Whirling Disease Initiative

Final Report

submitted by the

**WHIRLING DISEASE STEERING COMMITTEE
OF THE NATIONAL PARTNERSHIP
FOR THE MANAGEMENT OF WILD AND NATIVE
COLDWATER FISHERIES**

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Whirling Disease Background

Since the mid-1990's, the microscopic parasite *Myxobolus cerebralis*, which causes whirling disease in many salmonid fish species, has spread and infected hundreds of river and stream reaches in the United States. A Eurasian native, *M. cerebralis* made its way to North America in the 1950s. It was once believed to be relatively harmless to wild fish, but research in the mid-1990s found that it was decimating rainbow trout populations in some of the Rocky Mountain region's finest river fisheries. Many hatchery populations were also powerfully impacted. The impacts of this parasite on susceptible trout can be dramatic (Figure 1): darkening of the tail, skeletal deformities, frenzied tail chasing (hence the name "whirling" disease), and death.

The whirling disease parasite is extremely hardy and long-lived. Like the malaria parasite, it infects two very different hosts alternately (Figure 2). In the case of whirling disease, the life cycle involves a fish host and an aquatic worm host (*Tubifex tubifex*). Consequently, reaching an understanding of the parasite's biology and effects has required defining the biology of susceptible fish and worms, as well as the parasite spores and the triactinomyxon or "TAM" life stage.

Most salmonids have been found to be susceptible to whirling disease. It therefore represents a major threat both to biological diversity and to the nation's multi-million-dollar fishing and tourism economy. To date, the whirling disease parasite has been reported in 25 states in the U.S. (Figure 3).

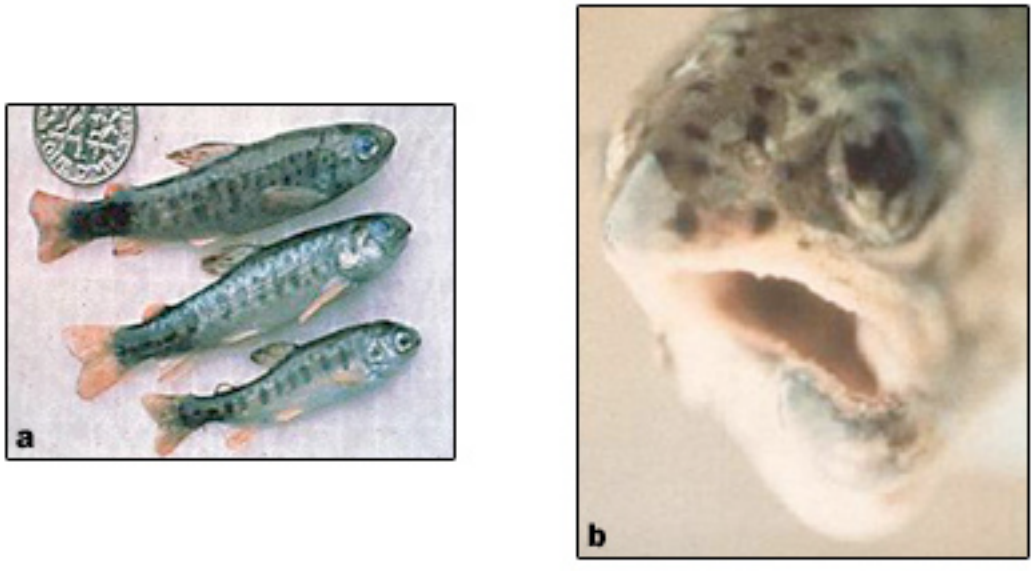

Figure 1. Infected juvenile rainbow trout: a) black tail; b) skeletal deformity

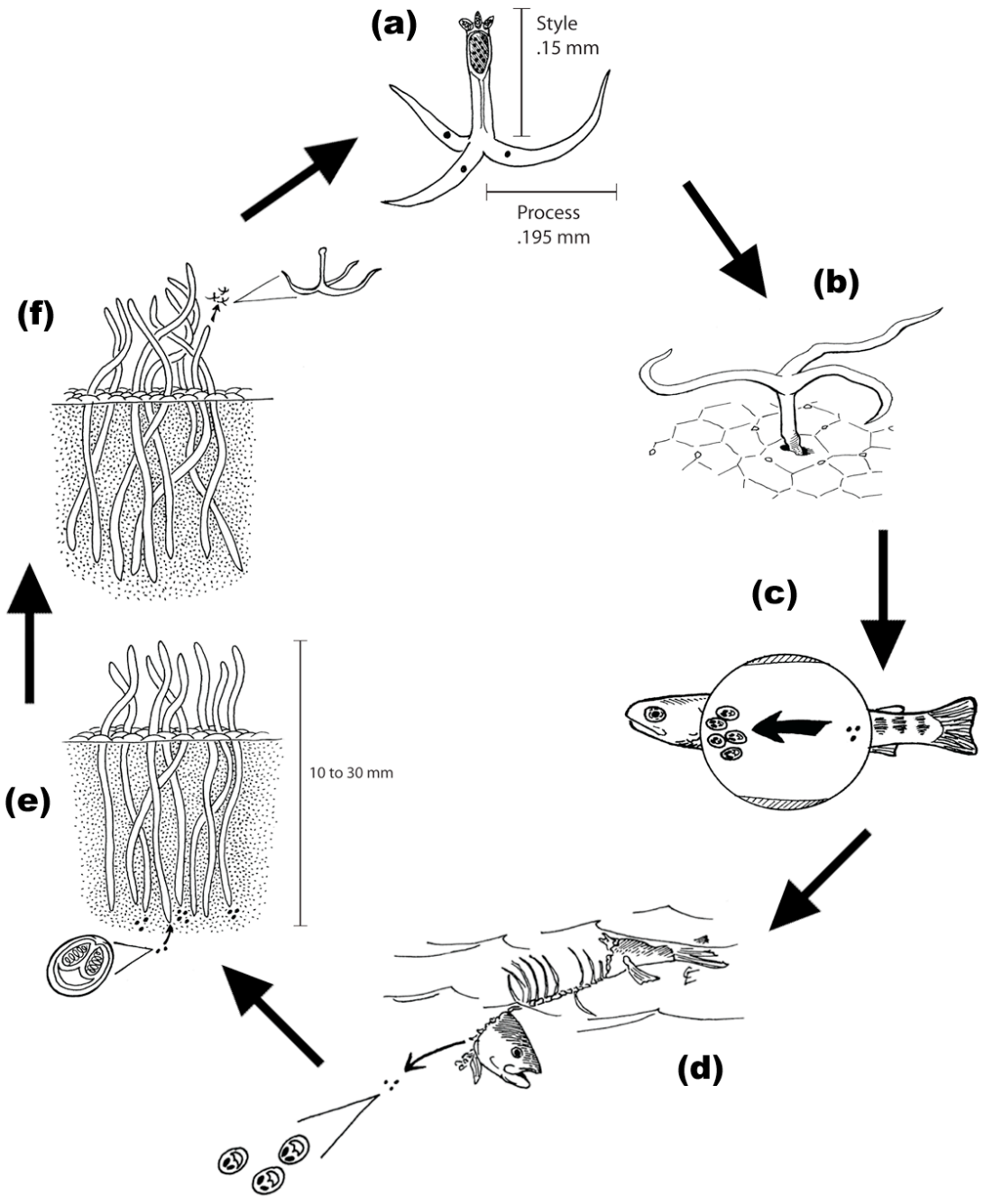

Figure 2. Life cycle of *Myxobolus cerebralis*. (a) The triactinomyxon (TAM) is suspended in the water column; (b) when it encounters a salmonid fish, the TAM attaches to the skin and the active infectious agent, the sporoplasm, is injected into the fish; (c) the parasite travels along the fish's nervous system, feeds on cartilage, replicates and eventually develops into mature myxospores; (d) when the infected fish dies, its carcass releases mature myxospores into the water; (e) *Tubifex tubifex* worms feeding in stream-bottom sediment ingest myxospores; (f) within the worms, the parasite develops into TAMs, which are subsequently released into the water column. Illustrations by Claire Emery.

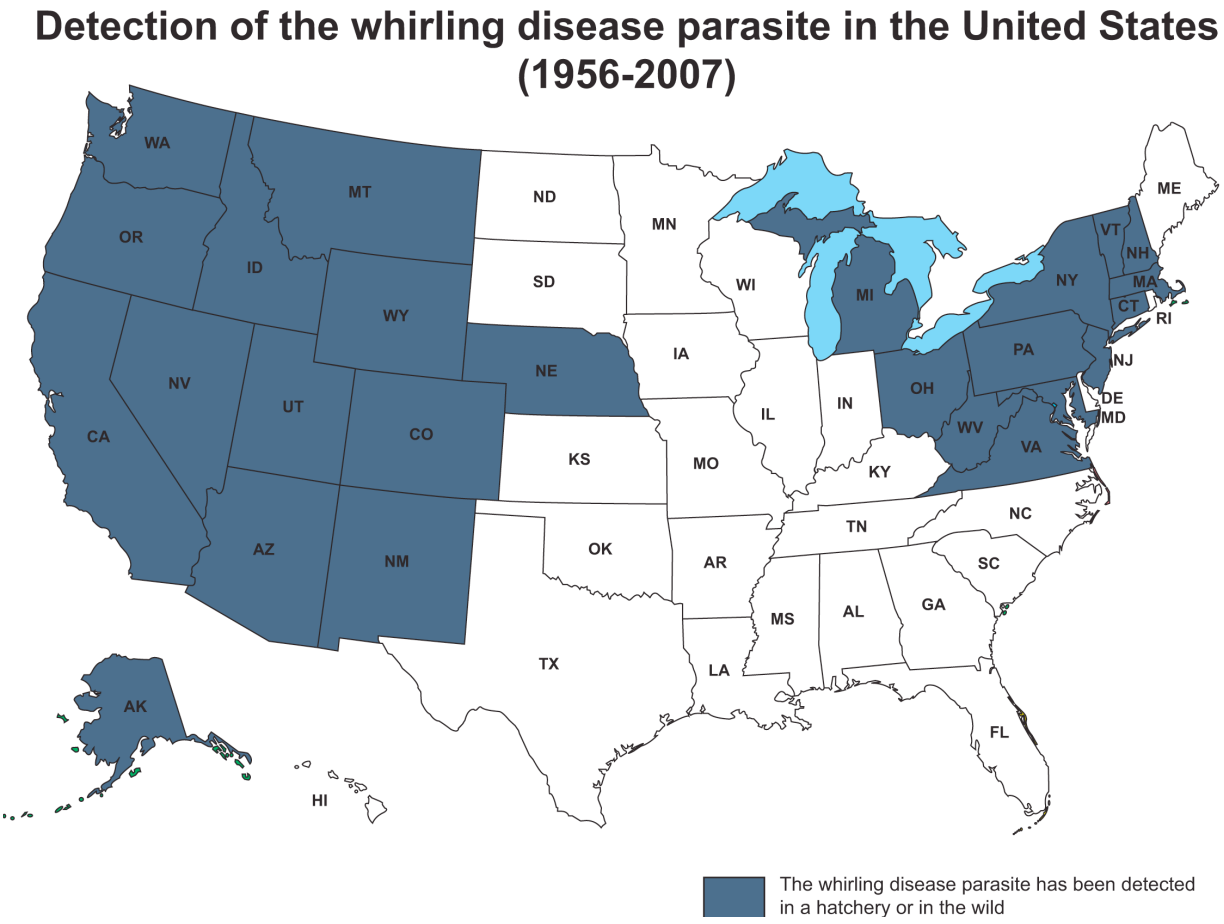

Figure 3. Whirling disease detections in the United States

History and Operation of the Whirling Disease Initiative

The Whirling Disease Initiative (hereinafter referred to as the Initiative) was established by Act of Congress in 1997; it concluded on June 30, 2009. Its purpose was to conduct research to develop practical management solutions to maintain viable, self-sustaining wild trout fisheries in the presence of the whirling disease parasite. The Initiative's ultimate clients were state, tribal, and federal fisheries-management agencies, and the constituencies they serve. The Initiative was funded by federal earmark appropriation. Each year between 1996 and 2006, Federal funding earmarked in the Interior Appropriations Bill came to the Initiative through the Division of the National Fish Hatchery System, US Fish and Wildlife Service.

General oversight of the Initiative was provided by the National Partnership for the Management of Wild and Native Coldwater Fisheries. The National Partnership was a consortium of organizations concerned with the status of wild and native fisheries in the United States—Federal and state agencies, professional associations, and private advocacy organizations (Appendix A). The overall goal of the Partnership was to move biological research and management trials forward to make available to fishery managers practical options for controlling the disease. The National Partnership provided long-term direction to the Whirling Disease Initiative. To do this, the Partnership's Board of Representatives convened annually for a detailed briefing by whirling disease researchers, and participated in discussions concerning fisheries health and research needs. The Partnership operated under a simple charter that was updated annually (Appendix B).

The Montana Water Center was the administrative entity that managed the program and coordinated outreach and educational activities. In-depth scientific direction was given to the Initiative by its Steering Committee. The committee was made up of representatives from state fish and wildlife agencies, Federal natural resource agencies, and the Whirling Disease Foundation (Appendix C). Working in collaboration with Water Center staff, the Steering Committee prepared an annual research plan, issued Requests for Proposals based on its topical priorities, selected and approved projects for funding following scientific peer review, and distributed the research results within the scientific and fishery management communities and to other stakeholders. Responsibilities of the various collaborator organizations are shown in Table 1.

In 2001 an independent panel was chartered to examine all aspects of the Initiative and recommend any needed changes. Dr. Ted Myers of the Alaska Department of Fisheries chaired the panel. Appendix D is a summary of the panel's findings and recommendations. On the basis of these recommendations, the Steering Committee membership was altered to include representatives from all geographic regions of the U.S. experiencing whirling disease infection. In addition, the direction of research projects was gradually shifted from disease biology towards field-scale, applied projects.

During the years 2003-2007, Initiative activities were guided by a strategic plan that was updated annually by the Steering Committee. Appendix E is the last update of the Strategic Plan.

AGENCY / ENTITY	ADMINISTRATION		TECHNICAL OVERSIGHT	RESEARCH WORK	OUTREACH ACTIVITIES
	PROGRAM	FINANCIAL			
Montana Water Center	X	X	X		X
US Fish and Wildlife Service	X	X	X		X
Montana State University		X			
National Partnership Board	X		X		
WD Steering Committee	X		X		X
Whirling Disease Foundation/ Trout Unlimited	X	X	X		X
MSU Wild Trout Research Lab			X	X	
State Universities				X	
State Agencies				X	X
Federal Agencies				X	X
Private Firms				X	X

Table 1. Whirling Disease Initiative Cooperator Responsibilities

Budgets

Table 2 is a compilation of the annual budgets of the Whirling Disease Initiative. The total Initiative funding from USFWS grants was $7,614,059. Of this, 21% was expended on administration, laboratory operation and project management, 4.7% went to outreach during the years 2004-2007, and 0.3% was used to develop an Internet-accessible database. The balance of federal funding was expended on research projects. A substantial portion of the value of Initiative activities took the form of match, estimated at $5,081,168. This was composed of investigator salaries, in-kind match by Steering Committee and Partnership Board members and proposal peer reviewers, and direct funding from other sources – state agencies, other federal grants and non-profit organizations, principally the Whirling Disease Foundation. In a typical research project, Initiative funding was augmented by cash or in-kind match equal to 75% of the federal grant.

Component	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007-9	TOTAL
Program Administration	$157,601	$121,775	$123,412	$142,654	$164,629	$165,584	$132,865	$171,441	$196,167	$203,027	$0	$1,579,155
Outreach Program	NA	NA	NA	NA	NA	NA	$5,000	$100,000	$135,000	$120,000	$0	$360,000
Database Project									$10,000	$10,000	$0	$20.000
Match	$80,000	$80,000	$76,000	$79,000	$84,000	$79,000	$69,000	$107,000	$80,000	$80,000	NA	$814,000
Total Admin & Outreach	$237,601	$201,775	$199,412	$221,654	$248,629	$244,584	$206,865	$378,441	$421,167	$413,027	$0	$2,773,155
Research	$342,399	$578,225	$576,588	$557,346	$535,308	$534,416	$557,585	$676,990	$643,625	$652,359	$0	$5,654,841
Match	$408,693	$477,605	$600,381	$502,600	$386,673	$442,292	$516,270	$343,870	$423,048	$244,736	$0	$4,346,168
Total Research	$751,092	$1,055,830	$1,176,969	$1,059,946	$921,981	$976,708	$1,073,855	$1,020,860	$1,066,673	$897,095	$0	$10,001,009
Total Initiative	$500,000	$700,000	$700,000	$700,000	$700,000	$700,000	$695,450	$948,431	$984,792	$985,386	$0	$7,614,059
Total Match	$488,693	$557,605	$676,381	$502,600	$470,673	$521,292	$585,270	$450,870	$503,048	$324,736	$0	$5,081,168
Total Program	$988,693	$1,257,605	$1,376,381	$1,202,600	$1,170,673	$1,221,292	$1,280,720	$1,399,301	$1,487,840	$1,310,122	$0	$12,685,227

Notes: Match and in-kind contributions for administration and outreach are a combination of: National Partnership Board member donated time; Steering Committee member donated time; proposal reviewer donated time; and Montana Water Center forgone indirect cost returns [14% (1997-2002) and 17% (2003-2005) were assessed]; Montana State University negotiated federal research rates were 40% (1997-1999) and 41.5% (2000-2007). In-kind match contributed in 2007-2009 toward database development, outreach and administration was not tracked.

Table 2. Initiative Budget by Funding Year

Research

Research Summary, 1997-2009

Between 1997 and 2006 the Initiative sponsored 3-15 new investigations in each research cycle. A cycle generally ran from May of one year through December of the following year, allowing for two field seasons. Projects were chosen for funding by the Steering Committee following peer review by at least three independent reviewers. One hundred and twenty-three awards supported 109 unique research projects, carried out by university investigators, public-agency scientists and private firms between 1997 and 2009 (Table 3). Typically two to four investigators were involved in each project. Students took part in most projects, either as technicians or, more often, graduate research assistants. Summaries of the research projects are available on the Initiative web site at http://whirlingdisease.montana.edu/.

Figure 4. Wild Trout Research Laboratory

Between 1997 and the final round of new projects in 2006 the Steering Committee chose to support projects on topics ranging from basic biological research, to applied research on potential management solutions, to large-scale ecological investigations. In the early years, intensive efforts were needed to define the basic biology of whirling disease and develop diagnostic techniques. To this end, a partnership among Montana State University, the US Fish & Wildlife Service, Montana Fish, Wildlife & Parks and non-profit organizations, chiefly the new Whirling Disease Foundation, came together under the aegis of the Initiative to construct, furnish and staff the Wild Trout Research Laboratory at Montana State University (Figure 4). This lab hosted a number of projects to develop research protocols, ascertain infective doses of *M. cerebralis* TAMs, and determine susceptibility of salmonid species (Figure 5).

Figure 5. Determining infectious and lethal doses of *M. cerebralis* TAMs

Other early lines of investigation were immunity and the course of disease in individual fish, natural cycles of TAM production and development of field techniques.

In 2002 the Steering Committee began deliberately shifting the research priorities toward field investigations that took more environmental factors into account. Water temperature and flowrate, stream gradient, substrate size and organic matter content fell under investigation. The biology of the tubificid worm host, especially its taxonomy and the resistance of different lineages to *M. cerebralis* infection, became a major focus of investigation during the middle years of the Initiative. Another focal area was developing tools for risk assessment. The goal was to assist field biologists project the likelihood and severity of infection in wild trout populations they managed. The risk and magnitude of an outbreak of whirling disease

Descriptor	Research Funding Cycle										Total
	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-7/8/9	
Number of proposals submitted	24	25	30	23	21	22	17	13	16	13	188
Number of projects funded	14	16	16	14	13	12	8	13	11	6	123
Additional contracts issued	0	4	0	1	1	0	1	1	0	1	9
Number of states representd	6	4	7	6	9	6	6	7	6	8	18
Number of investigators	23	25	46	42	35	24	36	24	25	18	--
Number of peer reviewers	24	39	31	23	34	29	23	23	23	23	--
Note: “additional contracts” were for database development, research program review and manuscript preparation based on past research.											

Table 3. Research Project Summary Statistics

are influenced by myriad factors, many of which formed the subjects of research during the later years of the Initiative (Figure 6). In its final funding cycle (2006-2009) the Initiative supported two large-scale, long-term projects addressing the ecology of whirling disease and trout. Table 4 is a tally of funded projects by general topic, and Appendix F is a full listing of the investigators and projects. Project reports through 2007 can be downloaded from http://whirlingdisease.montana.edu/research/past_research.htm. Final reports are not made public until two years after submittal, to allow for publication in professional journals.

Throughout the Initiative, the Steering Committee chose not to fund the collection of field data for the purpose of tracking the spread of the disease; that effort was deemed to be the responsibility of state agencies. And, although the Initiative sponsored research into the mechanisms of fish resistance to the disease, it did not fund the testing of lab- or hatchery-developed resistant trout strains, because introduction of such strains into natural watercourses is prohibited by the policies of some state fishery agencies.

Projects Concluding in 2009

The final three research projects concluded in 2009, and are summarized below.

Myxobolus cerebralis risk to Yellowstone cutthroat trout related to variation in *T. tubifex* abundance and susceptibility. Billie Kerans, Montana State University, and Todd Koel Yellowstone National Park. May 2005-March 2009.

The consequences of introductions of exotic pathogens are of great concern for conservation of native susceptible species. *Myxobolus cerebralis* (Myxozoa: Myxosporea), the metazoan parasite that causes whirling disease (WD) in several species of trout and salmon, has the potential to devastate native fauna in the continental United States. *Myxobolus cerebralis* has spread to tributaries to Yellowstone Lake, which threatens the viability of the population of native Yellowstone cutthroat trout (YCT), a keystone species in the Yellowstone Lake ecosystem. Infected tributaries are characterized by variable WD risk and unique environmental features, which makes them ideal sites to investigate factors which may drive differences in risk.

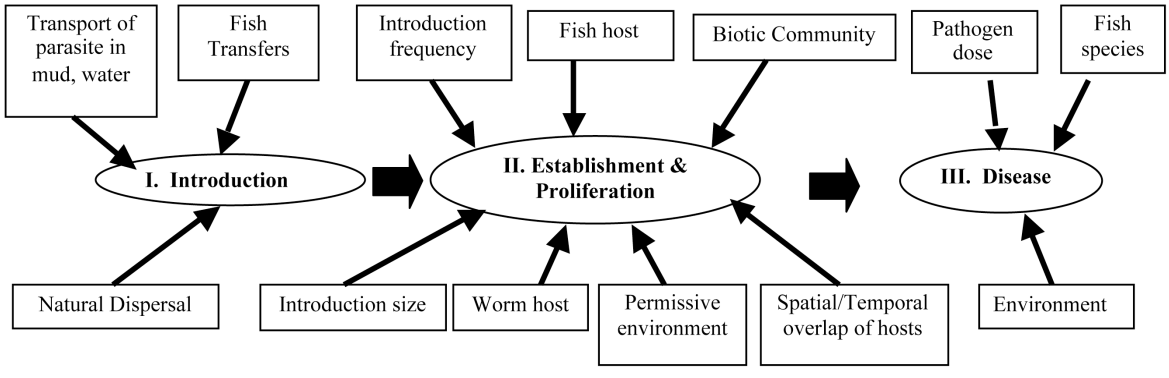

Figure 6. Risk factors influencing disease propagation. Figure modified from J. L. Bartholomew, B. L. Kerans, R. P. Hedrick, S. C. MacDiarmid and J. R. Winton. 2005. A Risk Assessment-Based Approach for the Management of Whirling Disease. *Reviews in Fisheries Science*. 13:205-230.

General Topic	Number of projects			Total
	1997 - 1999	2000 - 2002	2003 - 2009	
Ecological modeling and statistics		1	3	4
Habitat	1	6	6	13
Epidemiology	1	5	4	9
Fish Culture		1		1
Fish Populations and Management	4	3	4	11
Immunology	2	2	1	5
Fish Pathology	7	3	2	12
Parasitology	4	3	3	10
Invertebrate Biology	7	7	5	19
Lab Methods	6	3	3	12
Salmonid Ecology			2	2
Other	7	3	1	11

Notes: Several projects spanned more than one subject. The projects that received awards in more than one year are lumped in this compilation. "Other" projects included economics, field method development and hatchery management.

Table 4. Subjects of research projects.

It is important to determine the factors that cause the substantial variation in the severity of WD risk among different river systems, geographic areas and salmonid species in order to predict the effects of the anticipated range expansion and to develop appropriate management actions. Variation in local stream populations of *T. tubifex* and their interactions with environmental features likely influence differences in WD severity in YCT, but the patterns and underlying mechanisms are not well understood. The goals of this project were to begin to develop quantitative parameters for a risk assessment for Yellowstone cutthroat trout and improve the understanding of *T. tubifex* genetics and their relationships to infection of YCT by *M. cerebralis*.

The specific objectives were to: 1) measure WD risk and examine potential for factors, including abundances of oligochaetes, *T. tubifex* and infected *T. tubifex*, for use in predicting WD risk in fish, 2) assess habitat and examine potential utility of habitat features for predicting WD risk factors , 3) determine if genetic variants of *T. tubifex* exist in this system, and if so, whether susceptible *T. tubifex* strains are more prevalent and abundant where WD risk is severe, 4) determine susceptibility of genetically variable *T. tubifex* strains from sites with varying WD risk, and 5) field validate and test the results concerning *T. tubifex* strains and habitat conditions. The investigators tested the objectives at two spatial scales: within (site scale) and among catchments (catchment scale) on the Yellowstone River, including Yellowstone Lake in Yellowstone National Park. At each of these scales, the investigators *a priori*

defined habitat types based on relative confinement, thermal influence, stream order and location on the mainstem or tributary.

At the within-catchment scale the investigators found that habitat types were relatively homogeneous, however, trends suggested that confinement type was potentially an important WD risk factor. At the among catchment scale, the investigators found that *T. tubifex* were most abundant, and most frequently infected, in unconfined habitat types, which were characterized by higher proportions of fine sediments including silt and clay, and higher amounts of organic material. Infected *T. tubifex* were useful for predicting WD risk at the among catchment scale, but not at the within catchment scale, which may reflect the importance of differences in the production/availability of parasite spore stages. Genetic variation in *T. tubifex* was low: The investigators detected only three mitochondrial lineages of *T. tubifex* (III, VI, and I). Lineage III was common, detected at 100% of sites where the investigators detected *T. tubifex*. Lineages VI and I were rare, detected at only two, and one sites, respectively. The investigators detected 12 strains of lineage III *T. tubifex* using randomly amplified polymorphic DNA (RAPDs). With the exception of one strain, which occurred in four drainages (three of which were infected with *M. cerebralis*), RAPD strains were associated with geographic location (catchment). 100% of tested RAPD strains of *T. tubifex* were susceptible to *M. cerebralis*, however, susceptibility varied both within and among strains. Field validation of confinement types suggested that catchment scale variables including confinement type (confined versus unconfined) and substrate composition were useful predictors of oligochaete and *T. tubifex* abundance, as well as infection prevalence in *T. tubifex* and abundance of infected *T. tubifex*. While further research is needed to identify specific mechanisms, the results suggest that a very basic risk assessment using environmental data that are easily collected may be useful for assessing WD risk at broad (among catchment) scales when the oligochaete host is characterized by low genetic variability.

Southwest regional risk assessment for whirling disease in arid and semi-arid lands: Arizona, Colorado, New Mexico, and Utah. Colleen Caldwell, New Mexico State University Cooperative Fish & Wildlife Research Unit and Wayne Landis, Western Washington University. May 2006-June 2009.

Interest in halting the spread of whirling disease has led to intensive study of *M. cerebralis* biology in the laboratory, plus study of its prevalence in wild populations of trout. This research has produced copious data, and fishery managers need a method of systematically analyzing the data for areas of elevated risk of disease. The goal of this project was to perform a risk assessment to assist fishery managers in the southwestern U.S. The investigators assessed the risk of whirling disease to two species of trout. The first case study examined isolated populations of the native Rio Grande cutthroat trout in northern New Mexico and southern Colorado. The second and more extensive case study investigated the geographic management units of Colorado River cutthroat trout in Wyoming, Colorado, New Mexico, Arizona and Utah.

Through discussions with managers as well as review of the literature, the investigators constructed a conceptual model incorporating the pathogen, the intermediate host, the spores of the pathogen and the pathways that transmit the organism to uninfected habitat in both case studies. In the case of the Rio Grande cutthroat trout, distances between infected and uninfected sites, likelihood of fishing and the isolation of the fish population were the factors considered. In the case of the Colorado River cutthroat trout the connection between spawning habitat, the habitat for the intermediate worm host, and the connection between infected and uninfected populations were the variables incorporated. The extent of the study site dictated that Bayesian networks be used to estimate risk for each river sub-basin.

Because of insufficient data relating to most potential disease transport pathways, the investigators were only able to predict the likelihood of infection using fish migration as the causal pathway. They found that, of 141 isolated populations of Rio Grande cutthroat trout, 42 (30%) were at high risk of whirling disease, 30 (21%) were at medium risk, and 69 (49%) were at low risk of infection from in-migration of infected fish. When these risk scores are compared to streams with known infection status, 45% of high-risk streams were infected with only 3% of medium- and low-risk streams showing infection. The river sub-basins showing the highest risk of whirling disease to Colorado River cutthroat trout were found in the southwestern portion of their range in (from highest to lowest) the Lower Colorado, San Juan and Lower Green. The three sub-basins with the lowest risk scores (from lowest to highest) were the Upper Colorado, Gunnison and Yampa. The variables that were most important in determining risk using the Bayesian models were stream gradient and elevation; higher values of either correlated with lower disease risk. Of secondary importance were whether a stream reach was used to spawn or not, and the presence or absence of barriers to fish passage.

An ecological assessment of large-scale spatial and temporal patterns of whirling disease risk and salmonid population response. Billie Kerans and Tom McMahon, Montana State University. May 2006-June 2009.

One of the perplexing problems of whirling disease has been the wide variation in its effects on fish populations. Despite numerous reports of trout declines following disease outbreaks, there has been very little in-depth analysis of population responses to the disease. Such analysis is vital for predicting trout population dynamics following a disease epizootic. This project capitalized on sentinel cage data (an estimate of disease risk) collected by Montana Fish, Wildlife and Parks on an annual basis since 1997, that comprise a large database encompassing approximately 400 sites. Data from eight watersheds (Madison, Missouri, Rock Creek, Blackfoot, Upper Ruby, Big Hole, Upper Bitterroot, Gallatin) having both pre- and post-whirling disease sentinel cage data and pre- and post-infection fish population data were used. The working hypothesis was that establishment and proliferation of the parasite as measured by disease risk correlates with salmonid population dynamics and that the correlations vary in space and time in relation to environmental risk factors such as discharge, water temperature, level of habitat disturbance in a watershed and oligochaete assemblages. Using earlier and newly-collected data, the specific project objectives were to:

- examine large-scale spatial and temporal patterns in parasite establishment and proliferation (i.e., infection risk) and how different risk factors correlate with infection risk;
- examine fish population dynamics before and after the invasion of *M. cerebralis*; and
- develop a technical synthesis of the "state-of-the-science" of whirling disease.

Infection risk and risk factors

The investigators examined the spatial and temporal patterns in whirling disease risk (sentinel cage data) and the correlation of disease risk with risk factors (oligochaete assemblages, physicochemical characteristics, land use). It was found that whirling disease risk did not remain constant over time, but in at least one stream had a period of decline followed by a steady increase. Statistical analyses showed that disease risk increased over time in the Blackfoot, Gallatin, Madison, and Missouri drainages. Sixteen sub-basins (8 with high disease risk and 8 with low disease risk) were selected to assess the relationship between disease risk and lineage composition of *T. tubifex*, physicochemical features, and landscape structure. Sub-basins (i.e., the entire area draining into one sentinel cage location) within watersheds were selected such that the collections were independent of each other and paired sub-basins

were of similar size. Analysis results indicated that lineage III (the "susceptible lineage") was more prevalent than lineage I (the "less susceptible lineage") in high-disease-risk sub-basins than in low-risk sub-basins. High-risk sub-basins were found to feature deeper stream channels and a higher proportion of fine sediment in the streambeds. They also had a lower percentage of forested land in their tributary watersheds than low-risk sub-basins.

Whirling disease and fish population dynamics

Questions addressed in this objective were:

- Do trout populations respond in a similar fashion to a whirling disease epizootic?
- Do populations with severe infections recover over time?
- Do populations exposed to high infection differ in their response to the disease, and if so, how do factors such as drought affect this response?

Using a database of 384,938 trout captured during the years 1980-2007, the investigators employed a before-after control-impact (BACI) study design that included comparison of infected river sections to non-infected reference sections among six Montana rivers infected with whirling disease. The BACI comparison allowed determination of how much change in rainbow and brown trout populations was due to whirling disease versus other factors such as water temperature and flow. In addition to the effects of disease on trout numbers, its effect on trout recruitment, growth, condition, biomass, and age structure was also examined. A Bayesian mark-recapture model indicated that disease had a strong negative effect on abundance of small rainbow trout, with abundance declining an average of 50% from pre-disease levels. This marked decline was consistent across all study rivers. In contrast, numbers of moderate-size rainbow trout stayed the same after disease, and very large rainbow trout doubled in numbers, although the extent of the increase varied substantially among rivers. With the exception of one stream, brown trout generally showed little or no change in abundance before and after disease across all size classes. Whirling disease did not affect condition of rainbow trout or brown trout; both species remained in good condition before and after whirling disease. However, the mean length of age-4 and older rainbow trout in the Missouri River increased by almost 30 mm after whirling disease, likely reflecting improved survival of older age classes. The abundance of young rainbow trout was positively correlated to stream flow during the summer, and adding summer flow as a covariate to the rainbow trout BACI model significantly improved model fit. There appeared to be an interaction of disease and flow on abundance of small rainbow trout, with lower flows and high disease interacting to negatively affect young rainbow trout in the years since 2000.

Technical synthesis

The investigators created a synthesis document focused on the response to the disease outbreak as a model of how to approach an emerging infectious disease in wildlife. They documented the structure of the institutional responses to disease and examined its success. They focused on the Whirling Disease Initiative and the Whirling Disease Foundation and examined their success in promoting research, outreach, and incorporation of research into management. They concluded that the approach was highly productive: the Initiative and the Foundation had a coordinated response to the disease outbreak and placed about $9 million into research. From 1996 until 2009 there were 171 papers published in the peer-reviewed scientific literature, of which the Initiative and the Foundation funded 49% (84 articles). Fully 71% of these 84 articles were also funded by other sources, suggesting that both the Initiative and the Foundation promoted collaborations between researchers and other groups interested in disease research. Prominent research findings include:

- The susceptibility of salmonid species is variable, and resistant rainbow trout exist

- There are genetically-distinct *T. tubifex* lineages whose disease susceptibility and TAM production differ, and these distinct lineages coexist in natural stream communities
- Salmonid population response to *M. cerebralis* infection is highly variable
- Disease risk to fish is spatially and temporally variable within and among drainages, possibly providing fish with refuges from the parasite
- Some environmental characteristics correlate with disease risk.

A number of research findings have been incorporated into fishery management. Examples are:

- Wide use of a rapid, inexpensive genetic test for *M. cerebralis*
- Limiting the spread of *M. cerebralis* by hatchery closings and retrofitting that resulted from better detection methods and development of effective decontamination techniques
- Incorporation of resistant rainbow trout genes into fish that will be stocked in states that stock rainbow trout (e.g., Colorado), and tracking the development of natural resistance in rainbow trout populations in states that do not stock streams (e.g., Montana)
- Test-introductions of "resistant" *T. tubifex* as a means of reducing the parasite load in natural streams
- Assessment methodologies that allow managers to evaluate the risk of parasite introduction, establishment and disease outbreaks in natural waters.

Research Publications and Presentations

Although most whirling disease research has taken place with Initiative sponsorship, other research has occurred with direct US Fish & Wildlife Service sponsorship, or state-agency support, or, in recent years, funding from the Whirling Disease Foundation. A principal objective of the Initiative was to coordinate whirling disease research, so that data and analyses of all investigators were available promptly to others, waste was prevented and discovery was expedited. To this end the Initiative supported technical symposia, and the Steering Committee judged research proposals in part on the basis of the investigators' history of publication and sharing of past findings. At least 70 papers reporting Initiative-funded research are known to have been published in the peer-reviewed literature since 1999. Those papers are listed in Appendix G and many are available electronically from the Initiative website at http://whirlingdisease.montana.edu/biblio/default.htm. In addition, several dozen graduate researchers successfully defended masters' theses, and several wrote PhD dissertations based on the research of the Initiative. For example, Initiative research supported 13 students who earned masters' degrees and three PhD graduates from the Ecology Department at Montana State University.

The annual Whirling Disease Symposium has been the principle venue for interaction among researchers. The symposium has been organized by the Whirling Disease Foundation, with financial and organizational support from the Initiative. Table 5 lists the symposia that have taken place since 1997. Each symposium included both oral-presentation and poster sessions at which research updates were presented. Additional presentation venues for Initiative-sponsored projects were state, regional and national conferences of the American Fisheries Society, conferences of other biology professional organizations, and occasional meetings such as the Wild Trout Symposium that takes place every third year in West Yellowstone, Montana.

Date	Symposium Title	Location	Initiative-Funded Project Reports
March 6-7, 1997	Expanding the Database: 1996 Research Progress Reports	Logan, UT	11
February 19-21, 1998	Research in Progress	Fort Collins, CO	16
February 18-20, 1999	Research and Management Perspectives	Missoula, MT	12
February 3-4, 2000	Solutions to Whirling Disease: Putting the Pieces Together	Coeur d'Alene, ID	14
February 8-9, 2001	A Decade of Discovery	Salt Lake City, UT	12
February 13-15, 2002	Putting a Fresh Spin on Whirling Disease	Denver, CO	8
February 6-7, 2003	Managing the Risk	Seattle, WA	7
March 2-3, 2004	Whirling Disease Management: Practicalities & Realities	Salt Lake City, UT	11
February 3-4, 2005	Recipes for Recovery	Denver, CO	7
February 9-10, 2006	War of the Whirlds	Denver, CO	4
February 12-13, 2007	Resistance on Two Fronts	Denver, CO	11
February 4-5, 2008	Solving the Puzzle	Denver, CO	6
February 4-5, 2009	Conserving Cold Water Fisheries	Denver, CO	2
Notes: The Whirling Disease Foundation organized the 1997-2008 symposia; during those years the symposia received financial support from the Whirling Disease Initiative. The last column tallies reports of ongoing or recently-concluded Initiative projects; it does not include projects based on past Initiative research, or research posters displayed.			

Table 5. Whirling Disease Symposia, 1997-2009

Outreach

During the early years of the Initiative there was no formal outreach program; outreach activities consisted of operating a project website and referring inquiries to funded investigators. The 2002 independent review of the Initiative recommended the development of an outreach program to disseminate the voluminous information that was accumulating and to better serve the various audiences for this information. That year the National Partnership Board directed the Water Center to initiate the program with a market survey, to be followed by the development of an outreach program plan.

2003 Market Survey

In 2003 Strategicom, Inc., of Bozeman, Montana was contracted to conduct a market survey of targeted fisheries professionals concerning whirling disease – how much they know, what they need to know, how they prefer to acquire professional continuing education. One hundred and one biologists in 23 states where the disease has been detected completed detailed questionnaires, and the fish health officers from 10 states participated in phone interviews. Strategicom analyzed the results and presented the Partnership Board with a set of findings and recommendations:

- establish contact lists of fish professionals at local, state, regional, federal and tribal levels
- assess the current situation for whirling disease, including pertinent state laws and the true geographic scope and severity of the disease
- develop annual updates for key stakeholders to keep them apprised of the situation and to combat apathy
- create and promote the authoritative whirling disease electronic resource
- customize the outreach effort by audience
- present to gatherings of fisheries professionals
- build strategic alliances to leverage resources.

These recommendations were prioritized by the Board, and formed the foundation of the outreach program. Specific components are summarized below.

Website

(http://whirlingdisease.montana.edu)

The Initiative web site is the authoritative source for whirling disease information on the Internet, and a portal to other sites. It is the primary outreach vehicle for the Initiative. Its major components are:

- an online bibliography with, at present 770 references that are searchable by title, author, keyword, and year of publication. These include all the final research reports generated by the Whirling Disease Initiative from 1997 through 2007, and the individual abstracts from the annual Whirling Disease Symposia
- the downloadable quarterly newsletter of the Initiative, 2006-2007 (see below)
- biological information about the *M. cerebralis* life history, modes of transmission and current range in the U.S.
- information on the relative susceptibility of various salmonids
- special information for anglers – how to spot diseased fish, how not to transmit whirling disease, etc.
- detailed information about the Whirling Disease Initiative, including all the annual reports
- an image gallery and downloadable publications
- links to experts and other references.

During 2008, there were 91,040 visitor sessions (not 'hits') on the website, and 7169 files were downloaded from it. The most popular files to be downloaded were the descriptive summaries of completed research projects.

Outreach Coordinator

Between 2004 and 2007 the Water Center employed an Outreach Coordinator for the Initiative. The coordinator was tasked with developing and disseminating materials for anglers, the general public and non-specialist field biologists. This involved:

- building a contact list
- making presentations to audiences of fisheries professionals, and some lay audiences
- interacting with journalists and placing articles in lay publications
- distributing quarterly newsletters to more than 1000 recipients
- issuing press releases
- responding to telephone and Internet requests for information and resources.

As an example, in 2006 the Coordinator presented at these meetings:

- Whirling Disease Symposium; February 9 and 10, 2006; Denver, CO
- Montana Natural Resources Professionals; March 21, 2006; Bozeman, MT
- Western Division AFS Meeting; May 15-18, 2006; Bozeman, MT
- Federation of Fly Fishers Conclave; July 25-29, 2006; Bozeman, MT
- 5th International Symposium on Aquatic Animal Health; September 2-6, 2006; San Francisco, CA
- AFS National Meeting; September 10-14, 2006; Lake Placid, NY
- USFWS Hunting and Fishing Day Celebration; September 16, 2006; Tishomingo, OK
- Montana State University Student AFS Unit; October 3, 2006; Bozeman, MT
- Montana Watershed Symposium; December 3, 2006; Great Falls, MT

That year, more than 100 articles in professional and lay publications featured or mentioned the Initiative.

Brochure

A full color brochure on whirling disease was developed for the lay public, and more than 7000 copies were distributed, mostly at conferences (Figure 7). Topics covered include whirling disease background and life cycle, frequently asked questions and recommendations for anglers. Funding for the brochure was provided by the Whirling Disease Initiative, Whirling Disease Foundation, and Montana Department of Fish, Wildlife and Parks.

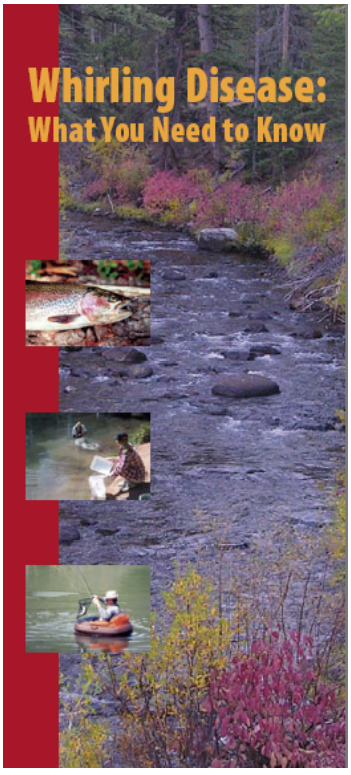

Figure 7. The whirling disease brochure

Black Tail DVD

In 2005-2006 the Water Center worked with two graduate filmmakers in the Natural History Filmmaking Program at Montana State University to create a documentary film on whirling disease. This film, *Black Tale: The Whirling Disease Invaders*, is available in 26-minute and 14-minute versions on a single DVD (Figure 8). Distribution began in fall 2006. More than 800 DVDs were distributed nationwide, chiefly in the western states. The longer version of the film can be viewed on the TERRA website: http://www.lifeonterra.com/index.php.

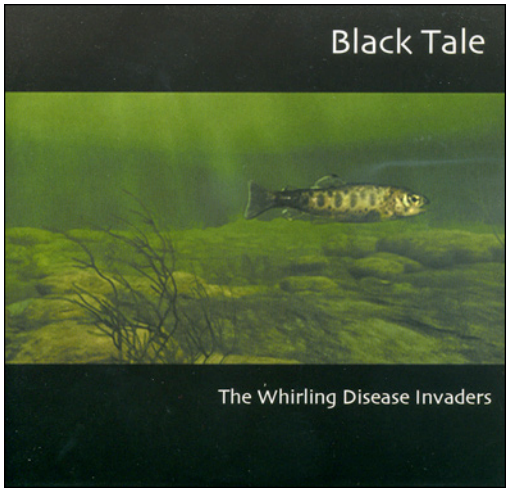

Figure 8. Black Tale DVD

2009 White Paper

In summer 2009 Trout Unlimited and the Whirling Disease Initiative released *Whirling Disease in the United States: A Summary of Progress in Research and Management*. This publication overviews the complex life cycle of the parasite, biological and environmental factors influencing its spread and severity, and current prevention and management techniques. The text is copiously illustrated and augmented with a detailed bibliography. It should be most useful to field biologists and others who deal with aquatic nuisance species. The document is available for download from the Initiative website at http://whirlingdisease.montana.edu/resources/publications.htm.

Whirling Disease Incidence Maps

In 2006 Water Center personnel began compiling geographic data on the incidence of whirling disease in western watersheds, to create web-accessible maps. As of the completion of the Initiative, the maps of *M. cerebralis* detections available via this interface include data from 11 western states and two eastern states. The states and the years of most recent range information are:

- Arizona: 2004
- California: 2007
- Colorado: 2006 (watersheds) and 1999 (point data)
- Idaho: 2006
- Maryland: 2007
- Montana: 2006
- Nevada: 2005
- New Mexico: 2006
- New York: 2006
- Oregon: 2007
- Utah: 2006
- Washington: 2007
- Wyoming: 2003

Most of the data were provided by state fish and game agencies; in some cases they are from the US Fish & Wildlife Service Wild Fish Health Survey. The website was built in collaboration with the Big Sky Institute (BSI) at Montana State University, which is a partner in the US Geological Survey NBII Nodes Program. BSI personnel continue to collect updated information from the states, with support from the NBII. Both static and interactive map formats are supported, with state-based and regional scales, and data plotted either by watershed or as points. Figure 9 shows an example static map, with incidence plotted by major watershed. Interactive maps can be accessed from

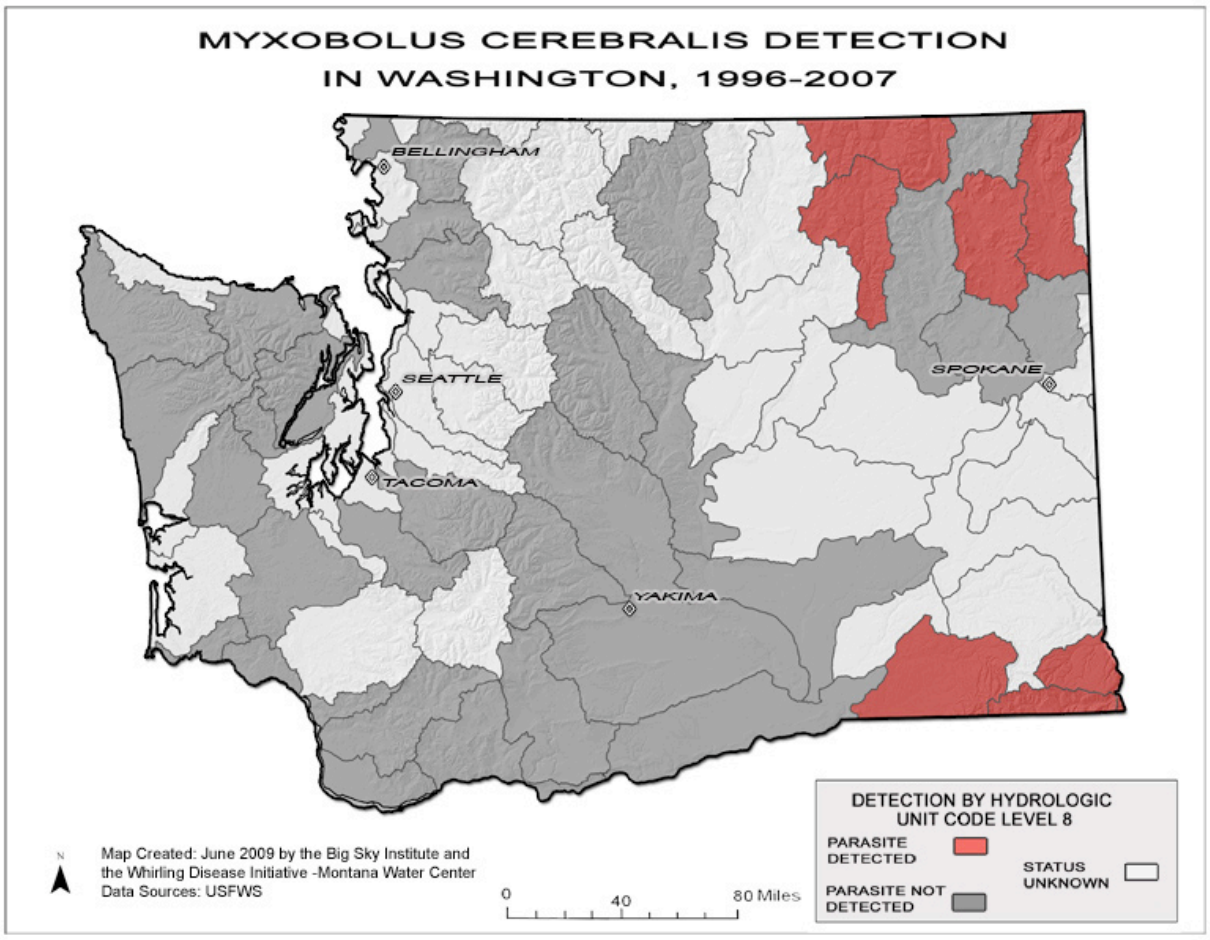

Figure 9. Whirling disease incidence by watershed, Washington, 2007

http://bsi1.msu.montana.edu/whirlingdisease/default.aspx and static maps in several different formats are found on the Initiative website at http://whirlingdisease.montana.edu/about/map2.htm.

Whirling Disease Data Repository

In 2004, the Partnership Board charged the Initiative with developing a data repository - an archive of scientific information (reports, publications, datasets and metadata) that had been generated through the Initiative. The goal was to develop and build a web-enabled, searchable repository that would function as a resource for fisheries managers working on whirling disease or for researchers investigating similar disease epidemics. In summer 2005 the Initiative chartered a panel of experts on ecological research and data to recommend how best to do this, the types of questions that could be addressed by such a tool, and more generally, whether and how the Initiative should push forward with ecological research. The panel was chaired by James Karr of the University of Washington. Its charge from the Initiative and the executive summary of its report and recommendations comprise Appendix H.

Between January 2005 and September 2007 the Initiative employed a project manager to collect Initiative-funded data and oversee construction of a repository of metadata and datasets. Her duties included investigation of potential web sites where data could be served, data mining and assembly, metadata development, identification of database structure and overall needs, establishment of the database, internet interface, and access, and ongoing project support.

Data Submission and Use Guidelines were prepared, approved by Montana State University Legal Counsel and publicized as a new requirement in the November 2005 Request for Preproposals and March 2006 Request for Proposals. Investigators on the six projects that began in 2006, the last projects of the Initiative, were required to abide by this policy, which includes guidelines and requirements for data and metadata submission, and requirements and restrictions for data access and use (Appendix I).

Final site design was completed and the data repository was publicly launched in January 2007. Data and metadata submitted to the data repository are archived in a password-protected MySQL database at the Big Sky Institute. This database is secured behind both the MSU and BSI firewalls. Uploaded datasets are securely stored on the Water Center server, administered by the Burns Technology Center.

At the site http://data.whirlingdisease.montana.edu/ users must establish a password and login. They can then:

- Browse a list of all Initiative-funded research projects
- Read summaries of all projects, and link to complete final reports for projects completed by December 2007
- Search projects by keywords, PI, or funding period
- Limit searching to projects with metadata and datasets
- View metadata for datasets (including comments from PIs regarding significant results, management applications, and subsequent questions)
- Upload data and metadata for their Initiative-funded projects.

At present more than 100 datasets from 23 projects are resident on the site. Nearly all are accompanied by comprehensive metadata files.

Conclusions

The Whirling Disease Initiative was established to provide a rapid, science-based response to a serious fish health issue that threatened the wellbeing of highly valued fish populations and economically important fishery resources. This response initially focused on providing a clear understanding of the *M. cerebralis* pathogen, its affinity for and the susceptibility of its fish and worm hosts, and developing technologies for rapid and accurate detection of the pathogen. The research agenda was broadened to include intensive study of biological and environmental factors influencing the establishment and severity of the pathogen in differing types of waters and different geographic regions. The Initiative can claim notable accomplishments:

- In-depth understanding of the biology of *Myxobolus cerebralis* in its two hosts
- Establishment of the relative susceptibility of the North American salmonid species, and the lineages of *T. tubifex*
- Synthesis of knowledge regarding infection and disease risk factors for watercourses
- A suite of diagnostic techniques for assessing infection in different organisms and media
- Description of disease immunology, and the limits of a vaccination approach, in fish
- A synoptic understanding of the effects of disease in wild fish populations under different environmental circumstances.

While the research supported by the Whirling Disease Initiative uncovered no "silver bullet" to eliminate established whirling disease infections, successes in maintaining populations and fisheries have been attained. Much was learned and this information was effectively communicated to scientists, resource managers, and citizens interested in and dealing with this fish health challenge.

Appendix A

National Partnership Board of Representatives

NATIONAL PARTNERSHIP FOR THE MANAGEMENT OF WILD AND NATIVE COLDWATER FISHERIES

Board of Representatives
1997-2009

American Fisheries Society

Eileen Ryce and Brad Shepard
Montana Fish, Wildlife & Parks

Bob Gresswell
Research Ecologist
Forest & Range Ecosystem Science Center

Bureau of Land Management

Don Prichard
Fishery Biologist/ Riparian-Wetland Specialist

Jay Thompson
Fisheries Biologist

International Association of Fish and Wildlife Agencies

Mike Stone
Fisheries Chief
and Chico Pistono
Assistant Fisheries Chief
WY Game and Fish Department

National Park Service

Jim Tilmant
Fisheries Program Leader
Water Resources Division

Todd Koel
Chief of Aquatic Resources
Yellowstone National Park

Dan Mahoney
Fish Biologist
Yellowstone National Park

National Trout Unlimited

Dave Nickum
Regional Director
Colorado Trout Unlimited

US Fish and Wildlife Service

Stuart Leon, Joe Moran, Tom Bell, Bill Knapp
Division of Fish Hatcheries

Robert Bakal
National Aquatic Animal Health Coordinator

US Forest Service

Kate Walker and Linda Ulmer
Northern Region Fisheries Program Leaders

Georgina Lampman
Rocky Mountain Region Fisheries Program Leader

US Geological Survey

Dick Jachowski and Jeff Kershner
Directors
Northern Rocky Mountain Science Center

Robin Schrock
Assistant Program Coordinator
Fisheries & Aquatic Resources

Native American Fish & Wildlife Society

Ken Pointer and Ira New Breast
Executive Directors

Appendix B

Partnership Charter, Final Version

CHARTER of the NATIONAL PARTNERSHIP for the MANAGEMENT of WILD and NATIVE COLDWATER FISHERIES

Purpose

This Charter establishes the purpose, mission, and operating guidelines for the National Partnership for the Management of Wild and Native Coldwater Fisheries (the Partnership), a whirling disease research and management consortium administered by the Montana University System Water Center (Water Center), located at Montana State University-Bozeman (MSU).

Mission

The mission of the Partnership is to advance the understanding of whirling disease biology and management, by overseeing the Whirling Disease Initiative funded by the US Fish & Wildlife Service. The scope of the Initiative includes 1) research concerning whirling disease biology; 2) development and testing of diagnostic techniques, sampling methods and control methods; and 3) dissemination of the results to fishery managers and other audiences. The specific objectives of the Partnership are to 1) assure that all appropriate parties participate in the Initiative planning process; 2) advise the Water Center on filling vacancies on the Initiative Steering Committee; 3) provide year-to-year evaluation of the progress of the Initiative; 4) assist in developing each year's work plan; and 5) advise the Steering Committee as it formulates and modifies the long-term work plan. The overall goal of the Partnership is to move biological research and management trials forward to make available to fishery managers practical options for controlling the disease. This goal is to be pursued as expeditiously as possible, in a manner that does not duplicate work conducted by entities other than the Initiative.

Administration

Administration, management, and the operational infrastructure of the Partnership will be housed at MSU. The Water Center will serve as prime contractor and custodian of funds through the MSU Grants and Contracts Office, and will receive, hold, disburse, and account for payments in connection with government-sponsored and/or private sector-sponsored programs subject to the regulations of the State of Montana and MSU.

The Water Center will be responsible for the general administration of the Whirling Disease Initiative, including convening the Steering Committee. The Initiative will be conducted and funds disbursed by means of written subcontracts between the Water Center and principal investigators. The Water Center will also be responsible for maintaining communication within the Partnership, including convening meetings of its Board of Representatives. It will provide the US Fish & Wildlife Service with a detailed annual report, including interim and final reports for each subcontract.

Board of Representatives

The Partnership will function through a Board of Representatives (Board). Research, management, and stakeholder groups with interest and expertise pertaining to management of wild and native cold water fisheries will be invited to identify a representative plus an alternate to serve on the Board. These individuals will serve following confirmation by the Board. Stakeholder groups currently represented on the Board are:

American Fisheries Society
National Trout Unlimited
US Fish and Wildlife Service
US Forest Service
International Association of Fish and Wildlife Agencies
National Park Service/Yellowstone National Park
Bureau of Land Management
US Geological Survey - Biological Resources Division.

The list of participating stakeholder groups and their representatives may be modified at any time, following stakeholder input and a vote of the Board. In their participation on the Board, representatives of stakeholder groups or agencies will be considered as spokespersons for their organizations, with all the authority inherent in that role.

Executive functions and staff support for the Board will be provided by the Water Center. The Water Center will convene the Board at least once per calendar year to: 1) evaluate general trends in Initiative operations; 2) review the state-of-the-science regarding whirling disease biology and management strategies; 3) provide the Steering Committee direction on the following year's research, development, testing and outreach priorities; 4) review and provide direction on the long-term program plan; and 5) make recommendations on filling vacancies on the Board of Representatives and the Steering Committee.

The Board will elect from within itself by majority vote a Chairperson and Vice Chairperson. The duties of the Chairperson will be to collaborate with the Water Center to plan and conduct the annual meeting and to represent the Partnership in other settings, such as the Whirling Disease Symposium. The duty of the Vice Chairperson will be to assist the Chairperson in these tasks as needed.

The Partnership budget will cover travel expenses for Board members to attend the annual meeting if they are not compensated by their organization or agency. If a Board member or alternate is unable to attend the annual meeting in person, he/she may participate by electronic communication. The Chairperson or other members of the Board of Representatives may also be funded to travel to additional meetings to represent the Partnership in integrated planning for long-term whirling disease research, development and demonstration activities.

Steering Committee

Members of the Whirling Disease Steering Committee will be selected by the Water Center, from lists of candidates submitted by the Board and by the Committee. The Steering Committee will develop and periodically modify a long-term program plan, formulate an annual work plan and Request for Proposals, supervise a peer review process for allocating funds to projects, and publicize the research results widely. The members of the Steering Committee will be drawn from stakeholder agencies and organizations of diverse perspective. At least half the positions on the Steering Committee will be held by representatives of agencies that manage fisheries.

Effective Date and Duration

This Charter is effective upon approval by a majority of the Partnership Board of Representatives, which can be polled either at the annual meeting or via telephone, e-mail or regular mail. The Charter can be revised at any time, by majority vote of the Board of Representatives. Specific research and development cycles of the Whirling Disease Initiative will commence and terminate upon signing of Grant Agreements between the US Fish & Wildlife Service and MSU.

Effective Date: November 10, 2003

APPENDIX: Current Grant Agreement between the US Fish and Wildlife Service and Montana State University, No. 98210-2-G308 (Whirling Disease Initiative)

Appendix C

Whirling Disease Initiative Steering Committee

WHIRLING DISEASE STEERING COMMITTEE
1997- 2009

Montana Water Center

Dorothy Bradley
and Gretchen Rupp
Project Directors

US Geological Survey

Bob Gresswell
Research Ecologist
and Jeff Kerchner
Director
Northern Rocky Mountain Science Center

State Fisheries Representative, East Infected Region

Phil Hulbert
Superintendent of Fish Culture
New York State DEC

State Fisheries Representative, West Infected Region

Mark Jones
Research Leader
Colorado Division of Wildlife

Whirling Disease Foundation

Sue Higgins and Dave Kumlien
Executive Directors

Harry Piper
President

US Fish and Wildlife Service

Beth MacConnell
Bozeman Fish Health Center

Montana Fish, Wildlife and Parks

Eileen Ryce
ANS Coordinator, Fisheries Division

Dick Vincent
Montana Whirling Disease Coordinator

West At-Large

Steve Wolff
Staff Aquatic Biologist
Wyoming Game and Fish Department

Montana Whirling Disease Task

Marshall Bloom
Director
Rocky Mountain Biological Laboratory

Environmental Health Representative

Bill Tietz
Former President
Montana State University

Appendix D

Review Panel Recommendations, 2001

WHIRLING DISEASE PROGRAM REVIEW

Autumn, 2001

Review Panel:

Dr. John Schachte, New York
Dr. Karl Johnson, New Mexico
Dr. Ted Meyers, Alaska (chair)

Activities:

The panel was charged with evaluating all aspects of the Whirling Disease Initiative, from the functioning of the National Partnership to the identification of promising research avenues. Panel members used a questionnaire to interview 45 people who had knowledge of the Initiative - researchers, state fisheries biologists and administrators. They then met in Bozeman and developed a detailed set of recommendations for further administration of the Initiative.

Summary of Recommendations:

National Partnership: The Review Panel recommended dissolving the National Partnership. They found substantial legal and institutional impediments that prohibit it from either closely monitoring and advising on the Whirling Disease Initiative or developing new initiatives in response to fisheries emergencies.

Whirling Disease Steering Committee: Regarding committee membership, the principal recommendation was to enlarge the committee with the addition of state fishery biologists from the southern Rockies and the Northwest. The panel also made recommendations concerning the topical expertise needed on the Steering Committee, how and by whom proposals are reviewed, and how data should be treated to protect the researchers ability to publish their findings. The panel recommended a funding model used by the Western Regional Aquaculture Consortium, that requires projects to be multi-institutional. The Steering Committee chose not to adopt that recommendation, but to encourage such projects with an appropriate funding structure.

Program Administration: The panel found the current administration satisfactory. It recommended seeking block grant funding if and when that becomes available, and lobbying the Fish and Wildlife Service for an indirect cost rate that adequately covers the expenses that must be funded this way.

Wild Trout Research Laboratory: The panel concluded that the current mechanism for lab funding, i.e. self-funding through user fees, is appropriate and should not be altered. The lab should not receive operating funds directly from the Whirling Disease grant.

Research Thrust and Topics: The review panel concurred with the current deliberate re-direction of priorities from basic biology towards field-scale, applied projects. A number of specific topics were cited as worthy of investigation. The Steering Committee adopted most of these into the Research Plan for 2002-2003. Since the Whirling Disease Foundation was funded separately to investigate disease-resistant trout, this subject was not adopted as a priority for Initiative research.

Appendix E

Initiative Strategic Plan, January 2007

Appendix E. PHASE III PROGRAM PLAN
2003-2008
WHIRLING DISEASE INITIATIVE

Report revised: January 12, 2007

Section I. INTRODUCTION

Purpose of Five-Year Plan

The purpose of this Five-Year Plan is to guide the third and final phase of the Whirling Disease Initiative (also referred to as the Initiative or WDI). In the program's final phase, activities will focus on: (1) addressing preliminary data gaps (as identified by the Risk Assessment); (2) development, testing, and dissemination of tools to allow fishery, hatchery and watershed managers to achieve the two goals of the Initiative; and (3) developing and implementing a *formal* Whirling Disease Initiative outreach program. The five-year plan should serve as the foundation for future, annual research/development plans and requests for proposals, as well as outreach activities. The activities described herein are anticipated to take place over roughly the next five-year period (2003 to 2008), although development of a full suite of effective, well-characterized management tools could take longer. This is a research initiative and we cannot be certain when all the goals and objectives will be accomplished. This five-year plan revision is an attempt to lay out a plan for program closure within a defined timeframe; however, it must be emphasized that our research projections are speculative and unforeseen actions may be warranted.

Whirling Disease Background

Over the past decade, the microscopic parasite *Myxobolus cerebralis*, which causes whirling disease in many salmonid fish species, has spread and infected hundreds of river and stream reaches throughout the United States. The impacts of this parasite on susceptible trout can be dramatic: darkening of the tail, skeletal deformities, frenzied tail chasing (thus the name "whirling" disease), and death. The whirling disease parasite is extremely hardy and long-lived. Like the malaria parasite, it infects two very different hosts alternately. In the case of whirling disease, the life cycle employs a fish host and an aquatic worm host (*Tubifex tubifex)*; and therefore, reaching an understanding of the parasite has required defining the biology of infected fish, infected worms, and parasite life stages.

A Eurasian native, *M. cerebralis* made its way to North America in the 1950s. It was once believed to be relatively harmless to wild fish, but research in the mid-1990s found that it was decimating rainbow trout populations in some of the Rocky Mountain Region's finest river fisheries. Most salmonids have been found to be susceptible.

Whirling disease is therefore a major threat both to biological diversity and to the nation's multi-million-dollar fishing and tourism economy. The whirling disease parasite has been reported in 24 states—from New York to California—and has generated great concern among anglers, scientists, and fisheries managers.

The Whirling Disease Initiative

The Whirling Disease Initiative was established by Act of Congress in 1997. Its purpose is to conduct research that develops practical management solutions to maintain viable, self-sustaining wild trout fisheries in the presence of the whirling disease parasite. The Initiative's ultimate clients are state, tribal, and federal fisheries-management agencies, and the constituencies they serve.

General oversight of the Initiative is provided by the National Partnership for the Management of Wild and Native Coldwater Fisheries. The National Partnership is a consortium of organizations concerned with the status of wild and native fisheries in the United States—Federal and state agencies, professional associations, and private advocacy organizations (*Appendix A. Board of Representatives*). The overall goal of the Partnership is to move biological research and management trials forward to make available to fishery managers practical options for controlling the disease. The National Partnership provides long-term direction to the Whirling Disease Initiative. To do this, the Partnership's Board of Representatives convenes annually for a detailed briefing by whirling disease researchers, and participates in discussions concerning fisheries health and research needs (*Appendix B. Partnership Charter*).

In-depth scientific direction is given to the Whirling Disease Initiative by its Steering Committee. The committee is made up of representatives from state fish and wildlife agencies, federal natural resource agencies, and the Whirling Disease Foundation (*Appendix C. Steering Committee*). Working in collaboration with Montana Water Center staff, the Steering Committee prepares an annual research plan, issues requests for proposals based on its topical priorities, selects and approves projects for funding following scientific peer review, and distributes the research results within the scientific and fishery management communities and to other stakeholders. The Montana Water Center is the administrative entity that manages the program and coordinates outreach and educational activities.

Each year, federal funding earmarked in the Interior Appropriations Bill comes to the Initiative through the Division of the National Fish Hatchery System, US Fish and Wildlife Service. Projects are chosen for funding by the Steering Committee, following peer review by three independent reviewers. During the Initiative's nine-year history, the Steering Committee has chosen to support a variety of projects, ranging from basic biological research to applied research directly testing potential management solutions. Early projects were principally aimed at explicating the biology of whirling disease. In

2000, the Steering Committee began deliberately shifting the Initiative priority toward field research more closely tied to possible management strategies. This "applied" focus has become stronger, with the encouragement of large-scale field projects addressing the ecology of whirling disease and the testing of potential methods for controlling its effects or spread.

A total of $8.1 million in USFWS funding has supported the Initiative to date. The Initiative has sponsored from six to 20 research projects in each funding cycle. A research cycle generally runs from May of one year through December of the following year, thus allowing for two research field seasons and an 18-month timeframe. In 2006, the Initiative funded two broad-scale projects, which were given 28 months for project completion. More than 120 research projects have been carried out by university, public-agency scientists, and private firms since 1997. Typically two to four investigators are involved in each project, and they bring to the project cash or in-kind match of 25 to 150 percent of the amount of the federal grant. Students are involved in most projects, either as technicians or, more often, as graduate research assistants. A total of more than $5.6 million of federal and $4.3 million in matching funds have been expended or committed by WDI research investigations (*Tables 6* and *7*).

Although not a formal Initiative requirement, publication of research results is strongly encouraged by the Partnership Board and the Steering Committee. To date, 38 peer-reviewed publications have been produced.

Initiative Cooperating Organizations/Agencies

The Whirling Disease Initiative strives to foster collaboration amongst many scientific entities, governmental agencies, and fisheries organizations. *Table 1* identifies those entities and their roles.

Table 1. Whirling Disease Initiative Cooperator Responsibilities

Agency/Entity	Administration		Technical Oversight	Research Work	Outreach Activities
	Program	Financial			
Montana Water Center	X	X	X		X
US Fish and Wildlife Service	X	X	X		X
Montana State University		X			
WDI National Partnership Board	X		X		
WDI Steering Committee	X		X		
WD Foundation	X	X	X		X
MSU Wild Trout Lab				X	
State Universities				X	
State Agencies				X	X
Federal Agencies				X	X
Private Firms				X	X

Section II. INITIATIVE STRUCTURE & OVERVIEW

In the nine-year history of the Whirling Disease Initiative, the emphases of program objectives and their associated activities have changed. Two objectives—program administration and research project management—are ongoing and take place every year. In the early years of the Initiative there was very heavy emphasis on the biological research objective (Objective 3) since the disease is complex and its severity and spread are dependent on a number of biological and environmental factors. In autumn 2002, the Board of Representatives of the National Partnership directed that program emphasis move away from biological research toward testing and demonstration of field strategies (Objective 4), and ultimately the development of management tools. Potential management tools were identified and evaluated by the Steering Committee and subsequently modified by the National Partnership Board in 2003. For the 2006-2007 research cycle, the Partnership Board and Steering Committee further expanded the program's emphasis to include projects that (1) take an epidemiological or ecological research approach focusing on the incidence, severity, spread and effects of whirling disease across populations of wild fish; (2) synthesize information on what is known about whirling disease; and consistent with their 2003 decision (3) generate information that will be directly usable in formulating fishery management tools. In the final research cycle for Phase III of the Five-Year Plan (2007-2008), the National Partnership Board directed the Steering Committee and Montana Water Center to pursue research proposals that focus on data gaps and highly-targeted, state-specific research needs.

In a complementary action to management tool development in 2002, the Board also directed that an outreach program to fishery professionals be initiated (Objective 5B) in Phase III of the Initiative. A marketing firm was engaged in 2003 to help the Initiative

focus its outreach program goals and to survey fisheries professionals about their informational needs and favored methods of receiving research results. The consultant's findings and recommendations provided the backbone of the Phase III outreach program effort and are outlined in Objective 5B (also see *Section VI. Establishment and Implementation of Outreach Program* of this report for details).

In 2003, the Montana Water Center—in partnership with the Steering Committee and several Partnership Board members—developed a preliminary draft of a five-year program plan to guide the remainder of the Initiative's work. That five-year plan was further revised and subsequently approved at the October 2003 National Partnership Board meeting. This plan has been updated each year since then. The USFWS requests that a structured format be used when reporting on Whirling Disease Initiative actions, projects, and deliverables. The next section of this report was specifically prepared to satisfy that request.

Whirling Disease Initiative Purpose, Goals, and Objectives

PURPOSE:

Provide fishery managers with as complete and effective a set of management tools as possible, to allow them to maintain populations of wild and native salmonids in the presence of the whirling disease parasite.

GOALS:

Goals of fishery managers that are supported by the Initiative:

Goal 1. To prevent introduction and establishment of the disease into streams that are parasite negative.

Goal 2. In parasite-positive streams, to maintain or re-establish self-sustaining fish populations.

OBJECTIVES, TASKS, & PRODUCTS:

Objective 1. Provide Administrative Framework

Administrative services performed by Montana Water Center staff are those necessary to support overall Initiative goals. Work performed under this objective has continued through all phases of the Whirling Disease Initiative.

Task 1A. Perform administrative and management services: Administration, management and operational infrastructure of the Whirling Disease Initiative; contractor and custodian of funds; hire and supervise Whirling Disease Initiative staff; National Partnership Board meeting coordination; communication link with Montana State University administration and Office of Sponsored Programs; manage and maintain Whirling Disease Initiative office; report to Congress and the USFWS (sponsoring agency).

Methods/Activities: Montana Water Center staff are responsible for seeing that multiple administrative tasks are accomplished, including: acting as administrator for Cooperative Agreement and budget with USFWS; administer and manage all subcontracted research projects; disburse funds for the principal investigators; documenting use of public resources for Initiative's funders/sponsors; maintain financial filing system; plan, organize, and coordinate the annual National Partnership Board meeting.

Products: Whirling Disease Initiative staff and office; annual Cooperative Agreement; reports (comprehensive annual report to Congress, annual budgets, briefings); contracts and subcontracts; grant expenditures and financial statements/files; annual National Partnership Board meeting.

Objective 2. Research Project Management & Oversight

Whirling Disease Initiative research project management is conducted in a three-tiered process. The National Partnership Board oversees the Whirling Disease Initiative and provides long-term program planning, direction, and evaluation. The Steering Committee develops and modifies a long-term program plan, formulates an annual work plan and Request for Proposals, and supervises a peer-review process for allocating funds to projects. The Montana Water Center is responsible for the general administration of the Whirling Disease Initiative, including: convening the Board of Representatives and Steering

Committee, maintaining communication within the Partnership Board, and submitting detailed reports on all research components of the Initiative.

Task 2A. Administer competitive research grant program

Methods/Activities: Develop and distribute annual research grant Request for Proposals; organize and operate proposal peer-review and proposal ranking process; award research contracts and subcontracts; communication link with research teams; monitor research progress; write research progress reports; maintain research archives; document work progress and track project spending; ensure full performance of all subcontractors and grantees, consistent with funds received and expended.

Products: Research contact lists; research projects; research project filing system; annual reports; research project final reports; research project briefings and summary reports; research team publications; research archives.

Task 2B. Organize and support sponsoring agency and technical advisors (USFWS, National Partnership Board and Steering Committee): Incorporate into the Initiative the technical expertise and institutional concerns of the public agencies, professional associations, and advocacy organizations concerned with fisheries health in the United

States; meeting management and facilitation; review and modify the Initiative program plan as appropriate; review progress of the Initiative (goals, objectives, cooperative agreement, charter).

Methods/Activities: Develop briefings and summary reports for distribution to partners and advisory committees; schedule, organize, and facilitate: meetings, conferences, annual meetings, field trips; solicit feedback from National Partnership Board at autumn annual meetings; review the status of the disease; review progress of the Initiative; review and potentially revise the Partnership Charter; advise the Steering Committee on conduct of the grants program and the outreach program; review and revise the Initiative program plan; make recommendations on filling vacancies on Board and Steering Committee.

Products: Reports and briefings, meeting minutes, Cooperative Agreement, Partnership Charter, program plan.

Task 2C. Provide organizational/financial support for Whirling Disease Symposium

Methods/Activities: Facilitate funded investigators to present their findings; work with Whirling Disease Foundation on program planning; report on the status of the Initiative; and fund travel to the Symposium by non-federal Steering Committee and Partnership Board members.

Products: The Annual Whirling Disease Symposium, project completion presentations, discussion session, proceedings, annual publication of symposium and proceedings available on the WDI Web site.

Objective 3. Conduct Whirling Disease Research
Objective 3A. Conduct Basic Research
Objective 3B. Conduct Applied Research

Task 3A. Conduct basic research projects: Investigate and promote a better understanding of: the parasite's life cycle; the susceptibility of different salmonid species and strains; the ecology and epidemiology of the disease; correlation between environmental and landscape features, and disease occurrence; and correlation between habitat characteristics (flow regime/channel configuration) and severity of disease.

Task 3B. Conduct applied research projects: Field sampling methods; diagnostic techniques; ways of quantifying the severity of the disease in fish and worms; effects of habitat modification (enhancement, rehabilitation, and degradation) on worm and fish populations; effect of land types and stream strata on infection rate; feasibility of direct

filtration for TAM removal; the role of anglers and other vectors in the spread of the disease; and the effects of anadromous fishery management strategies.

Methods/Activities: Solicit research proposals; conduct targeted whirling disease research investigations within 20-month time fame; write progress and final project reports; compile publications.

Products: Research team results and final reports, student theses and dissertations, presentations at Whirling Disease Symposium, and research team publications.

Objective 4. Test Management Strategies

Task 4A. Test management strategies: Evaluate at full scale subjects such as controls on point sources of infection, enhancing the resistance of wild fish stocks, reducing oligochaete habitat, or the effects of riparian restoration projects.

Task 4B. Develop applied management tools (e.g. risk assessment, prevention, detection, treatment).

Methods/Activities: University and public agency biologists and fishery managers conduct targeted research investigations that test whirling disease management strategies (e.g. risk assessment, prevention, detection, treatment, etc.).

Products: Research team results and final reports; presentations at Whirling Disease Symposium; research team publications; defined management tools.

Objective 5. Conduct Outreach and Education Activities
Objective 5A. Document Results from Research Projects (Phases I & II)
Objective 5B. Develop and Implement a Formal Whirling Disease Outreach Program (Phase III)

Conducting outreach activities has been an ongoing, yet somewhat limited, effort since the inception of the Whirling Disease Initiative in 1997. Now, in Phase III of the Initiative, a concerted effort to increase accessibility and availability of whirling disease information has been launched. The primary audience to be served through the outreach program is technical professionals—fishery managers and administrators, hatchery operators and fish health professionals, researchers and agency land managers. The secondary audience is comprised of the general public (particularly the angling public) and aquatic information and education professionals, both within the agencies and in private organizations such as the Whirling Disease Foundation, Trout Unlimited and the Federation of Fly Fishers.

Objective 5A. Document Results from Research Projects (Phases I & II)

Task 5A. Document results from research projects.

Methods/Activities: Publish summary reports for distribution to project partners; facilitate publicity; establish and maintain Whirling Disease Initiative Web site; link Web site to Whirling Disease Foundation; establish technical library/archive of project proposals, reports, and publications; disseminate research results to interested parties; maintain communications links with researchers, project partners, and technical advisors.

Products: Summary reports (annual reports, five-year report); contact lists; Whirling Disease Initiative Web site; Montana Water Center filing system; technical library/archives; data repository.

Objective 5B. Develop and Implement Formal Whirling Disease Outreach Program (Phase III)

Assure that those who need to know the research and testing results and pertinent information generated outside the Whirling Disease Initiative, have full access to the data and their interpretation by experts.

Task 5B. Communicate findings from research and testing projects to fishery managers and NGOs.

Task 5C. Disseminate applied management tools (e.g. risk assessment, prevention, detection, treatment) to interested parties: Develop outreach materials/learning tools; give presentations; expand current Whirling Disease Initiative Web site, build interactive component to Web site; serve as central point of contact for persons seeking whirling disease information; distribute outreach materials; report to project partners.

Methods/Activities: Montana Water Center hired an outreach specialist in summer 2004 to: lead the outreach effort; develop outreach plan; compile audience lists; develop and distribute printed and multi-media materials explaining the biology and spread of the disease and techniques for mitigating its spread and severity; make formal presentations at regional or national fisheries meetings; make targeted visits to fishery managers at their workplaces; respond to requests for information from biologists, agency personnel and land managers; expand the Whirling Disease Initiative Web site with detailed project results and management guidance; assess the current situation for whirling disease, including pertinent state laws and the true geographical scope and severity of the disease; develop annual updates for key stakeholders to keep them apprised of the situation and to combat apathy; further develop the risk assessment methodology and make it into a useful product for fishery managers; compile status-and-trend information and mount it on the Web site; compile state-by-state information on policies and regulations and mount a compendium on the Web site; create and promote the authoritative whirling disease electronic resource that is

both customized by audience and an easy-to-use central information repository; develop and distribute a periodic newsletter; collaborate with the Whirling Disease Foundation on outreach activities; build strategic alliances to leverage resources; and maintain communication links with researchers, project partners, technical advisors, fishery managers, MSU, the media, and the general public.

Products: Contact lists; whirling disease bibliography; interactive Web site; outreach materials/technical handouts; presentations; newsletter; whirling disease documentary film; brochure; publications; media coverage.

PROJECT MILESTONES

As a first step in achieving the objectives previously listed, the Initiative typically outlines activities proposed for the next program funding cycle each autumn (see *Table 2*). However, this schedule will not be followed, since as of January 2007 FY2007 funding for the WDI is still indeterminate. Consequently, the Montana Water Center and Steering Committee postponed the 2007 Request-For-Proposals process until funding is secured. *Table 3* below illustrates how—under a much shorter time frame—the WDI proposes to conduct the 2007 Request-For-Proposals process, if funding is secured.

Milestone *Tables 4* and *5* lay out a more comprehensive overview of WDI program activities. *Table 4* documents activities and deliverables from Phases I and II of the Initiative (1997-2002) and *Table 5* focuses on Phase III activities and deliverables (2003-2008).

Table 2. Milestones for the final program cycle (May 2007 to December 2008) developed in October 2006:

Activity	Proposed Date
Meeting of the National Partnership Board of Representatives	September 10, 2006
Request for Preproposals issued by the Steering Committee/Water Center	November 15, 2006
Preproposals submitted to the Water Center	December 20, 2006
Interim reports for projects concluding in 2007 and 2008 due	December 31, 2006
Final reports for 2005-2006 projects due	December 31, 2006 – March 30, 2007
Steering Committee selects projects for full proposals	January 4, 2007
Request for full proposals released	January 5, 2007
Launch new Data Repository to the public	January 30, 2007
Annual Report to Congress and USFWS due	January 31, 2007
Distribution of outreach materials and outreach presentations to fishery managers	Ongoing, 2007-2008
Database/data repository project activities (work with PIs on metadata and dataset exchange, etc.)	Ongoing, 2007-2008
Whirling Disease Symposium, Denver	February 12-13, 2007
Full proposals due to the Montana Water Center	March 2, 2007
Peer review of proposals	March 5 – March 28, 2007
Research projects chosen for funding	April 2-3, 2007
Contracts in place; research projects begin	May 1-15, 2007
Interim reports for projects concluding in 2008 due	December 31, 2007
Final reports for 2006-2007 projects due	December 31, 2007 – March 30, 2008
Annual report to Congress and USFWS due	January 31, 2008
Metadata and datasets for 2006-2007 projects due	June 30, 2008
2006-2008 projects conclude; final reports due 2007-2008 projects conclude; final reports due	December 31, 2008 – March 30, 2009
Metadata and datasets for 2006-2008 projects due Metadata and datasets for 2007-2008 projects due	June 30, 2009 June 30, 2009

Table 3. Milestones for the final WDI program cycle (May 2007 to December 2008) developed in January 2007

Activity	Proposed Date
Meeting of the National Partnership Board of Representatives	September 10, 2006
Request for Preproposals cancelled by the Steering Committee/Water Center	November 15, 2006
Interim reports for projects concluding in 2007 and 2008 due	December 31, 2006
Final reports for 2005-2006 projects due	December 31, 2006 – March 30, 2007
Steering Committee meets to re-evaluate the FY07 funding situation	January 11, 2007
If FY07 WDI funding is secured, Steering Committee will contact individual researchers and request full proposals on specific research topics	January 15-30, 2007
Launch new Data Repository to the public	January 30, 2007
Annual Report to Congress and USFWS due	January 31, 2007
Liz Galli-Noble, WDI Program Director, leaves	January 31, 2007
Distribution of outreach materials and outreach presentations to fishery managers	Ongoing, 2007-2008
Database/data repository project activities (work with PIs on metadata and dataset exchange, etc.)	Ongoing, 2007-2008
Whirling Disease Symposium, Denver	February 12-13, 2007
Full proposals due to Steering Committee	March 2, 2007
Peer review of proposals	March 5 – March 28, 2007
Research projects chosen for funding	April 2-3, 2007
Contracts in place; research projects begin	May 15-30, 2007
Interim reports for projects concluding in 2008 due	December 31, 2007
Final reports for 2006-2007 projects due	December 31, 2007 – March 30, 2008
Annual report to Congress and USFWS due	January 31, 2008
Metadata and datasets for 2006-2007 projects due	June 30, 2008
2006-2008 projects conclude; final reports due 2007-2008 projects conclude; final reports due	December 31, 2008 – March 30, 2009
Metadata and datasets for 2006-2008 projects due Metadata and datasets for 2007-2008 projects due	June 30, 2009 June 30, 2009
Whirling Disease Initiative program ends	June 30, 2009

Table 4. Milestones for Whirling Disease Initiative; 1997 to 2002

The administration of all milestones outlined in this table is the responsibility of the Montana Water Center.

Objective/Task	Product/Output	Quantity of Outputs (if applicable)					
		1997	1998	1999	2000	2001	2002
Objective 1: Provide Administrative Framework Task 1A. Perform administrative & management services	Cooperative Agreement & Budget	1	1	1	1	1	1
	Managing subcontracts	12	20	16	14	13	12
	Administer & maintain expenditures/financial records	12	22	36	30	28	26
	Reporting: Annual Report to Congress 5-Year Plan	 1 NA	 1 NA	 1 NA	 1 NA	 1 NA	 1 1
	Manage WDI staff & maintain WDI office	X	X	X	X	X	X
Objective 2: Research Project Management & Oversight Task 2A. Administer competitive research grant program Task 2B. Organize & support sponsoring agency & technical advisors Task 2C. Organizational/financal support for Whirling Disease Symposium	Maintain research contact lists	X	X	X	X	X	X
	Steering Committee meetings facilitated				4	6	6
	National Partnership Board meetings facilitated Conference calls Annual autumn meeting	 0	 1	 1	 1	 1 1	 1 1
	WD Symposia: Research presentations	1 NA	1 12	1 21	1 17	1 15	1 21
	Grant Process: RFPs Proposals peer reviewed Projects funded	 1 24 12	 1 25 20	 1 30 16	 1 23 15	 1 21 14	 1 22 12
	Communication w/research teams	X	X	X	X	X	X
	Reporting: Briefings Summary reports	 X 1	 X 1	 X 1	 X 1	 X 1	 X 1
Objective 3: Conduct Whirling Disease Research **3A. Conduct Basic Research** **3B. Conduct Applied Research** Task 3A. Investigate parasite's life cycle, susceptibility of salmonid species and strains, ecology and epidemiology of disease, etc. Task 3B. Field sampling methods, diagnostic techniques, quantifying severity of disease in fish & worms, etc.	Research projects/results/final reports by category: 1. Ecological Modeling & Stats	0	0	0	0	1	2
	2. Habitat Restoration & Mgt/Hydrology	0	0	0	3	2	2
	3. Epidemiology	0	0	3	1	1	4
	4. Fish Culture	0	1	1	1	1	1
	5. Fishery Mgt/Population Censusing	2	1	1	0	1	0
	6. Immunology	0	5	4	1	0	1
	7. Fish Pathology	2	0	0	1	2	0
	8. Parasitology	1	0	0	0	0	0
	9. Invertebrate Ecology & Taxonomy	5	3	2	3	4	1
	10. Methods	2	3	3	1	1	1
	11. Salmonid Ecology	0	2	2	3	0	0
	12. Other	0	5	0	0	0	0
	Total	12	20	16	14	13	12

Objective/Task	Product/Output	Quantity of Outputs (if applicable)					
		1997	1998	1999	2000	2001	2002
	Publications	0	0	0	1	5	16
Objective 4: Test Management Strategies Task 4A. Evaluate projects, resistant stock, host habitat, etc. Task 4B. Develop applied management tools.	Tests/results/final reports by category: 1. Risk Assessment application 2. Evaluate full-scale projects 3. Resistant fish stock 4. Host habitat 5. Reclaim degraded watercourses 6. Others	0	0	0	0	0	0
	Management Tools	NA	NA	NA	NA	NA	NA
Objective 5: Conduct Outreach & Education Activities **5A. Document Results from Research Projects (Phases I & II)** **5B. Develop & Implement WD Outreach Program (Phase III)** Task 5A. Document results from research projects. Task 5B. Communicate findings from research/testing projects to fishery managers. Task 5C. Disseminate applied management tools.	WDI Web site (update & maintain)	NA	Establish Web site	X	X	X	X
	Interactive WDI Web site	NA	NA	NA	NA	NA	NA
	Archive research products: reports, publications, etc.	NA	X	X	X	X	X
	WDI Bibliography (update, maintain)	NA	X	X	X	X	X
	Expanded WD Bibliography	NA	NA	NA	NA	NA	NA
	Publicity products: Press releases Media contact: interviews						
	Reporting: Briefings Summary reports	X 1	X 1	X 1	X 1	X 1	X 1
	Outreach materials: Contact lists Educational mailings/handouts Newsletter Outreach CDs (tech transfer)	NA	NA	NA	NA	NA	NA
	Outreach/education presentations						
	Outreach publications	NA	NA	NA	NA	NA	NA

Key:
NA = Not Applicable.
= Information not available.
X = Ongoing activity.

Table 5 projects program activities and deliverables for Whirling Disease Initiative Phase III, 2003 through 2008. This plan and timeline are based on the fact that the disease is still spreading. It assumes that the Initiative will continue to be funded through the US Fish and Wildlife Service at the levels shown through 2008. As in the past, Initiative activities will be coordinated with those of the Whirling Disease Foundation to optimize the benefits from both.

Previous to the request for a long-term program plan by the USFWS, the Steering Committee and the National Partnership Board had chosen **not** to establish timelines for either the research/testing program or the outreach program, beyond the 20-month, 2004-2005 funding cycle. Consequently, we emphasize that some of the outputs shown in *Table 5* are speculative and will likely be adjusted in the future.

Table 5. Milestones for Whirling Disease Initiative Phase III, 2003 to 2008
The administration of all milestones outlined in this table is the responsibility of the Montana Water Center.

Objective / Task	Product / Output	Quantity of Outputs, if applicable (2007 - 2008 estimated)					
		2003	2004	2005	2006	2007	2008
Objective 1: Provide Administrative Framework Task 1A. Perform administrative & management services	Cooperative Agreement & Budget	1	1	1	1	1	1
	Managing subcontracts	21	19	22	20	15-20	10-15
	Administer & maintain expenditures/financial records	X	X	X	X	X	X
	Reporting: Annual Report to Congress 5-Year Plan	 1 1	 1 1	 1 updated	 1 updated	 1 NA	 1 NA
	Manage WDI staff & maintain WDI office	X	X	X	X	X	X
Objective 2: Research Project Management & Oversight Task 2A. Administer competitive research grant program Task 2B. Organize & support sponsoring agency & technical advisors	Maintain research contact lists	X	X	X	X	X	X
	Steering Committee meetings facilitated	5	6	7	7	4-6	2-4
	National Partnership Board meetings facilitated Conference calls Annual autumn meeting	 1 1	 2 1	 1 1	 0 1	 1-3 1	 1 1
	WDF Symposia: Research presentations/posters	1 16	1 15	1 12	1 22	1 10-20	1 10

Objective / Task	Product / Output	Quantity of Outputs, if applicable (2007 - 2008 estimated)					
		2003	2004	2005	2006	2007	2008
Task 2C. Organizational / financial support for Whirling Disease Symposium	Grant Process:						
	RFPs	1	2	1	1	1	0
	Preproposals reviewed	NA	18	28	16	0	0
	Full proposals requested & peer reviewed	17	20	21	13	5-10	0
	Projects funded	8	12	10	6	2-8	0
	Communications w/research teams	X	X	X	X	X	X
	Reporting:						
	Briefings	X	X	X	X	X	X
	Summary reports	1	1	1	1	1	1
Objective 3: Conduct Whirling Disease Research **3A. Conduct Basic Research** **3B. Conduct Applied Research** Task 3A. Investigate parasite's life cycle, susceptibility of salmonid species and strains, ecology and epidemiology of disease, etc. Task 3B. Field sampling methods, diagnostic techniques, quantifying severity of disease in fish & worms, etc.	Research projects/results/final reports by category:						
	1. Ecological Modeling & Stats	0	0	0	2	+	0
	2. Habitat Restoration & Mgt/Hydrology	0	4	3	1	+	0
	3. Epidemiology	1	1	1	1	+	0
	4. Fish Culture	0	0	0	0	-	0
	5. Fishery Mgt/Population Censusing	0	2	2	0	+	0
	6. Immunology	1	0	0	0	-	0
	7. Fish Pathology	0	1	0	0	-	0
	8. Parasitology	1	3	3	1	+	0
	9. Invertebrate Ecology & Taxonomy	0	0	0	1	+	0
	10. Methods	2	1	0	0	-	0
	11. Salmonid Ecology	0	0	0	0	-	0
	12. Other	0	0	1	0	?	0
	Total	5	12	10	6	2-8	0
	Publications	5	1	10	12	5-10	5-10

Objective / Task	Product / Output	Quantity of Outputs, if applicable (2007 - 2008 estimated)					
		2003	2004	2005	2006	2007	2008
Objective 4: Test Management Strategies Task 4A. Evaluate projects, resistant stock, host habitat, etc. Task 4B. Develop applied management tools.	Tests/results/final reports by category:						
	1. Risk Assessment application	2	2	2	2	+	0
	2. Evaluate full-scale projects	0	0	+	+	+	0
	3. Resistant fish stock	0	0	1	1	+	0
	4. Host habitat	1	1	2	1	+	0
	5. Reclaim degraded watercourses	0	0	+	1	+	0
	6. Others	0	0	?	?	?	0
	Total	3	1	5	5	2-5	0
	Management Tools	0	?	2	2	2-5	0 3-5
Objective 5: Conduct Outreach & Education Activities **5A. Document Results from Research Projects (Phases I & II)** **5B. Develop & Implement WD Outreach Program (Phase III)** Task 5A. Document results from research projects. Task 5B. Communicate findings from research/testing projects to fishery managers. Task 5C. Disseminate applied management tools.	WDI Web site (update & maintain)	NA	Establish	X	X	X	X
	Archive research products: reports, publications, etc.	X	X	X	X	X	X
	WDI Bibliography (update, maintain)	X	X	X	X	X	X
	Expanded WDI Bibliography	NA	X	X	X	X	X
	Publicity products:						
	Press releases	3	5	3	5	5	5
	Media contact: interviews, PSAs, etc.	NA	1	4	2	2	3
	Reporting:						
	Briefings	X	X	X	X	X	X
	Summary reports	1	1	1	1	1	1
	Outreach materials:						
	Contact lists		X	X	X	X	X
	Educational mailings/handouts		3	6	10	5	5
	WDI Newsletter		Establish	3	4	4	4
	Newsletter recipients		850	1500	1500	2000	2000
	WDI Brochure		0	0	1	1	1
	Brochure recipients	NA	NA	NA	12,000	10,000	10,000
	Outreach video produced		0	0	1	0	0
	Video/DVD recipients		NA	NA	250	1500	1000
	Outreach/education presentations	2	2	7	15	5-10	5-10
	Outreach publications (articles, editorials, etc.)	NA	2	5	10	1-5	1-5
	Outreach program evaluation	NA	NA	NA	1	1	1

Key: NA = Not Applicable. = Information not available. **X** = Ongoing activity. **-** = It is predicted that the trend from 2005 to 2008 will be a decrease in the number of basic research projects conducted. **+** = It is predicted that the trend from 2005 to 2008 will be an increase in the number of applied research projects conducted, management strategies tested, and management tools developed. **?** = It is not possible to predict what the trend will be for this task.

Section III. MANAGEMENT TOOLS

Potential management tools were identified and evaluated by the Whirling Disease Steering Committee in 2003. The committee rated each tool according to its expert judgment of the tool's feasibility of development, technical and administrative feasibility of application, likely degree and breadth of effectiveness, time requirement for implementation, financial and other costs, and likely side effects. The uncertainty associated with each was also taken into consideration: some techniques are much better developed or demonstrated than others. A ranking matrix was developed and used by the Steering Committee to evaluate potential tools. Various potential types of tools are listed below, as rated by the Steering Committee and supported by the National Partnership Board in Phase III of the Initiative.

The following research and demonstration projects that contribute directly to the development of these types of tools were supported by the Steering Committee in Phase III of the WDI:

Watershed and riparian management actions - these include such actions as flow augmentation, channel modification or monitoring the effects of changed practices in the riparian zone or upland areas.

Filtration - straining of tributary flows (including hatchery effluent) to remove TAMs, using either constructed or wetland systems.

Exploitation of fish disease resistance - capitalizing on genetic or life-history traits that confer resistance to whirling disease in wild or stocked fisheries.

Diagnosis - assaying fish, water and worms for the presence and intensity of a whirling disease infection. Characterizing Tubifex habitat is also of interest.

Vector control actions - these will depend on what are judged the most important modes of disease spread: fishing gear, wild birds, stocking of infected fish into private ponds, "bucket biologists," interbasin transfer of water, etc.

Semi-quantitative risk assessment - using a scheme incorporating knowledge of life history traits to prioritize among risk factors and identify populations most at risk of disease introduction and spread. And assess risks to native species conservation and recovery.

Exploitation of resistance in worms - potential disease-control tools that would exploit Tubifex biology have been debated by the Steering Committee over the years. Stocking resistant worms was judged not feasible early in Phase III, but subsequent research findings indicated that this line of research warranted a second look in the latter half of Phase III.

Development of these types of tools was considered less urgent and generally has not been supported in Phase III of the WDI:

Mathematical models - the Steering Committee does not believe that advanced mathematical models to predict the spread and severity of the disease have promise in the foreseeable future.

Hatchery manipulations - the needed structures and practices are well known, and are being implemented by hatchery managers.
Prophylactics - there has been sporadic work over the course of several years on drugs to control whirling disease. The results have never shown promise.
Fish passage barriers - these are judged ineffective for control of the spread of whirling disease.

Section IV. RESEARCH EMPHASIS BROADENS IN 2006-2007 RFP PROCESS

In October 2005, the National Partnership Board made the decision to broaden the 2006-2007 RFP process to include broad-scale, synthetic research projects and the solicitation for a comparative analysis of whirling disease testing methods. The Steering Committee was directed to consider projects that (1) take an epidemiological or ecological research approach focusing on the incidence, severity, spread and effects of whirling disease across populations of wild fish, (2) synthesize information on what is known about whirling disease, and (3) generate information that will be directly usable in formulating fishery management tools. Research preproposals were also sought under the "topical, management-oriented research projects" category, which has been a research focus since 2003.

Section V. FINAL RESEARCH CYCLE FOR PHASE III OF THE INITIATIVE

In the final research cycle of the Whirling Disease Initiative (July 2007 through December 31, 2008), the National Partnership Board directed the Steering Committee to conduct a targeted proposal request process. Research proposals will be sought under two categories: Category 1 investigations that develop management tools, synthesize knowledge, or address specific data gaps; and Category 2 broad-scale analyses of whirling disease effects and risk. Further, innovative proposals will also be entertained by the Steering Committee, but in order for a proposal to be considered for funding, it must be cost-effective, address a clearly defined data gap, and have direct application to fisheries management.

If FY2007 program funding is secured, the Steering Committee will contact individual researchers and request full proposals on the following research topics:

Category 1

1. **Mountain Whitefish Investigation:** An ecological assessment of whirling disease impacts upon populations of wild mountain whitefish *(Prosopium williamsoni).*

2. **Arctic Grayling Investigation:** An evaluation of juvenile arctic grayling *(Thymallus arcticus)* mortality upon contact to *M. cerebralis* triactinomyxons.

3. ***Tubifex tubifex* Investigations:** Exploring the phenomenon of resistance among *T. tubifex* and the potential to exploit this as a management tool to reduce impacts of whirling disease among fish.
    a. ***T. tubifex* Lineage Manipulation:** Evaluations of *T. tubifex* manipulation as a management tool including explicit feasibility analysis; and the use of this tool for small-scale, organically-enriched areas such as hatchery settling ponds, small reservoirs, beaver ponds, and off-channel private ponds.

    b. ***T. tubifex* Genetics of Resistance:** An accurate identification of *T. tubifex* genetic indicators of resistance.

    c. **Environment, Density, and/or Community Influence on *T. tubifex* Resistance:** A conclusive analysis of how factors such as substrate, worm density, and community dynamics influence the resistance of *T. tubifex* to *M. cerebralis,* preferably through controlled laboratory experiments. Analysis must include consideration of disease impacts among fish.

Category 2

A comparative evaluation of whirling disease impacts in three regions of the United States: East Coast, West Coast and Intermountain West. The reported impacts of whirling disease on wild populations of salmonids have been widely variable among these regions. An evaluation that analyzes the widely-varied impacts of whirling disease on wild populations of salmonids reported in these regions, using long-term datasets. Include an analysis of wild salmonid population impacts in the three regions due to whirling disease related to environmental factors and *T. tubifex* population qualities.

Monitoring and Revision

The Steering Committee and National Partnership Board have chosen not to implement a formal process for monitoring the success of particular lines of research, and changing research priorities as a result. However, this is done informally by the Steering Committee each year as it develops its request for proposals and selects projects for funding. The Five-Year Plan has been reviewed annually by the Partnership Board and altered as appropriate. The program plan is revised, and provided to all appropriate entities, annually to reflect these alterations.

Section VI. ESTABLISHMENT AND IMPLEMENTATION OF OUTREACH PROGRAM

Foundation of the Program

At its October 2002 meeting, the National Partnership Board charged the Steering Committee with beginning to distribute research results to fishery managers. The first step taken by the committee was to engage a marketing firm (Strategicom) to focus its outreach goals and survey fishery managers about their information needs and favored methods of receiving research results. The conclusions reached by the consultant, after surveying 90 fisheries professionals in 23 states where whirling disease is found, were:

- fisheries professionals were interested in receiving more information on whirling disease,
- these professionals did not view the information they were currently receiving as of the highest quality,
- whirling disease was an important part of the job for those surveyed,
- no specific topic relating to whirling disease was of more interest than another.

In its September 2003 report to the Steering Committee, the consultant recommended these activities within the outreach program:

- establish contact lists of fish professionals at local, state, regional, federal and tribal levels,
- assess the current situation for whirling disease, including pertinent state laws and the true geographical scope and severity of the disease,
- develop annual updates for key stakeholders to keep them apprised of the situation and to combat apathy,
- create and promote an authoritative whirling disease electronic resource that is both customized by audience and an easy-to-use central information repository,
- enhance outreach efforts by going where the fish professionals are,
- build strategic alliances to leverage resources.

The foundation of the outreach program was laid by the Steering Committee and the Partnership Board when they met October 21-23, 2003, with the following guidelines established for the program:

1. Goal

The goal of the program is that everyone who needs to know will have a full set of usable current information on whirling disease biology and control.

2. Audience

The primary audience to be served is technical professionals - fishery managers and administrators, hatchery operators and fish health professionals, researchers and agency land managers. The secondary audience comprises fishery information and education professionals, both within the agencies and in private organizations such as

the Whirling Disease Foundation, Trout Unlimited and the Federation of Fly Fishers. These technology transfer professionals in turn will serve anglers and the general public.

3. Disseminating Information

Research results are the primary matter to be conveyed. It would be impossible to disseminate only results of Partnership-funded work, since nearly every project draws from multiple funding sources. Insofar as possible, information on disease status and trends will also be compiled and distributed.

4. Level of Effort

The annual range of financial expenditure considered appropriate for the outreach program is $50,000 minimum, up to 20 percent of the full budget ($200,000) if the Initiative is funded at $1 million. The Water Center was directed to create a new position for a Whirling Disease Initiative Outreach Coordinator, to build and run the outreach program. The Center will also involve students, and a marketing firm may be engaged to develop information products under contract. All activities will be coordinated with the Whirling Disease Foundation, which has an active outreach program.

5. Initial Program Guidance

During the 2004-2005 project cycle, the Water Center was directed to: 1) compile updated contact lists for the audiences named above; 2) update the Whirling Disease Foundation bibliography of funded work and mount a searchable version (that includes theses and dissertations) on the Web; 3) create presentations and technical handouts for fishery professionals and take them on the road to meetings sponsored by state fish and game agencies and state and regional American Fisheries Society groups; and 4) distribute periodic electronic newsletters.

Additional activities that will be taken on as time allows include: 1) mount final reports of Initiative-funded projects (more than two years old) on the Web site, searchable by keyword; 2) further develop the RAW risk assessment methodology and make it into a useful product for fishery managers; 3) compile status-and-trend information and mount it on the Web site; and 4) compile state-by-state information on policies and regulations and mount a compendium on the Web site.

2004-2005 Outreach Program Accomplishments

From June to August 2004, the Montana Water Center conducted a search for a Whirling Disease Outreach Coordinator. Amy Rose was hired on August 16, 2004 and she developed and managed the outreach program until September 30, 2005. As directed by the Partnership Board and Steering Committee, the Outreach Coordinator is responsible for developing and implementing the Whirling Disease Initiative outreach

program and disseminating outreach materials to a primary audience of technical professionals and a secondary audience comprised of fishery I&E professionals. The coordinator also has primary responsibility for making whirling disease presentations to fish professionals throughout the country, compiling whirling disease research and outreach information, developing informational materials, developing and maintaining the Whirling Disease Initiative Web site, and developing and distributing a Whirling Disease Initiative newsletter.

In the outreach program's first year (August 2004 to October 2005), a great deal was accomplished. A preliminary, one-year outreach program plan was established and approved by the Partnership Board in fall 2004. An up-to-date contact list was compiled, comprised of more than 800 fishery professionals at local, state, regional, federal, and tribal levels. Those individuals, in turn, have been the recipients of all Initiative outreach information and publications since, including the new *Whirling Disease Initiative Newsletter*. Issue 1 of the newsletter was released in January 2005, and Issues 2 and 3 were released in April and September 2005, respectively.

Ms. Rose worked extensively with the Montana Water Center Web-site specialist to create the new Whirling Disease Initiative Web site at: http://whirlingdisease.montana.edu, which was launched in early January 2005. The site provides a platform to showcase an extensive whirling disease bibliography, whirling disease project research information, publications, event announcements, and outreach tools targeted at fishery and land managers.

Further, Ms. Rose presented at six regional and national fishery meetings in 2005, conducted four research team field visits in spring and summer 2005, started work on a whirling disease documentary film, and began the development of a national whirling disease brochure.

2005-2006 Outreach Program Accomplishments

Between October 2005 and October 2006, the Whirling Disease Initiative Outreach Program continued to grow in scope and effectiveness. A new Outreach Coordinator, Kajsa Stromberg, was hired in October to manage the program. An annual program plan was developed based on the recommendations of Strategicom's survey, the successes of the previous year, and feedback from participants. This plan provided an additional level of detail to the program's goals, priorities, and methods.

Augmented Outreach Program Plan and Structure, 2006

Primary Goal

The primary goal of the WDI Outreach Program is to provide a comprehensive source of current information about whirling disease research and management. Ultimately, by providing and disseminating this information about whirling disease, the WDI will

enable improved fishery management and protection of aquatic resources. Specifically, the WDI supports the following management goals:

1. Prevent the introduction and establishment of whirling disease in parasite-negative waters.
2. In parasite-positive waters, to maintain or re-establish self-sustaining fish populations.

Audience

Primary Audience: *Technical professionals* - Fishery professionals including fishery managers and administrators, hatchery operators and fish health professionals, researchers and agency land managers. In addition, legislators and those who direct policy are key stakeholders.

Secondary Audience: *General public* – The general public, particularly the angling public. Information and Education officers for agencies and organizations may be efficient ways to reach this audience. The public may also be reached through agencies, businesses, schools, and non-profit organizations.

Geographic Scope

The primary target area for the program is states with known detection of *M. cerebralis*. The secondary target area is states without known detection of *M. cerebralis*, particularly those perceived to be at highest risk. As a tertiary target area, the program may reach other nations concerned about the issue.

Methods

The WDI Outreach Program uses multiple communication methods to achieve program goals effectively and efficiently.

Web site: The WDI Web site was developed in 2004 and has been established as the authoritative source for whirling disease information on the Internet. The Web site is the primary outreach vehicle for the WDI. In spring 2006, the Web site was reorganized for ease of navigation. Features are being continually added to enhance content. There is a popular "Ask an Expert" e-mail function and interactive distribution maps have been recently added.

White paper update: The "white paper update," *Whirling Disease in the United States: A Summary of Progress in Research and Management, 2006*, was contracted through the Whirling Disease Foundation. This peer-reviewed publication is an update to similar Trout Unlimited publications from 1996 and 1999. This publication was planned to be an outreach material, designed for a primary audience of fishery professionals whose specialty is something other than whirling disease. It was also planned to be accessible for interested members of the public. The final publication will be released in 2007.

Newsletter: The WDI Newsletter is a quarterly publication distributed by mail and e-mail to a national audience of researchers, managers, and interested members of the public.

The first issue was published in January 2005 and distribution now reaches more than 1,000 recipients.

Brochures: Brochures can be developed and tailored for specific audiences. So far, one general brochure has been developed by the WDI and more than 7,000 have been distributed widely across the country. More brochures are planned for the future targeting specific topics like private ponds and spread of *M. cerebralis* on wading gear.

Documentary Film: Montana State University offers research outreach programs excellent opportunities to collaborate with graduate student filmmakers. One ten-minute whirling disease-focused segment has been created and shown on a local PBS station. A second documentary film project was completed in August 2006. This film, *Black Tale: The Whirling Disease Invaders* is available as a 26-minute and a 14-minute version on a single DVD. Distribution began in Fall 2006.

Posters: Posters can be developed and tailored for specific audiences. Technical posters have been created by the WDI Outreach Program and presented to professional audiences at conferences and trainings. More basic posters can be developed and distributed to reach the public through clubs, conservation groups, outfitters, and businesses.

Publications: There are many publications and types of publications that can be utilized by the WDI Outreach Program to share information about whirling disease. The publications pursued depend on the desired audience. Potential publications include newspapers, popular fishing magazines, industry newsletters and journals, and peer-reviewed scientific journals. During 2006, the Whirling Disease Initiative was featured in a wide variety of media including newspapers, trade journals, and magazines.

Other Internet Resources: The WDI Outreach Program often shares materials with other Internet resources such as flyfisher discussion boards, ANS Web sites, biological Web sites, and agency Web sites. The WDI is a clearinghouse of material for these resources and provide any needed up-to-date materials.

PSAs: Radio public service announcements can be developed and distributed nationally.

Table 6. Whirling Disease Initiative Budget, Phases I, II, and III

(Note: The outputs and associated costs shown for the years 2007 and 2008 are estimates.)

Component/Task	Program & Budget Summary (shows Federal Fiscal Years)											
	Phase I			Phase II			Phase III					
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
											Numbers & costs estimated	
1. Program Administration & Project Management (includes IDCs)	$157,601	$121,775	$123,412	$142,654	$164,629	$165,584	$132,865	$171,441	$196,167	$203,027	$210,000	$0
Outreach Program	NA	NA	NA	NA	NA	NA	$5,000	$100,000	$135,000	$120,000	$130,000	$0
Database Project									$10,000	$10,000	$10,000	$0
Match or In-Kind Contributions[1]	$80,000	$80,000	$76,000	$79,000	$84,000	$79,000	$69,000	$107,000	$80,000	$80,000	$80,000	NA
2. Research Projects	12	20	16	14	13	12	8	12	10	6	3-6	0
Whirling Disease Initiative Funding	$342,399	$578,225	$576,588	$557,346	$535,308	$534,416	$557,585	$676,990	$643,625	$652,359	$150,000	$0
Match or In-Kind Contributions	$408,693	$477,605	$600,381	$502,600	$386,673	$442,292	$516,270	$343,870	$423,048	$244,736	$100,000	$0
Total WDI Award	$500,000	$700,000	$700,000	$700,000	$700,000	$700,000	$695,450	$948,431	$984,792	$985,386	$500,000	$0
Total Match	$488,693	$557,605	$676,381	$502,600	$470,673	$521,292	$585,270	$450,870	$503,048	$324,736	$180,000	$0

[1] Match and in-kind contributions shown are a combination of: National Partnership Board members donated time; WDI Steering Committee members donated time; proposal reviewers donated time; and Montana Water Center forgone indirect cost returns [14% (1997-2002) and 17% (2003-2005) were assessed]; MSU negotiated research rates with OMB were 40% (1997-1999) and 41.5% (2000-2007).
Total WDI Award though 2007 = $8,114,059

Table 7. Whirling Disease Initiative Research Statistics (1997 to 2007/08)

Descriptors	Funding Cycle										Totals
	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07/08	
Number of proposals submitted	24	25	30	23	21	22	17	13	16	13	188
Number of projects funded	14	16	16	14	13	12	8	13	11	6	123
Additional contracts issued	0	4	0	1	1	0	1	1	0	0	8
Total Federal dollars	$342,399	$578,225	$576,588	$557,346	$535,308	$534,416	$557,585	$676,990	$643,624	$652,359	$5,654,840
Total match dollars	$408,693	$477,605	$600,381	$502,600	$386,673	$442,292	$516,270	$343,870	$423,048	$244,273	$4,346,168
TOTAL RESEARCH DOLLARS	$751,092	$1,055,830	$1,176,969	$1,059,946	$921,981	$976,708	$1,073,855	$1,020,860	$984,792	$985,386	$10,089,299
Number of states represented	6	4	7	6	9	6	6	7	6	8	18
Number of investi-gators	23	25	46	42	35	24	36	24	25	18	--
Number of peer reviewers	24	39	31	23	34	29	23	23	23	23	--

Appendix F

Research Projects, 1997-2007

Appendix F. Research Projects Sponsored by the Whirling Disease Initiative

Topic(s)	Title	Investigators	Initiative Funding
1997			
Invertebrate Biology	**Ecological Associations of *Tubifex tubifex* in Enzootic Waters in Northeastern Oregon**	**Jerri Bartholomew**; John L Fryer, Oregon State University	$40,000
Field Censusing of trout, worms, TAMS	**Dynamics of Whirling Disease on the Cache La Poudre River**	**Eric P. Bergerson**, Colorado State University; Brady Allen, R. Barry Nehring, Colorado Division of Wildlife	$67,835
Fish Populations & Management	**Relation of Life History Type to Whirling Disease Susceptibility in Missouri River Rainbow Trout**	**Thomas E. McMahon,** Billie L. Kerans, Alexander V. Zale and Michael M. Gangloff, Montana State University ; E. Richard Vincent, and Steve Leathe, Montana Fish, Wildlife & Parks (MTFWP)	$100,090
Immunology	**An Evaluation of Immune Responses to Whirling Disease among Trout above and below a Potential Point Source of *Myxobolus cerebralis* Infectivity in the Colorado River**	**R. Barry Nehring**, Colorado Division of Wildlife	$30,000
Field method development	**Development of a Method for Field Collecting the Triactinomyxon Stage of *Myxobolus cerebralis* using Paired Rotating-drum Filtration**	**Frederic T. Barrows,** USFW Service; Alexander V. Zale, and Thomas McMahon, MSU-Bozeman; Ronald P. Hedrick, University of California-Davis	$22,932
Invertebrate Biology	**Parameters that Determine Development and Production of *Myxobolus cerebralis* in *Tubifex tubifex***	**Willard O. Granath, Jr.,** University of Montana	$89,082

Topic(s)	Title	Investigators	Initiative Funding
Invertebrate Biology	**Tubificid Ecology and *Myxobolus cerebralis* Infections in the Madison River Drainage**	**Billie L. Kerans**, and Michael M. Gangloff, Montana State University; E. Richard Vincent, MTFWP	$47,402
Epidemiology	**Partnerships to Provide Integrated and Expanded Data from Promising Laboratory and Field Techniques to Enhance Understanding of Factors Affecting the Epidemiology of Whirling Disease**	**Christine M. Moffitt,**University of Idaho; Kathy Clemens, USFWS, Steven M. Huffaker, Idaho Fish and Game	$15,000
Lab method development	**Development of New Cultured Cell Line from Salmonids**	**C.A. Speer**, Montana State University	$20,000
Laboratory method development	**Field and Laboratory Evaluation for Whirling Disease using a Novel Polymerase Chain Reaction Diagnostic Assay and Assessing Risk of Whirling Disease becoming Established in Wisconsin**	**Daniel R. Sutherland**, and Scott Cooper, University of Wisconsin; Diane L. Waller, Upper Mississippi Science Center, USGS—NBS; Becky A. Lasee, La Crosse Fish Health Center, USFWS	$25,000
Diagnostic Workshop	**Occurrence and Distribution of Aquatic Oligochaete Worms as Related to Whirling Disease**	**R. Deedee Kathman**, ID Fish and Game; Colorado Division of Wildlife; Oregon State University; Utah Department of Natural Resources	$9,028
1998			
Lab method development	**Determination of the Sensitivity of a PCR Assay for *Myxobolus cerebralis***	**Thomas J. Baldwin,** and Gayle C. McGhee, Washington State University Pullman	$24,104
Economics	**Economic Consequences of Whirling Disease in Montana Stream Fisheries**	**John W. Duffield** and David A. Patterson, University of Montana; John Loomis, Colorado State University; Chris Nehar, Bioeconomics, Inc.,	$60,000

Topic(s)	Title	Investigators	Initiative Funding
Lab method	**Efficacy of Fumagillin to Prevent Experimentally Induced Whirling Disease in Rainbow Trout *Oncorhynchus mykiss***	**Dave Erdahl,** US Fish & Wildlife Service; Crystal Hudson, and Jim Bowker, USFWS; C.A. Speer, and Robert G. White, MSU-Bozeman	$67,050
Invertebrate Biology	**Production of *Myxobolus cerebralis* Triactinomyxons: Potential Alternative Hosts and Effects of Tubificid Assemblage Structure**	**Billie L. Kerans,** Montana State University	$28,956
Fish Pathology	**Effects of Age, Dose, and Environmental Stress on Development of Whirling Disease in Rainbow Trout**	**Elizabeth MacConnell,** US Fish and Wildlife Service, Alexander V. Zale, MSU-Bozeman	$40,196
Fish Pathology	**Laboratory Investigations of Mountain Whitefish *Prosopium Willliamsoni* Susceptibility to *Myxobolus cerebralis***	**Elizabeth MacConnell,** US Fish and Wildlife Service; Alexander V. Zale, MSU-Bozeman	$26,870
Fish Pathology	**Identify and Characterize the Adhesion Molecules Involved in Infection, Migration and Propagation of *Myxobolus cerebralis* in Salmonid Hosts**	**C.A. Speer,** Montana State University; Robert F. Bargatze, Montana Immuno Tech, Inc.; Crystal Hudson, Bozeman Fish Health Center, USFWS	$35,000
Parasitology	**Distribution and Seasonal Occurrence of *Myxobolus cerebralis* in the Lostine River, Oregon**	**Jerri L. Bartholomew,** John L. Fryer, Oregon State University	$77,277

Topic(s)	Title	Investigators	Initiative Funding
Parasitology	**Relationship of *Myxobolus cerebralis* Infected *Tubifex* to Infection Rates and Severity of Whirling Disease in Trout: An Integrated Study of Rock Creek, Montana**	**Willard O. Granath, Jr.,** University of Montana; E. Richard Vincent, MTFWP; Billie L. Kerans, MSU-Bozeman; James R. Winton, and Charlotte Rasmussen, USGS; James E. Gannon, University of Montana	$79,801
Habitat	**Maintaining Wild Trout in Whirling Disease Infected Rivers: Mitigating Trout Declines by Enhancing Habitat and Life History Types of Survivors in the Upper Madison River**	**Thomas E. McMahon,** Montana State University ; Bradley B. Shepard and E. Richard Vincent, MTFWP	$11,343
Fish Populations & Management	**An Assessment of Possible Resistance to Whirling Disease among Rainbow Trout and Snake River Cutthroat Trout after Exposure to *Myxobolus cerebralis* Infection in the Upper Colorado River in Middle Park, Colorado**	**R. Barry Nehring,** Colorado Division of Wildlife	$53,000
Fish Pathology	**Laboratory Assessment of Possible Selection for Resistance to Whirling Disease Among Progeny of Colorado River Rainbow Trout *(Oncorhynchus mykiss)***	**Alexander V. Zale,** and Eileen K. N. Ryce, Montana State University	$22,000
Invertebrate Biology	**Aquatic Oligochaete Workshop**	**R. Deedee Kathman,** Aquatic Resources Center	$10,072.11
Lab Methods	**Standard Field and Laboratory Protocols for Oligochaete Analysis (in cooperation with the Fish Health Database)**	**R. Deedee Kathman,** Aquatic Resources Center	$10,292.24

Topic(s)	Title	Investigators	Initiative Funding
Database Creation	**Fish Health Database**	**Daniel Goodman,** Montana State University	$20,000
Parasitology	**Finding Solutions to Whirling Disease in Wild Trout: Interactions Among the Parasite and its Hosts**	**Mansour El-Matbouli,** University of California	$20,000
1999			
Fish Populations & Management	**Assessment of the Effects of Spawning Site Selection by Snake River Cutthroat Trout on Exposure to *Myxobolus cerebralis* Triactinomyxons and Clinical Signs of Whirling Disease in Spring Streams among Age-0 Fish, Salt River Valley, Wyoming**	**Wayne A. Hubert,** University of Wyoming; Robert Gipson, David Money, David Zafft, and Deedra Hawk, WY Game & Fish Dept.	$49,750
Fish Populations & Management	**Spawning Areas as Loci of Infection for Whirling Disease in the Upper Madison River**	**Billie L. Kerans** and Thomas E. McMahon, Montana State University; James Munro, Patrick Byorth, and E. Richard Vincent, MTFWP	$50,251
Field census of disease	**Initial Survey of the Present Distribution of *Myxobolus cerebralis* in Yellowstone Cutthroat Trout, *Onchorynchus clarki bouvieri*, in Yellowstone Lake and Surrounding Tributaries**	**Daniel Mahony**, National Park Service; Crystal Hudson, USFWS, Bozeman	$13,500
Invertebrate Biology	**Integrated Studies of Whirling Disease in Montana Rivers Part III: Phylogenetic and Population Genetic Studies of the Oligochaete Host, *Tubifex tubifex***	**Billie L. Kerans**, Montana State University; Charlotte Rasmussen, USGS	$50,320

Topic(s)	Title	Investigators	Initiative Funding
Parasitology	**Development and Characterization of Strains of *Tubifex tubifex* that Differ in Susceptibility to *Myxobolus cerebralis***	**Willard O. Granath, Jr.,** University of Montana	$10,973
Lab methods	**Purification of Selected Proteins from Different Developmental Stages of *Myxobolus cerebralis* for Use in Antigenic Characterization, Assay Development and Studies of the Immune Response in Trout**	**Ronald P. Hedrick**, and Mark A. Adkison, University of California-Davis	$4,500
Fish Pathology	**The Use of Molecular Biological Methods to Study the Pathogenesis of *Myxobolus cerebralis***	**Ronald P. Hedrick** and Karl B. Andree, University of California-Davis	$37,000
Fish Pathology	**An Experiment to Determine if Living Brown Trout (*Salmo Trutta*) are capable of expelling viable *Myxobolus cerebralis* Myxospores**	**R. Barry Nehring,** Colorado Division of Wildlife	$37,000
Fish Pathology	**The Effect of Initial Exposure to *Myxobolus cerebralis* on the Development of Resistance to Re-infection in Rainbow Trout**	**Eileen K. N. Ryce** and Alexander V. Zale Montana State University; Elizabeth MacConnell, USFWS	$61,651
Immunology	**Biochemistry and Ultrastructure of the Adhesion Molecules Involved in Infection, Migration and Propagation of *Myxobolus cerebralis* in Salmonids**	**C.A. Speer,** Montana State University; Crystal Hudson, USFWS	$40,533

Topic(s)	Title	Investigators	Initiative Funding
Field method development	**Non-Lethal Sampling of Salmonid Species by Operculum Punch for the Identification of *Myxobolus cerebralis* by Polymerase Chain Reaction (PCR)**	**Linda Vannest**, U.S. Fish and Wildlife Service; C.A. Speer, MSU-Bozeman; Crystal Hudson, and Linda Staton, USFWS	$11,377
Invertebrate Biology	**The Effect of Water Quality Variables on Viability of the *Myxobolus cerebralis* Actinospore**	**Eric J. Wagner**, Utah Division of Wildlife Resources	$32,655
2000			
Field method development	**Development of a Method for Collection and Quantification of the Triactinomyxon Stage of *Myxobolus cerebralis* in the Field**	**Frederic T. Barrows**, U.S. Fish & Wildlife Service; Alexander Zale, and Thomas McMahon, MSU-Bozeman	$25,878
Fish Populations & Management	**Effects of *Myxobolus cerebralis* Infection on Chinook Salmon and Steelhead Trout in Northeastern OR**	**Jerri L. Bartholomew**, and Paul W. Reno, Oregon State University	$144,388
Parasitology	**Distribution of *Myxobolus cerebralis* during the Migration Period for Juvenile Anadromous Salmonids in the Snake and Salmon Rivers of Idaho**	**Ken Cain**, University of Idaho; Keith A. Johnson, ID Dept. of Fish & Game	$29,954
Epidemiology	**Epidemiology of Whirling Disease and the Effects of Habitat Restoration on Infection Rates and Disease Severity in Trout: An Integrated Study of the Rock Creek Drainage, Montana**	**Willard O. Granath, Jr.,** University of Montana; Eric Reiland, MTFWP; Billie L. Kerans, MSU-Bozeman; Charlotte Rasmussen, USGS	$50,160

Topic(s)	Title	Investigators	Initiative Funding
Lab Methods	**The Use of Molecular Genetic Markers to Study Susceptible and Non-susceptible *Tubifex* Species to *Myxobolus cerebralis* in Various Colorado Drainages**	**Ronald P. Hedrick**, and Katherine A. Beauchamp,University of California-Davis; R. Barry Nehring, CO Division of Wildlife	$48,000
Habitat	**Assessment of the Effects of Landscape Features on the Distribution of *Myxobolus cerebralis* and Occurrence of Whirling Disease among Age-0 Trout in the Salt River Drainage, Wyoming-Idaho**	**Wayne A. Hubert,** University of Wyoming; Robert Gipson; David Zafft; David Money; Deedra Hawk; WY Game & Fish Dept	$60,750
Immunology	**Cross Protection Against *Myxobolus cerebralis* infections by exposure to *Myxobolus arcticus***	**Michael L. Kent**, Oregon State University; Ronald P. Hedrick, UC-Davis; Robert Olfason, University of Victoria, Victoria, BC	$17,480
Invertebrate Biology	**Whirling Disease in the Madison River: Research for Solutions**	**Billie L. Kerans**, Montana State University; Charlotte Rasmussen, USGS	$55,579
Epidemiology	**Epidemiology of Whirling Disease in the Missouri River Ecosystem**	**Thomas E. McMahon** Andrew Munro, Montana State University; Alexander Zale, MT Cooperative Fishery Research Unit; Stephen Leathe, MTFWP	$41,781
Fish Populations & Management	**A Study to Determine the Effects of Fish Size and Release Location on the Survival of Rainbow Trout *Oncorhynchus mykiss* Fingerlings Stocked in the CO River Drainage**	**R. Barry Nehring** and Kevin G. Thompson, Colorado Division of Wildlife	$29,613

Topic(s)	Title	Investigators	Initiative Funding
Invertebrate Biology	**Molecular Examination of the Species Complex and Geographic Population Structure of *Tubifex tubifex*, the Oligochaete Host of the Whirling Disease Parasite**	**Charlotte Rasmussen** and Billie L. Kerans, Montana State University ; James R. Winton and Alison E. L. Colwell ,USGS; Willard O. Granath Jr., UM-Missoula	$50,115
Invertebrate Biology	**Distribution of *Myxobolus cerebralis* Infections in *Tubifex tubifex*, its Secondary Host**	**Anne C. Rusoff**, Montana State University	$18,179
Fish Pathology	**Effects of Size versus Age on the Development of Whirling Disease in Rainbow Trout**	**Alexander V. Zale** and Eileen K.N. Ryce, Montana State University-Bozeman	$52,554
Habitat	**Modeling Stream Temperatures with the GIS System in the National Wild Fish Health Survey Data Base**	**Daniel Goodman,** Montana State University	$20,000
2001			
Invertebrate Biology	**Application of DNA-based Genetic Markers to Determine Differences in Susceptible and Non-susceptible *Tubifex tubifex* Populations to *Myxobolus cerebralis* from the Upper Colorado River and Windy Gap Reservoir**	**Katherine A. Beauchamp** and Ronald Hedrick, University of California, Davis; R. Barry Nehring, CO Division of Wildlife	$55,000
Fish Culture	**The Effect of Chemical Control of *Tubifex tubifex* on the Incidence of Whirling Disease in Colorado Hatcheries**	**Eric P. Bergersen,** and Dan Kowalski, Colorado State University	$15,390

Topic(s)	Title	Investigators	Initiative Funding
Invertebrate Biology	**Ecological Differentiation and Survivability of *Tubifex tubifex* Infested with *Myxobolus cerebralis* in the San Juan River, New Mexico Tailwater "Blue-Ribbon Trout Fishery"**	**Colleen Caldwell** and Robert DuBey, New Mexico State University	$50,000
Epidemiology	**Epidemiology of Whirling Disease: An Integrated Study of the Rock Creek Drainage, Montana**	**Willard O. Granath,** and Michael Gilbert, University of Montana; Eric Reiland, MTFWP; Billie L. Kerans, MSU; Charlotte Rasmussen, USGS	$222,041
Fish Pathology	**Mechanisms of Resistance to *Myxobolus cerebralis* Infection in Brown Trout, Cutthroat Trout and Coho Salmon in Comparison to the Highly Susceptible Rainbow Trout**	**Ronald P. Hedrick,** and Mark A. Adkison, University of California, Davis	$25,536
Invertebrate Biology	**Competitive Effects of Tubificid Assemblages on Triactinomyxon Production of *Tubifex tubifex***	**Billie L. Kerans,** Montana State University; Charlotte Rasmussen, USGS	$47,909
Habitat	**Prevalence and Severity of *Myxobolus cerebralis* Infection Related to Water Temperature and flow Regimes of Native Cutthroat Trout, *Onchorynchus clarki bouvieri*, Spawning Tributaries of Yellowstone Lake**	**Todd Koel,** National Park Service; Crystal Hudson, USFWS Bozeman Fish Health Center	$52,000

Topic(s)	Title	Investigators	Initiative Funding
Habitat	**Demonstration and Evaluation of Alternative Methods of Filtering Triactinomyxons of *Myxobolus cerebralis* for Control of Whirling Disease**	**Eric Krch, Buckhorn Geotech;** R. Barry Nehring, Colorado Division of Wildlife	$49,260
Fish Populations & Management	**Interaction of Life History, Fish Size, and Infection Risk on Population-Level Effects of Whirling Disease on Wild Rainbow Trout**	**Thomas E. McMahon,** Andrew Munro, and Alexander Zale, Montana State University; Stephen A. Leathe, and George Liknes, MTFWP	$49,864
Ecological Modeling	**Development of Empirical Models of *Myxobolus cerebralis* to Predict Risks for Populations of Fish Across River Drainages**	**Christine M. Moffitt,** University of Idaho; Keith Johnson, ID Fish & Game; Bruce Rieman, USForest Service	$62,587
Invertebrate Biology	**Characterization of the Response of Genetically Distinct *Tubifex tubifex* Populations to *M. cerebralis* Infection in Laboratory and Natural Systems**	**Charlotte Rasmussen,** James Winton, and Alison E.L. Colwell, Western Fisheries Research Center; Billie L. Kerans, MSU-Bozeman	$50,685
Lab Methods	**Rapid Identification of Immature and Mature *Tubifex tubifex* by Monoclonal Antibodies**	**Donald W. Roberts** and Nabil N. Youssel, Utah State University	$35,123
2002			
Immunology, Fish Pathology	**Temporal Analysis of Immunity to *Myxobolus cerebralis* in Resistant and Susceptible Species Using Real-Time Taqman Quantitative PCR to Track Replication of the Parasite in the Fish**	**Mark Adkison** and Ronald Hedrick, University of California, Davis	$49,731

Topic(s)	Title	Investigators	Initiative Funding
Habitat	**Effects of Spring Creek Rehabilitation on Infection Rates of Whirling Disease in Trout**	**Patrick Byorth**, Montana Fish, Wildlife and Parks	$4,000
Lab Methods	**A Quantitative PCR (QPCR) Approach to Rapidly Distinguish Between *Myxobolus* Species and Assess Infection Severity in Fish**	**Ken Cain**, Matt Powel and Ken Overturf, University of Idaho; Keith Johnson, ID Dept. of Fish & Game; John Wood, Pisces Molecular, Inc.	$35,167
Epidemiology	**Relating *M. cerebralis* Infection in Native Yellowstone Cutthroat Trout and *T. tubifex* with Environmental Gradients at Multiple Spatial Scales**	**Billie L. Kerans**, Montana State University; Todd M. Koel, National Park Service; Charlotte Rasmussen, USGS	$112,973
Field Method	**Demonstration and Evaluation of Wetlands Treatment for *Myxobolus cerebralis* actinospore attenuation**	**Eric Krch**, Buckhorn Geotech, Inc.	$10,000
Parasitology	**Determination of ß, the Infection Efficiency, of Myxospores and TAM Stages of *M. cerebralis* Infection and a Laboratory Model of the Entire Infectious Cycle**	**Paul W. Reno**, Oregon State University	$49,922
Habitat Restoration	**Evaluating the Efficacy of Physical Habitat Modification to Reduce the Impacts of *M. cerebralis* Infection in Streams**	**Kevin G. Thompson**, CO Division of Wildlife	$39,000

Topic(s)	Title	Investigators	Initiative Funding
Epidemiology, Parasitology	**Temporal, Spatial, and Discharge, Mediated Dynamics of Triactinomyxon Abundances and Infection Risk Estimated Directly by Packed-Bed Filtration**	**Alexander V. Zale**, Montana State University; Frederic T. Barrows, Bozeman Fish Technology Center, USFWS	$55,128
2003			
Immunology, Fish Pathology, Lab Methods	**Evaluation of Quantitative Real-Time PCR for Rapid Assessments of the Exposure of Sentinel Fish to *Myxobolus cerebralis***	**Mark Adkison** and Ronald Hedrick, University of California, Davis	$56,361
Fish Populations & Management	**Evaluation of Management Actions to Control the Spread of *Myxobolus cerebralis in* a Lower Columbia River Tributary**	**Jerri L. Bartholomew,** and Antonio Amandi, Oregon State University	$66,390
Habitat	**Testing Impacts of Channel Modifications to Reduce *T. tubifex* Habitat**	**Eric P. Bergersen**, Colorado State University; Terry Waddle and Jim Terrell USGS: Kevin Thompson, Colorado Div. Of Wildlife	$51,785
Habitat	**Effect of Riparian Zone and Associated Stream Substrata on *Tubifex tubifex*: Density and Infection Rate with *Myxobolus cerebralis***	**Deborah Cartwright,** University of Georgia; Vicki Blazer, and W. Bane Schill, USGS, National Fish Health Laboratory	$87, 282
Epidemiology	**Development and Testing of Risk Assessment Tools for *Myxobolus cerebralis* Infection of Native Cutthroat Trout in Yellowstone National Park**	**Billie L. Kerans,** Montana State University; Dr. Todd Koel, National Park Service	$96,470

Topic(s)	Title	Investigators	Initiative Funding
Lab methods	**Analysis of Non-Lethal Techniques for Detection of *Myxobolus cerebralis***	**Molly Bensley** and Linda Stanton, U.S. FWS	$11,500
Lab methods	**Development of Molecular Markers Linked to Whirling Disease Resistance in Rainbow Trout**	**Eric Wagner** and Chris Wilson, Utah Division of Wildlife Resources; Karen Mock and Mark Miller, Utah State University	$99,120
2004			
Lab methods	**Non-lethal testing for *Myxobolus cerebralis* infection by Enzyme Linked Immunosorbent Assay (ELISA)**	**Mark A. Adkison**, Dr. Ronald P. Hedrick, and Garry O. Kelley, University of California, Davis	$53,542
Fish Populations & Management	**Assessment of the risk of *Myxobolus cerebralis* introduction as a result of straying adult steelhead and spring Chinook salmon in the Columbia River Basin**	**Jerri L. Bartholomew**, Antonio Amandi, Oregon State University; Susan K. Gutenberger, USFWS,	$153,173
Epidemiology	**Susceptibility of Rio Grande cutthroat trout (*Oncorhynchus clarki virginalis*) to experimentally induced infection with *Myxobolus cerebralis***	**Colleen Caldwell**, and Robert DuBey, New Mexico State University	$53,235
Fish Populations & Management	**Evaluation of increased survival of young-of-the-year wild rainbow trout in the upper Madison River in the face of increased whirling disease infection intensities in wild rainbow trout spawning areas**	**Patrick T. Clancy**, Montana Department of Fish Wildlife and Parks; Billie L. Kerans, Montana State University	$23,911

Topic(s)	Title	Investigators	Initiative Funding
Habitat	**Analysis of epidemiology data for whirling disease in the Rock Creek (Montana) drainage: 1998-2003**	**Willard O. Granath Jr.,** University of Montana	$49,678
Fish Populations & Management	**Movements of resident and non-resident anglers in Montana: implications of transferring whirling disease among drainages**	**Christopher S. Guy**, and Alexander V. Zale, Montana State University; Travis B. Horton, MTFWP	$106,641
Lab Methods	**Forensic applications of otolith microchemistry for tracking sources of illegally stocked whirling disease positive trout**	**Brett M. Johnson**, Dana Winkelman, and Gregory Whitledge, Colorado State University; Patrick J. Martinez, Colorado Division of Wildlife	$114,659
Habitat; Field Methods	**Use of high resolution thermal imagery as a tool to locate *Tubifex tubifex* in Pelican Creek, a *Myxobolus cerebralis* positive stream in Yellowstone National Park**	**Billie L. Kerans**, Montana State University; Todd Koel, Yellowstone National Park	$67,378
Parasitology	***Myxobolus cerebralis* in a pristine environment: the role of American white pelicans as a dispersal vector in the Greater Yellowstone Ecosystem**	**Todd Koel**, Yellowstone National Park; Billie Kerans, Montana State University	$35,219
Parasitology	**The potential of vehicles and fomites to transfer the agent of whirling disease**	**Paul W. Reno,** Oregon State University	$70,892

Topic(s)	Title	Investigators	Initiative Funding
Habitat	**The role of sediment size distribution and other microhabitat factors in the abundance and relative dominance of various *T. tubifex* lineages**	**Dana Winkelman**, Colorado State University; Terry Waddle, Jim Terrell, and Robert Milhous, USGS; Kevin Thompson, Colorado Div of Wildlife	$55,006
2005			
Ecological Modeling & Statistics	**Resolving uncertainties in *Myxobolus cerebralis* introduction and establishment risks**	**Jerri L. Bartholomew** and Antonio Amandi, Oregon State University	$123,307
Epidemiology	**Effect of benthic invertebrate populations, riparian zone and associated water quality on infection rates of *Tubifex tubifex* with *Myxobolus cerebralis***	**Deborah Cartwright Iwanowicz**, Vicki Blazer, and W. Bane Schill, USGS	$83,070
Invertebrate Biology	**Whirling disease risk at multiple spatial scales**	**Billie Kerans**, Montana State University; E. Richard Vincent, MTFWP	$74,345
Parasitology	**The viability of *Myxobolus cerebralis* myxospores after passage through the alimentary canal of avian piscivores in the Greater Yellowstone Ecosystem**	**Todd Koel,** Yellowstone National Park; Billie Kerans, Montana State University	$59,415
Fish Pathology	**Characterization of whirling disease resistance patterns in rainbow trout from Harrison Lake, Montana: classification of resistant and susceptible individuals and elucidation of the effects of recent natural selection**	**Eric Wagner** and Chris Wilson, Utah Division of Wildlife Resources	$83,816

Topic(s)	Title	Investigators	Initiative Funding
Invertebrate Biology	**Assessing the density and distribution of *Tubifex tubifex* lineages in Windy Gap Reservoir, Colorado**	**Dana Winkelman**, Colorado State University; and R. Barry Nehring, Colorado Division of Wildlife	$31,758
Invertebrate Biology	**Investigating competition among lineages of *T. tubifex* and the potential for biological control of whirling disease in natural streams**	**Dana Winkelman**, Colorado State University; and Kevin Thompson, Colorado Division of Wildlife	$76,247
2006			
Epidemiology	***Myxobolus cerebralis* risk to Yellowstone cutthroat trout related to variation in *T. tubifex* abundance and susceptibility**	**Billie Kerans**, Montana State University; Todd Koel, Yellowstone National Park	$44,905
Ecological Modeling & Statistics; Salmonid Ecology	**Southwest regional risk assessment for whirling disease in native salmonids in arid and semi-arid lands: Arizona, Colorado, New Mexico, and Utah**	**Colleen Caldwell** and Robert DuBey, New Mexico State University; Wayne Landis, Western Washington University	$196,310
Ecological Modeling & Statistics; Salmonid Ecology	**An ecological assessment of large-scale spatial and temporal patterns of whirling disease risk and salmonid population response**	**Billie Kerans**, Tom McMahon, Jay Rotella, and James Robinson-Cox, Montana State University; Travis Horton, MTFWP	$245,605

Topic(s)	Title	Investigators	Initiative Funding
Habitat	**Effect of Substratum on the Development and Release of the Triactinomyxon Stage of *Myxobolus cerebralis* in Mitochondrial DNA 16S *Tubifex tubifex* Lineages**	**Dolores V. Baxa** and Ronald P. Hedrick, University of California	$60,000
Note: Several projects that were funded in more than one cycle have been shown as a single project, the year of the first award, with the total dollars awarded shown in the last column.			

Appendix G

Publications Reporting Initiative Projects

Publications based on Whirling Disease Initiative Research

2009

K.K. Gates, C.S. Guy, A.V. Zale and T.B. Horton. In press. Angler awareness of aquatic nuisance species and potential transport mechanisms. *Fisheries Management and Ecology*.

E.R. Vincent. In press. Impacts of whirling disease on populations of wild brown and rainbow trout in the upper Madison River, Montana. *North American Fisheries Management Journal*.

S.L. Hallett, H.V. Lorz, S.D. Atkinson, C. Rasmussen, L. Xue and J.L. Bartholomew. Propagation of the myxozoan parasite *Myxobolus cerebralis* by different geographic and genetic populations of *Tubifex tubifex*: An Oregon perspective. *Journal of Invertebrate Pathology* 102: 57–68.

R.J. DuBey. Genetic differentiation of lineages of *Tubifex tubifex* from the San Juan River, New Mexico. *Southwestern Naturalist* 53(2): 268-272.

D.V. Baxa, G.O. Kelley, K.S. Mukkatira, K.A. Beauchamp, C. Rasmussen and R.P. Hedrick. Arrested development of the myxozoan parasite *Myxobolus cerebralis*, in certain populations of mitochondrial 16S lineage III *Tubifex tubifex*. *Parasitology Research* 102(2): 219-228.

R.J. DuBey, C.A. Caldwell and W.R. Gould. Relative susceptibility and effects on performance of Rio Grande cutthroat trout and rainbow trout challenged with *Myxobolus cerebralis*. *Transactions of the American Fisheries Society* 136(5): 1406-1414.

L.C. Steinbach Elwell, B.L. Kerans and J. Zickovich. Host-parasite interactions and competition between tubificid species in a benthic community. *Freshwater Biology* 54(8): 1616-1628.

M.P. Miller and E.R. Vincent. Rapid natural selection for resistance to an introduced parasite of rainbow trout. *Evolutionary Applications* 1(2): 336-341.

A.J. Kaeser and W.E. Sharpe. The Ecology of *Tubifex tubifex* in two *Myxobolus cerebralis* enzootic streams in Pennsylvania. *Journal of Freshwater Ecology* 23(4): 575-588.

E.L. Arsan and J.L. Bartholomew. Potential for dissemination of the nonnative salmonid parasite *Myxobolus cerebralis* in Alaska. *Journal of Aquatic Animal Health* 20(3): 136-149.

D.K. Gibson-Reinemer, B.M. Johnson, P.J. Martinez, D.L. Winkelman, A.E. Koenig and J.D. Woodhead. Elemental signatures in otoliths of hatchery trout: distinctiveness and utility for detecting origins and movement. *Canadian Journal of Fisheries and Aquatic Sciences* 66: 513-524.

2008

W.O. Gilbert and M.A. Granath Jr. Susceptibility of *Tubifex tubifex* (Annelida: Oligochaeta: Tubificidae) from the Rock Creek drainage of west central Montana, U.S.A., to *Myxobolus cerebralis* (Myxozoa: Myxosporea: Myxobolidae), the causative agent of salmonid whirling disease. *Comparative Parasitology* 75(1): 92–97.

J.L. Bartholomew and S.L. Hallett. Effects of water flow on the infection dynamics of *Myxobolus cerebralis. Journal of Parasitology* 135: 371–384.

B.L. Kerans, C. Rasmussen, J.R. Winton and J. Zickovich. Variability in triactinomyxon production from *Tubifex tubifex* populations from the same mitochondrial DNA lineage infected with *Myxobolus cerebralis,* the causative agent of whirling disease in salmonids. *Journal of Parasitology* 94(3): 700–708.

K.J. Anlauf and C.M. Moffitt. Models of stream habitat characteristics associated with tubificid populations in an intermountain watershed. *Hydrobiologia* 603: 147–158.

M.E. Colvin and C.M. Moffitt. Evaluation of irrigation canal networks to assess stream connectivity in a watershed. *River and Research Applications* 25: 486-496.

K.K. Gates, C.S. Guy and A.V. Zale. Adherence of *Myxobolus cerebralis* myxospores to waders: implications for disease dissemination. *North American Journal of Fisheries Management* 28: 1453–1458.

F.T. Barrows, H.J. Lukins and A.V. Zale. A packed-bed filtration system for collection of *Myxobolus cerebralis* triactinomyxons. *Journal of Aquatic Animal Health* 19: 234–241.

2007

E.L. Arsan, S.D. Atkinson, S.L. Hallett, T. Meyers and J.L. Bartholomew. Expanded geographical distribution of *Myxobolus cerebralis*: first detections from Alaska. *Journal of Fish Diseases* 30: 483-491.

L. Arsan, S. Hallett and J.L. Bartholomew. *Tubifex tubifex* from Alaska and their susceptibility to *Myxobolus cerebralis. Journal of Parasitology* 93 (6): 1332-1342.

J.L. Bartholomew, H.V. Lorz, S.D. Atkinson, S.L. Hallett, D.G. Stevens, R.A. Holt, K. Lujan and A. Amandi. Evaluation of a management strategy to control the spread of *Myxobolus cerebralis* in a Lower Columbia River tributary. *North American Journal of Fisheries Management* 27: 542-550.

R.J. DuBey, C.A. Caldwell and W.R. Gould. Relative susceptibility and effects on performance of Rio Grande cutthroat trout and rainbow trout challenged with *Myxobolus cerebralis*. *Transactions of the American Fisheries Society* 136: 1406-1414.

W.O. Granath Jr., M.S. Gilbert and E.J. Wyatt-Pescador. Epizootiology of *Myxobolus cerebralis*, the causative agent of salmonid whirling disease in the Rock Creek drainage of west-central Montana. *Journal of Parasitology* 93: 104-119.

S.L. Hallett and J.L. Bartholomew. Effects of water flow on the infection dynamics of *Myxobolus cerebralis*. *Journal of Parasitology* 135: 371-384.

R.P. Hedrick, B. Petri, T.S. McDowell, K. Mukkatira and L.J. Sealey. Evaluation of a range of doses of ultraviolet irradiation to inactivate waterborne actinospore stages of *Myxobolus cerebralis*. *Diseases of Aquatic Organisms* 74: 113-118.

H.J. Lukins, A.V. Zale and F.T. Barrows. A packed-bed filtration system for collection of *Myxobolus cerebralis* triactinomyxons. *Journal of Aquatic Animal Health* 19: 234-241.

K.G.Thompson. Use of site occupancy models to estimate prevalence of *Myxobolus cerebralis* infection in trout. *Journal of Aquatic Animal Health* 19: 8-13.

2006

E.J. Wagner, C. Wilson, R. Arndt, P. Goddard, M. Miller, A. Hodgson, R. Vincent and K. Mock. Evaluation of disease resistance of the Fish Lake-DeSmet, Wounded Man, and Harrison Lake strains of rainbow trout exposed to *Myxobolus cerebralis*. *Journal of Aquatic Animal Health* 18: 128-135.

T.M. Koel, D.L. Mahony, K.L. Kinnan, C. Rasmussen, C.J. Hudson, S. Murcia and B.L. Kerans. *Myxobolus cerebralis* in native cutthroat trout of the Yellowstone Lake ecosystem. *Journal of Aquatic Animal Health* 18: 157-175.

R.C. Krueger, B.L. Kerans, E.R. Vincent and C. Rasmussen. Risk of *Myxobolus cerebralis* infection to rainbow trout in the Madison River, Montana. *Ecological Applications* 16(2): 770-783.

L.C. Steinbach Elwell, B.L. Kerans, C. Rasmussen and J.R. Winton. Interactions among two strains of *Tubifex tubifex* (Oligochaeta: Tubificidae) and *Myxobolus cerebralis* (Myxozoa). *Diseases of Aquatic Organisms* 68: 131-139.

S. Murcia, B.L. Kerans, E. MacConnell and T.M. Koel. *Myxobolus cerebralis* infection patterns in Yellowstone cutthroat trout after natural exposure. *Diseases of Aquatic Organisms* 71: 191-199.

2005

B.L. Kerans, R.I. Stevens and J.C. Lemmon. Water temperature affects a host-parasite interaction: *Tubifex tubifex* and *Myxobolus cerebralis*. *Journal of Aquatic Animal Health* 17: 216-221.

C.R. Sipher and E.P. Bergersen. The effects of whirling disease on growth and survival of Snake River cutthroat and Colorado River rainbow trout yearlings. *Journal of Aquatic Animal Health* 17: 353-364.

R. DuBey, C. Caldwell and W. Gould. Effect of temperature, photoperiod, and *Myxobolus cerebralis* infection on growth, reproduction and survival of *Tubifex tubifex* lineages. *Journal of Aquatic Animal Health* 17: 338-344.

J.L. Bartholomew, B.L. Kerans, R.P. Hedrick, S.C. MacDiarmid and J.R. Winton. A risk assessment-based approach for the management of whirling disease. *Reviews in Fisheries Science* 13: 205-230.

2004

S.A. Sollid, H.V. Lorz, D.G. Stevens, P.W. Reno and J.L. Bartholomew. Prevalence of *Myxobolus cerebralis* at juvenile salmonid acclimation sites in northeastern Oregon. *Journal of Fisheries Management* 24: 146-153.

E.K. Ryce, A.V. Zale and E. MacConnell. Effects of fish age and parasite dose on the development of whirling disease in rainbow trout. *Diseases of Aquatic Organisms* 59: 225-233.

B.L. Kerans, C. Rasmussen, R. Stevens, A.E.L. Solwell and J.R. Winton. Differential propagation of the metazoan parasite *Myxobolus cerebralis* by *Limnodrilus hoffmeisteri, Ilyodrilus templetoni,* and genetically distinct strains of *Tubifex tubifex. Journal of Parasitology* 90(6): 1366-1373.

2003

J.L. Bartholomew, H.V. Lorz, S.A. Sollid and D.G. Stevens. Susceptibility of juvenile and yearling bull trout to *Myxobolus cerebralis* and effects of sustained parasite challenges. *Journal of Aquatic Animal Health* 15: 248-255.

S.A. Sollid, H.V. Lorz, D.G. Stevens and J.L. Bartholomew. Age-dependent susceptibility of Chinook salmon to *Myxobolus cerebralis* and effects of sustained parasite challenges. *Journal of Aquatic Animal Health* 15: 136-246.

M.A. Gilbert and W.O. Granath Jr. Whirling disease of salmonid fish: life cycle, biology, and disease. *Journal of Parasitology* 89(4): 658-667.

R.B. Nehring, K.G. Thompson, D.L. Shuler and T.M. James. Using sediment core samples to examine the spatial sistribution of *Myxobolus cerebralis* actinospore production in Windy Gap Reservoir, Colorado. *North American Journal of Fisheries Management* 23: 376-384.

2002

E. Wagner, R. Arndt, M. Brough, C. Wilson and G.Nelson. Survival, performance, and resistance to *Myxobolus cerebralis* infection of lake trout X brook trout hybrids. *North American Journal of Fisheries Management* 22(3): 760-769.

K.D. Arkush, A.R. Giese, H.L. Mendonca, A.M. McBride, G.D. Marty and R.P. Hedrick. Resistance to three pathogens in the endangered winter-run Chinook salmon (*Oncorhynchus tshawytscha*): effects of inbreeding and major histocompatibility complex genotypes. *Canadian Journal of Fisheries and Aquatic Science* 59(6): 966-975.

T.J. Baldwin and K.A. Myklebust. Validation of a single round polymerase chain reaction assay for identification of *Myxobolus cerebralis* myxospores. *Diseases of Aquatic Organisms* 49(3): 185-190.

K.G. Thompson, R.B. Nehring, D.C. Bowden and T. Wygant. Response of rainbow trout *Oncorhynchus mykiss* to exposure to *Myxobolus cerebralis* above and below a point source of infectivity in the upper Colorado River. *Diseases of Aquatic Organisms* 49 (3): 171-178.

E. Wagner, R. Arndt, M. Brough and D.W. Roberts. Comparison of susceptibility of five cutthroat trout strains to *Myxobolus cerebralis* infection. *Journal of Aquatic Animal Health* 14 (1): 84-91.

K.A. Beauchamp, M. Gay, G.O. Kelley, M. El-Matbouli, D. Kathman, R.B. Nehring and R.P. Hedrick. Prevalence and susceptibility of infection to *Myxobolus cerebralis*, and genetic differences among populations of *Tubifex tubifex. Diseases of Aquatic Organisms* 51: 113-121.

D.C. Downing, T. McMahon, B.L. Kerans and E.R. Vincent. Relation of spawning and rearing life history of rainbow trout and susceptibility to *Myxobolus cerebralis* infection in the Madison River, Montana. *Journal of Aquatic Animal Health* 14: 191-203.

B. Allen and E.P. Bergersen. Factors influencing the distribution of *Myxobolus cerebralis*, the causative agent of whirling disease, in the Cache La Poudre River, Colorado. *Diseases of Aquatic Organisms* 49 (1): 51-60.

J.L. Bartholomew and J.C. Wilson, editors. Whirling Disease: reviews and current topics. *American Fisheries Society Symposium 29, Bethesda, MD.* Papers covering work partially or fully funded by the National Partnership:

J.L. Bartholomew and P.W. Reno. The history and dissemination of whirling disease. *American Fisheries Society Symposium 29:* 3-24.

W.O. Granath Jr. and M.A. Gilbert. The role *Tubifex tubifex* (Annelida: Oligochaeta: Tubificidae) in the transmission of *Myxobolus cerebralis* (Myxozoa: Myxosporea: Myxobolidae). *American Fisheries Society Symposium 29:* 79-86.

E.R. Vincent. Relative susceptibility of various salmonids to whirling disease with emphasis on rainbow and cutthroat trout. *American Fisheries Society Symposium 29:* 109-116.

S.A. Sollid, H.V. Lorz, D.G. Stevens and J.L. Bartholomew. Relative susceptibility of selected Deschutes River, Oregon, salmonid species to experimentally induced infection by *Myxobolus cerebralis. American Fisheries Society Symposium 29:* 117-124.

R.B. Nehring, K.G. Thompson, K.A. Taurman and D.L. Shuler. Laboratory studies indicating that living brown trout *Salmo trutta* expel viable *Myxobolus cerebralis* myxospores. *American Fisheries Society Symposium 29:* 125-134.

T.A. Sandell, H.V. Lorz, S.A. Sollid and J.L. Bartholomew. Effects of *Myxobolus cerebralis* infection on juvenile spring Chinook salmon in the Lostine River, Oregon. *American Fisheries Society Symposium 29:* 135-142.

B.L. Kerans and A.V. Zale. The Ecology of *Myxobolus cerebralis. American Fisheries Society Symposium 29:* 145-166.

W.A. Hubert, M.P. Joyce, R. Gipson, D. Zafft, D. Money, D. Hawk and B. Taro. Whirling disease among Snake River cutthroat in two spring streams in Wyoming. *American Fisheries Society Symposium 29:* 181-194.

M.A. Smith, E.J. Wagner and A. Howa. The effect of water characteristics on viability of the *Myxobolus cerebralis* actinospore. *American Fisheries Society Symposium 29:* 227-238.

L. Staton, D. Erdahl and M. El-Matbouli. Efficacy of fumagillin and TNP-470 to prevent experimentally induced whirling disease in rainbow trout *Onchohynchus mykiss. American Fisheries Society Symposium 29:* 239-247.

2001

T.R. Stevens, B.L. Kerans, J.C. Lemmon and C. Rasmussen. The effects of *Myxobolus cerebralis myxospore* dose *on Triactinomyxon* production and biology of *Tubifex tubifex* from two geographic regions. *Journal of Parasitology* 87(2): 315-321.

E.K. Ryce, A.V. Zale and R.B. Nehring. Lack of selection for resistance to whirling disease among progeny of Colorado River rainbow trout. *Journal of Aquatic Animal Health* 12: 63-68.

E.K. Ryce, A.V. Zale and R.B. Nehring. Lack of selection for resistance to whirling disease among progeny of Colorado River rainbow trout. *Journal of Aquatic Animal Health* 12: 63-68.

M.A. Gilbert and W.O. Granath Jr. Persistent infection of *Myxobolus cerebralis*, the causative agent of salmonid Whirling Disease. *Journal of Parasitology* 87(1): 101-107.

M.L. Kent, K.B. Andree, J.L. Bartholomew, M. El-Matbouli, S.S. Desser, R.H. Devlin, S.W. Feist, R.P. Hedrick, R.W. Hoffman, J. Khattra, S.L. Hallet, R.J.G. Lester, M. Longshaw, O. Palenzeula, M.E. Siddall and Xiao-Chongxie. Recent advances in our knowledge of the myxozoa. *Journal of Eukaryotic Microbiology* 48(4): 395-413.

T.A. Sandell, H.V. Lorz, D.G. Stevens and J.L. Bartholomew. Dynamics of *Myxobolus cerebralis* in the Lostine River, Oregon: implications for resident and anadromous salmonids. *Journal of Aquatic Animal Health* 13: 142-150.

1999

K.B. Andree, M. El-Matbouli, R.W. Hoffman and R.P. Hedrick. Comparison of 18S and ITS-1r DNA sequences of selected geographic isolates of *Myxobolus cerebralis*. *International Journal of Parasitology* 29: 771-775.

Appendix H

Data Panel Charge and Recommendations, 2005

Whirling Disease Initiative
CHARGE TO THE ADVISORY PANEL

May 20, 2005

The National Partnership on the Management of Wild and Native Coldwater Fisheries, through its administrative arm the Montana Water Center, wishes to convene a short-term advisory panel to help direct its planning for use of a data and metadata repository (database). The data repository will contain: (1) discrete biological and environmental datasets that have been collected since 1997 under the aegis of the Whirling Disease Initiative (http://whirlingdisease.montana.edu/); and (2) the federally-compliant metadata records associated with these datasets. These datasets have been gathered by several dozen research teams who were grantees in an annual competitive process that generates research investigating whirling disease. The main function of the data repository is to facilitate the synthetic examination of data of many types, that have been collected by many investigators, in order to identify long-term and large-scale phenomena of the disease that are not evident in the results of individual research projects. In addition, the data repository will serve fisheries managers who seek information on research-tested management tools.

In priority order, the charge to the panel is:

1) Review web sites and documents and speak with program administrators to become familiar with the Whirling Disease Initiative, the projects it has sponsored, and the types of data that have been collected. If time permits, speak with investigators funded through the Initiative, and with Whirling Disease Steering Committee members.

2) Develop a draft data-compilation-and-use policy for the Initiative. At a minimum, this should answer the questions:
- Who should have access to the compiled data, and for what purposes?
- What metadata should be gathered from Initiative grantees, in additional to those listed in the draft *Metadata Questionnaire*?
- What length of 'grace period' is appropriate, during which grantees can analyze data and prepare manuscripts for publication, before their datasets are 'owed' to the Initiative for the data repository?
- In potential future studies that draw on datasets from the repository, how should attribution for the original research be made? What are the rights of the original investigators?

3) Develop recommendations for how existing data can guide future investigations. In order of priority:
(a) What studies should be undertaken, that would synthesize existing data across projects to answer landscape-level questions?
(b) What data gaps should be filled so that management strategies and risk assessments can be fully realized?

(c) Should the Initiative collaborate with state agencies to make use of their existing data to answer questions of disease spread and severity?

4) Submit the recommendations and the draft policy to the Montana Water Center by August 31, 2005.

Whirling Disease Advisory Panel Final Report

August, 2005

EXECUTIVE SUMMARY

The Montana Water Center and its Whirling Disease Initiative (WDI) convened a Panel in May 2005 for advice on policies related to data management and to provide recommendations for future whirling disease (WD) research. This document is our response to that call.

In response to the WDI's specific questions about data management, we recommend that data collected with WDI funding be made available to other researchers after two years. For data to be archived, we recommend that selected past researchers be funded to edit and organize their data for that purpose and that future grantees be informed before research begins regarding expectations for sharing their data. Project budgets should reflect that expectation. We also make specific recommendations regarding the types of metadata that should be collected to describe research projects funded by the WDI.

Another component of our charge was to recommend how to assemble a database containing data from previously funded projects. This is a nontrivial task and our report includes several suggestions on how this might be done, as well as some priority issues that should be considered in deciding programmatic goals and what data are most useful for archiving in light of the specific questions that could be addressed using such a database. As recognized by the WDI, many questions remain about landscape-scale patterns and processes of the disease, the pattern of contagion, and fish population responses. The desire to put together a larger database of all past WDI-funded studies represents one response to these information gaps. After reviewing project summaries of WDI-funded projects, however, the Panel concluded that data from many studies may not be very useful in that context; often those data focus on a local scale or on the details of disease transmission. Thus, they may not yield a regional perspective on disease dynamics among watersheds or basins.

We also note that the effort required to develop and manage a database of previous WDI projects might more appropriately be spent putting together information in a regional database describing the incidence and severity of WD. This type of database would be more relevant in the search for answers to questions about regional patterns of WD than would data from many previously funded projects, especially the large proportion of studies that focus on the mechanics of disease transmission.

Many projects funded in the early years of the WDI emphasized the mechanics of disease transmission in hopes of finding a simple way to interrupt or short-circuit the disease process. This early research illuminated the complexity and scope of the disease as well as its resilience. We know now, for example, that most simple solutions, such as fish vaccination, are unlikely to be effective.

The WDI is at a crossroads in terms of their stated mission, "to conduct research that develops practical management solutions to maintain viable, self-sustaining wild trout fisheries."

With that mission statement in mind, we developed two sets of recommendations designed to synthesize research efforts to date and to guide future research and management. The first set of recommendations involve summarizing what is known about WD, but in ways that deliberately foster a synthesis across disciplines with the goal of creating new knowledge or guiding new research initiatives about WD. We envision this as more than a list of tasks to be accomplished and we provide specific suggestions designed to encourage a multi-disciplinary, but at its core ecological, approach to WD. In looking toward the past, we identified a need for the following items:

- A technical synthesis of WD research to date
- Lay summary of the state-of-the-science
- Comparative analysis of the relative costs and benefits of various diagnostic techniques
- Synthesis of existing state data

Our second set of recommendations look to the future, identifying promising directions in research and management. We urge a shift from the details of the disease process to a broader perspective that brings the disparate aspects of WD ecology together. Examples of the types of research questions that could be answered from ecological, regional, epidemiological, and temporal perspectives are described.

- Embrace the idea that WD is a complex ecological process
- Address questions at the landscape scale
- Develop epidemiological, risk-assessment, and other relevant models
- Support long-term studies

The temptation exists in any endeavor to continue doing what has been done in the past, particularly when past efforts have been successful. We urge the WDI to resist this programmatic inertia by taking the time now to synthesize what is known and chart a new path that carefully and consciously selects from among the many potential research and management topics related to WD.

Appendix I

Data Repository – Data Submission and Use Guidelines

Whirling Disease Initiative Data Submission and Use Guidelines

May 2, 2006

Whirling Disease Initiative
Montana Water Center
101 Huffman Building
Montana State University
Bozeman, MT 59717-2690
406-994-6690

Whirling Disease Initiative Data Submission and Use Guidelines

Introduction

The Whirling Disease Initiative (WDI) exists to counter the effects of the fish parasite *Myxobolus cerebralis*. The purpose of the Initiative is to provide fishery managers with a set of management tools that are as complete as possible, in order to allow them to maintain populations of wild and native salmonids in the presence of the whirling disease parasite. Initiative goals are to prevent introduction and establishment of the disease into streams that are parasite-negative, and to maintain or re-establish self-sustaining fish populations in parasite-positive streams.

From 1997 to 2005, the WDI did not have a formal data submission and use policy. In 2006, the WDI established a formal data policy; **all WDI Principal Investigators and grantees are now required to abide by this policy**, which includes guidelines and requirements for data and metadata submission. This document also includes guidelines for dataset access and use.

Purpose

Availability and sharing of data and samples in a timely fashion is becoming increasingly important to scientific and management endeavors. In 2001, the National Academy of Sciences created the Committee on Responsibilities of Authorship in the Biological Sciences and charged its members to evaluate responsibilities of authors to share data and materials. The committee found that: "An author's obligation is not only to release data and materials to enable others to verify or replicate published findings…*but also to provide them in a form on which other scientists can build with further research* (italics added)."[1] The Internet makes it possible for this information to be made available easily and at no cost to users.

The establishment of the WDI electronic research archive/database is a response to this need for data sharing across disciplines and amongst researchers, land managers, agency personnel, and the general public. Its functions are two-fold: (1) Interested parties will be able to use an easy data retrieval system to find datasets and metadata

associated with completed research; and (2) The archive will also protect against the data loss that can occur when projects are discontinued, when students graduate, or when data are misplaced.

Responsibilities of the Grantee

Acceptance of research funding signifies agreement that the Principal Investigator (grantee) will submit datasets and metadata from all project data collected during the funding period. The Principal Investigator agrees to submit data in the required format and according to the timeline outlined below.

1. The Principal Investigator must make initial contact with the WDI data manager **within three months of the project funding period start date (project commencement).** The Principal Investigator and WDI data manager will review data and metadata requirements of the research grant.

2. Metadata and datasets are due to the WDI **within six months of project funding period end date (project completion)**.
   - All metadata must follow Federal Geographic Data (FGDC) metadata standards and will minimally contain adequate information on proper citation, access, contact information, geographic references, methods, and quality control. The WDI data manager will provide Principal Investigators with assistance in creation of metadata records using the *Metadata Questionnaire*.
   - All data[2] collected with WDI funding must be submitted to the WDI electronic data repository, available through the WDI Web site: http://whirlingdisease.montana.edu.

3. Principal Investigators are also responsible for the quality and correctness of data submitted to the WDI and must interact with WDI personnel to ensure that: a) data comply with basic scientific standards; b) data subject to revision are updated promptly; and c) queries and criticisms from other users are promptly solved.

4. WDI-funded Principal Investigators will typically be given two years to write and publish findings before data are released (See *Appendix 1*). If researchers do not publish during this time period, data will be released so that others may utilize them.

5. Principal Investigators who do not comply with these guidelines will not be considered for future funding by the WDI.

Responsibilities of WDI Data Management Office

1. The WDI will provide a secure archive and a web-based data retrieval system. The WDI will catalog submitted data and metadata such that they can be retrieved using criteria such as time, location, keyword, principal investigator, agency/university, and/or sample identifier.

2. The WDI will provide Principal Investigators with assistance in creation of metadata records using the *Metadata Questionnaire*.

3. Metadata generated through the WDI will be distributed at no cost to a wide variety of audiences, including the general pubic, via the Internet or in writing.

4. The WDI will release datasets according to the appropriate Data Use Agreement[3].

5. Requirements of data users will be determined by the appropriate Data Use Agreement and access to data will be regulated by the WDI through user registration.

6. The WDI will provide a communication link between the Principal Investigators and data users, encourage and evaluate community feedback regarding data and metadata availability, and ensure that community needs are being met.

7. The WDI will periodically post announcements of newly available datasets on the WDI Web site.

Maintenance of Electronic Information

All metadata submitted to the WDI will be archived in a password-protected MySQL database at the Big Sky Institute (Montana State University). This database is secured behind both the MSU and BSI firewalls. Principal Investigators will submit datasets at a password-protected file upload site managed and secured by the Montana Water Center. Users of the file upload site only have access to their own data files. Principal Investigator usernames and passwords are encrypted and stored in a database, and uploaded datasets will be securely stored on the Montana Water Center's server, administered by the Burns Technology Center.

Release of Metadata and Data

Data and information derived from publicly funded WDI research are made available with as few restrictions as possible, on a nondiscriminatory basis.

All metadata will be available by request as soon as submitted by a researcher and regardless of any restrictions on access to the data. Metadata will be distributed at no cost via the Internet or in writing.

The WDI will release datasets according to the type of dataset (I or II, See *Appendix 1*) and by the guidelines of the appropriate Data Use Agreement. Most datasets will be Type I; these data will be released to the general public according to the terms of the General Data Use Agreement (*Appendix 2*), within **two years of project completion**. Type II data will be subject to a Restricted Data Use Agreement; these data have a restricted release that will be determined on a case-by-case basis.

Use and Misuse of Datasets

Individuals seeking access to datasets will be required to register on the repository web site and disclose their purpose in acquiring the data. Users will receive a free data account and will have to login with a user name and password to download data. Registration is implemented as a courtesy to the intellectual property rights of the

original Principal Investigator and for tracking the use of individual datasets. Registered users must complete registration and agree to the terms of the Data Use Agreement before downloading data. A short list of key terms of the Agreement will appear and must be accepted each time before a user downloads data.

The WDI shall have the right to terminate a user's access immediately by written notice upon the data user's breach of, or non-compliance with, any of its terms. The data user may be held responsible for any misuse that is caused or encouraged by the data user's failure to abide by the terms of the Data Use Agreement.

WDI Program Collaborators

The WDI is administered by the Montana Water Center, housed on the campus of Montana State University. The WDI archive/database is managed by the Water Center in collaboration with the Big Sky Institute and the Mountain Prairie Information Node (NBII) program of the US Geological Survey. Long-term management of datasets and metadata is the responsibility of the Big Sky Institute at Montana State University. Should the BSI cease to exist, the databases will revert to the Montana Water Center.

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[1] National Research Council. 2003. *Sharing publication-related data and materials: responsibilities of authorship in the life sciences*. The National Academies Press: Washington, DC. p.4.

[2] If a dataset is considered "incomplete" by the Principal Investigator, the data should still be submitted to the WDI with an explanation of why the data are of no use to other researchers.

[3] Data Use Agreement – Agreement that specifies the conditions for data use. For Type I data the General Data Use Agreement specifies general roles, obligations, and rights enjoyed by users regarding the use of datasets released for the general public. For Type II data (released under specific restrictions) a Restricted Data Use Agreement will be developed; it will be unique to the dataset, and in most cases, the General Data Use Agreement can be modified as appropriate.

Appendix 1 - Data Types and Data Release Timeline

It is the responsibility of the Principal Investigator to submit metadata and all datasets from funded research **within six months of project completion**. Release of datasets by the WDI to the public will depend on the data type.

Data Types

Metadata—Metadata documenting projects and datasets will be released to the scientific community and the general public as soon as possible after submission to the WDI.

Type I—Data will be released to the scientific community and the general public within two years of project completion. These data are subject to the General Data Use Agreement (*Appendix 2)*. This document specifies general roles, obligations, and rights enjoyed by users regarding the use of Type I datasets released for the general public.

Type II—Data will be released under specific restrictions, according to a Restricted Data Use Agreement. Type II data are considered to be exceptional and should be rare in occurrence. The Restricted Data Use Agreement is expected to be unique to the dataset, so no template is provided; in most cases, the General Data Use Agreement (*Appendix 2*) can be modified as appropriate.

Conditions Justifying Type II Status for Datasets

Principal Investigators who wish to designate datasets as Type II must provide written justification that describes a well supported need. Justification must be approved by the WDI Program Director and the Whirling Disease Steering Committee. Possible conditions warranting Type II data restrictions are described below. Once distribution concerns have been satisfied, these data will become Type I data and will be released.

Legal Questions

- The data includes the location of sensitive resources that might be endangered by revealing the location. This would include locations of artifacts, threatened or endangered species, and certain permanent plots.
- Data that are covered by copyright laws.

Data Quality Assurance and Control Issues

- The quality of the data is insufficiently defined for the data to be released. Data proofing and QA/QC have not yet been conducted or completed, but could occur if resources become available.
- The data include measurements using new techniques that require further research before their value/limitations are understood.
- The data are 'legacy data' that have significant problems in metadata, measurement methods, or other issues that make their value questionable without significant investment of resources. Examples of this category would be data which were stored prior to adoption of rigorous metadata and QA/QC standards. While the potential value of this legacy data may be high, significant resources are required to validate these data before distribution.

Publication Issues

- Special protection is required for a vulnerable investigator. These datasets are those collected by graduate students, Post-Doc's, and others who have a limited number of datasets to their name and whose professional development might be compromised by releasing the data too early.
- Data for which the sampling interval is longer than the WDI funding interval may justify restricted release. These would be datasets that might take a decade or more to detect a trend. In these cases, data will be partially restricted, but intermediate data from earlier measurement periods may be made accessible as Type I datasets.

APPENDIX 2 – General Data Use Agreement

Definitions:

"Data Use Agreement" – Agreement that specifies the conditions for data use. For Type I data the General Data Use Agreement specifies general roles, obligations, and rights enjoyed by users regarding the use of datasets released for the general public. For Type II data (released under specific restrictions) a Restricted Data Use Agreement will be developed; it will be unique to the dataset, and in most cases, the General Data Use Agreement can be modified as appropriate.

"Dataset" – Digital data and its metadata derived from any research activity such as field observations, collections, laboratory analysis, experiments, or the post-processing of existing data and identified by a unique identifier issued by a recognized cataloging authority such as a site, university, agency, or other organization.

"Data User" – Individual to whom access has been granted to a Dataset, including his or her immediate collaboration sphere, defined here as the institutions, partners, students and staff with whom the Data User collaborates, and with whom access must be granted, in order to fulfill the Data User's intended use of the Dataset.

"Dataset Creator" – Individual or institution that produced the Dataset.

"Dataset Owner" – Individual or institution that holds intellectual property rights to the dataset. Note that this may or may not be defined as a legal copyright. If no other party is designated in the metadata as Dataset Owner, it may be presumed that these rights are held by the Dataset Creator.

"Dataset Distributor" – Individual or institution providing access to the Datasets.

"Dataset Contact" – Party designated in the accompanying metadata of the Dataset as the primary contact for the Dataset.

Conditions of Use

The re-use of scientific data has the potential to greatly increase communication, collaboration and synthesis within and among disciplines, and thus is fostered, supported and encouraged. Permission to use this dataset is granted to the Data User free of charge subject to the following terms:

(1) *Acceptable Use*. Use of the Dataset will be restricted to academic, research, educational, government, recreational, or other not-for-profit professional purposes. The Data User is permitted to produce and distribute derived works from this dataset provided that they are released under the same license terms as those accompanying this Dataset. Any other uses for the Dataset or its derived products will require explicit permission from the Dataset Owner.

(2) *Redistribution*. The data are provided for use by the Data User. The metadata and this license must accompany all copies made and be available to all users of this

Dataset. The Data User will not redistribute the original Dataset beyond this collaboration sphere.

(3) *Citation.* It is considered a matter of professional ethics to acknowledge the work of other scientists. Thus, the Data User will properly cite the Dataset in any publications or in the metadata of any derived data products that were produced using the Dataset. Citation should take the following general form: Creator, Year of Data Publication, Title of Dataset, Publisher, Dataset Identifier. For example:

> Vincent, R. 2006. Water Temperature of Montana Streams During Sentinel Cage Exposure. Bozeman, MT: Whirling Disease Data Repository. http://bsi.montana.edu/web/whirling/ (1 May 2006).

(4) *Acknowledgement.* The Data User should acknowledge any institutional support or specific funding awards referenced in the metadata accompanying this dataset in any publications where the Dataset contributed significantly to its content. Acknowledgements should identify the supporting party, the party that received the support, and any identifying information such as grant numbers. For example:

> Datasets were provided by the Whirling Disease Initiative, a partnership between the Montana Water Center, Montana State University-Bozeman, and the U.S. Fish and Wildlife Service. Significant funding for collection of these data was provided by the U.S. Fish and Wildlife Service (USFWS Grant # 98210-6-J009).

(5) *Notification.* The Data User will notify the Dataset Contact when any derivative work or publication based on or derived from the Dataset is distributed. The Data User will provide the data contact and the Montana Water Center (101 Huffman Building, Montana State University, Bozeman, MT 59717-2690) with two reprints of any publications resulting from use of the Dataset and will provide copies, or on-line access to, any derived digital products. Notification will include an explanation of how the Dataset was used to produce the derived work. The Data User also must notify users that such derivative work is a modified version and not the original data and documentation distributed by the WDI.

(6) *Collaboration*. The Dataset has been released in the spirit of open scientific collaboration. Data Users are thus strongly encouraged to consider consultation, collaboration and/or co-authorship with the Dataset Creator.

By accepting this Dataset, the Data User agrees to abide by the terms of this agreement. The Data Owner shall have the right to terminate this agreement immediately by written notice upon the Data User's breach of, or non-compliance with, any of its terms. The Data User may be held responsible for any misuse that is caused or encouraged by the Data User's failure to abide by the terms of this agreement.

Disclaimer

While substantial efforts are made to ensure the accuracy of data and documentation contained in this Dataset, complete accuracy of data and metadata cannot be guaranteed. All data and metadata are made available "as is". The Data User holds all parties involved in the production or distribution of the Dataset harmless for damages resulting from its use or interpretation.