

DISEASE INTERACTIONS BETWEEN WILD AND CULTURED SALMONIDS

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PROJECT OBJECTIVES

1. Identify and collect data on the fish health of natural populations of fish in western states, with particular reference to the states of Idaho, Montana, Wyoming, Colorado, Utah, Nevada, Arizona, Washington, Oregon, and California.
2. Examine and evaluate the database for completeness and extent and determine correlations among historical data using time series analysis. Choose appropriate techniques for analysis.
3. Prepare preliminary maps of the distribution of salmonid pathogens and identify geographic areas to be studied in future surveys.
4. Develop deterministic models of the dynamics of disease/pathogen presence in wild salmonid populations and design risk assessment models for the likelihood of pathogen transmission between wild and cultured fish.

ANTICIPATED BENEFITS

No one has previously compiled the reported historical data on presence of pathogens in populations of free ranging and cultured salmonids on a large geographic scale. Retrieval of these data is an important first step to understanding the dynamics of fish diseases, and the interactions among wild and cultured fish. By examining the strengths and weakness of existing data, and posing conceptual models for the important pathogens, we will identify data sets that are complete enough to model epidemiology, and begin to estimate the risks of transmission between free ranging and cultured fishes. By this process we will determine the additional data needs for research and monitoring of pathogens to better understand the risks that fish diseases and their potential transmission pose to the aquaculture industry and to the natural resources communities. Finally, these scientific based models and presentations of data will help the regulatory community to review and propose better methods for protecting and regulating the aquaculture industry and natural resource community.

PROGRESS & PRINCIPAL ACCOMPLISHMENTS

Responsibilities for collection and analysis of data from western states are divided into two regions for this project: Arizona, California, Nevada, Oregon and Washington are the responsibility of Oregon State University (OSU); and Idaho, Montana, Wyoming, Colorado and Utah are the responsibility of University of Idaho (U of I). In April 1999, graduate student Dr. Tim Miller-Morgan, began work on the OSU portions of the project. Tim is a PhD candidate in the College of Veterinary Medicine and comes to the project with a strong background in fish health, and interest and background in epizootiology. Steven Intelmann, MS student at the U of I began the project in January 1998.

Staff at OSU and U of I have worked independently to collect data, and we have met to discuss progress and plans on several occasions. In February 1999, participants attended the annual Whirling Disease Workshop in Missoula, MT, and the two principal investigators and Intelmann discussed standardization of methods. Reno and Miller-Morgan visited the U of I on separate occasions to see the GIS facilities, and review progress. In June, all researchers attended the AFS Fish Health Section meeting in Twin Falls ID and Intelmann and Moffitt presented a poster presentation of preliminary results of *Myxobolus cerebralis* in two drainages in Utah.

Objective 1. Identify and collect data on the fish health of natural populations of fish in western states.

The data collection is nearly completed. At OSU, data from wild and cultured salmonids were collected during 1998 from the US Fish and Wildlife Service (USFWS) Region 2 (AZ, NM, TX), California Dept of Fish & Game, Nevada Dept of Fish & Wildlife, Cal-Nev Fish Health Center (USFWS). Reno and Miller-Morgan collected fish health data on the bacteria, viruses, and parasites of salmonids from the Oregon Department of Fish & Wildlife (ODFW); USFWS, Region 1; Washington Department of Fish & Wildlife (WDFW). These data were substantive (>20,000 records) and were primarily in digital format. In addition, data from the semiannual fish health surveys presented to the Pacific Northwest Fish Health Protection Committee (agencies and participating tribes in Oregon, Washington, Idaho, Montana, Alaska, and private facilities via the Idaho Aquaculture Association) for 1989–1999 were collected and entered into a Filemaker Pro database. Dissertation abstracts and the thesis holdings at Oregon State University libraries have been searched, (especially the library at Hatfield Marine Science Center which has more than 25 theses from OSU students) for those related to fish health.

At U of I, data collections from 1998 were supplemented with additional travel. In 1999, Intelmann made follow up visits to the Montana Department of Fish, Wildlife, and Parks, the Wyoming Department of Fish and Game, and the USFWS laboratory in Bozeman, to obtain spatial coordinates for data collected from these labs during the previous summer. During this same trip, Intelmann also met with project industry advisor Peter Walker and spent a week collecting records from the Colorado Division of Wildlife's fish health laboratory in Brush, CO. The records obtained from Colorado were in paper and were copied at the lab and are currently being entered into an electronic database. Locations of sampling sites were obtained during visits to the laboratory.

In 1999, data were obtained from Dworshak National Fish Health Lab to supplemental records on pathogen screening in Idaho. Unfortunately a majority of the historical records had been discarded from the laboratory, however, data describing thorough disease inspections were obtained for three private facilities and for the three national hatcheries in Idaho from the mid 1980's.

USEFULNESS OF FINDINGS

Although in its early stage, this project will benefit the aquaculture communities and fish regulatory agencies. This effort assesses the extent of historical information on pathogens of salmonid fish in the western states. Once compiled, it can serve as a resource for others. We have already been contacted by researchers at Colorado State University who were contracted to compile a database on pathogens of wild fish for the USFWS. We will use our database to model factors affecting the transmission of infectious agents and to better predict the risks of disease transmission within and between regional water-

sheds.

Objective 2. Examine and evaluate the database for completeness and extent.

In fall of 1998, student Intelmann defined a digital database structure compatible with project goals and began to enter data collected from the Wyoming Department of Fish and Game, Montana Department of Fish, Wildlife, and Parks, and the USFWS laboratory in Bozeman, MT. Data from digital databases obtained from Utah Division of Wildlife, and the Idaho Department of Fish and Game were manipulated from their original software formats and transferred into this new defined database structure.

The final data set from Utah includes 3,543 records from 11 state hatcheries, two federal hatcheries, 50 private hatcheries or ponds, and from approximately 200 locations in the streams and rivers. In Montana, we obtained 3,628 pathogen records with the oldest records from 1961. Records were obtained from ten state fish hatcheries, three national hatcheries, and 33 private hatcheries or ponds in Montana. In addition, data were obtained from over 300 locations in Montana from free-ranging fishes. We obtained 2,773 individual records from 14 state hatcheries, 2 national fish hatcheries, 15 private hatcheries or ponds, and over 160 locations in the wild from Wyoming. We have not completed the entry or screening for Colorado.

At OSU all data collected except for approximately 1/3 of WDFW data (6,000 of 18,000 records) and 1/3 of California data (500/1500 records) have been entered into or databases. Paper and digital records have been examined for completeness and validity of the data. With the exception much of the WDFW hatchery data, all longitude and latitude locations were gathered from computer or paper topographic maps. Some locations need further refining, interviews of participants of collections are being interviewed and GIS tools are being used to assist with defining locations of some collections of fish. Investigations have begun to obtain information on stocking of fish for areas of interest.

Objective 3. Prepare preliminary maps of the distribution of salmonid pathogens and identify geographic areas to be studied in future surveys.

In the fall of 1998, we began to map the sampling distributions of the important pathogens in Utah. Mapping efforts initially focused on the Utah dataset since spatial coordinates describing the sampling distributions were readily available, thereby allowing prototype maps to be created using GIS software with ease. The thoroughness of the Utah data set also allowed us to further refine our database structure and provided us with a opportunity to finalize the mapping projection that would also be used in mapping the sampling distributions for the other states as well. In Utah a few records from the Springville NFH (now a part of the Springville SFH system) in the 1950s, however the majority of the records were from the late 80s and 90s in Utah. Most of the samples from free-ranging fish populations were examinations for *Myxobolus cerebralis*, and a handful of these were sites of brood stock programs. Few sites have consistent yearly sampling. With the exception of *M. cerebralis*, no important pathogens were described in free-ranging fishes in Utah. Some samples from free-ranging fishes were positive for infectious pancreatic necrosis virus (IPNV), and these were from fish that had been stocked into Scofield Reservoir from the state's hatcheries that were experiencing outbreaks of IPNV. The state destroyed its hatchery populations, disinfected their systems and no recurrent outbreaks of IPNV have been reported since. *Renibacterium salmoninarum*, the causative agent of bacterial kidney disease, was detected in 1996 in at the Jones' Hole National Fish Hatchery near Vernal, at three private facilities throughout the state on various dates, and in a small population of captive wild Lahontan cutthroat trout that were being held by a state biologist in a small pond for potential population enhancement in western Utah. The program was terminated after subsequent isolations of the organism in these fish. Infectious hematopoietic necrosis virus (IHNV) was isolated each year from 1983-1988 from three separate private facilities being leased by one individual in the Cache Valley area of northern Utah. Stocks were eventually destroyed and the facilities disinfected and subsequent outbreaks have not occurred since, however the

main facility is no longer participating in commercial aquaculture, but has instead initiated a fee fishing operation.

In Montana, we obtained 3,628 pathogen records, with the oldest records from 1961. Records were obtained from ten state fish hatcheries, three national hatcheries, and 33 private hatcheries or ponds. In addition, data were obtained from over 300 locations in the state from free-ranging fishes. As with Utah, the majority of the free-ranging samples were examined for *M. cerebralis* in the mid to late 90s after discovery of the parasite in the Madison River. *M. cerebralis* has been found in many watersheds throughout western Montana as well as in three private fishing ponds. One small statewide survey was conducted for *R. salmoninarum* in 1993 and again in 1997 using the ELISA (Pascho et al) as the diagnostic method. These surveys revealed widespread presence of antigen of *R. salmoninarum* in most samples, but most absorbances were low. No outbreak of bacterial kidney disease has been reported in free-ranging fishes in Montana. A survey of golden trout (*Oncorhynchus aquabonita*) populations in high mountain lakes found *Yersinia ruckerii*. Pathogen inspections of brood stock from several locations in Montana report isolations of *Aeromonas salmonicida* and *Yersinia ruckerii*. Infectious hematopoietic necrosis virus (IHNV) was isolated in 1979 in free-ranging rainbow trout (*Oncorhynchus mykiss*) at one location, however the virus was also isolated at a private hatchery in that same stream system ten years earlier and the year following this isolation. The infectious pancreatic necrosis virus (IPNV) was isolated at two state hatcheries, one federal hatchery, two private facilities, and from fish from two small lakes in Montana in the early 60s. The virus was isolated in free-ranging brook trout (*Salvelinus fontinalis*) in the water supply at the Jocko River SFH in 1983, however it was never isolated from the hundreds of fish that were examined within the hatchery system itself. In general, IPNV isolations have been very rare in Montana. The proliferative kidney disease organism was rarely screened for in hatchery inspections. PKD was found on two occasions in free-ranging fish in Montana: in rainbow trout taken from Cherry Creek in 1995 (in which a concurrent infection with *M. cerebralis* was determined in one fish); and in 1990 from cutthroat trout (*Oncorhynchus clarkii*) in Middle Creek Reservoir. The records indicated that the last stocked fish were from the Giant Springs SFH in 1947.

In Wyoming, *Y. ruckerii* was detected at three state hatcheries, one national hatchery, two private facilities, and two locations in samples from free-ranging fish. *R. salmoninarum* was detected at three state hatcheries, two federal facilities, and in two separate areas from free-ranging fishes within the state. An active epizootic of bacterial kidney disease occurred in wild brook trout in the French Creek and Brush Creek drainages in southeastern Wyoming from 1972-1978. Mitchum et al. (1979, 1981) conducted surveys in this area before actively depopulating the area and restocking the entire drainage in August 1979 with native cutthroat trout, which were thought to be less susceptible to bacterial kidney disease. However, *R. salmoninarum* was again isolated in this same area in 1981, 1985 and 1990 after this repopulation effort. Fish had been stocked into this system prior to the occurrence of the epizootic from a facility that had a history of bacterial kidney disease (Mitchum et al. 1979). Infectious pancreatic necrosis virus was detected one time in Wyoming in rainbow trout at one private hatchery that had received fish from a hatchery in Colorado where IPNV had previously been isolated (Wyoming Game and Fish Research Annual Report 1983). *M. cerebralis* has never been isolated in a hatchery in Wyoming. The parasite has been found in the Salt River drainage near the Idaho border, and in the Platte River drainage. First detections of *M. cerebralis* in Wyoming were linked to stocking of fish from a *M. cerebralis* positive hatchery in Colorado. *A. salmonicida* was isolated from numerous locations and on many dates. (Table 1; Figure 1). *A. salmonicida* appears to be resident in a few watersheds of the Snake River, and Green River sub-basins (around the Dubois SFH in west central Wyoming), and in the Platte River sub-basin in the southeastern portion of the state (Figure 1). Samples and isolations span over 30 years for some locations, with increasing sampling effort in more recent years (Figure 2). Brook trout and kokanee salmon (*Oncorhynchus nerka*) appear to be the most susceptible to *A. salmonicida* in Wyoming, with 67/5,238 and 49/3,387 fish testing positive for each species respectively (Figure 3). Similar tables and maps have been created for all of the important pathogens in Wyoming, Utah and Montana.

Objective 4. Develop models of the dynamics of disease/pathogen and design risk assessment models for the likelihood of pathogen transmission between wild and cultured fish.

We have examined the data from most states and are defining clusters of pathogens/diseases which would provide a basis for the modeling of risks of pathogen transmission between cultured and wild/feral fish. Focal points for pathogens and diseases found at various locations in the past which will lend themselves to more in depth investigation in the coming year for this project.

We have selected three criteria for optimizing the data in developing risk assessment models for selected pathogens.

Table 1. Summary of locations that tested positive for *Aeromonas salmonicida* (1953-1998) in Wyoming. Colored watershed boundaries are for Figure 1, and represent sub-basin areas with localized *A. salmonicida*. Value of one was entered for fish number when insufficient data were provided.

Site	Location	# Tested	#Pos	Years Positive
Auburn SFH	1	2,216	4	53
Boulder SFH	2	4,018	4	55, 56
Daniel SFH	3	3,325	4	54, 93
Dubois SFH	4	2,882	30	54–55, 57, 561–62, 83, 86–88, 90
Story SFH	5	4,400	4	93
Jackson NFH	6	4,148	3	60–62, 69
Saratoga NFH	7	5,548	4	61–61
Private Hatchery	A	2,983	19	96
Private Hatchery	B	666	4	97
Green River sub-basin	Yellow	4,300	66	55, 69, 91, 93–97
40 Rod Creek		1	1	55
Flaming Gorge Reservoir		835	3	91
Flume Creek		1,007	46	94–97
New Fork River		1	1	69
Soda Lake		2,456	15	93–97
Snake River sub-basin	Green	820	26	61, 86, 92–93, 95
Bar BC Spring Creek		86	2	95
Hoback River		2	2	61
Lake of the Woods		670	1	86
Three Channel Spring		62	6	92–93
Platte River sub-basin	Puple	181	20	56, 58, 61, 71, 73, 74, 78, 79, 84
Brush Creek Drainage		1	1	78
Douglas Creek		3	3	58, 79, 84
Leazenby Lake		1	1	56
Libby Creek Beaver Ponds		15	2	61
Little Laramie River		2	2	71,73
S. F. Little Laramie River		1	1	74
North Platte River		157	9	79
West Carrol Lake		1	1	61

SUPPORT (FOR BOTH UNIVERSITIES)

FISCAL YEAR	WRAC-USDA FUNDS	OTHER SUPPORT		TOTAL SUPPORT
		UNIVERSITY	INDUSTRY	
98	48,438	4,000		52,438

WORK PLANNED FOR NEXT YEAR

M. cerebralis (whirling disease, eukaryotic parasite). This pathogen is sporadically distributed in several states and enzootic at low levels in others. A prime area of interest is California/Nevada, where two scenarios seem to have occurred. In Nevada two facilities (NV has only 4 fish rearing facilities which simplifies the study) had perennial isolations of *M. cerebralis*, and fish from these sources were used to stock a number of sites in the state. These sites were subsequently tested for *M. cerebralis* with varying results. We will examine the stocking records and physical parameters of the sites to attempt to correlate them with pathogen presence. The second cluster involves one of the Nevada facilities with *M. cerebralis*. It is less than a km from the border with CA on the Truckee River. Sampling of fish from this river in both CA and NV has resulted in the widespread detection of the pathogen in this watershed. The river is relatively short and flows from Lake Tahoe northeastward into NV and terminates in Pyramid Lake. It is thus a closed system that should lend itself to further study. In OR we have the records of *M. cerebralis* sampling in both wild and cultured fish in the northeastern portion of the state from the 1960s. Our studies will follow a similar pattern to those in CA/NV. The lack of *M. cerebralis* in WA, bounded as it is on 2 sides by enzootic areas of *M. cerebralis*, is also interesting and we will approach this topic in terms of the probabilities of detecting the pathogen at the levels sampled at present and in the past (i.e., detection is predicated on adequate sampling regime). The large database from Utah, Colorado, Montana and Idaho all provide additional opportunities for comparisons within and between drainages.

b) Infectious pancreatic necrosis virus (IPN disease, virus). Unlike the case in the Eastern US and internationally, the presence of IPNV in the western US is, with few exceptions, localized. Our efforts will focus on determining the risk of dispersal of the pathogen from data collected from these states. In AZ, a facility on the Colorado River was found positive for IPN in the 1970s and subsequent sampling of fish up to 25 miles downstream indicated the presence of the virus. In CA feral fish downstream of a state facility were infected with the virus and apparently contaminated the facility with consequent catastrophic losses. In NV, a single facility (which also had M.c.) had stocked fish regularly into a number of lakes in western NV until 1980. We will evaluate the post stocking data to determine if the virus has survived in these populations of fish in closed waters. In OR a constrained outbreak of IPN disease occurred in several facilities in the 1970s. Fish from these facilities were stocked into several high mountain lakes in the Cascade Mountains. We will examine data from subsequent sampling to determine how long the virus was retained in the fish. Thus far, the only 2 locations in which IPNV appears to be enzootic are ID, where it is widespread, and at a single federal facility on the Columbia River. At the latter facility, virus abruptly appeared in summer steelhead trout broodfish in 1983 and has been detected in only this stock approximately biennially. We will contrast the situation in WA with that of ID to try to determine why the pathogen is widespread in one state and not the other. Interestingly, testing with monoclonal antibodies put the WA virus in a serotype identical to virus primarily isolated from ID fish.

A. salmonicida (furunculosis, bacterial). Overall, bacterial pathogens were enzootic at higher levels than with the parasites or virus groups. These studies will be more complicated by proximity of co-infected populations and ready transfer of the pathogen among populations. We have not as yet chosen specific sites for study of this pathogen because we are still in the process of evaluating the accrued

databases. Preliminary maps prepared for Wyoming illustrate the extent of positive isolations. Bacterial kidney disease may be too widespread to study easily. Further perusal of the data may indicate that enteric redmouth disease, caused by *Y. ruckeri*, will be a suitable subject for study since it also causes acute disease and is not as widespread as *R. salmoninarum*.

1. Study of clusters of disease/pathogens in localized geographic areas, especially in those situations in which a pathogen is perennially present at a site. These infected sites, either culture facilities or natural waters, could serve as foci for the potential dissemination of the pathogens.
2. Study of sites which have been monitored routinely, and at which a novel pathogen/disease suddenly appears. This situation would potentially allow the determination of the pathogen source and the subsequent effects on the fishing the local waters.
3. Study of sites which are positive for pathogen/disease and from which fish are disseminated, either naturally or anthropogenically, to other waters that have been subsequently sampled. This would allow us to evaluate whether the pathogen is maintained in the population or whether the transmission coefficient (R_0) is reduced to less than 1.0 and the pathogen is eliminated from the population.

In addition, we will focus on at least one pathogen from each of the broad categories of infectious agents affecting fish: viral, bacterial, and parasitic eukaryotes. Utilizing these criteria to begin our analysis of the accrued data we propose the following list of pathogen/locations or initial analysis and modeling efforts.

IMPACTS

Continued funding of this project will result in data bases and models for the aquaculture industry that will be useful to other sectors.

REFERENCES

- Mitchum, D.L., L.E. Sherman, and G.T. Baxter. 1979. Bacterial kidney disease in feral populations of brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), and rainbow trout (*Salmo gairdneri*). *Journal of the Fisheries Research Board of Canada* 36: 1370- 1376.
- Mitchum, D.L., and L.E. Sherman. 1981. Transmission of bacterial kidney disease from wild to stocked hatchery trout. *Canadian Journal of Fisheries and Aquatic Sciences* 38: 547-551.
- Wyoming Department of Fish and Game. 1983. Diagnosis of diseases in fishes, period July 1, 1983 - June 30, 1984. Job performance report number FXSWCAD551, Laramie, Wyoming.

PAPERS PRESENTED

- Intelmann, S.S., and C.M. Moffitt. 1999. Using GIS to visualize epidemiological interactions among hatchery and free-ranging salmonids: A preliminary analysis of *Myxobolus cerebralis* in Utah. Poster paper presented at AFS/Fish Health Section Annual Meeting and Western Fish Disease Workshop, Twin Falls, Idaho, June 9-11, 1999.