruckeri*
Columnaris	*Flexibacter columnaris*

Table 3. Fish pathogens and diseases detected at Sacramento River basin hatcheries, 1991-2000 (Pers. comm. Dr. Bill Cox, CDFG 2003).

Bacteria	**American River**	**Nimbus**	**Thermalito Annex**	**Feather River**	**Coleman NFH**	**Darrah Springs**	**Crystal Lake**	**Mt. Shasta**
Aeromonas hydrophila	X	X	X	X	X	X	X	X
Aeromonas salmonicida					X			
Aeromonas spp.	X	X	X	X	X	X	X	X
Flavobacterium branchiophilum	X	X	X	X	X	X	X	X
Flavobacterium columnare	X	X	X	X	X	X	X	X
Flavobacterium psychrophilum	X	X	X			X	X	X
Myxobacteria spp.	X	X	X	X		X	X	
Pseudomonas fluorescens	X	X	X	X	X	X	X	X
Pseudomonas spp.	X	X	X	X	X	X	X	X
Renibacterium salmoninarum	X	X	X				X	
Serratia liquifasciens	X							
Yersinia ruckeri		X	X	X		X	X	
Parasites								
Ambiphyra	X	X			X			
Apiosoma	X	X						
Capriniana (Trichophyra)	X	X	X	X			X	
Ceratomyxa shasta	X	X	X	X			X	
Chilodinella	X	X			X		X	
Cryptobia								X
Epistylis	X	X		X	X		X	
Gyrodactylus	X	X		X	X	X	X	X
Hexamita	X			X	X	X		
Ichthyobodo necatrix (costia)	X	X	X	X	X	X	X	X
Ichthyopthirius multifilis	X	X	X	X	X	X		
Loma	X					X	X	
Nanophyetes					X	X		
Nucleospora salmonis	X	X				X		
Rosette agent					X			
Sanguinicola					X	X		
Tetracapsula bryosalmonae	X	X	X					
Trichodina	X	X				X	X	
Virus								
Cutthroat trout virus (CTV)							X	X
IHN		X	X	X	X			
Paramyxovirus		X		X				
Misc.								
Gas bubble syndrome	X	X			X			
Phoma				X	X			
Saprolegnia	X	X		X	X	X	X	X

Figure 2. Hatchery locations in the Sacramento River basin.



7.0 ECOLOGICAL BRIEFS FOR SIGNIFICANT DISEASES IN PROJECT WATERS

Significant diseases identified in the SP-F2 Study Plan (Table 2) include infectious haematopoietic necrosis (IHN), salmonid ceratomyxosis, bacterial kidney disease (BKD), cold water disease (also known as rainbow trout fry syndrome), and whirling disease. Of note is that review of hatchery records indicates that IHN and ceratomyxosis are the most significant diseases in terms of fish mortalities. Dr. Bill Cox, CDFG, further identified enteric red mouth and columnaris as diseases that are actively managed at many hatcheries in California, including FRH and Thermalito Annex. Following is a description of the life history of the causative agent, mechanism of transmission, control methods, and salient environmental factors that affect transmission for each of these significant diseases.

7.1 Salmonid Ceratomyxosis

Causative Agent

Salmonid ceratomyxosis is caused by the parasite: *Ceratomyxa Shasta* (Myxozoa:Myxosporean) and was first observed in 1948 in fall spawning rainbow trout from Crystal Lake Hatchery, Shasta County, California (Wales and Wolf 1955). *C. shasta*, is endemic to the Feather River basin and is present upstream of the Feather River Hatchery in the North Fork and Lake Oroville (Pers. comm. Dr. Bill Cox, CDFG 2003). The parasite has two primary life stages, the actinosporea and myxosporean stages. Various salmonid fish species are the primary hosts for this parasite. The actinosporean stage is found in the water column and is the infective stage for salmonids. Ceratomyxosis is known to infect rainbow trout/steelhead (*Oncorhynchus mykiss*), cutthroat trout (*Oncorhynchus clarki*), pink salmon (*Oncorhynchus gorbuscha*), chum salmon (*Oncorhynchus keta*), coho salmon (*Oncorhynchus kisutch*), sockeye salmon (*Oncorhynchus nerka*), Chinook salmon (*Oncorhynchus tshawytscha*), Atlantic salmon (*Salmo salar*), brown trout (*Salmon trutta*), and brook trout (*Salvelinus fontinalis*) (Bartholomew 2001). Bartholomew et al. (1997) demonstrated that completion of the parasite life cycle requires development of the actinosporean stages in an alternate host, the freshwater polychaete (*Manayunkia speciosa*). Myxosporeans are released back into freshwater following salmonid mortality, then the spores infect the polychaete. The complete life cycle, host and vector interaction, is not fully understood, especially the ecology of the polychaete host (PacifiCorp 2002). The distribution of the polychaete is likely the factor that has defined the geographic distribution of the parasite (Bartholomew 2001).

The following information on pathogenesis is from Bartholomew (2001). Depending on a number of factors (e.g. host species), a variety of organs may be affected. However, *C. shasta* has an attraction for the digestive tract (especially posterior intestine and pyloric caeca) and, secondarily, the kidney. Development of *C. shasta* infections in the posterior intestine typically triggers acute inflammation. The epithelial lining necrotizes, fragments, and ultimately sloughs, and is replaced by fibrous connective tissue containing host cells and trophozoites. The lumen may contain epithelial cells, epithelial cell fragments, PMN’s, fibroblasts, trophozoites, pansporoblasts, and spores in later stages. Pathological changes are less pronounced in the pyloric caeca. Trophozoites are often abundant between epithelial cells and in the muscularis externa. There may be separation of muscle layers due to the large number of trophozoites, but muscle necrosis is normally not severe. The kidney is more severely affected in salmon than in trout. In chum salmon, kidney necrosis is severe, affecting both renal and hematopoietic elements. All normal tissue may be destroyed and replaced by developing parasites. Focal lesions are also common in the liver.

Ceratomyxosis causes losses in wild and domestic trout and salmon of all ages and sizes and has been reported as a significant contributor to prespawning mortality among infected adult fish (Bartholomew 2001). Adult Chinook salmon mortality is generally caused by intestinal perforations and co-occurring bacterial infections (Pacificorp 2002). High mortalities have occurred in out-migrating juvenile Chinook salmon (Pacificorp 2002).

Mechanisms of Disease Transmission

Natural transmission occurs when susceptible salmonids come into contact with the waterborne actinosporean stage of *C. shasta* following its release from the polychaete. Bartholomew (2001) hypothesized that the distribution of the polychaete is likely the primary factor that delineates the geographic distribution of *C. Shasta*. Neither horizontal (fish to fish), nor vertical (fish to egg) transmissions have been documented in laboratory testing. Resistance to infection varies between species and stocks. Fish stocks endemic to enzootic waters are often more resistant to infection than stocks endemic to non-enzootic waters (Bartholomew 2001).

Methods of Control

In a culture environment, treatment of incoming water supply using a combination of ultraviolet irradiation, chlorination, and sand filtration or by ozonation, has been successful in decreasing infections in fish culture facilities (PacifiCorp 2002). Avoidance and quarantine are also important strategies (Noga 2000).

Ultraviolet water treatment and temperature control at the FRH and use of well water at the Thermalito Annex have been used extensively to minimize *C. shasta* exposure at these culture facilities.

Environmental Conditions Impacting Transmission

Temperature is thought to be an important factor in disease progression, although data suggests that temperature alone is not the controlling factor in the host/pathogen/environment relationship. Mortality generally occurs when water temperatures exceed 50°F; however, fish can become infected at temperatures as low as 39°F (Bartholomew 2001). Increased temperatures have also been shown to decrease time to mortality. For example, at 44°F and 74°F time to mortality for rainbow trout were 155 and 14 days, respectively (Udey et al. 1975). However, recent temperature trials conducted by the USFWS California –Nevada Fish Health Center in the Klamath basin showed that at high level of pathogens mortality could be 100% regardless of temperature (Pers. comm. Scott Foott, USFWS California-Nevada Fish Health Center 2002). Salinity can prevent infection at concentration greater than 15 ppt; however, if fish are infected before they enter salt water the disease progression may continue (Bartholomew 2001). Low flow is thought to increase infection potential (Noga 2000). Low flow may contribute to water warming and the total pathogen concentration (Noga 2000). The alternate polychaete host is thought to require fine sediment substrate although the life history of the polychaete is poorly understood.

7.2 Infectious Haematopoietic Necrosis

Causative Agent

Infectious haematopoietic necrosis virus (IHNV) is a rhabdovirus that causes losses among wild (Williams and Amend 1976) and cultured salmonids (Groberg and Fryer 1983). The virus is endemic to western portions of North America (LaPatra 2001). Very little information is available on the ecology of this virus. Sockeye, Chinook, and chum salmon, steelhead/rainbow trout, and Atlantic salmon can all contract the virus (British Columbia 2002).

The existence of an IHNV carrier state has been debated for many years. Amend (1975) demonstrated that fish which survive an IHNV infection as a juvenile can shed virus when they spawn. The conclusion of the Amend (1975) study was that the virus resides in a latent carrier state in IHN survivors and can emerge again when the fish reach sexual maturity. Other studies by Chiou et al. (1995), Drolet et al. (1995), and Kim et al. (1999) have found some evidence that supports the contention that IHNV may enter a latent or persistent state. Viral RNA and truncated particles were detected in kidney, spleen and liver tissues; however, reactivation and recovery of infectious virus from the possible "latent" form of the virus could not be demonstrated. A recent study on Atlantic salmon suggested that IHNV may persist in the anterior kidney in a small number of fish once an IHN epizootic has subsided (St-Hilaire et al. 2001). However, fish captured over a three year period from a population, which had a high prevalence of IHNV, did not become infected when held to sexual maturity in specific pathogen-free (SPF) water (Amos et al. 1989). Results from studies on wild sockeye salmon from Washington suggested that fish did not have latent infection, but become re-infected by horizontal or waterborne transmission (LaPatra 2001).

The gills are implicated as a major portal for entry and gill tissue has large amounts of virus just before spawning (Noga 2000). Virus has also been isolated from leeches, copepods, and mayflies; however, the role these animals may play in the life history of the virus is not known (Winton 1991). IHN primarily affects the blood forming tissues including the kidney and spleen, but can also infect other cells, and causes tissue necrosis and anemia (Noga 2002). The virus replicates in the infected cells, becoming so numerous that the cell wall breaks and expels the replicated virus strands.

Generally, sensitivity to the virus is inversely proportional to fish size (Bootland and Leong 1999). Yolk-sac fry and fish up to two months of age are highly susceptible with mortality often over 90%. The mortality of older fish up to six months of age is lower but can still be as high as 50% (Bootland and Leong 1999). Adult salmonids are either latent carriers or are re-infected before spawning and adult mortality can occur (Bootland and Leong 1999).

<u>Mechanisms of Disease Transmission</u>

IHN outbreaks in culture situations are derived from three possible sources: virus in the water supply, horizontal transmission from other infected fish in the hatchery, and vertical transmission from infected parents. The available evidence regarding transmission of fish diseases suggest that wild fish populations are the natural hosts and reservoirs of infection and that there is not high risk of IHN transmission from hatchery to wild fish populations (Amos and Thomas 2002). Chinook salmon collected from wild populations were exposed to IHN infected hatchery fish for different time intervals, but failed to demonstrate viral transmission (Foott et al. 2000). These findings were consistent with other studies assessing risk of IHN horizontal transmission in Idaho (LaPatra et al. 2001). Conversely, the presence of IHN in natural waters poses risk to hatchery populations raised in these waters. Once a hatchery population is infected, vertical transmission of IHN is thought to occur from the adult to the offspring by transport of the virus in reproductive fluids and/or on the outside of the egg (Noga 2000). Virus is abundant in the sexual fluids shed into water during hatchery spawning of infected fish (Noga 2000).

Methods of Control

There are no effective chemical treatments or anti-IHNV drugs available to treat infected fish. Preventing infection with disinfection and quarantine are the only proven means of controlling IHN epidemics (Noga 2000). Since a high percentage of many wild and cultured salmonid stocks may carry latent IHNV, preventing exposure to the virus may be virtually impossible (Noga 2000). Use of IHNV free water, such as from springs, wells or disinfected surface water can be used for rearing susceptible fish stocks or species to control IHNV exposure (Wedemeyer et al. 1979). Warm water temperature above 15ºC can stop epidemics of IHN (Noga 2000), but may exacerbate other disease problems such as ceratomyxosis. In addition, some virus strains, such as the Buhl, Idaho strain of IHNV, are resistant to high water temperature. Treatment of eggs with iodophore can greatly reduce the chance of vertical transmission. Complete elimination of IHNV in California hatcheries having IHNV free water supplies followed soon after adoption of routine iodophore egg treatments (Pers. comm. Dr. Bill Cox, 2003). A new technology currently being developed to increase fish resistance is the use of recombinant subunit vaccines (Leong et al. 1993).

The FRH has successfully operated for years in the presence of IHNV by using iodophore disinfection of eggs, temperature control and ultraviolet water treatment at the FRH, well water for the Thermalito Annex, and warmer water temperatures to control IHN outbreaks (Pers. comm. Dr. Bill Cox, CDFG 2003).

Environmental Conditions Impacting Transmission

Temperature is perhaps the strongest environmental parameter related to the expression of IHN (Noga 2000). The disease is most severe at 50°F and rare at temperatures above 59°F (Moeller 2001). Simultaneous exposure to copper (Hetrick et al. 1979) when the virus is present in the environment is thought to increase fish susceptibility (Noga 2000). Although environmental conditions can impact the occurrence and severity of IHN outbreaks, the role that environmental conditions play in the host/pathogen/environment relationship is poorly understood.

7.3 Whirling Disease

Causative Agent

Whirling disease is caused by the myxosporean protozoan parasite: *Myxobolus cerebralis*. This parasite was first reported in 1903 in central Europe (Hofer 1903), and has a two-host life cycle involving a fish and the aquatic oligochaete (*Tubifex tubifex).* Tubifex is the only tubificid that has been identified as being susceptible to *M. cerebralis*; other genera of oligochaetes have been tested, but did not produce infectivity for whirling disease (Markiw and Wolf 1983, Wolf et al. 1986.). Two separate spore stages occur (myxosporean and actinosporean), one in each host (Markiw and Wolf 1983, Wolf and Markiw 1984, Wolf et al. 1986).

The following life cycle information is primarily from El-Matbouli and Hoffmann (1991) and Markiw (1992b). Spores of *M. cererbralis* are released into the water column when infected fish die or are consumed by predators or scavengers. The myxosporean spores are ingested by tubificid worms. In the tubifex worm gut the myxosporean spores transform into the actinosporean *Triactiomyxon* in about 3.5 months at 54.5°F, which is the fish infective stage. After the mature *Triactinomyxon* develops they are released into the water column from several weeks (up to two years) (Gilbert 2001). The *Triactinomyxon* stage enters susceptible fish through the epithelial cells of the skin, fins, buccal cavity, upper esophagus, and lining of the digestive tract. Actinospores inject sporoplasms under the epithelium. Sporoplasms migrate up the peripheral nerves to the spinal cord, where they feed on cartilage. In the cartilage, the sporoplasms develop into trophozoites and undergo asexual mitosis forming numerous myxosporean spores (Moeller 2001). Transformation into the myxosporean stage takes about 2.6 months at a water temperature of 54.5°F. Spores released from necrotic cartilage can pass in the feces, but most spores remain trapped in the skeletal tissues until the fish dies (Hoffman and Putz, 1969).

Mechanisms of Disease Transmission

Salmonids contract whirling disease by brief contact with waterborne *Triactinomyxons* released from infected tubificids (Markiw 1992b). O'Grodnick (1975) demonstrated that whirling disease cannot be transmitted vertically from adult fish to eggs. Predators and scavengers, such as birds can consume infected fish and release viable *M. cerebralis* spores into the environment (Taylor and Lott 1978). An outbreak of whirling disease can occur after stocking with infected fish or transferring fish from one location to another where the infection has not yet occurred (Markiw 1992b). Juvenile and adult salmonids are susceptible to infection, but the severity of infection decreases with age (Markiw 1992a). One-day old rainbow trout are not susceptible to infection (Markiw 1991). Susceptibility to infection varies among salmonid species, stocks, and individual fish (Markiw 1992a). Susceptible species ranked in descending order of apparent susceptibility include: rainbow trout, sockeye salmon, golden trout (*Oncorhynchus aguabonita*), cutthroat trout, brook trout, steelhead, Chinook salmon, Atlantic salmon, brown trout, and coho salmon (O'Grodnick 1979, Hoffman 1990).

Methods of Control

There are no known treatments to counteract the affects of whirling disease in infected fish. However, preventive measures can decrease the intensity of the disease in fish culture facilities. Because tubificids are an essential intermediate host for development of the fish infective stage and tubificids are particularly abundant in rich organic soils, earthen ponds for rearing fish should be avoided to inhibit tubificid proliferation (Markiw 1992b). Disinfection of the water supply using filtration and ultraviolet irradiation has been effective in controlling disease outbreaks (Hoffman 1974, 1975).

Although *M. cerebralis* is present in several watersheds in California including the North and South forks of the Feather River, no adverse effects on salmon or trout populations have been observed in California (Modin 1998). Whirling disease is managed indirectly by CDFG by not planting fish from certain out-of-state growers that have whirling disease problems (Pers. comm. Dr. Bill Cox, CDFG 2003).

Environmental Conditions Impacting Transmission

Development time for both stages of *M. cerebralis* is directly related to water temperature (Markiw 1992b). Development time decreases as temperature increases; about 50 days at 63°F and 120 days at 45°F (Halliday 1973). Spores are thought to last in the aquatic environment for at least 50 years (Pers. comm. Dr. Bill Cox, CDFG 2003). Tubificid worms are thought to require fine sediment substrate (Markiw 1992b), but the life history of the *T. tubifex* is poorly understood.

7.4 Bacterial Kidney Disease

Causative Agent

Bacterial kidney disease (BKD) is caused by the bacteria *Renibacterium salmoninarum*. The disease was first reported in the United States by Belding and Merrill (1935) in brook trout. *R. salmoninarum* is a nonmotile and asporogenous diplobacillus bacterium (Bullock and Herman 1988) and only has been reported in salmonids (Bullock and Herman 1988).

Mechanisms of Disease Transmission

Transmission of BKD is thought to occur via direct contact with contaminated fish (Moeller 2001), either horizontally or vertically (Evelyn et al. 1984). Infected peritoneal fluid is a major source of egg infection, but there is evidence that intraovum infections may also occur before ovulation (Evelyn 1993). Male broodstock do not seem to be a significant source of vertical transmission, even when milt is heavily infected with the bacterium (Evelyn 1993). Once the egg is infected, *R. salmoninarum* resides in the yolk, protected from antiseptics (Evelyn et al. 1986).

Subclinically infected or latent carrier salmonids are reservoirs of infection (Bullock and Herman 1988). Mitchum and Sherman (1981) reported that naturally infected wild brook trout transmitted BKD to newly stocked rainbow trout, brown trout, and brook trout, and that newly stocked trout began dying within 9 months. Austin and Rayment (1985) reported that *R. salmoninarum* is excreted in the feces of clinically infected trout, and that the organism can survive up to 21 days in feces or pond sediments. Infected salmonids that survive in the ocean can infect other salmonids (Bullock and Herman 1988). Banner et al. (1986) demonstrated that BKD could cause mortality in Chinook salmon in salt water. Brook trout are the most severely affected species (Moeller 2001).

Methods of Control

There are no proven therapies that can unequivocally cure fish of BKD (Elliott et al. 1989). However, nutrition/diet and use of antibiotics can slow the progression of the disease. Bell et al. (1984) reported that survival of experimentally infected sockeye salmon was inversely proportional to dietary levels of vitamin C in rations that also contained low levels of zinc and manganese. The disease was reduced in Atlantic salmon that were fed a diet high in iron, copper, manganese, iodine, cobalt and fluorine, or a diet low in calcium (Patterson et al. 1981). Injections of adult salmonids with erythromycin can reduce or possibly prevent vertical transmission of the disease (Bullock and Herman 1988). Under laboratory conditions, erythromycin given orally at the rate of 910 g per 100 kg of fish per day for three weeks gave the best control (Wolf and Dunbar 1959). Austin (1985) tested more than 70 antimicrobial compounds including clindamycin, erythromycin, kitasamycin, penicillin, and spiramycin, which effectively controlled early clinical cases of BKD. Injection of erythromycin base (as Eryghro® 100 or Erythro® 200) into female broodstock before spawning can significantly reduce the incidence of infected eggs (Moffitt 1991).

At the FRH Facilities, BKD is controlled by using the warmer raceway water at the Thermalito Annex facility for rearing, since BKD progression is slowed and/or suppressed in warmer waters.

Environmental Conditions Impacting Transmission

With BKD disease progression is influenced by water temperature. Juvenile coho salmon and rainbow trout are most sensitive to *R. salmoninarum* at 44° to 54°F (Sanders et al. 1978). As temperature increases mortality declines, and at 68°F the disease is suppressed (Sanders et al. 1978). However, other salmonids, such as sockeye salmon, infected with *R. salmoninarum* sustain high mortality levels at temperatures ranging form 44° to 68°F (Sanders et al. 1978). There can be a higher incidence of BKD in soft water (low concentrations of dissolved minerals) (Noga 2000).

7.5 Cold Water Disease

Causative Agent

Cold water disease, also known as rainbow trout fry syndrome, is caused by the bacterium *Flavobacterium psychrophilum*, which exhibits an attraction for the cartilage present in the spinal column and head of salmonids. Coho salmon and steelhead are most susceptible species, but other salmonid species can be infected or act as carriers of this diseases (Noga 2000).

Mechanisms of Disease Transmission

The results of a study by Brown et al. (1997) showed that *F. psychrophilum* could be transmitted both horizontally and vertically within salmonid hatcheries. Vertical transmission is likely because the bacterium is commonly found on eggs and can be isolated from reproductive tissues of a high percentage of fish (up to 76%) (Holt et al. 1993).

Methods of Control

Treatment methods for fish infected with cold water disease include quaternary ammonium bath, antibiotic treatment, and diquat bath (Noga 2000). Early cases of cold water disease may be successfully treated with quaternary ammonium or oxytetracycline baths (Noga 2000). However, systemic infections are common, requiring treatment with systemic antibiotics, such as Oxytetracycline, which is more effective than sulfa treatments (Wood 1974).

Antibiotic treatments and water temperature control are used to control cold water disease outbreaks at the FRH and Thermalito Annex facilities.

Environmental Conditions Impacting Transmission

F. psychorphilum is usually pathogenic at less than 61°F. This disease is most commonly observed in fry and fingerling salmonids in the spring held at water temperatures between 40° to 50°F (Bowser 1999, Holt et al. 1993). Mortality is most acute at 41°F and mortality decreases at higher temperatures (Holt et al. 1993). In California, high mortality has been observed at water temperatures up to 65°F.

7.6 Enteric Red Mouth

Causative Agent

Enteric red mouth (ERM) is caused by the bacterium *Yersinia ruckeri*. The following description of ERM is summarized from Noga (2000). Rainbow trout are especially susceptible to ERM, but steelhead, cutthroat trout, brown trout, brook trout, and coho, sockeye, Chinook, and Atlantic salmon are also affected. ERM primarily affects adult fish, although any age salmonid is susceptible. ERM can cause hemorrhagic septicemia, exophthalmia, hemorrhaging in mouth and eyes, swollen abdomen, and blindness.

Mechanisms of Disease Transmission

The incubation period is about one week at 59ºF. A high percentage (greater than 75 percent) of recovered fish may become carriers. Subclinical carriers can cyclically shed bacteria from the lower intestine. The carrier state can be maintained indefinitely. The pathogen is spread by horizontal transmission.

Methods of Control

Antibiotics, such as oxytetracycline, can be used for treatment, but some isolates of *Y. ruckeri* are resistant. Keeping the water supply free of carrier fish is the best method of control. Commercial *Y. ruckeri* bacterins off good protection and are important in managing populations at risk for ERM.

Antibiotics in conjunction with water temperature control are used to control ERM at the Thermalito and FRH facilities.

Environmental Conditions Impacting Transmission

Water temperature above 50°F increases mortality. High temperatures (59° to 64°F) can cause carriers to begin shedding pathogens. Copper exposure may also initiate outbreaks.

7.7 Columnaris

Causative Agent

Columnaris is a common bacterial disease that affects the skin or gills of freshwater fish. The following description of columnaris is summarized from Noga (2000). The bacterium *Flexibacter columnaris* is the most prevalent member of this group, which has a world wide distribution and can probably infect most freshwater fish. Flexibacteria occur naturally on healthy wild fish. Columnaris is primarily an epithelial disease causing erosive/necrotic skin and gill lesions that may become systemic.

Mechanisms of Disease Transmission

The pathogen is spread through horizontal transmission.

Methods of Control

Early cases of columnaris may be successfully treated with surfacant baths or prolonged immersion in potassium permanganate or copper sulfate. Systemic antibiotics can be used effectively. Lowering water temperature can reduce disease severity.

Antibiotics and water temperature control are used to control columnaris at the Thermalito and FRH facilities.

Environmental Conditions Impacting Transmission

Water temperature and strain virulence are the most important factors determining disease severity. *F. columnaris* is usually pathogenic at water temperatures higher than 59°F. Both mortality and acuteness increase with water temperature. *F. columnaris* is also reported to be less pathogenic in soft water. Low oxygen, high organic pollution, high nitrite, and exposure to high arsenic levels can increase disease susceptibility.

8.0 OCCURRENCE AND DISTRIBUTION OF DISEASES IN PROJECT WATERS THAT ARE NOT ACTIVELY MANAGED

Diseases present in Project waters that are not actively managed normally do not cause significant mortality and are easier to treat, and therefore do not pose a threat to fish in the basin. These diseases only occur when environmental conditions such as water temperature or quality deteriorate. Attributes of these non-managed diseases are summarized in Table 4.

Little is known about warmwater fish disease occurrence in the Project waters or what affect fish disease may have on the warmwater fish populations. Although epistylis was detected in Lake Oroville bass in 2000, to date, there has been no mortality reported on the warmwater fish in the project area, (Pers. comm. Dr. Bill Cox, CDFG 2003). The warmwater fishery in Lake Oroville is the main recreational fishery in terms of hours fished and number of anglers and is self-sustaining. It is believed that the existing populations are healthy. It is also believed that significant diseases that jeopardize the warmwater fishery are not present since a self-sustained fishery normally only exists in a healthy population.

Table 4. Attributes of non-actively managed fish diseases that are known to be present in the study area. Information from Noga (2000), Woo (1995), Woo and Bruno (1999), Plumb (2002), Mendoza et al. (2002), Pers. comm. Dr. Bill Cox (CDFG 2003).

Disease (Pathogen)	Organism Attributes	Species Affected	Pathogenesis	Treatment	Environmental Conditions Favorable to Disease
Furunculosus (*Aeromonas salmonicida*)	bacteria probably an obligate pathogen, may survive up to 3 weeks in water and months in sediments	many diverse fish, Atlantic salmon most susceptible, catfish, bass, carp, chub, dace, sculpin, bull head, rainbow trout resistant	causes typical hemorrhagic septicemia, bacteria disseminate in many tissues	antibiotics, some vaccines available.	high water temperature
Proliferative Kidney Disease (*Tetracapsula bryosalmonae*)	Amoeboid parasite	rainbow, brown trout, steelhead, Chinook, coho, Atlantic salmon, grayling	primarily targets kidney, causes exophthalmia, anemia, also affects the spleen, liver, muscle, gills	disinfection, avoidance, quarantine, malachite green bath, salt bath	highest mortality at water temperature of 54° to 57°F
White Spot Disease "Ich" (*Ichthyopthirius multifilis*)	Protozoan ectoparasite	virtually all freshwater fish, catfish especially vulnerable	targets skin or gills, forms cysts on skin or gill epithelium, can cause ulceration	formalin immersion, 1ppt salinity, therapeutic drugs	common temperature for outbreaks 59°F to 77°F, below 50°F in spring
Ichthyobodosis, formerly Costia (*Ichthyobodo necator*)	very small protozoan ectoparasite, dangerous to young fish	Freshwater fish, and marine adapted salmonids, may be some marine fish	Attaches to skin or gills, causes tissue irritation, can lead to epithelieal hyperplasia	formalin bath, potassium permanganate, salt bath (fresh water fish only)	causes disease over wide temperature range, 36°F to 86°F
Gill Maggot Disease (*Salmincola californiensis*)	copepod, infests gills of older salmonids in freshwater, can survive in salt water	salmonids and coregonids	attach on skin, fin base, in gill chamber, on gill filaments, oral chamber, causes hyperplasia, hypertrophy of gills	treatment with organophosphates, disinfection	copepod development is more rapid at warmer temperatures
Epistylis (*Epistylis sp.*)	protozoa, feeds on bacteria/other small organisms, use fish as surface for attachment	bass, perch, catfish, many other warm water fish	attachment points are associated with bacterial infections of fins, jaws, gills other hard calcified tissue	salt baths/ prolonged salt exposure, advanced cases may need treatment for systemic infection	common in pond-raised fish in southern U.S. and elsewhere, especially during warmer months
Iridovirus (*Lymphocystivirus*)	virus is viable in water for about 1 week, incubation ranges from weeks to months	teleosts, such as bass, does not affect salmonids, catfish, cyprinids	infects dermal fibroplasts, causes large neoplasitc hypertrophied cells	no treatment known, rarely causes mortality, fish can become severely disfigured	outbreaks occur after stress, handling or crowding.
Sturgeon Herpes Type 2 (*White Sturgeon Herpes Virus Type 2*)	Infects older sturgeon, mortality less than 10%	white sturgeon, shovelnose and pallid sturgeon infected experimentally	causes small white blisters, open lesions on body surface, lesions frequently infected with secondary pathogens	avoidance, treat infected fish for other parasites to reduce secondary infection in open lesions	unknown
Rosette Agent (Undescribed)	obligate intracellular fish parasite, may be new protozoan genus and species	Chinook and Atlantic salmon, brown and rainbow trout	causes severe anemia/ lymphocytosis, affects kidney, spleen	none known	none known
Infectious Pancreatic Necrosis (IPN) (IPN Virus)	birnavirus, only causes clinical illness in young fish <6 months old	rainbow, brook, cutthroat trout, coho, Atlantic, kokanee salmon, Arctic char.	primarily causes necrosis of pancreatic acinar cells, organs such as liver may become necrotic	disinfection, quarantine, raise fish in SPF water for first 6 months of life	mortality most rapid at water temperatures of 50° to 57°F, less mortality below and above this range

9.0 DESCRIPTION OF PROJECT OPERATIONS

The Oroville Facilities were developed as part of the State Water Project (SWP), a water storage and delivery system of reservoirs, aqueducts, power plants, and pumping plants. The main purpose of the SWP is to store and distribute water to supplement the needs of urban and agricultural water users in northern California, the San Francisco Bay area, the San Joaquin Valley, and southern California. The Oroville Facilities are also operated for flood management, power generation, to improve water quality in the Delta, provide recreation, and enhance fish and wildlife. The Oroville Project encompasses 41,100 acres and includes Oroville Dam and Reservoir, three power plants (Hyatt Pumping-Generating Plant, Thermalito Diversion Dam Power Plant, and Thermalito Pumping-Generating Plant), Thermalito Diversion Dam and Diversion Pool, the Feather River Fish Hatchery and Fish Barrier Dam and Fish Barrier Pool, Thermalito Power Canal, Oroville Wildlife Area (OWA), Thermalito Forebay and Forebay Dam, Thermalito Afterbay and Afterbay Dam, and transmission lines, as well as a number of recreational facilities. The Oroville Dam, along with two small saddle dams, impounds Lake Oroville, a 3.5-million-acre-feet (maf) capacity storage reservoir with a surface area of 15,810 acres at its normal maximum operating level.

The hydroelectric facilities have a combined licensed generating capacity of approximately 762 megawatts (MW). The Hyatt Pumping-Generating Plant is the largest of the three power plants with a capacity of 645 MW. Water from the six-unit underground power plant (three conventional generating and three pumping-generating units) is discharged through two tunnels into the Thermalito Diversion Pool just downstream of Oroville Dam. The plant has a generating and pumping flow capacity of 16,950 cfs and 5,610 cfs, respectively. Other generation facilities include the 3-MW Thermalito Diversion Dam Power Plant and the 114-MW Thermalito Pumping-Generating Plant.

Thermalito Diversion Dam, four miles downstream of the Oroville Dam creates a tail water pool for the Hyatt Pumping-Generating Plant and is used to divert water to the Thermalito Power Canal. The Thermalito Diversion Dam Power Plant is a 3-MW power plant located on the left abutment of the Diversion Dam. The power plant releases a maximum of 615 cubic feet per second (cfs) of water into the Fish Barrier Pool.

The Power Canal is a 10,000-foot-long channel designed to convey both generating flows of 16,900 cfs to the Thermalito Forebay and pumping flows of 9,000 cfs to the Hyatt Pumping-Generating Plant. The Thermalito Forebay is an off-stream regulating reservoir for the 114-MW Thermalito Pumping-Generating Plant. The Thermalito Pumping-Generating Plant has generating and pumping flow capacities of 17,400 cfs and 9,120 cfs, respectively. When in generating mode, the Thermalito Pumping-Generating Plant discharges into the Thermalito Afterbay, which is contained by a 42,000-foot-long earth-fill dam. The Afterbay is used to release water into the Feather River downstream of the Oroville Facilities, helps regulate the power system, provides storage for pump-back operations, and provides recreational opportunities. Several local irrigation districts receive water from the Afterbay.

The Feather River Fish Barrier Dam is downstream of the Thermalito Diversion Dam and immediately upstream of the Feather River Fish Hatchery. The flow over the dam maintains fish habitat in the low-flow channel of the Feather River between the dam and the Afterbay outlet, and provides attraction flow for the hatchery. The hatchery was intended to compensate for spawning grounds lost to returning salmon and steelhead from the construction of Oroville Dam.

9.1 General Project Operational Constraints

Operation of the Oroville Facilities varies seasonally, weekly and hourly, depending on hydrology and the objectives DWR is trying to meet. Typically, releases to the Feather River are managed to conserve water while meeting a variety of water delivery requirements, including flow, temperature, fisheries, recreation, diversion and water quality. Lake Oroville stores winter and spring runoff for release to the Feather River, as necessary for project purposes (water delivery, power generation, flood protection, fish and wildlife enhancement, and recreation). Ordinarily, power is generated when water releases are being made for these other purposes. Power is not generated when deliveries are being made to local irrigation districts at the Afterbay, or when pump-back operations are in effect. Annual operations planning is conducted for multi-year carry over, in which half of the Lake Oroville storage above the minimum pool is assumed available for subsequent years. The operations plan is updated regularly to reflect changes in hydrology and downstream operations. Typically, Lake Oroville is filled to its maximum annual level of up to 900 feet above mean sea level (msl) in June and then can be lowered as necessary to meet downstream requirements, to its minimum level in December or January. During drier years, the lake may be drawn down more and may not fill to the desired levels the following spring. Daily project operations are directly constrained by downstream operational constraints and flood management criteria as described below.

9.2 Downstream Operation

An August 1983 agreement between DWR and DFG entitled, "Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish & Wildlife," sets criteria and objectives for flow and temperatures in the low flow channel and the reach of the Feather River between Thermalito Afterbay and Verona. This agreement: (1) establishes minimum flows between Thermalito Afterbay Outlet and Verona which vary by water year type; (2) requires flow changes under 2,500 cfs to be reduced by no more than 200 cfs during any 24-hour period, except for flood management, failures, etc.; (3) requires flow stability during the peak of the fall-run Chinook salmon spawning season; and (4) sets an objective of suitable temperature conditions during the fall months for salmon and during the later spring/summer for shad and striped bass. In addition, a Biological Opinion issued by the National Marine Fisheries Service (NMFS) on interim operations of the Central Valley Project and State Water Project (of which Oroville is a part) for 2002 through 2004 sets water temperature criteria for the Feather River.

9.3 Instream Flow Requirements

The Oroville Facilities are operated to meet minimum flows in the Lower Feather River as established by the 1983 agreement (referenced above). The agreement specifies that Oroville Facilities release a minimum of 600 cfs into the Feather River from the Thermalito Diversion Dam for fisheries purposes. This is the total volume of flows from the diversion dam outlet, diversion dam power plant, and the Feather River Fish Hatchery pipeline. This 600 cfs makes up the flow of the Feather River from the Fish Barrier Dam to the Afterbay Outlet, this section of river is often referred to as the low flow section.

Generally, the instream flow requirements below Thermalito Afterbay are 1,700 cfs from October through March, and 1,000 cfs from April through September. However, if runoff for the previous April through July period is less than 1,942,000 acre-feet (af) (i.e., the 1911-1960 mean unimpaired runoff near Oroville), the minimum flow can be reduced to 1,200 cfs. A maximum flow of 2,500 cfs is maintained from October 15 through November 30 to prevent spawning in overbank areas that might become de-watered.

9.4 Temperature Requirements

The Diversion Pool provides the water supply for the Feather River Fish Hatchery. This facility is managed to meet several water temperature objectives for the hatchery. These operations include releases from the Hyatt Power Plant and pump-back operations from the Thermalito Complex. The hatchery objectives are 52°F for September, 51°F for October and November, 55°F for December through March, 51°F for April through May 15, 55°F for last half of May, 56°F for June 1-15, 60°F for June 16 through August 15, and 58°F for August 16-31. A temperature range of plus or minus 4°F is allowed for objectives, April through November.

There are several temperature objectives for the Feather River downstream of the Afterbay Outlet. During the fall months, after September 15, the temperatures must be suitable for fall-run Chinook salmon. From May through August, they must be suitable for shad and striped bass, as well as Chinook salmon.

The NMFS Interim Biological Opinion (September 20, 2002) sets temperature requirements for water year 2002 through 2004. This Biological Opinion requires that daily average water temperatures do not exceed 65°F from June 1 to September 30 at the end of the low flow channel (Pers. comm. Bruce Oppenheim, NMFS 2003). The water temperature objectives sometimes conflict with temperatures desired by agricultural diverters. A May 1969 agreement between DWR and Joint Water Districts obligates DWR to provide water for production within the Joint Water District service area. DWR attempts to accommodate these needs by releasing water that is as close as possible to the maximum temperature allowable under the DFG-DWR agreement (i.e., 4°F higher than the hatchery objectives stated above). During the previous two years the temperature requirements of the 2002 Interim Biological Opinion have been met (Pers. comm. Bruce Oppenheim, NMFS 2003).

9.5 Water Diversions

Monthly irrigation diversions of up to 150,000 af are made from the Thermalito Complex during the May through August irrigation season. Total annual diversions are slightly less than 1 maf, leaving on average about 3 maf for flow in the Feather River downstream of the Oroville Facilities. Flows into the lower Feather River continue into the Sacramento River and into the Sacramento-San Joaquin Delta. In the northwestern portion of the Delta, water is pumped into the North Bay Aqueduct. In the south Delta, water is diverted into Clifton Court Forebay where the water is stored until it is pumped into the California Aqueduct.

9.6 Water Quality

Flows through the Delta are maintained to meet Bay-Delta water quality standards arising from DWR's water rights permits. These standards are designed to meet several water quality objectives such as those addressing dissolved oxygen, salinity, Delta outflow, river flows, and export limits. The purpose of these objectives is to attain the highest water quality, which is reasonable, considering all demands being made on the Bay-Delta waters. In particular, they protect a wide range of fish and wildlife including fall-run salmon, Delta smelt, striped bass, and the habitat of estuarine-dependent species.

9.7 Flood Management

The Oroville Facilities are an integral component of the flood management system for the Sacramento Valley. During the wintertime, the Oroville Facilities are operated under flood management requirements specified by the U.S. Army Corps of Engineers (USACE). Under these requirements, Lake Oroville is to be operated to maintain up to 750,000 af of storage space to allow for the capture of significant inflows. Flood management releases are based on the release schedule in the flood control diagram or the emergency spillway release diagram, whichever requires the greater release. Decisions regarding such releases are made in consultation with the USACE.

The flood management requirements are designed for multiple use of reservoir space. During times when flood management space is not required to accomplish flood management objectives, reservoir space can be used for storing water. From October through March, the maximum allowable storage limit varies from about 2.8 to 3.2 maf to ensure adequate space in Lake Oroville to handle flood flows. The actual limit is based on a wetness index, computed from accumulated basin precipitation. This allows higher levels in the reservoir when the prevailing hydrology is dry while maintaining adequate flood protection. When the wetness index is high in the basin (i.e., wetness in the watershed above Lake Oroville), the flood management space required is at its greatest amount to provide the necessary flood protection. From April through June, the maximum allowable storage limit is increased as the flooding potential decreases, which allows capture of the higher spring flows for use later in the year. During September, the maximum allowable storage decreases again to prepare for the next flood season. During flood events, actual storage may encroach into the flood reservation zone to prevent or minimize downstream flooding along the Feather River.

10.0 POTENTIAL PROJECT EFFECTS ON FISH DISEASES

As is depicted in Figure 1, multiple environmental factors acting alone or synergistically with other factors influence a fish's susceptibility to disease. Most fish are hardy in the wild but can become more susceptible to disease when reared in high-density culture conditions (Plumb 2002). Poor water quality can produce chronic stress in fish and can potentially lower the fish's tolerance to disease (Plumb 2002). Water quality and environmental pollutants can directly influence the transmittal of fish diseases. Factors that influence water quality often involve several distinct human activities in a localized area and may require broad management in order to improve water quality conditions. In addition, changes in any one environmental factor may have different effects on specific pathogens. For example, while warmer water temperatures may increase the prevalence of ceratomyxosis, warmer water temperatures also may inhibit IHN. At this time, it appears that disease outbreaks in Project waters have been primarily associated with stocked hatchery fish. Disease outbreaks in stocked hatchery fish may have had more to do with the species and stock origin, with respect to using stocks with low natural resistance to endemic diseases, rather than poor water quality conditions. However, the cause of specific disease outbreaks in Project waters is poorly understood. The following analysis is preliminary. Several studies not yet complete will provide additional data which will be used to further evaluate the potential Project effects on fish diseases in Project waters with respect to water quality, water temperature, and flow impacts potentially caused by Project operations. Data are anticipated from the following studies.

? SP-F3.1 Project Effects on Fish and their Habitat (Task 1A Migration barrier assessment - Lake Oroville tributaries)

? SP-E1/3, Oroville Reservoir Thermal Model (to Sacramento River) (ongoing, results not likely available until 2004).

? SP-F5/7, Effects of Fisheries Management on Project Fisheries (expected to be complete in December 2003).

? SP-F10, Evaluation of Project Effects on Salmonids and Their Habitat in the Feather River Below the Fish Barrier Dam (expected to be complete in December 2003).

? SP-W1, Project Effects on Water Quality Designated Beneficial Uses.

? SP-F15, Evaluation of the Feasibility to Provide Passage for Anadromous Salmonids Past Oroville Facilities Dam (expected to be complete in December 2003).

10.1 Fish Hatcheries

10.1.1 FRH and Thermalito Annex Facility Overview

The Feather River Fish Hatchery, completed in 1967, was built to compensate for spawning grounds that were lost to salmon and steelhead after the closing of Oroville Dam. Each year, approximately 9,000 to 18,000 salmon and 2,000 steelhead are artificially spawned, a process which produces 18 to 20 million eggs. Salmon and steelhead raised at the hatchery are transported for release in the Feather and Sacramento rivers, in Lake Oroville and other California reservoirs, and in San Pablo Bay north of San Francisco Bay. These fish contribute to the ocean sport and commercial catch of Chinook salmon in the Pacific Ocean and in California's anadromous and inland waters. The facility is operated by the CDFG and maintained by DWR.

The primary purpose of the hatchery is to compensate for the loss of spawning habitat in the Feather River for two Chinook salmon stocks (the spring and fall runs) and steelhead/rainbow trout. This mitigation is particularly important now since the spring-run Chinook salmon and steelhead are listed as threatened under the federal Endangered Species Act. The fall-run Chinook salmon is a candidate species. In addition, the Feather River Fish Hatchery has assumed six additional important functions. The Feather River Fish Hatchery provides for:

1. Juvenile Chinook salmon for release in San Pablo Bay under CDFG's Ocean Enhancement Program;

2. Coho salmon rearing for planting in Lake Oroville;

3. Juvenile Chinook salmon for planting into other Northern California reservoirs as part of the Inland Chinook Salmon Program;

4. Steelhead for stocking the Feather River as part of the Delta Pumps Fish Protection Agreement;

5. Chinook salmon eggs for the Mokelumne River Fish Facility; and

6. Juvenile Chinook salmon used in various studies, leading to a better understanding of salmon life history and management.

The Thermalito Annex was constructed in 1984 to provide a rearing facility with warmer water than the main FRH area, in order to reduce FRH Chinook salmon losses from IHNV. With the successful use of iodophore egg disinfection in the early 1990's, IHNV was controlled in the main FRH area so the Annex was used primarily as an extension facility for FRH production. The Annex was again used for IHNV control during the recent period of outbreaks at the FRH, which began in 2000. It is anticipated that these IHNV epizootics will decline over the next year or two as a result of the 2001 cessation of Chinook salmon stocking in Lake Oroville. The Annex enhances the overall effectiveness of the FRH in rearing salmonids, when not used to specifically address IHNV problems, the increased raceway space can be used to reduce overall fish density at the FRH which results in reduced stress, enhanced growth, and generally fewer disease problems. In addition, the warmer water can reduce the probability of outbreaks of other (besides IHNV) diseases that are more virulent in colder waters, such as BKD and cold water disease. As an example, the coho salmon that are currently stocked in Lake Oroville are reared in these raceways for a portion of the year in order to limit the chance of a BKD outbreak.

10.1.2 Sacramento Basin Hatchery Releases

As summarized in Table 5, many hatchery facilities (including FRH) exist in the Sacramento River basin and release millions of salmonids each year in a variety of locations.

Table 5. Summary of current hatchery releases in the Feather River basin (Pers. comm. Armando Quinones, CDFG 2003 and Stephen Brightwell, CDFG 2003).

Hatchery	Species Run	Production Goal	Release Location
American River	rainbow trout	1,550 lbs catchable trout	Middle Fork Feather R.
American River	rainbow trout	6,400 lbs catchable trout	North Fork Feather R.
American River	rainbow trout	15,500 lbs catchable trout	Thermalito Forebay
Crystal Lake	brook trout	5,200 lbs catchable trout	Thermalito Forebay
Feather River	fall Chinook salmon	12,000,000 eggs reared to smolt	San Pablo Bay
Feather River	spring Chinook salmon	7,000,000 eggs reared to smolt	San Pablo Bay
Feather River	Steelhead	450,000 yearlings	Feather R.
Feather River	coho salmon	300,000 eggs reared to smolt	Lake Oroville

10.1.3 Effects of FRH On Significant Diseases

Although most fish diseases originate (Oliver 2002) and/or are maintained by wild fish host and reservoir species (Amos and Thomas 2002) they are not easily observed or detected in the wild. The operations and environment of fish cultural facilities allow for full disclosure of disease presence because symptomatic fish and mortalities are protected from predators and therefore are easily observed. Disease management is a normal component of every aquaculture program. All hatcheries in the Sacramento River basin have a history of active fish health management programs and, as summarized previously in Table 3, have a variety of diseases present. In addition, all of these hatcheries release millions of fish in a wide variety of locations throughout the basin.

Currently, the FRH employs best management practices and protocols to avoid the spread of diseases from the hatchery. At the FRH some disease concerns have been addressed by the installation of an ultra violet treatment system, modifications to the stocking of Lake Oroville, periodic pathological testing, as well as prescribed use of therapeutic treatments. The FRH has been successful in adaptively managing disease concerns as they arise and has continued to operate productive and successful hatchery programs.

In California IHNV is present in Central Valley and Trinity River anadromous salmonids, IHNV was once common in cultured fish in California, but since the statewide adoption of egg disinfection with iodophor solutions (~1990) has rarely been seen in hatcheries. The specific strains of IHN found in California have been isolated from Chinook salmon and typically have not been transmitted to steelhead (Pers. comm. Scott Foott, USFWS California-Nevada Fish Health Center 2002). In the mid- to late-1990s, two unique strains of IHN, FR type I and II, were isolated from adult Chinook salmon returning to the Feather River Hatchery (Pers. comm. Dr. Bill Cox, CDFG 2003). In 2000, DWR fisheries biologists observed Chinook salmon that were symptomatic of IHN while conducting a snorkeling survey between the Feather River Hatchery and Live Oak and collected wild Chinook salmon that tested positive for FR Type II. It was suspected that either this strain of IHN was extremely virulent or that heavy stocking of Chinook salmon in Lake Oroville was resulting in conditions that allowed for amplification of the virus. The lake was managed for Chinook salmon and brown trout from 1992 through 2000 (DWR 2000). The stocking of Chinook salmon and brown trout in Lake Oroville was dramatically reduced in 2000 and completely eliminated in 2001 due to the detection of virus positive adult Chinook salmon in the lake and concerns for hatchery and wild salmonids below the lake. Coho salmon were stocked in 2002 as a replacement for Chinook salmon and brown trout, as coho salmon are less susceptible to IHN. In 2001, FR Type II was isolated from juvenile steelhead at Feather River Hatchery (Pers. comm. Dr. Bill Cox, CDFG 2003).

Although the FR Type II infection in some wild fish was speculated to be caused by heavy stocking of Chinook salmon in the lake, the available evidence regarding transmission of IHN primarily suggest that wild fish populations are the natural hosts and reservoirs of infection and that there is not high risk of IHN transmission from hatchery to wild fish populations (Amos and Thomas 2002). This was recently confirmed for the Nimbus strain of IHN found at Coleman National Fish Hatchery in the upper Sacramento River basin (Foott et al. 2000). The virulence and transmissibility of the FR Type II infection are not known but are currently under investigation as a component of SP-F9.

The pathogen, *C. shasta*, is also endemic to the Sacramento River basin. Local salmonid stocks have co-evolved with this pathogen and show varying degrees of resistance. The FRH has experienced periodic fish losses due to *C. shasta*, although steelhead can be successfully held at the FRH on untreated water without incidence of disease (Pers. comm. Anna Kaster, CDFG 2002). To help control mortality from ceratomyxosis, the FRH uses an ultra violet water treatment system on four of its raceways. In one episode, FRH experienced steelhead and rainbow trout losses to *C. shasta* when fish at the Thermalito Annex were held on Afterbay water (Pers. comm. Dr. Bill Cox, CDFG 2003). It is possible that ceratomyxosis outbreaks that have occurred at FRH were related to amplification of *C. shasta* in rearing waters due to the stocking of susceptible salmonid species and stocks in the Thermalito Forebay and Lake Oroville tributaries.

On the other hand, because *C. Shasta* is found naturally in the Feather River, native salmonids exhibit some natural resistance to ceratomyxosis. Thus, the risk of C. shasta transmission to fish populations in the Feather River below FRH is minimal. There is some potential for change in water temperature and/or water quality in the Lower Feather River due to FRH operations; however, this effect is suspected to be minor. Results from SP-E1/3, SP-5/7, and SP-W1 will provide further data to evaluate FRH impacts on water temperature and water quality, which could impact disease outbreaks.

10.2 Thermalito Complex

Pumpback operations in the Thermalito Complex are generally thought to warm Project waters during the May through August irrigation season. This may have reduced the incidence of IHN, which is limited by warmer water, but may be favorable to ceratomyxosis, which is more common in warmer temperatures. However, this mechanism is poorly understood in the Project waters. Currently, It is unknown if pathogens can survive water temperature and water quality changes between the Thermalito Forebay and Lake Oroville. Diseases are normally temperature specific and can only infect certain fish species. Some fish species and stocks are more resistant to particular disease. Some pathogens like *C. Shasta* and *M. cerebralis* require intermediate hosts to complete their life cycle. At this point, it is unclear if these supporting factors exist within the Thermalito Complex and allow disease transmission from the Forebay and Afterbay to Lake Oroville to occur, and vise versa. It is also unclear whether project operations, such as pumpback, affect disease transmission or outbreaks. As was mentioned under the FRH discussion, it may be that outbreaks of ceratomyxosis observed at FRH were related to stocking of susceptible salmonid stocks. Interaction with FRH, increased water temperature in the Thermalito Complex, and stocking of nonresistant rainbow trout in the Thermalito Complex could result in disease amplification at the FRH and might increase risk of transmission to salmonids rearing downstream. The SP-E1/3 is currently underway and is expected to provide additional information on temperature impacts in the Thermalito Complex. This information will be reviewed, compared with the pathogen temperature requirements listed in Table 7, and incorporated into this section of this report when available.

Table 6. Temperature conditions favorable to managed and non-managed fish diseases present in the study area; Noga (2000), Plumb (2002), Woo and Bruno (1999).

Disease	Pathogen	Active Temperature Range (°F)	Temperature Conditions Favorable to Disease
BKD	*Renibacterium salmoninarum*	41° to 77°F	Optimum temperature is at 59° to 64°F and does not grow at 77°F.
Ceratomyxosis	*Ceratomyxa shasta*	39° and higher	The infection progresses faster at higher temperature. Fish can be infected at 39° to 43°F. Mortality occurs when the water temperature is greater than 50°F.
Cold Water Disease	*Flavobacterium psychrophilum*	41° to 65°F	The disease exist at 65°F or less and becomes severe at about 60°F.
Columnaris	*Flavobacterium columnare*	50° to 90°F	The disease is common in salmonids at temperatures above 59°F. The disease progresses faster at higher temperature.
Enteric Red Mouth	*Yersinia ruckeri*	49° to 99°F	Higher mortality at temperatures greater than 50°F.
Epistylis	*Epistylis sp.*	No specific temperature	Commonly occurs during warmer months.
Furuncululosis	*Aeromonas salmonicida*	Below 55°F	Chronic cases usually occur at temperatures below 55°F. Latent cases may develop during low temperature periods.
Gill Maggot Disease	*Salmincola californiensis*	No specific temperature	Copepod development is more rapid at warmer temperatures.
Ichthyobodo (Costia)	*Ichthyobodo necator (formerly: Costia necatrix)*	36° to 86°F	Can exist at a wide range of water temperatures.
IHN	IHNV	Below 59°F	The disease is severe at 50°F. Outbreaks are rare when the temperature is above 59°F.
IPN	IPNV	50° to 59°F	Most severe at 50° to 57°F and reduced at lower temperatures. Less mortality above 57°F.
Lymphocystisvirus	Iridovirus	No specific temperature	Progresses faster at higher temperature.
PKD	*Tetracapsula bryosalmonae*	No specific temperature	Highest mortality at water temperature of about 54° to 57°F.
Rosette Agent	Undescribed	Little is known	Little is known.
Sturgeon Herpes Type 2	White Sturgeon Herpes Virus Type 2 (WSHV-2)	41°F to 77°F	Cease to grow when temperature is less than 41°F and more than 77°F.
Whirling Disease	*Myxobolus cerebralis*	45° to 60°F	Progresses faster at higher temperature, clinical signs appear to be more evident at 63°F. Spores can survive in frozen fish over 3 months at - 4°F.
White Spot Disease	*Ichthyopthirious multifilis*	39°F to 86°F	Commonly occurs at warmer temperatures. Can infect salmonid or coldwater fish at as low as 39°F. Slow growth at water temperature of less than 50°F, temperatures above 86°F are fatal for the pathogen.

10.3 Lake Oroville

Lake Oroville becomes thermally stratified in the spring, this breaks down in the fall and the lake remains uniform during winter months. The reservoir supports both coldwater and warm water fish species. The coldwater fish use the deeper and cooler hypolimnion, whereas the warmwater fish use the warmer and shallower epilimnetic and littoral zones. When the lake becomes uniform, both coldwater and warm water fish can mix in their habitat utilization. The combination of mixing fish species, stocking of fish species susceptible to disease, water quality conditions, and elevated water temperature in the summer may increase the potential for disease outbreaks in Lake Oroville. However, FRH has discontinued stocking Chinook salmon in Lake Oroville due to disease concerns and plans to stock coho salmon, which have low susceptibility to IHN, although, some coho salmon stocks are susceptible to ceratomyxosis. SP-E1/3, SP-W1, SP-F15, and SP-F3.1 are currently underway. We anticipate that these studies will provide additional information on potential temperature, flow, and water quality impacts arising form Project operations that may affect disease outbreaks in Lake Oroville. This information will be reviewed and incorporated into this section of this report when available.

10.4 Lower Feather River

Current information provides no evidence to suggest that disease outbreaks or disease-related fish kills have ever occurred downstream of the project. Moreover, fish that were captured at the screw traps in the lower Feather River downstream of the Project did not indicate that captured fish were infected with significant diseases of concern (unpublished data). Stress is the main cause of fish mortality, and several stressors exist downstream of the project that potentially influence outbreak of fish diseases downstream. Environmental conditions, such as poor water quality, specific fish species present (host), and pathogen presence are among the factors that affect the spread of disease. Baseline information, such as the distribution of IHNV is lacking for the Feather River basin, although this information does exist for *C. Shasta* (Hendrickson et al. 1989). SP-E1/3, SP-W1, SP-F15, and SP-F4 are currently underway. We anticipate that these studies will provide additional information on potential temperature, flow, and water quality impacts arising form Project operations that may affect disease outbreaks in the Lower Feather River. This information will be reviewed and incorporated into this section of this report when available.

11.0 RECOMMENDATIONS

Based on literature review and current understanding of Project operations, the following actions are recommended to minimize the potential for Oroville Project operations to impact fish diseases.

1. Evaluate potential effects of stocking *C. shasta* susceptible rainbow trout in the Thermalito Complex on ceratomyxosis outbreaks in Project waters.

2. Evaluate potential effects of water temperature and water quality on fish disease outbreaks in Project waters when data becomes available.

3. An evaluation of disease impacts should be included as a component of any proposed management action that would result in rearing salmonids in the Feather River above the FRH hatchery intake. Potential actions such as fish stocking, reintroduction of salmonids, establishing fish passage and salmon carcass supplementation above Lake Oroville should be evaluated to determine if these actions have the potential to amplify IHNV or *C. shasta* downstream in Lake Oroville, the Thermalito Complex, and the FRH.

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