Pest Risk Assessment for Whirling Disease (*Myxobolus cerebralis*) in Oregon

IDENTITY
Name: *Myxobolus cerebralis*
Taxonomic Position: Phylum Myxozoa, Class Myxosporea, Order Bivalvulida, Family Myxobolidae
Common Names: whirling disease, black-tail

RISK RATING SUMMARY
Relative Risk Rating: High
Numerical Score: 6 (on a 1-9 scale)
Uncertainty: MODERATE

The moderate level of uncertainty attributed to this risk assessment is due to several factors. Although the risk for *M. cerebralis* to establish has been designated as high it should be noted that even when fish and worms are exposed to their respective susceptible spore stages of the parasite they do not always contract the disease. The format the risk assessment follows was originally developed for forest pest species and, as such, fails to take into consideration characteristics of invasive species that may be unique to aquatic microorganisms.

RECOMMENDATION
Confirmed establishment of *Myxobolus cerebralis*, presence of host species and host species habitat, and various vectors for spread imply that whirling disease has a high risk for impact in the state of Oregon. Since *M. cerebralis* is already established in the northeastern part of the state measures should be continued to isolate the parasite within this region and any new regions where it may be found. A continued focus on the major pathways of spread and control measures remain as vital to management as education efforts on whirling disease in those areas.

RISK RATING DETAILS
Establishment Potential is HIGH
Justification: *Myxobolus cerebralis*, the parasite causing whirling disease, has a complex life cycle including two obligate hosts and two spore stages. *M. cerebralis* cannot complete its life cycle without a host fish (susceptible salmonid species) and host worm (*Tubifex tubifex*) (El-Matbouli et al. 1999). The spore stages of *M. cerebralis* include the myxospore stage (developing within salmonids) and the triactinomyxon actinospore (TAM) stage (developing within *Tubifex tubifex*). The myxospore is a very durable spore that is deposited in the stream sediment when the infected fish dies. *Tubifex tubifex* then ingests the spore-contaminated sediment and becomes infected (Whirling Disease Initiative 2008). The parasite transforms within the gut epithelium of the worm into a TAM and upon full development is released by the oligochaete host into the water (El-Matbouli and Hoffmann 1998). The TAM then attaches and enters the epidermis of a susceptible fish where it travels through the nervous system to end up in cartilage

tissue where it multiplies and consumes cartilage. The consumption of fish tissue by the parasite causes deformities affecting the fish's skull, gills and vertebral column (Hedrick et al. 1998). During this period, the *M. cerebralis* parasite returns to the myxospore stage within the salmonid and, upon the death of the fish, it is released into the water as the fish decomposes (El-Matbouli et al. 1992).

In an infected fish, the parasite can cause tissue damage and affect nerves. External indications of whirling disease are abnormal whirling or tail-chasing behavior exhibited by infected fish. Black tails appear in younger fish and head or body deformities may be indications in older fish, although fish can carry the disease with no visible signs. Severe infections from *M. cerebralis* can kill fish, primarily fry and small fingerlings (Myxozoan Network 2006).

Although *M. cerebralis* has an intricate life cycle and is non-native to the United States (U.S.), established populations currently exist within the state of Oregon.   The parasite is native to Europe and was first described in Germany in 1903. It is thought that the parasite was introduced to the U.S. via frozen trout shipments that harbored spores (Markiw 1992). Since the early 1950s the species has resided in the U.S. and today 25 states have confirmed its presence (Arsan et al. 2007). *Myxobolus cerebralis* was first detected in the Pacific Northwest in 1986 during an inspection of a private trout hatchery in the Grande Ronde watershed on the Lostine River (in northeastern Oregon) (Lorz et al. 1989). Statewide surveys of wild and hatchery fish from 1987-1989 found the infection was limited to fish in the Grande Ronde and Imnaha basins (Lorz et al. 1989; ODFW 2008). In 1987 a positive stray adult steelhead from the Snake River was detected in the lower Deschutes River. Continuous surveys performed in the Deschutes River basin by Oregon Department of Fish and Wildlife (ODFW) from 1997 to present have detected *M. cerebralis* spores in stray fish but the disease has not established itself within naturally reared and hatchery fish populations in the basin above the Pelton Round Butte Hydroelectric Project (Engelking 2002; ODFW 2008). Proposed reconfiguration of the PRB Hydroelectric Project to reestablish anadromous fish runs in the Deschutes River Basin raises the concern that *M. cerebralis,* recently determined to be established in Trout Creek a tributary of the lower Deschutes River (Zielinski, 2008), could be moved upstream negatively impacting native salmonids, particularly listed species such as the redband rainbow trout (*Oncorhynchus mykiss*).

In 2001, *M. cerebralis* was found in juvenile rainbow trout outside of the enzootic (or endemic) zone in northwestern Oregon at a private aquaculture facility along Clear Creek, a tributary of the Clackamas River (Bartholomew et al. 2007). After closure of the facility, the parasite was transiently detected in the creek for a period of time but failed to become established in the system.

Oregon provides suitable habitat to support both hosts needed for the life cycle of *M. cerebralis*. Salmonid habitat is not simple to describe but in general a river system supporting salmonids should have a combination of pools and riffles, woody cover to protect fish from predators, and stream-side vegetation to shade and keep water cool and clean (Whatcom Salmon Recovery 2003). *Tubifex tubifex* habitat is described as that with fine sediment and organic matter with low flow (Brinkhurt and Gelder 1991). Although, in the Deschutes River basin, oligochaetes were found more often in areas with fast moving water, course sediment and little to or no organic matter (Zielinski 2008). Salmonid species that are known to be vulnerable to whirling disease in Oregon

include: rainbow trout, steelhead trout, cutthroat trout, Chinook salmon and kokanee salmon. Fish that are of less concern include: brook trout, bull trout, brown trout and coho salmon. The parasite does not infect lake trout, warm water game fish, sturgeon or nongame fishes (ODFW 2008).

The potential risk for *M. cerebralis* to establish in other areas of Oregon is high mainly because the parasite can be transferred by anadromous salmonids during their migrations. Not all areas of Oregon are at risk but areas that support hosts and have suitable habitat have a higher probability. Other areas at risk include those along the migration pathway of salmon from enzootic regions, and where fish are imported for use in private ponds that have outflows into natural waters. Although the risk for *M. cerebralis* to establish has been designated as high it should be noted that establishment requires that a complex series of events enfolds, including myxospores going undetected long enough for a population to establish.

Spread Potential is MODERATE to HIGH

Justification: In risk assessments performed in specific regions of Oregon for *M. cerebralis*, the potential pathways in which the species can spread have been outlined as: human movement, natural dispersal and recreational activities (Zielinski 2008; Arsan 2007). Human movement includes the movement of salmonid fry and smolts, and fish. The movement of fish appears to have varying levels of risk associated with it depending on the area of concern and the ingress and egress of the water system and if the parasite is detected prior to movement (Zielinski 2008). Hatchery fish that have been exposed to the parasite are considered a high risk to spread the organism and fish health regulations restrict stocking outside of the enzootic region. Until recently, hatchery fish that have been exposed to and carry the spores of *M. cerebralis* have been destroyed. Currently, releases of fish that may carry the parasite occur only into known endemic areas.

Natural dispersal or spread of *M. cerebralis* includes movement of stray fish (fish from outside watersheds) and movement via birds. Stray fish are those salmonids that divert from their enzootic region to another watershed. Fish straying from the Grande Ronde watershed would pose the highest threat, as it is the closest region with an established population of the parasite. Fish migrating from Idaho streams, where some are parasitized by this organism also pose a risk for spread. Birds have the potential to spread the parasite and Arsan (2007) describes the chain of events that must take place for *M. cerebralis* to be introduced. For a bird to act as a pathway for the parasite the following events must occur: bird must eat an infected fish, myxospores must survive passage through the gut of the bird, the bird must then fly to a new location, retain infected fish during flight and release viable spores into a new water body. It was noted that the birds might not have to pass the parasite through the digestive track to release spores as they tend to regurgitate pellets with undigested pieces of food (Zielinski 2008). Oregon supports many species of piscivorous birds including but not limited to: eagles, osprey, and cormorants. These bird species also have the ability to travel extensive distances (up to hundreds of kilometers per day).

Recreation can also serve as a pathway for *M. cerebralis* spread within the state of Oregon. Angling and boating are the main recreational types of concern regarding parasite spread. A laboratory study observing the transfer of myxospores and TAMs

via fishing equipment, specifically felt-soled waders, revealed that the spores could reasonably survive for 8 hours (Gates et al. 2007). Myxospores could most likely live longer (up to 24 hours) and avoid desiccation if trapped in absorbent material such as felt (Arsan 2007). This would allow an angler to travel a significant distance, enter a new water body, and introduce the spores to a new location. Although this is a low risk occurrence, the risk may be magnified by an increasing number of anglers traveling from areas with *M. cerebralis*.

Boaters could also act as vectors for parasite spread but, like birds, require a specific sequence of events that must occur for successful transport (Gates et al. 2007). Myxospores and TAMs entrained in boat bilge and engine-cooling water may survive onboard for days and even weeks depending on the water temperature (El-Matbouli et al. 1999). Also, *T. tubifex* has a large threshold for temperature variance, which implies that they can withstand changing conditions (El-Matbouli et al. 1999).

Privately stocked ponds have been known to be a source of the parasite (particularly if there is an outflow) and may be a cause of spread.

It should be noted that aside from the pathways whirling disease can spread, there is a high number of spores that can be released per fish. One fish harboring myxospores, like steelhead, can release over a million spores (Sollid et al. 2002). Although fish may be releasing many spores not all lineages of *T. tubifex* are susceptible to *M. cerebralis*. North America has 5 lineages of *T. tubifex* and all are found in the state of Oregon. Lineages I and III are susceptible to the parasite causing whirling disease and IV, V and VI are resistant (Beauchamp et al. 2006; Arsan 2007).

Myxobolus cerebralis has a moderate to high risk rating for spread because of the various pathways the parasite can move and because of the established population in northeastern Oregon and now in the lower Deschutes River. It's possible to reduce the risk of these pathways create by educating recreationalists and the general public about *M. cerebralis* and whirling disease across Oregon.

Environmental Impact Potential is MODERATE to LOW

Justification: The impacts from whirling disease on susceptible fish can be great. Signs of severe disease include: crazy tail chasing or whirling to the point of exhaustion when trying to feed, darkening of the tail in younger fish, permanent skeletal deformities (mostly in the head), and death of young susceptible fish (Nickum 1999). The whirling action was originally thought to be caused by cartilage damage and an equilibrium imbalance caused by a mass of cells around the organs but research by Rose et al. (1998) implied that the cause was due to spinal cord and axon damage which transmits swimming control signals. Whirling disease can result in compromised performance among infected fish such as lower growth rates (Hoffman 1974). Infected fish may be more vulnerable to other factors such as parasite, bacterial or viral diseases, and malnutrition (Hoffmann et al. 1962).

Myxobolus cerebralis can infect native fish species such as rainbow trout and bull trout. Bull trout appear to be more resistant to the parasite and tend to become infected more often when exposed more frequently at low doses than a single exposure with a high dose of *M. cerebralis* (Bartholomew et al. 2003). Rainbow trout appear to be more

sensitive to whirling disease than non-native brown trout. In a study performed by Walker and Nehring (1995), overwintering mortality was much higher in exposed rainbow trout (73%) than in exposed brown trout (7%).

Myxobolus cerebralis and whirling disease in Oregon (there actually have never been documented cases of whirling disease in the state) are not as prevalent as in states like Colorado and Montana where severe impacts on wild trout populations have been noted. The infestation of *M. cerebralis* in Colorado has hit most major river drainages and wild trout in many popular streams have been nearly wiped out (some of these populations have rebounded over time). In Montana, parasites have spread to about 150 rivers, including world-class rivers such as the upper Missouri, Gallatin, and upper Bitterroot. Isolated fish populations of the west slope and Yellowstone are considered to be in a stage of "dire threat" (Montana Outdoors Magazine 2007).

Economic Impact Potential is LOW

Justification: The economic impacts caused to Oregon by *M. cerebralis* are not comprehensively understood. There are several industries within Oregon fisheries that may suffer from the wide spread of the parasite. These include but are not limited to: a reduction in recreational fishing related to infected fish reduction, monies spent on management and control of parasites, monies lost to closed fish hatcheries. Other states have suffered economic impacts from whirling disease but in general much of the research has been focused on the biological side of the problem.

In the final report, *Economic consequences of whirling disease in Montana and Colorado trout fisheries*, John W. Duffield describes research performed to determine monetary impacts from reduction of anglers and local economies due to the *M. cerebralis* parasite. The results from this report were determined by examining the link between fish populations and angler use, and secondly, by the relationship of angler use and local economies. Colorado's annual expenditure on trout fishing is $158 million dollars. The results indicate moderate economic impacts accruing a 10% reduction in angler use equaling $20 million dollars and a 10% loss of spending related to trout fishing equaling $15.8 million dollars. Totaling a reduction of $35.8 million dollars (or ~20%) not spent on trout fishing annually due to whirling disease impacts on trout fisheries. Although the economic impacts imposed by *M. cerebralis* appear to be significant for Colorado, the report did not include costs the disease may accrue through management and control at hatchery operations.

Human Health Impact Potential is NO RISK

Justification: *Myxobolus cerebralis* does not infect humans and is not known to cause any harmful effects (Whirling Disease Initiative 2008).

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FORMAT
This pest risk assessment (PRA) is based on the format used by the Exotic Forest Pest Information System for North America. For a description of the evaluation process used, see Step 3 – Pest Risk Assessment under Guidelines at:
<http://spfnic.fs.fed.us/exfor/download.cfm>

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