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Status review of Mountain Whitefish (*Prosopium williamsoni*) in the Blackfoot Basin: a data compilation to help identify risk of whirling disease

A report to the Whirling Disease Foundation

Introduction

Mountain whitefish - *Prosopium williamsoni* - (MWF) is an endemic salmonid to the Pacific Northwest of both the U.S and Canada. Native to western Montana, they are found primarily in cold, medium-to large rivers and in some lakes and reservoirs, and their distribution extends east and west of the Continental Divide. West of the Divide, they range throughout the upper Clark Fork and Flathead Basins. East of the Divide, their range extends throughout the headwaters of both the upper Missouri and Yellowstone Basins. Despite their generally ubiquitous presence in the river systems of western Montana, the life histories and population status of MWF have not been fully documented, nor has the vulnerability of MWF to whirling disease been fully investigated.

To help document the status of MWF and to begin to identify relationships of MWF to whirling disease in the Blackfoot Basin, Montana Fish, Wildlife and Parks (FWP) in compiled all available historic fish population survey information within the Blackfoot Basin into a (GIS) database and began (in 2006) more targeted surveys of MWF within the Blackfoot River. This status review and related fieldwork are running concurrent with plans for controlled laboratory exposures of MWF fry to *Myxobolus cerebralis* followed by histological examination. If successful, laboratory tests will help identify the age and size of susceptible fry and develop measures of disease severity. The testing of MWF using sentinel exposures in the field is expected in the near future.

Only one laboratory test has focused on the susceptibility of MWF to whirling disease was attempted (MacConnell et al. 2000). These researchers found that MWF when exposed within seven weeks of life to a high dose of TAMs caused direct and rapid mortality. Other MWF exposed at lower doses that survived developed the clinical signs of whirling disease (blacktail, whirling behavior and skeletal (caudal) deformities). This study concluded that MWF that were susceptible to infection by *M. cerebralis,* could develop whirling disease, and could serve as host for developing of *M. cerebralis* myxospores. This study observed caudal lesions were prevalent in infected whitefish, and that these closely resembled lesions found in wild juvenile mountain whitefish collected from the Madison River in 1999. Certain aspects of the study were however inconclusive because of an unrelated level of high MWF mortality during testing.

In addition to early lab results, field-based research and anecdotal reports likewise indicate MWF may have a high prevalence of *M. cerebralis* infection and could suffer population-level impacts. Whirling disease has been detected in MWF in the Salt River of Wyoming (Gelwicks and Zafft. 2000). Barry Nehring of Colorado Division of Wildlife reported a 70% to 80% prevalence of *M. cerebralis* infection among wild MWF of the Roaring Fork River, Colorado. In Mission Creek, Montana, biologists from the Confederated Salish and Kootenai Tribes recently reported clinical signs of whirling and caudal deformities in MWF. (Craig Barfoot, personal communication) Likewise, caudal deformities in juvenile MWF were recently detected within infected waters of the middle Blackfoot River of Montana. One local example of possible population declines within the Blackfoot Basin appears to be the recent loss of MWF from Hoyt Creek, a small spring creek tributary to Monture Creek. In 1992 prior to the introduction of whirling disease to waters of the Blackfoot Basin, juvenile MWF were identified as common in lower Hoyt Creek; however in 2006 following the local escalation of whirling disease, MWF were absent from the same Hoyt Creek sampling location. Infected spring creeks like Hoyt Creek have been shown to support continuously high TAM production during the early MWF rearing period (i.e., from winter through early summer; Anderson 2004, R. Pierce, unpublished data). Infected basin-fed tributaries however show variable infection levels during the early summer depending on the environmental properties (e.g. water temperature) of individual streams (Pierce et al, in review).

MWF Status summary

MWF Distribution and WD overlap - Understanding potential MWF disease relationships requires understanding the distribution and basic life history of MWF with emphasis on the vulnerable juvenile life-stages. Fish population surveys conducted within the Blackfoot Basin between 1989-2006 identify the presence of MWF from the confluence of the Blackfoot River upstream ~125 river miles and present at the lower elevations with ~25 of the larger tributaries (Figure 1, Appendix A). This distribution identify MWF mostly in the larger streams of basin-fed origin as well as the lower reaches of connected tributaries including several smaller spring creeks like Hoyt Creek, all of which are located in streams within the lower-valleys of the Basin. This distribution overlaps closely with high infection rates based on sentinel exposures (Appendix B).

Our review of the historic MWF information identifies at a basin scale primary YOY rearing areas within the middle Blackfoot Basin from Elk Creek to Arrastra Creek and within the lower reaches of nearby tributaries (Figure 2). This distribution pattern overlaps closely with the known distribution of whirling disease including a large degree of spatial overlap with high severity of disease with rainbow trout (Appendix B).

Basic life history - MWF are long-lived and possess some life history variation that often involves

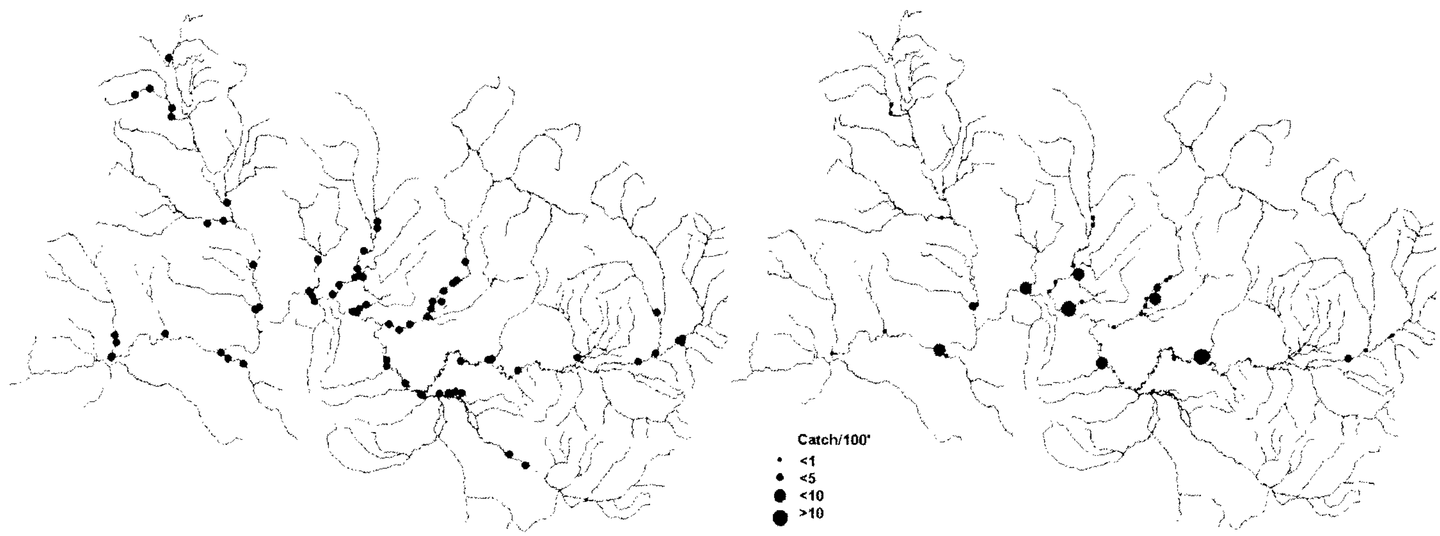


Figure 1 and 2. Fish populations survey sites (1989-2007) where the presence of MWF is documented (left) and YOY abundance classes (right).

movement between habitats at multiple life stages. Spawning migration and spawning areas are highly variable between regions (Northcote and Ennis 1994). Although not well documented, spawning migrations often range from 10-30km (Northcote and Ennis 1994), although spawning migrations >60 km have been identified (Davies and Thompson 1976). Migratory fish seem to undergo a complex sequence of seasonal movements beginning with passive dispersal of fry, followed by late summer movements to deeper water and higher velocity feeding habitats and autumn migrations to downriver over-wintering habitat. Spawning migrations of river populations are often in an upstream direction, although downstream spawning migrations from summer foraging areas to spawning locations in lower reaches of larger tributaries or into main-stem of rivers have also been documented (McPhail and Troffe 1998).

MWF are long-lived and usually reach sexually maturity by the age of six. Fecundity is a function of female body size, thus larger females produce more eggs than smaller females, ranging from 1,400 to 24,000 eggs in Montana females (Brown 1952). MWF seem to use a wide range of habitats for spawning, and no spawning site preparation (redd construction) occurs by females (McPhail and Troffe 1998). Instead, MWF often spawn in (small) groups and eggs are broadcast over the substrate in riffles or rapids in late fall or early winter. Egg collection in western Montana by FWP hatchery personnel indicate November as a primary spawning period. Spawning water temperatures usually occur at temperatures below 6^{0}C. Incubation requires ~360-400 temperature units (^{O}C) (Dick Vincent, FWP, personal communication). Eggs hatch in early spring about the time ice breakup on rivers.

According to Northcote and Ennis (1994), throughout their life MWF progressively move to faster and deeper waters as body size increases. Fry emergence occurs in spring at which time sac fry seek out side-channels or protected backwaters along stream margins (Brown 1952). Fry leave these habitats by early summer and passively dispersed downstream to protected areas where fish school, before further dispersing to deeper sections of stream during summer. Consistent with this movement pattern, in summer 2006, FWP and Dr. Lisa Eby undertook a targeted YOY survey in a known spawning area in Rattlesnake Creek (a tributary of the Clark Fork River near Missoula) where they detected very low densities of YOY. However, YOY were observed in nearby in relatively high abundance in riffles of a much larger River (the lower Blackfoot River), suggesting a run-off-related out-migration of YOY although high densities of YOY have been identified in the lower reaches of tributaries during summer as well (Figure X). This general pattern of early downstream dispersal is consistent with trapping studies in tributaries to the Flathead River, which identity and YOY out-movements during the runoff period (Craig Barfoot, Confederated Salish and Kootenai Tribe, personal communication). Older fish prefer pools however they are often associated with runs (riffle breaks) and riffles for foraging areas slightly upstream of pools or deeper depressions also in quiet areas associated with the downstream side of woody debris.

MWF survey in the Blackfoot River: Wales and Canyon Creek sections

MWF are identified as common at all mainstem Blackfoot River downstream of Lincoln (rm 108) based on electro-fishing observations; however as a non-target species, quantification of mainstem populations has not been a priority, until recently. To assess MWF sampling techniques and develop a monitoring baseline for the Blackfoot River, MWF were targeted in two population surveys sites in Blackfoot River under differing flow conditions in 2006. One survey was completed in May during the peak of runoff in the middle River (Wales Creek Section), and the other was completed in the upper Blackfoot River (Canyon) in September during base-flow conditions. Both surveys relied on mark-and-recapture methods and were undertaken using the same drift boat boom-mounted electrofishing methods. These surveys emphasized estimates of population densities and size structure metrics (length-weight and age-and-growth) within infected waters in the mid-to upper Blackfoot River.

Survey Results - The spring survey in the Wales Creek section identified a very low capture efficiency, which generated an unreliable estimate of density. Conversely, the fall survey in the Canyon Section resulted in much higher capture efficiency and a more reliable estimate of densities. A comparison of these density

Table X. Comparison of mark-and-recapture survey results for MWF (≥8.0") in two sections of the Blackfoot River. The Wales Creek is a spring estimate and the Canyon Section is a fall estimate.

Stream	River-mile mid-point	Date Sampled	Section Length (ft)	Species	Size Class (in)	Marked	Captured	Recaptured	Efficiency (R/C)	Total Estim ± CI	Estim/1000' ± CI
Wales Creek Section	63	20-May-02	7603	MWF	>8.0	74	77	4	0.05	1169 ± 923	154 ± 119
Canyon Section	95.3	20-Sep-06	5422	MWF	>8.0	177	121	23	0.19	904 ± 324	167 ± 59

estimates and related statistics for MWF over two years of age (≥8.0") for both sections is located in Table X

Weight-length and age-size class assessment – Length frequency and weight-length scatter grams and condition factor plots for both sites are presented in Figures X, X and X, respectfully. The data indicates the upper Blackfoot River supports a "top-heavy" population, particularly in the upper river (Canyon Section). Condition factor (Wr) measurements (Murphy et al. 1991) showed a higher mean condition of 107 in the Wales Creek section compared to a mean of 96 in the Canyon Section.

Scales from 36 MWF were also collected from the two sections on the Blackfoot River during sampling. Aging the scales from the Wales Creek section show little or no growth had occurred since winter annulus was formed; therefore the outer edge was considered the final annulus. Because the Canyon section scales were collected in September the ages were stated with a plus (+), although little growth probably will occur after the September collection data. The fall age size groups are probably the same because growth after late September

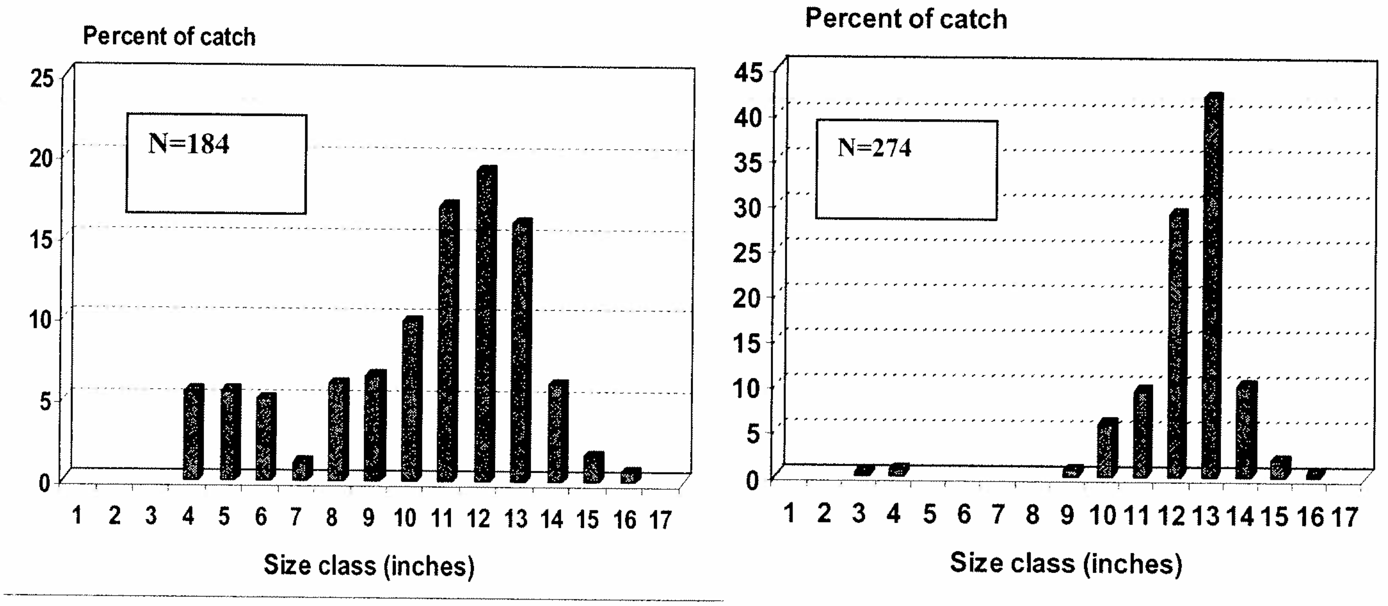


Figure X. Length-frequency histograms for MWF in the Wales Creek (left) and Canyon Creeks (right) sections of the Blackfoot River, 2006

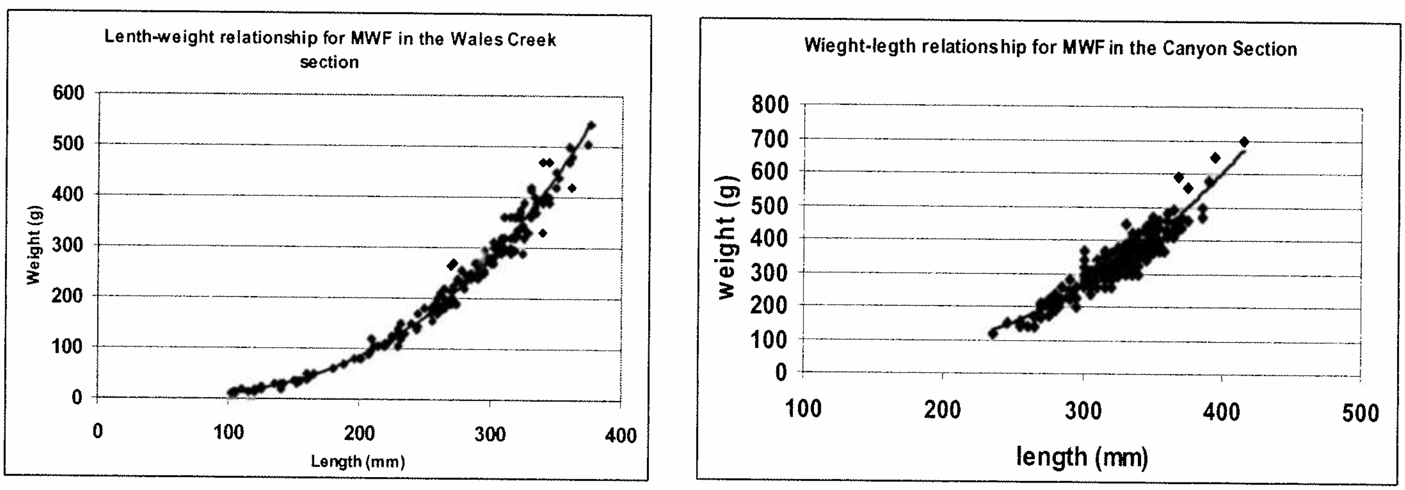
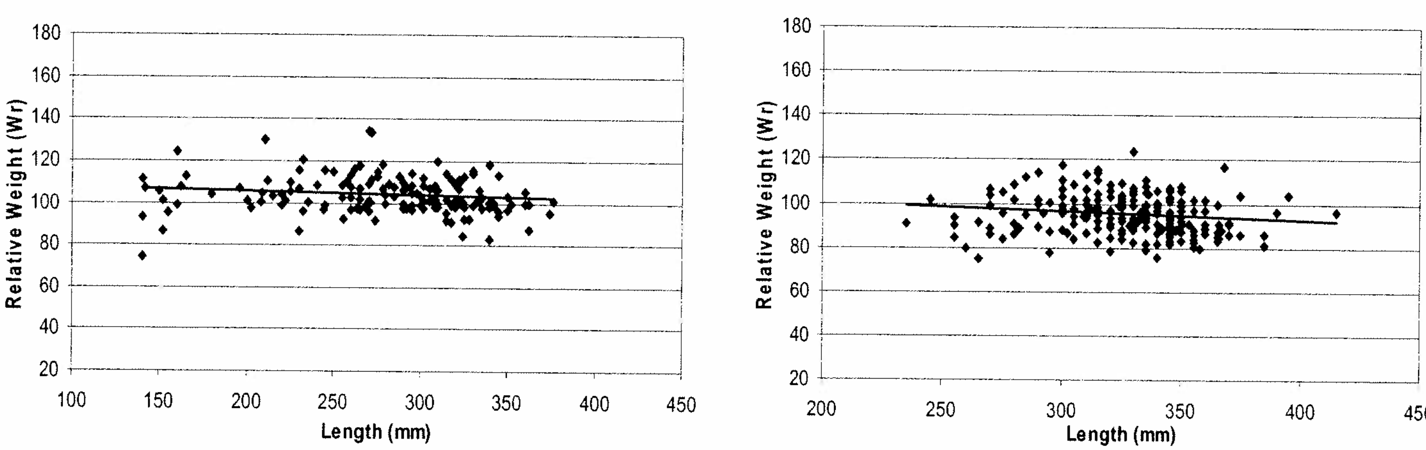


Figure X. Scatter graphs showing length-weight relationships for MWF in the Wales Creek (left) and Canyon Creek sections of the Blackfoot River.



Relative weight for MWF in the Wales Creek (left) and Canyon Section (right) of the Blackfoot River.

would not be significant; therefore 0+ mountain whitefish in the fall would be the same size as a yearling (age 1 fish) in the spring (Table 1).

Using the age structure comparisons for both survey sections, there is a noticeable lack of younger MWF in the Canyon section compared to the Wales Creek section (Figure 3). For the Canyon Section, all the year classes between 2005-2002 are either low or missing, however larger numbers of 2001 and older whitefish were collected. With exception of the low numbers of 2006-year class (YOY) the year class distribution in the Wales Creek section looks much better.

Discussion

Table 1. Estimated size-groups for each age classes found in the Wales Creek and Canyon section of the Blackfoot River, 2006.

Wales Creek Section		Canyon Section	
Age Class	Size Group (est.)	Age Class	Size Group (est.)
1	4 - 4.9 inches	0+	4 - 4.9 inches
2	5 – 7.9 inches	1+	5 – 7.9 inches
3	8 – 10.6 inches	2+	8 – 10.6 inches
4	10.7 – 11.8 inches	3+	10.7 – 11.8 inches
5+	> 11.9 inches	4+	> 11.9 inches

Although not always appreciated by the common angler, the ecological importance of MWF is high, particularly for large salmonids like bull trout or other predatory game fish. If whirling disease were to reduce MWF populations, this could potentially impact not only the fish community, but also the overall food web including a myriad of terrestrial predators (and scavengers) that also rely on MWF as a key forage species

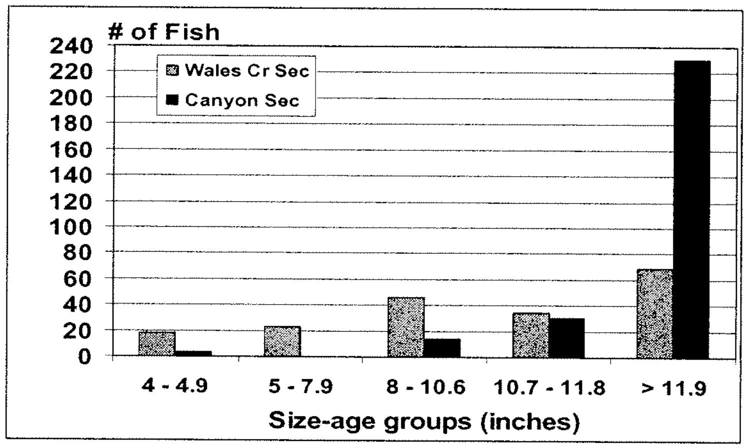


Figure 3. Comparisons of age structure between the Wales Creek section and Canyon section using size groups, 2006. Refer to table X for ages.

Although this review improves our understanding of MWF, still little is known about the local MWF life histories or the vulnerability of fry to whirling disease. What we do known is that many streams in the middle Blackfoot Basin, identified as supporting high densities of juvenile MWF in the past, are now highly infected and the clinical signs of whirling are now being detected in MWF in certain western Montana waters, including the middle Blackfoot River. The absence of MWF from Hoyt Creek elevates disease concerns for MWF. The spatial overlap of MWF and whirling disease is a specific concern in the middle Blackfoot Basin where the high densities of YOY regionally overlap with a high severity of disease in other species (e.g. rainbow trout). Until parasite exposures of MWF are complete, it is difficult to interpret local population changes in places like Hoyt Creek or examine the extremely weak juvenile MWF numbers in highly infected waters of the upper Blackfoot River.

In the case of MWF in the upper Blackfoot River, it is interesting to further consider the "top-heavy" population within a context of potential disease implications. Although other factors (e.g. movement) could explain the very low abundance of juvenile fish (age 0 through age 3) in the Canyon section, the near absence of juvenile year classes are consistent with recent increases in whirling disease to high levels of severity (i.e. prevalence of high severity >3 for rainbow trout on MacConnell-Baldwin scale) between 2003-2005. Unlike other susceptible salmonids such as rainbow trout, MWF is by comparison a long-lived fish with individuals approaching 30-years of age (Northcote and Ennis 1994). This longevity is important given the potential population effects resulting from whirling disease in waters like the Blackfoot River would not show up in adult populations for many years.

In summary, assessing impacts in the wild will likewise require and understanding of the movement and habitat use of MWF in the wild with emphasis on spawning sites, early rearing areas and related movement patterns. Once disease susceptibility is better identified, and if spawning and rearing sites of MWF can be better identified, the known temporal-spatial conditions associated with high (or low) whirling disease infection (and severity) in the Blackfoot Basin can be applied to MWF.

To aid in our understanding of local MWF life history, a pilot-level telemetry emphasizing movements and locations of spawning sites is planned for the Blackfoot River in 2008. Once timing and location of spawning is identified, existing winter temperature information and environmental predictors of WD (*see* Pierce et al. *in review*) could be used to identify the incubation and hatching and better assess exposure risk of *M. Cerebralis* to fry at a more refined spatial scale. With a better understanding of MWF life history, habitats and susceptibility, the effects of whirling disease on MWF populations could be examined using sentinel cages as well as the continuation of population densities surveys and winter water temperature monitoring in suspected spawning and early rearing areas. This information will help in evaluation overlap between *M. cerebralis* and vulnerable fry.

Recommended future work

- Complete lab exposures of MWF fry and identify the age and size and other factors related to susceptibility.
- Attempt sentinel exposures in the wild in areas where vulnerability and fry overlap.
- Repeat MWF sampling at pre-disease population survey sites in tributaries in order to detect possible disease-related MWF population changes.
- Identify adult spawning and early rearing life histories of MWF within the Blackfoot River Basin and various tributaries in order to determine specific MWF streams at risk.
- Continue to monitor the MWF population in the upper Blackfoot River Canyon Creek section.
- Identify a funding source to complete juvenile life-history work and develop a more refined study through a U of M graduate study

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Appendix A: Catch and size statistics for MWF in the Blackfoot Basin.

Stream	River Mile	Date Sampled	Section Length (ft)	MWF abundance	Total Number Captured	Number Captured 1st Pass	MWF (<4.0") Captured 1st Pass	Range of Lengths (in)	Mean Length (in)	Total CPUE (#/100')	YOY CPUE (#/100')
Arrastra Creek	0.3	15-Sept-99	360	Present	75	75	75	3.0-3.14	3.1	20.8	20.8
	0.5	23-Aug-89	360	Present							
	0.7	26-Aug-96	440	Present	18	12	12	2.9-3.5	3.2	2.7	2.7
		15-Sep-99	450	Present	32	32	32	3.0-3.7	3.7	7.1	7.1
Beaver Creek	0.2	24-Aug-89	477	Present	3	3	0	10.2-12.2	11.4	0.6	0.0
Belmont Creek	0.1	25-Jul-89	365	Present	2	2	2	3.3-3.6	3.5	0.5	0.5
		9-Aug-01	576	Present	2	2	2	3.3-3.6	3.5	0.3	0.3
Blackfoot River-Johnrud	13.5	30-May-06	17680	Common							
Scotty Brown	43.9	25-May-06	20064	Common							
Raymond Bridge	59.5	26-Aug-99	5745	Common							
Wales Creek Section	64	24-May-06	7603	Common	190	84	0	4.0 - 15.4	10.4		
H2-0 ditch	83.7	24-Jul-95	525	Common	7	7	0	2.7-3.2	2.9	1.3	0.0
		31-Aug-04	1000	Common	12	12	10	2.7-3.7	3.3	1.2	1.0
Pocha Ditch (trap) 5/19-7/15/05	86.5	19-May-05		Present	31	31	3	3.7-7.7	4.6		
Canyon reach	95.3	20-Sep-06	5422	Common	277	177	0	3.9-16.3	12.8		
Poorman/Dalton Section	107.2	21-Sep-06	6800	Common	4	4	0	12.6-15.5	14.1	0.1	0.0
Hefner Ditch	114	25-Jul-00	570	Common	10	10	10	2.7	2.7	1.8	1.8
		8-Aug-01	1340	Common	4	4	4	2.6-2.8	2.7	0.3	0.3
Hogum Section	119.6	11-Sep-06	4000	Common	18	15	2	3.5-15.3	12.2	0.4	0.1
Blanchard Creek	0.1	15-Sept-94	350	Present	11	9	9	3.1-3.8	3.9	2.6	2.6
		14-Sep-95	420	Present	7	7	6	3.3-4.3	3.8	1.7	1.4
		12-Aug-97	550	Present	1	0	0	3.1	3.1		
		23-Sep-98	425	Present	4	0	0	3.7-4.3	4.1		
		19-Sep-02	310	Present	1	1	0			0.3	0
Chamberlain Creek	0.1	22-Sept-89	200	Present							
		17-Sep-98	430	Present	1	1	0	4.1	4.1	0.2	0.0
Clearwater Ditch	0.1	2-Sep-03	4224	Present	2	2	1	3.7-4.3	4.0	0.0	0.3
		22-Sep-05	567	Present							
Clearwater River	8.8	8-Aug-95		Present	1	1	0	10.7	10.7		
	17.2	29-Aug-95	10496	Present	1	1	0	10.4	10.4	0.0	0.0
	37.5	17-Jul-95	492	Present	1	1	0	9.4	9.4	0.2	0.0
		23-Jun-06	66	Present	2	2	0	8.6-8.7		3.0	0.0
		11-Jul-06	66	Present	4	4	0	7.3-7.9		6.1	0.0
Copper Creek	1.1	2-Sep-04	555	Present	1	1		7.4	7.4	0.2	0.0
Cottonwood Creek	0.1	29-Aug-00	465	Present	2	2	2	3.6-3.7	3.7	0.4	0.4
		16-Sep-02	450	Present	30	30	30	3.1-3.8	3.4	6.7	6.7
		1-Oct-03	465	Present	1	1	0	4	4	0.2	0.0
	4.7	28-Jul-92	240	Present	1	1	0	2.7	2.7	0.4	0.0
	5.0	7-Jul-92	225	Present	3	3	0	15.2-15.6	15.5	1.3	0.0
Dick Creek	0.1	6-May-92	420	Present	4	4	0	7.9-11.0	9.4	1.0	0.0
		6-Sep-01	360	Abundant							
	0.8	6-May-92	243	Present	2	2	0	7.5-7.9	7.8	0.8	0.0
Elk Creek	0.1	3-Oct-91	198	Present	1	1	0	3.7	3.7	0.5	0.0
		5-Sep-00	375	Present	6	4	4	3.2-4.3	3.6	1.1	1.1
		22-Sep-03	430	Present	72	42	24	3.1-4.8	3.9	9.8	5.6
	1.1	5-Sep-00	354	Present	3	2	2	3.6-3.9	3.8	0.6	0.6
	3.0	3-Oct-91	108	Present	2	2	0	4.5-4.7	4.6	1.9	0.0
Gold Creek	0.2	17-Aug-00	490	Present	2	2	1	3.7-7.2	5.4	0.4	0.2
		16-Aug-01	510	Present	2	1	0	7.1-7.7	7.4	0.2	0.0
	1.9	10-Aug-98	400	Present	1	0	0	7.6	7.6	0.0	0.0
		21-Aug-00	387	Present	1	0	0	4.1	4.1		
	2.6	6-Aug-96	569	Present	1	1	0	11.6	11.6	0.2	0.0
Hogum Creek	0.1	10-Aug-95	108	Present	1	1	0	2.6	2.6	0.9	0.0
	0.4	28-Jul-99	405	Present	1	1	0	5.1	5.1	0.2	0.0
Hoyt Creek	0.2	8-Sep-92	200	Present	28	20	17	3.1-5.0	3.6	10.0	8.5
Landers Fork	0.1	13-Sept-89	781	Present	1	1	1	3.5	3.5	0.1	0.1
Marshall Creek	2	29-Jun-95	443	Present	1	1	0	8.7	8.7	0.2	0.0
	3.7	29-Jun-95	394	Present	1	1	0	7.3	7.3	0.3	0.0

Appendix A: Catch and size statistics for MWF in the Blackfoot Basin.

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Monture Creek	0.4	9-Aug-89	480	Present	2	2	0	10.2-10.5	10.3	0.3	0.0
		21-Aug-02	446	Present	1	1	1	2.4-3.2	2.8	0.2	0.2
	2.2	16-Aug-00	204	Present	1	1	1	3.7	3.7	0.5	0.5
	5.4	16-Aug-00	456	Present							
		18-Aug-05	460	Present	1	1	1	2.5	2.5	0.2	0.2
	8.6	14-Aug-02	680	Present							
	12.9	25-Sep-68	400	Present	2	2	2	2.4-2.7	2.5	0.4	0.4
	13.9	25-Sep-68	400	Present	1	1	1	2.7	2.7	0.2	0.2
Nevada Creek	0.3	14-Sep-00	465	Present	12	12	0	5.9	5.9	2.6	0.0
	0.7	1-Nov-89	650	Present	2	2		4.0-4.2	4.1	0.3	0.0
	5.1	29-Sep-05	6336	Present	60	60	3	3.3-8.8	4.7	0.9	0.0
	27	5-Jul-00	600	Present							
	29.0	12-Apr-90	400	Present	2	2	0	11.6-12.8	12.2	0.5	0.0
		9-Aug-94	430	Present	1	0	0	8.6	8.6	0.0	0.0
		27-Sep-00	522	Abundant							
Nevada Spring Cr.	0.8	21-Sep-04	500	Present	1	0	0	5.2	5.2	0.0	0.0
	1.1	15-Sep-05	500	Present	1	1	0	4.1	4.1	0.2	0.0
	2.8	26-Sep-00	450	Present	1	1	0	4	4.0	0.2	0.0
		18-Sep-01	450	Present	1	1	0	4.4	4.4	0.2	0.0
North Fork snorkel survey	1.2	19-Sep-85	12150	Present	17	17				0.1	
Blackfoot River	2.6	10-Aug-89	590	Present	4	4	0	6.4-11.7	9.1	0.7	0.0
		10-Sep-98	770	Present	1	1	1	3.5	3.5	0.1	0.1
		22-Aug-02	660	Present							
NF snorkel survey	4.0	17-Sep-85	20430	Present	305	305				1.5	
		29-Aug-98	20430	Abundant							
	7.6	29-Aug-02	850	Present	3	3	3	3.1-3.5	3.3	0.4	0.4
	7.9	16-Aug-89	735	Present	6	6	1	3.6-10.7	8.2	0.8	0.1
		15-Aug-00	672	Present	1	1	1	2.6	2.6	0.1	0.1
Weaver ditch at road xing	10.4	23-Sep-94	300	Present	2	2	1	3.1-4.0	3.6	0.7	0.3
		28-Aug-96	375	Present	4	4	0	-	-	1.1	0.0
		13-Aug-02	450	Present	12	12	12	1.8-2.4	2.1	2.7	2.7
Weaver ditch at road xing		22-Sep-94	210	Present	38	38	12	3.1-4.5	4.1	18.1	5.7
Rangitch Ditch at N.F. mile 11.6	11.6	23-Aug-05	300	Present	1	1	1	2.8	2.8	0.3	0.3
Rowland Fish camp	12	15-Aug-89	757	Present	1	1	1	2.7	2.7	0.2	0.2
NF snorkel survey	15.5	19-Aug-85	18480	Present	77	77				0.4	
Lund Ditch at N.F	15.5	24-Aug-05	310	Present	8	8	8	2.3-2.9	2.6	2.6	2.6
Owl Creek	1.2	23-Aug-90	500	Present	1	1	1	3.2	3.2	0.2	0.2
	4.2	19-Jul-95	50	Present	7	7	0	10.4-12.2	11.7	14.0	0.0
Rock Creek	0.0	2-Aug-94	385	Present	3	3	3	2.0-3.5	2.6	0.8	0.8
Wales Creek	0.1	8-Aug-00	396	Present	30	30	30	3.1	3.1	7.6	7.6
		6-Oct-03	391	Present	3	2	2	3.0-3.7	3.2	0.5	0.5
Warren Creek	0.1	11-Oct-91	186	Present	58	47	22	3.2-4.5	3.9	25.3	11.8
		11-Sep-00	294	Present	6	4	3	3.0-4.1	3.6	1.4	1.0
	0.4	11-Oct-91	180	Present	13	10	1	3.8-4.7	4.3	5.6	0.6
	1.1	11-Sep-02	576	Present	1	0	0	3.2	3.2		
		8-Sep-04	345	Present	1	0	1	3.7	3.7		
	2.1	12-Sep-00	333	Present	3	2	2	3.8-4.1	4.0	0.6	0.6
West Fork Clearwater River	2.3	22-Aug-06	492	Present	2	2	1	3.5-4.0	3.7	0.4	0.2
	3.3	23-Aug-06	492	Present	2	2	1	3.3-4.2	3.7	0.4	0.2

Appendix B: Sentinel cage results with mean grade histological scores at 28 sites. Site numbers in the table relate to locations on the below map.

Site	Waterbody	Mean Grade Infection							
	Blackfoot River	1998	1999	2000	2001	2002	2003	2004	2005
1	Blackfoot River-Below Go	0.22	nd	2.44	nd	0.59	2.42	2.2	2.06
2	Blackfoot River-Below Elk	nd	nd	2.3	nd	1.59	nd	2.3	nd
3	Blackfoot River-above Cle	1.1	0.22	3.11	nd	2.79	3.16	3.41	2.96
4	Blackfoot River-Below No	0.25	nd	nd	nd	nd	nd	2.64	2.86
5	Blackfoot River-below Nev	0	0	0.84	nd	0.9	2.12	3.93	3.28
6	Blackfoot River-Below Lin	0	0	0.6	nd	2.44	nd	nd	3.89
7	Blackfoot River-Headwate	nd	nd	0	nd	0.02	0.32	nd	0
	Basin-fed Streams								
8	Johnson Creek	nd	nd	nd	nd	nd	nd	nd	0
9	West Twin Creek	nd	nd	nd	nd	nd	nd	nd	0
10	East Twin Creek	nd	nd	nd	nd	nd	nd	nd	0
11	Gold Creek	nd	0.12	0	nd	0	0	nd	0
12	Belmont Creek	nd	nd	0	nd	0.19	0.38	1.55	2.48
13	Elk Creek	nd	0	0	nd	0	2.84	4.32	4.82
14	Clearwater Creek	nd	nd	nd	nd	nd	nd	0	nd
15	CottonwoodCreek	3.66	4.52	nd	nd	4.5	nd	nd	3.78
16	Chamberlain Creek	0.16	2.71	3.88	nd	2.63	nd	4.33	3.78
17	Monture Creek	0	0	1.76	nd	3.22	nd	nd	4.81
18	Warren Creek	0.21	2.1	1.72	nd	nd	nd	nd	0
19	North Fork Blackfoot Rive	0	nd	0	nd	0.78	nd	nd	0.27
20	Arrastra Creek	nd	nd	nd	nd	nd	0.34	1.23	0.02
21	Beaver Creek	nd	nd	nd	nd	nd	nd	0.45	0.85
22	Poorman Creek	nd	nd	nd	nd	nd	nd	0.78	ND
23	Landers Fork	nd	nd	nd	nd	nd	nd	0.14	0
	Spring Creeks								
24	Rock Creek	nd	0	2.3	3.9	nd	3.38	nd	nd
25	Kleinschmidt Creek	2.83	3.56	4.52	3.77	nd	4.9	4.7	nd
26	Nevada Spring Creek	nd	nd	nd	nd	0	nd	3.66	2.22
27	Grentier Spring Creek	nd	nd	nd	nd	nd	nd	0.06	1
28	Lincoln Spring Creek	nd	nd	nd	nd	nd	nd	5	4.7