Aquatic Plant Community and Eurasian watermilfoil (*Myriophyllum spicatum* L.) Management Assessment in Lake Pend Oreille, Idaho for 2008

A Report to the Idaho State Department of Agriculture

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Table of Contents

Preface

This report presents data collected by the Geosystems Research Institute on the Lake Pend Oreille and River in Idaho, under an agreement with the Aquatic Ecosystem Restoration Foundation of Flint, MI. Funding was provided by the Idaho State Department of Agriculture through a contract with the Aquatic Ecosystem Restoration Foundation, Mr. Carlton Layne, Executive Director. The monitoring activities were planned in cooperation with Mr. Thomas Woolf, Aquatic Plants Program Manager of the Idaho State Department of Agriculture, with input from Mr. Brad Bluemer, Bonner County Weed Supervisor. Mr. Brad Bluemer also provided additional logistic support during our surveys, which was invaluable. We would also like to thank the staff of GRI who assisted in preparing for and carrying out the survey: Wilfredo Robles and Jimmy Peeples. Wilfredo Robles, Brad Bluemer, and Tom Woolf provided reviews of this report before release. Any errors in presentation or fact, however, are the responsibility of the authors.

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Executive Summary

Lake Pend Oreille is the largest (91,000 acres) freshwater lake in located Idaho. Approximately 27% or 25,000 acres of the lake is considered littoral zone habitat and can support the growth of aquatic plants. Eurasian watermilfoil (*Myriophyllum spicatum* L.) has invaded large areas of this littoral zone habitat and established growing populations. The economic and ecological threats posed by Eurasian watermilfoil have prompted the development of a state-wide eradication program led by the Idaho State Department of Agriculture. An important component of any program is to monitor and quantify the extent of Eurasian watermilfoil infestations as well as the native plant community. Pursuant to this monitoring objective a littoral zone survey was conducted in July of 2007 and 2008 on Lake Pend Oreille to monitor the trends in the aquatic plant community and to assess the efficacy of control techniques on Eurasian watermilfoil. In 2008, the herbicides triclopyr, 2,4-D, endothall, and combinations of endothall with either triclopyr or 2,4-D were evaluated.

Similar to 2007, the 2008 littoral survey found a diverse aquatic plant community. Differences between the 2007 and 2008 surveys were primarily the inclusion of an early season survey in 2007. This early survey resulted in the finding of several early season mud flat annual plant species that are not present later in the season. Lake-wide, the presence of Eurasian watermilfoil significantly decreased from 2007 (12.5%) to 2008 (7.9%). Overall, the native plant community has remained relatively stable from 2007 to 2008 as indicated by the year to year pairwise comparison of species and no significant changes in native species richness. There are several native species that increased in occurrence from 2007 to 2008, most notably northern watermilfoil (*Myriophyllum sibiricum* Komorov).

Eurasian watermilfoil had a frequency of occurrence of 64.5% lake-wide in 2007 following the assessment survey. The frequency of occurrence was significantly reduced to 23.6% following treatments made in 2008 prior to September. The areas treated with 2,4-D were largely unprotected and subject to high flow and therefore the limited sites evaluated did not result in a significant reduction in Eurasian watermilfoil. When 2,4-D was combined with endothall the presence of Eurasian watermilfoil declined from 63% (2007) to 36.5% in 2008. Eurasian watermilfoil treated with triclopyr also declined significantly, 64% to 18.2%. There were few sites treated with triclopyr in combination with endothall; however the treatments made with this combination resulted in a significant decrease in the presence of Eurasian watermilfoil. When all treatment methods were pooled and compared to areas that were not treated until after September (an untreated reference for purposes of analysis), the presence of Eurasian watermilfoil was significantly greater (52.5%) in untreated areas as opposed to treated areas (23%). According to the 2008 assessment survey all treatments evaluated were successful in reducing the presence of Eurasian watermilfoil with the exception of 2,4-D; again however, we believe this is due to the fact that the majority of 2,4-D was applied after the assessment survey and analyses were conducted on plots in the river that were likely subjected to increased flow.

Chapter 1

Monitoring Temporal Changes in the Littoral Plant Community in Lake Pend Oreille

Introduction

Aquatic plants are important to lake ecosystems (Madsen et al. 1996, Wetzel 2001) and are essential in promoting the diversity and function of an aquatic system (Carpenter and Lodge 1986). Littoral zone habitat and associated plants may be responsible for a significant proportion of primary production for the entire lake (Ozimek et al. 1990, Wetzel 2001). Littoral zone habitats are prime areas for the spawning of most fish species, including many species important to sport fisheries (Savino and Stein 1989). Furthermore, aquatic plants anchor soft sediments, stabilize underwater slopes, remove suspended particles, and remove nutrients from overlying waters (Barko et al. 1986, Doyle 2000, Madsen et al. 2001). However, when non-native plants invade littoral zone habitat, changes in biotic and abiotic interactions often occurs (Madsen 1998). The growth of non-native species often results in reductions in littoral zone plant species resulting in decreases in fish production (Savino and Stein 1989), increases in sediment resuspension, turbidity, and algal production; the latter will further exacerbate plant loss (Madsen et al. 1996, Doyle 2000, Case and Madsen 2004, Wersal et al. 2006a).

Eurasian watermilfoil (*Myriophyllum spicatum* L.), is an invasive vascular plant that has invaded freshwater lakes across the United States. Eurasian watermilfoil has been associated with declines in native plant species richness and diversity (Madsen et al. 1991a,b, Madsen et al. 2008a), and reductions in habitat complexity (Krull 1970, Keast 1984). Infestations of Eurasian watermilfoil are often associated with the impeding of navigation, limiting recreation, and increasing flood frequency and intensity (Madsen et al. 1991a). In Idaho, Eurasian watermilfoil (*Myriophyllum spicatum*) has invaded and established populations in Lake Pend Oreille, the state's largest (91,000 acres) freshwater lake. Lake Pend Oreille has approximately 25,000 acres of littoral zone habitat for aquatic plant growth, meaning Eurasian watermilfoil could inhabit roughly 27% of the total lake area. The establishment of Eurasian watermilfoil and subsequent spread is likely perpetuated by the ease of fragmentation (both physical and physiological) of this plant, the large fetch of the lake, and high watercraft traffic that moves fragments to new areas. Once this species has invaded and established it is very difficult to control. Pursuant to the difficulty of control and the economic and ecological threats posed by Eurasian watermilfoil the Idaho State Department of Agriculture has developed and implemented a statewide Eurasian watermilfoil eradication program. An important component of any program is the development of an adequate monitoring system to evaluate the impact of control techniques on both the target and non-target plant species.

The point intercept method is an effective and efficient method to survey large areas and collect large quantities of data on plant distribution and abundance (Madsen 1999). Freshwater systems are often vulnerable to invasion due to repeated disturbance (Shea and Chesson 2002). Repeated disturbance such as current, wave action, human uses etc. results in temporal changes in the plant composition and creates new habitat for non-native plant colonization. The use of point intercept surveys will allow for a quantitative assessment of the temporal changes in aquatic plant species composition lake-wide (Wersal et al. 2007). This survey method is sensitive to inter annual changes in plant frequencies (Madsen 1999) that will offer further insights into how the native plant community is responding to the removal and or infestation of new areas by Eurasian watermilfoil.

Objectives

The objective of the littoral zone survey was to monitor temporal changes in the aquatic plant community within Lake Pend Oreille. The survey will provide information and insights regarding native species richness, changes in native species assemblages in response to the presence and or removal of Eurasian watermilfoil lake-wide, and the presence of new Eurasian watermilfoil infestations throughout Lake Pend Oreille.

Materials and Methods

Littoral Zone Surveys

The littoral zone aquatic plant community in Lake Pend Oreille was surveyed in July 2008 using a point intercept survey sampling the same points as in 2007 (Madsen and Wersal 2008) (Figure 1.1). The littoral zone was defined as those areas in 45 ft. (15 m) of water or less. The survey was conducted by boat using GPS (Global Positioning System) technology to navigate to each point. A Trimble AgGPS106^{tm} (Sunnyvale, California) receiver coupled with a Panasonic C-29 Toughbook^{tm} (Secaucus, New Jersey) computer was used to achieve 3-10 foot (1-3 m) survey accuracy. A total of 1614 points were surveyed. At each survey point, a weighted plant rake was deployed twice to determine the presence of plant species. Additionally, the depth at each point was recorded using a Lowrance LCX-28C depth finder (Tulsa, Oklahoma) or with a sounding rod in water depths of less than 10 feet. Spatial data were recorded electronically using FarmWorks Site Mate® software version 11.4 (Hamilton, Indiana). Site Mate® allowed for the navigation to specific survey points as well as displaying and collecting of geographic and attribute data while in the field, thus eliminating data entry errors and post processing time. Collected data were recorded in database templates using specific pick lists constructed exclusively for this project. Similar studies using this technology are described in Wersal and others (2006b, 2007, 2008) and Madsen and Wersal (2008).

Plant species presence was averaged over all points sampled and multiplied by 100. Total species richness was calculated and presented as the mean (± 1 SE) of all species observed at each point. Native species richness was calculated in a similar fashion as species richness however, non-native species were removed from the calculations. Comparisons between the 2007 and 2008 seasons were made using the late season survey from 2007 in an attempt to alleviate the effects of seasonal variability in plant growth between years. Changes in the occurrence of plant species was determined using McNemar's Test for dichotomous response variables that assesses differences in the correlated proportions within a given data set between variables that are not independent (Stokes et al. 2000, Wersal et al. 2006a). A pairwise comparison of species occurrences was made between years using the Cochran Mantel Haenszel statistic (Stokes et al. 2000, Wersal et al. 2006a). Total Species richness and native species richness for 2007 and 2008 were compared using a paired T-test. All statistical analyses were conducted at the p=0.05 level of significance using SAS or Statistix 8.0 software (Analytical Software 2003).

Results and Discussion

Littoral Survey

Similar to the 2007 survey, the 2008 survey yielded a diverse assemblage of aquatic plant species. A total of 42 plant species were recorded in 2008 (Table 1.1). Differences between the two years are a result of not observing the early season annual species that inhabit the exposed mud flats during times of low water. These mud flat annuals were recorded during the early season (May) survey in 2007, but not the 2008 survey which was conducted in July. Chara (*Chara* sp.) was the most common taxa observed in 2007 (29.4%) and 2008 (22.0%), a significant ($p < 0.01$) decline between years. Herbicides such as fluridone, endothall, and triclopyr have little to no impact on the growth of chara (Crowell et al. 2006, Hofstra and Clayton 2001, and Parsons et al. 2004); therefore the use of herbicides in Lake Pend Oreille for Eurasian watermilfoil control are likely not the cause of the decline. The decline is attributed to plants being missed during the survey or to temporal changes in environmental factors that would influence the growth of chara. Dominant native vascular plant species, excluding chara, were leafy pondweed (*Potamogeton foliosus* Raf.) that had frequency of occurrence of 13.7% and 14.3% in 2007 and 2008 respectively followed by elodea (*Elodea canadensis* Michx.), and sago pondweed (*Stuckenia pectinata* Böerner). The native northern watermilfoil increased ($p < 0.01$) from 2.0% in 2007 to 4.2% in 2008. The presence of Eurasian watermilfoil declined ($p < 0.01$) from 12.5% in 2007 to 7.9% in 2008, a 37% decline in the presence of this species lake wide between years. The decline in Eurasian watermilfoil is a result of the ongoing management of this species. At the time of the littoral survey the majority of Eurasian watermilfoil observations were in the river (i.e. west of the Sandpoint Bridge) and the Pack River area (Figure 1.2). In 2007, there were large areas west of Sandpoint that were not managed for Eurasian watermilfoil which would explain the increased observations in this area during the 2008 littoral survey.

Lake-wide, the presence of Eurasian milfoil has declined and the native plant community has remained relatively stable. Native species richness did not change ($p = 0.10$) from 2007 to 2008, nor did total species richness ($p = 0.46$). In lakes that historically have not had an extensive control program, the suppression and displacement of native plants by Eurasian watermilfoil has been observed (Madsen et al. 1991a,b). In three years (1987 – 1989) in the northwest bay of Lake George, New York, Eurasian watermilfoil spread from 30% coverage to over 95% coverage (Madsen et al. 1991b). During this same study it was empirically shown that the native plant diversity was reduced from 5.5 species per quadrat to 2 species, of which 1 was always Eurasian watermilfoil (Madsen et al. 1991b). In Waneta Lake and Lamoka Lake, New York, species richness was also reduced in the presence of uncontrolled growth of Eurasian watermilfoil (Madsen et al. 2008). If left unchecked Eurasian watermilfoil will suppress or eliminate native plant growth over time (Madsen 1994).

Eurasian watermilfoil can invade species rich native plant communities, in fact, areas of high native species richness have a greater probability of being invaded (Capers et al. 2007, Wersal and Madsen unpubl. data). The suitable habitats in oligotrophic lakes are usually much smaller and more isolated than those in eutrophic lakes and non-native plants such as Eurasian watermilfoil tend to form isolated beds due to the patchiness of suitable littoral zone habitat (Madsen 1994). Once an oligotrophic lake is colonized by non-native species, growth is slower, likely due to lower temperatures, shorter growing seasons, and reduced nutrient availability (Madsen 1994). Therefore, Eurasian watermilfoil is likely to invade areas in oligotrophic lakes that have native species already present because these areas provide an optimal environment for growth. Although native species richness does not impede invasion, it may be important to promote and maintain native plant density as this has been shown to resist invasion (Capers et al. 2007). Dense native plant beds are presumably better able to prevent the colonization and establishment by intercepting non-native propagules reducing the success of invasion (Capers et al. 2007). Additionally, Chadwell and Engelhardt (2008) concluded that reducing propagule pressure (i.e. the dispersal mechanism of the target plant either seeds, fragments, tubers, or turions) through targeted management is necessary to slow the spread of the target species. Also, the restoration of a dense native plant community may be a further defense against future invasion. Therefore, a combined strategy of targeted control and promotion of native plant growth may be the most sustainable and cost-effective strategy for eradicating Eurasian watermilfoil from Lake Pend Oreille. The fact that the presence of Eurasian watermilfoil has declined and the native community has remained stable is evidence that Eurasian watermilfoil can be selectively targeted leaving the native community to possibly resist further invasions.

Other Species of Concern

In addition to monitoring Eurasian watermilfoil, the Idaho State Department of Agriculture requested that we monitor other species of concern. Pursuant to this we recorded the locations of curlyleaf pondweed, flowering rush (*Butomus umbellatus* L.), and purple loosestrife (*Lythrum salicaria* L.) in 2007 and 2008.

Curlyleaf pondweed. The presence of curlyleaf pondweed (*Potamogeton crispus* L.) did not change between 2007 (7.8%) and 2008 (9.5%) (Figure 1.3). However, it was causing localized problems in and around marinas and docks where it was impeding boat traffic and recreation. Curlyleaf pondweed is widely considered to be an ecosystem transformer, but this species tends to accelerate internal nutrient loading and eutrophication (James et al. 2002). Increases in nutrient loading may further exacerbate the nuisance growth of this and other non-native species. Curlyleaf pondweed is very widespread throughout Lake Pend Oreille and is prolifically producing turions to facilitate its spread (Figure 1.4 and 1.5). Control of this species would take an effort equivalent to that of Eurasian watermilfoil. While this species bears continued monitoring, it is well beyond an early detection and response situation.

Flowering rush. Flowering rush (*Butomus umbellatus* L.) was found north of the Clark's Fork delta in both 2007 and 2008 (Figures 1.6 and 1.7). Although flowering rush has been reported elsewhere in Idaho, this is a unique population for Lake Pend Oreille (Ling Cao 2009). Flowering rush is polyploid meaning there is a diploid and triploid cytotype (Brown and Eckert 2005). The major difference between the two types is the ability to sexually reproduce. Diploid plants produce 20-50 pink flowers per plant. These flowers are self compatible, but cannot self fertilize (Eckert et al. 2000). In a given season, diploid plants will produce > 20,000 seeds per plant per year, whereas triploid plants will produce very few or no viable seed (Hroudová and

Zákravsky 2003). Furthermore, diploid plants also produce hundreds of vegetative bulbils per plant that serve as a form of clonal reproduction and another dispersal mechanism (Thompson and Eckert 2004). Additionally, the primary rhizome can be fragmented and new vegetative growth can occur (Brown and Eckert 2005). Populations typically consist of only one cytotype (Krahulcová and Jarolímová 1993); however outside its native range of Europe there has been an increasing shift to the diploid type in invading populations across North America (Kliber and Eckert *in press* cited in Brown and Eckert 2005). In Lake Pend Oreille it does not appear that this species is expanding its range very rapidly, however this may be a relatively new infestation and propagule (seeds and bulbils) density is still low. If the flowering rush population in Lake Pend Oreille is diploid as suggested by the literature, it has the ability to rapidly expand its range and the potential for long distance dispersal. We recommend further monitoring of this species and deployment of control techniques to eradicate it before it spreads to other areas of the lake.

Purple loosestrife. Purple loosestrife (*Lythrum salicaria* L.) was only observed at one location in the lake, Boyer Slough, during the 2007 and 2008 littoral zone surveys (Figure 1.8). Bonner County was already aware of this location. Purple loosestrife is a very invasive species which can form dense, monospecific stands in wetland areas and its presence warrants further monitoring.

Literature Cited

Analytical Software. 2003. Statistix 8. Analytical Software, Tallahassee, FL.

Barko, J.W., M.S. Adams, and N.S. Clesceri. 1986. Environmental factors and their consideration in the management of submersed aquatic vegetation: A review. Journal of Aquatic Plant Management 24:1-10.

Brown J.S. and C.G. Eckert. 2005. Evolutionary increase in sexual and clonal reproductive capacity during biological invasion in an aquatic plant *Butomus umbellatus* (Butomaceae). American Journal of Botany 92:495-502.

Capers, R. S., R. S. Selsky, G. J. Bugbee, and J. C. White. 2007. Aquatic plant community invasibility and scale-dependent patterns in native and invasive species richness. Ecology 88:3135-3143.

Carpenter, S.R. and D.M. Lodge. 1986. Effects of submersed macrophytes on ecosystem processes. Aquatic Botany 26:341-370.

Case, M. L. and J. D. Madsen. 2004. Factors limiting the growth of *Stuckenia pectinata* (Sago Pondweed) in Heron Lake, Minnesota. Journal of Freshwater Ecology 19:17-23.

Chadwell, T.B. and K.A.M. Engelhardt. 2008. Effects of pre-existing submersed vegetation and propagule pressure on the invasion success of *Hydrilla verticillata*. Journal of Applied Ecology 45:515-523.

Crowell, W.J, N.A. Proulx and C.H. Welling. 2006. Effects of repeated fluridone treatments over nine years to control Eurasian watermilfoil in a mesotrophic lake. Journal of Aquatic Plant Management 44:133-136.

Doyle, R. D., 2000. Effects of navigation on aquatic plants: effects of sediment resuspension and deposition on plant growth and reproduction. Upper Mississippi River – Illinois Waterway System Navigation Study, ENV Rep. 28. U.S. Army Corps of Engineers, Rock Island District, St. Louis District, St. Paul District. 64 pp.

Eckert, C.G., B. Massonnet and J.J. Thomas. 2000. Variation in sexual and clonal reproduction among introduced populations of flowering rush, *Butomus umbellatus* (Butomaceae). Canadian Journal of Botany 78:437-446.

Hofstra D.E. and J.S. Clayton. 2001. Evaluation of selected herbicides for the control of exotic submersed weeds in New Zealand: I. The use of endothall, triclopyr and dichlobenil. Journal of Aquatic Plant Management 39:20-24.

Hroudová, Z. and P. Zákravsky. 2003. Germination responses of diploid *Butomus umbellatus* to light, temperature and flooding. Flora 198:37-44.

James, W.F., J.W. Barko, H.L. Eakin, P.W. Sorge. 2002. Phosphorus budget and management strategies for an urban Wisconsin lake. Lake and Reservoir Management 18:149-163.

Keast, A. 1984. The introduced macrophyte, *Myriophyllum spicatum*, as a habitat for fish and their invertebrate prey. Canadian Journal of Zoology 62:1289-1303.

Krahulcová, A. and V. Jarolímová. 1993. Ecology of two cytotypes of *Butomus umbellatus* I. Karyology and breeding. Folia Geobotanica et Phytotaxonomica 28: 385-411.

Krull, J.N. 1970. Aquatic plant-invertebrate associations and waterfowl. Journal of Wildlife Management 34:707-718.

Ling Cao. 2009. *Butomus umbellatus*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL.<http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=1100> Revision Date: 8/11/2008

Madsen, J. D. 1994. Invasions and declines of submersed macrophytes in Lake George and other Adirondack lakes. Lake and Reservoir Management 10:19-23.

Madsen, J.D. 1998. Predicting invasion success of Eurasian watermilfoil. Journal of Aquatic Plant Management 36:28-32.

Madsen, J.D. 1999. Point and line intercept methods for aquatic plant management. APCRP Technical Notes Collection (TN APCRP-M1-02), U.S. Army Engineer Research and Development Center, Vicksburg, MS. 16 pp.

Madsen, J.D., C.F. Hartleb and C.W. Boylen. 1991a. Photosynthetic characteristics of *Myriophyllum spicatum* and six submersed macrophyte species native to Lake George, New York. Freshwater Biology 26:233-240.

Madsen, J.D., J.W. Sutherland, J.A. Bloomfield, L.W. Eichler, and C.W. Boylen. 1991b. The decline of native vegetation under dense Eurasian watermilfoil canopies. Journal of Aquatic Plant Management 29:94-99.

Madsen, J.D., J.A. Bloomfield, J.W. Sutherland, L.W. Eichler, and C.W. Boylen. 1996. The aquatic macrophyte community of Onondaga Lake: Field survey and plant growth bioassays of lake sediments. Lake and Reservoir Management 12:73-79.

Madsen, J.D., P.A. Chambers, W.F. James, E.W. Koch, and D.F. Westlake. 2001. The interactions between water movement, sediment dynamics and submersed macrophytes. Hydrobiologia 444:71-84.

Madsen, J.D., R.M. Stewart, K.D. Getsinger, R.L. Johnson and R.M. Wersal. 2008. Aquatic plant communities in Waneta Lake and Lamoka Lake, New York. Northeastern Naturalist 15:97-110.

Madsen, J.D. and R.M. Wersal. 2008. Assessment of Eurasian watermilfoil (*Myriophyllum spicatum* L.) populations in Lake Pend Oreille, Idaho for 2007. GRI #5028, GeoResources Institute, Mississippi State University.

Ozimek, T., R.D. Gulati, and E. van Donk. 1990. Can macrophytes be useful in biomanipulation of lakes? The Lake Zwemlust example. Hydrobiologia 200/201:399-407.

Parsons, J.K., K.S. Hamel, S.L. O'Neal and A.W. Moore. 2004. The impact of endothall on the aquatic plant community of Kress Lake, Washington. Journal of Aquatic Plant Management 42:109-114.

Savino, J.F. and R.A. Stein. 1989. Behavior of fish predators and their prey: habitat choice between open water and dense vegetation. Environmental Biology of Fishes 24:287-293.

Shea, K. and P. Chesson. 2002. Community ecology theory as a framework for biological invasions. Trends in Ecology and Evolution 17:170-176.

Stokes, M. E., C. S. Davis and G. G. Koch. 2000. Categorical Data Analysis Using the SAS® System, second edition. SAS Institute Inc., Cary, NC.

Thompson, F.L. and C.G. Eckert. 2004. Trade-offs between sexual and clonal reproduction in an aquatic plant: experimental manipulations vs. phenotypic correlations. Journal of Evolutionary Biology 17:581-592.

Wersal, R.M., J.D. Madsen, B.R. McMillan and P.D. Gerard. 2006a. Environmental factors affecting biomass and distribution of *Stuckenia pectinata* in the Heron Lake System, Minnesota, USA. Wetlands 26:313-321.

Wersal, R. M., J. D. Madsen and M. L. Tagert. 2006b. Aquatic plant survey of Ross Barnett Reservoir for 2005. GRI Report #5003, GeoResources Institute, Mississippi State University, Mississippi State, MS.

Wersal, R. M., J. D. Madsen and M. L. Tagert. 2007. Aquatic plant survey within the littoral zone of the Ross Barnett Reservoir for 2006. GRI Report #5011, GeoResources Institute, Mississippi State University, Mississippi State, MS.

Wersal, R.M., J.D. Madsen and M.L. Tagert. 2008. Littoral zone aquatic plant community assessment of the Ross Barnett Reservoir, MS for 2007. GRI Report #5027, GeoResources Institute.

Wetzel, R.G. 2001. Limnology: Lake and River Ecosystems, Third Edition. Academic Press, San Diego, CA, USA. 1006 pp.

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Table 1.1. Aquatic plant occurrence in Lake Pend Oreille for the 2007 and 2008 littoral zone surveys. Differences between years were determined at a p = 0.05 significance level using a Cochran Mantel Haenszel test. Water depth and species richness is reported as the mean ± 1 SE.

Species	Common Name	% Occurrence 2007	% Occurrence 2008	p-value
Butomus umbellatus **L.**	Flowering rush	0.1	0.1	**0.53**
Callitriche **sp.**	Water-starwort	0.1	0.1	**0.95**
Ceratophyllum demersum **L.**	Coontail	4.5	4.0	**0.38**
Chara **sp.**	Muskgrass	29.4	22.0	**< 0.01**
Elatine minima **(Nutt.) Fisch. & Mey.**	Waterwort	0.7	0.8	**0.88**
Elodea canadensis **Michx.**	Elodea	8.7	9.0	**0.95**
Heteranthera dubia **(Jacq.) Small**	Water stargrass	0.1	0.0	**0.33**
Hippuris vulgaris **L.**	Mare's tail	0.1	0.3	**0.43**
Isoetes macrospora **Dur.**	Lake quillwort	0.1	0.1	**0.59**
Juncus pelocarpus **Mey.**	Rush	1.7	0.3	**0.02**
Lemna minor **L.**	Common duckweed	0.1	0.1	**0.61**
Myriophyllum hippuroides **Torrey & Grey**	Western watermilfoil	0.1	0.1	**0.14**
Myriophyllum sibiricum **Komarov**	Northern watermilfoil	2.0	4.2	**< 0.01**
Myriophyllum spicatum **L.**	Eurasian watermilfoil	12.5	7.9	**< 0.01**
Myriophyllum verticillatum **L.**	Whorled watermilfoil	1.4	0.0	**0.02**
Najas flexilis **(Willd.) Rostk. & Schmidt**	Slender naiad, bushy pondweed	3.0	3.3	**0.62**
Nitella **sp.**	Nitella	0.5	0.9	**0.25**
Phalaris arundinacea **L.**	Reed canary grass	0.1	0.4	**< 0.01**
Polygonum amphibium **L.**	Water smartweed	0.1	0.1	**0.30**
Potamogeton amplifolius **Tuckerm.**	Large-leaved pondweed	0.1	0.0	**0.16**
Potamogeton crispus **L.**	Curlyleaf pondweed	7.8	9.5	**0.08**
Potamogeton diversifolius **Raf.**	Waterthread pondweed	0.4	0.0	**0.01**
Potamogeton epihydrus **Raf.**	Ribbonleaf pondweed	0.1	0.1	**0.53**
Potamogeton foliosus **Raf.**	Leafy pondweed	13.7	14.3	**0.69**
Potamogeton illinoensis **Morong**	Illinois pondweed	0.2	0.3	**0.02**
Potamogeton gramineus **L.**	Variableleaf pondweed	3.3	4.1	**0.29**
Potamogeton natans **L.**	Floating-leaved pondweed	0.4	0.2	**0.15**
Potamogeton nodosus **Poir.**	American pondweed	0.1	0.2	**0.37**
Potamogeton praelongus **Wulf.**	Whitestem pondweed	0.1	0.6	**0.02**
Potamogeton pusillus **L.**	Narrowleaf pondweed	0.5	0.2	**0.13**
Potamogeton richardsonii **(Ar. Benn.) Rydb.**	Clasping-leaved pondweed	6.2	5.1	**0.18**
Potamogeton robbinsii **Oakes**	Robbins' pondweed	0.1	0.1	**0.59**
Potamogeton zosteriformis **Fern.**	Flat-stemmed pondweed	0.8	1.1	**0.48**
Ranunculus aquatilis **L.**	White water-buttercup	3.5	3.9	**0.55**
Ranunculus reptans **L.**	Creeping spearwort	0.1	0.0	**0.16**
Sagittaria cuneata **Sheldon**	Arumleaf arrowhead	0.4	0.1	**0.02**
Sagittaria graminea **Michx.**	Grassy arrowhead	0.2	0.2	**0.76**
Sparganium angustifolium **Michx.**	Narrowleaf burreed	0.1	0.0	**0.33**
Stuckenia pectinata **(L.) Börner**	Sago pondweed	7.0	7.0	**0.79**
Typha latifolia **L.**	Common cattail	0.1	0.7	**0.01**
Utricularia vulgaris **L.**	Common bladderwort	0.2	0.1	**0.45**
Zannichellia palustris **L.**	Horned pondweed	0.1	0.1	**0.95**
Native Species Richness (per point)		1.1 ± 0.03	1.0 ± 0.03	**0.10**
Mean Species Richness (per point)		1.0 ± 0.03	1.0 ± 0.04	**0.46**
Mean Water Depth ft. (m)		21.6 ± 0.43 (6.5)	22.4 ± 0.53 (6.8)	**0.42**

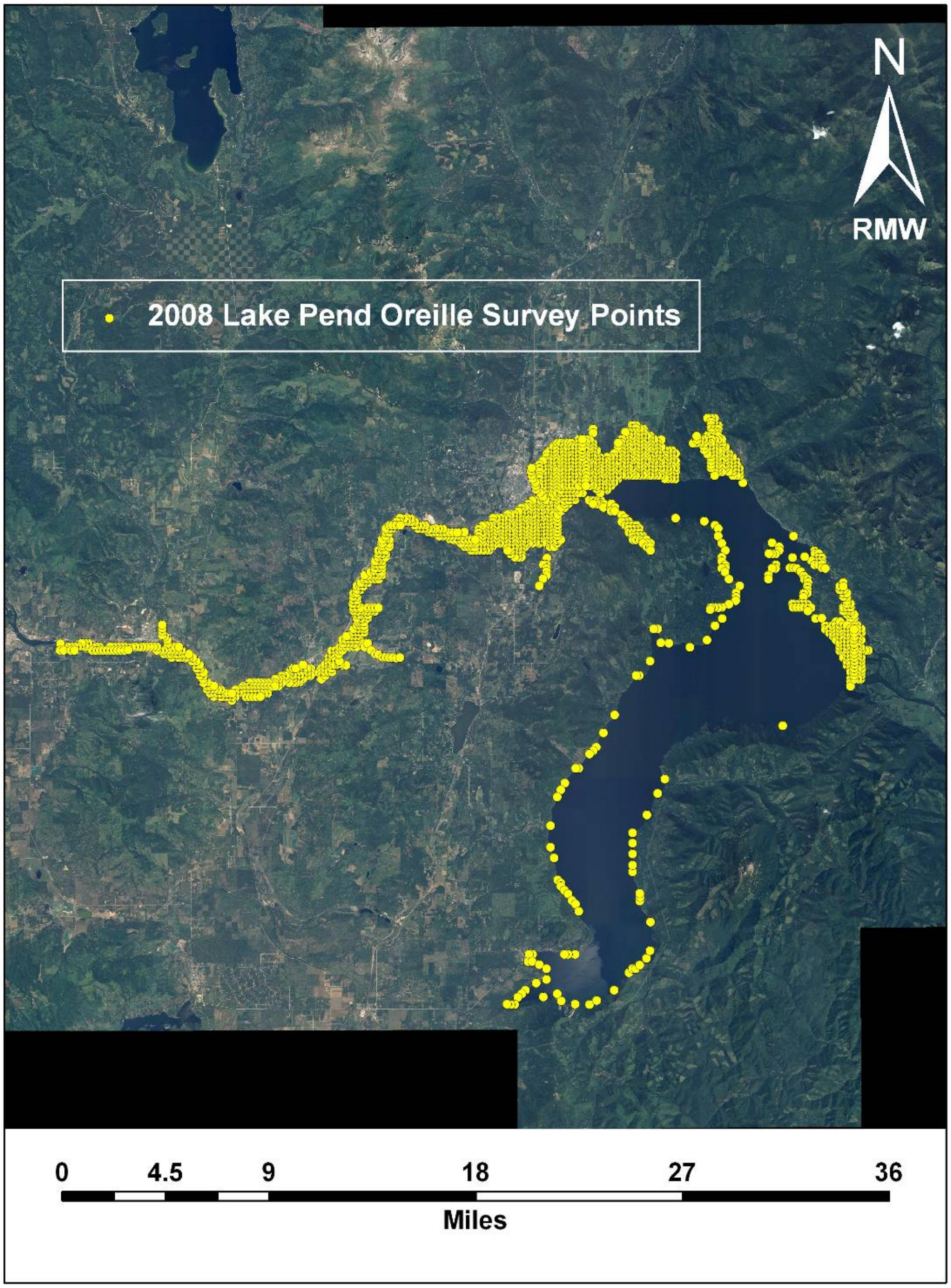

Figure 1.1. Sample locations for the 2008 littoral zone survey of Lake Pend Oreille, July 2008.

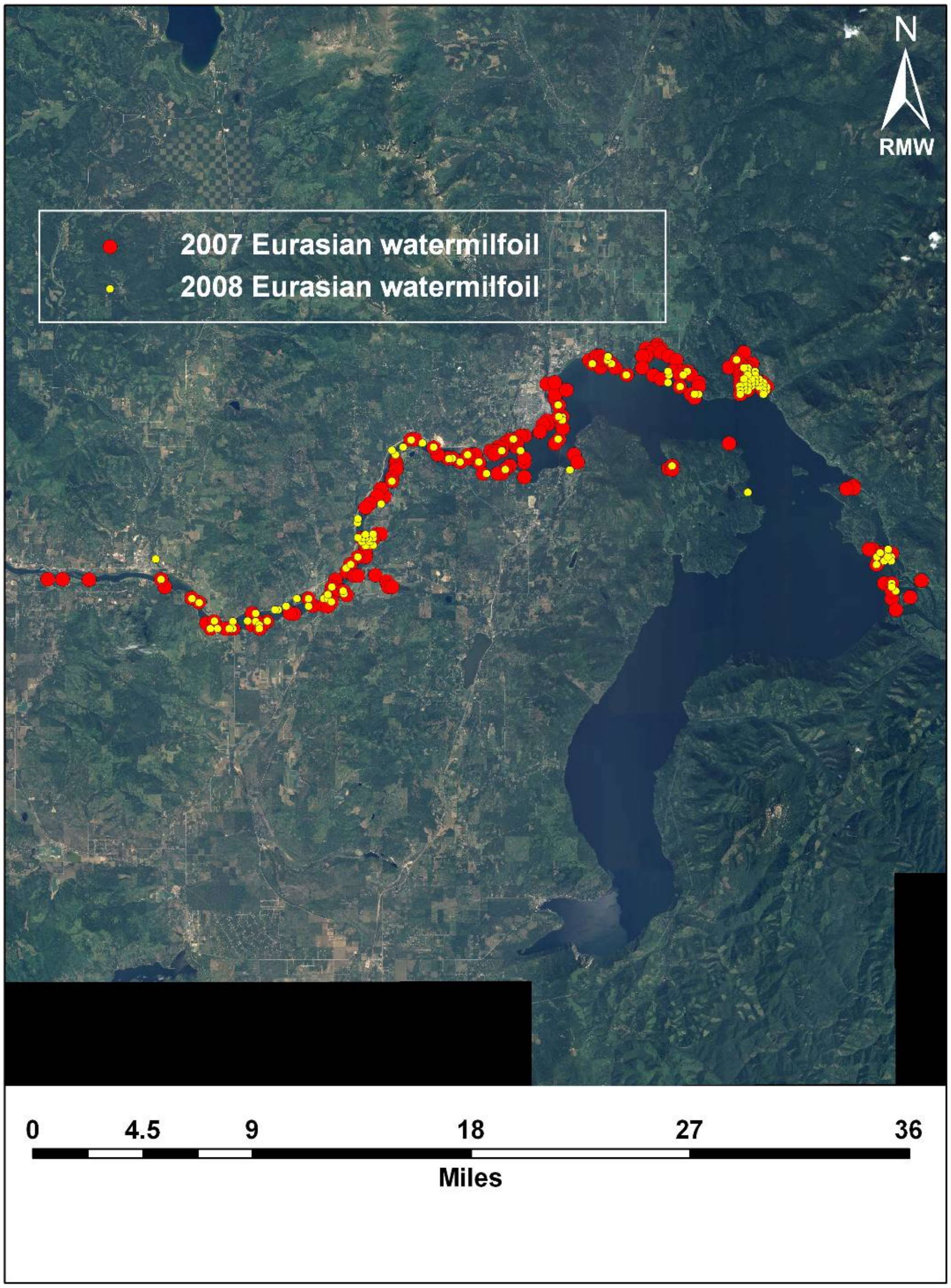

Figure 1.2. Eurasian watermilfoil locations during the July 2007 (Red) and 2008 (Yellow) littoral zone surveys of Lake Pend Oreille.

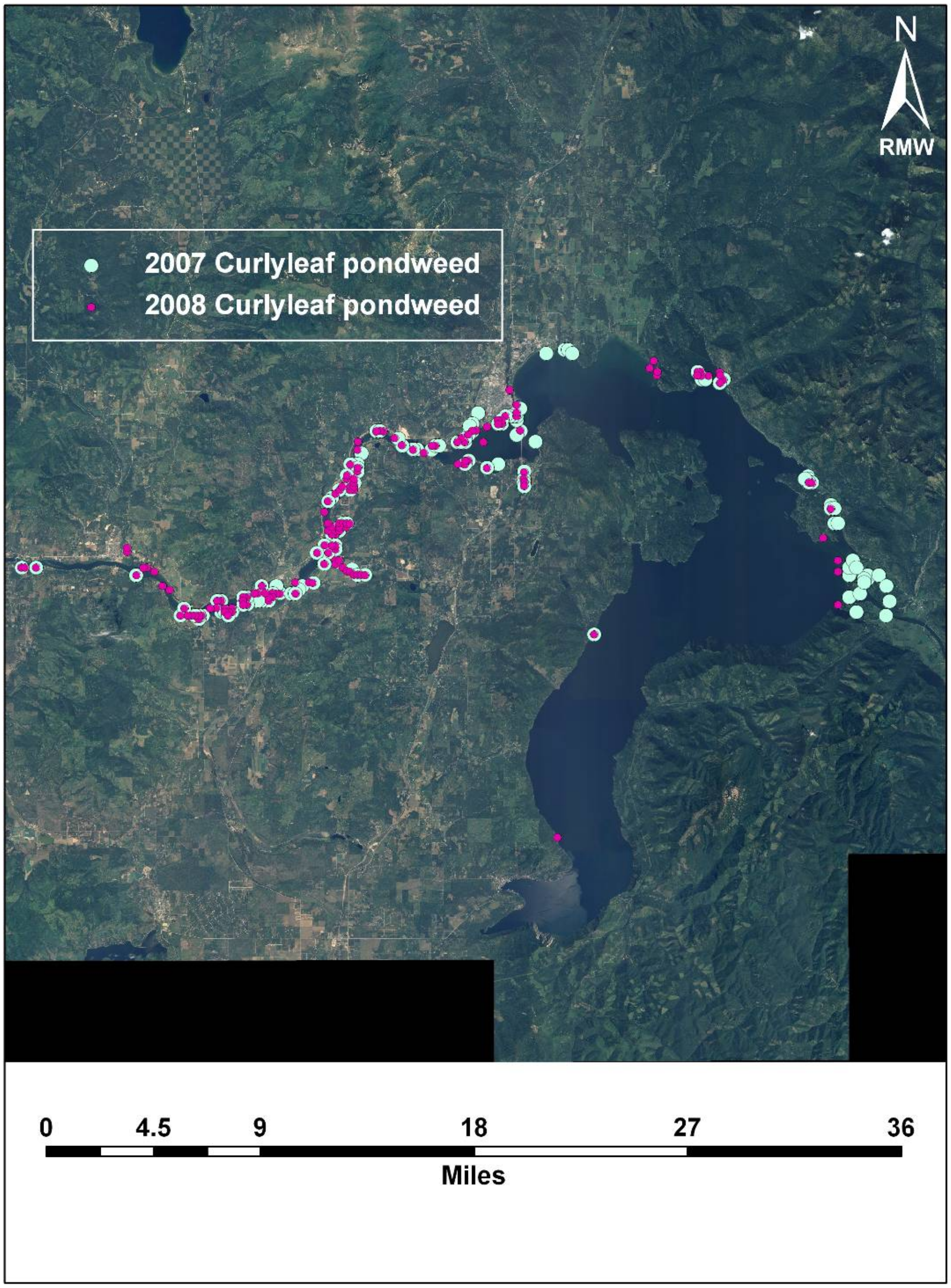

Figure 1.3. Curlyleaf pondweed locations during the July 2007 (Blue) and 2008 (Purple) littoral zone surveys of Lake Pend Oreille.

Figure 1.4. Curlyleaf pondweed turions that have sprouted new shoots, Lake Pend Oreille, Idaho, July 2008.

Figure 1.5. Curlyleaf pondweed sampled using the plant rake in Lake Pend Oreille, Idaho, July 2008.

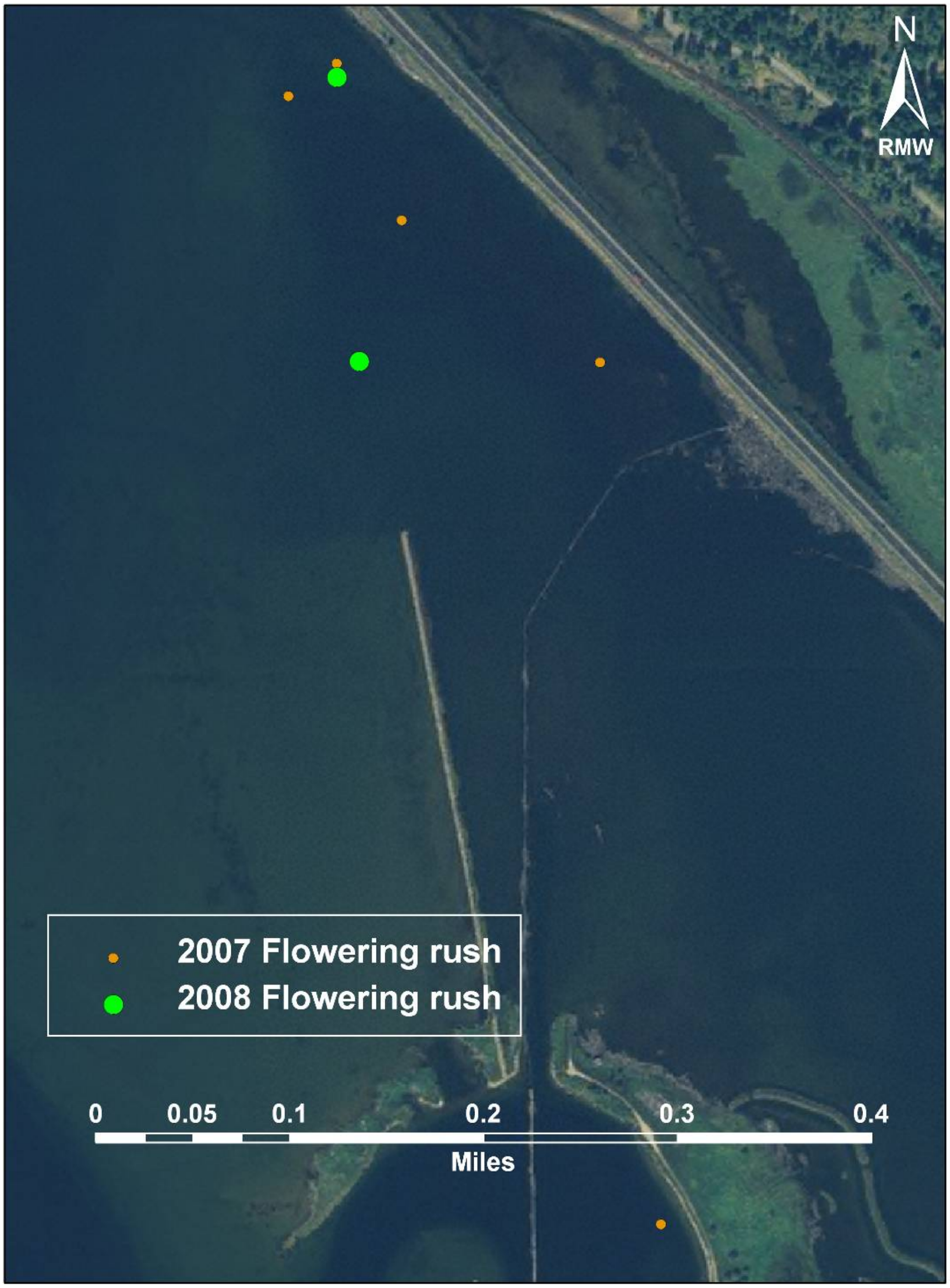

Figure 1.6. Flowering rush locations during the July 2007 (Orange) and 2008 (Green) littoral zone surveys of Lake Pend Oreille.

Figure 1.7. Flowering rush (*Butomus umbellatus*) growing in the Clark Fork River Delta, July 2008.

Figure 1.8. Purple loosestrife locations during the July 2007 (Blue) and 2008 (Purple) littoral zone surveys of Lake Pend Oreille.

Chapter 2

Assessment of Eurasian Watermilfoil Control in Lake Pend Oreille

Introduction

Eurasian watermilfoil (*Myriophyllum spicatum* L.) is a non-native aquatic plant in North America that has caused severe impacts to infested waters. The introduction of Eurasian watermilfoil to a waterbody often results in the alteration of the complex interactions occurring in aquatic ecosystems (Madsen 1998, Engelhardt and Ritchie 2002). Dense beds of Eurasian watermilfoil are often responsible for reductions in oxygen exchange, depletion of dissolved oxygen, increases in water temperature, and internal nutrient loading (Madsen 1998). Monotypic stands of Eurasian watermilfoil reduce native plant species richness and diversity (Madsen et al. 1991b, Madsen et al. 2008), and also impact habitat complexity resulting in reductions in macroinvertebrate abundance (Krull 1970, Keast 1984), and reductions in fish growth (Lillie and Budd 1992). In areas where Eurasian watermilfoil has invaded, water resource managers are concerned about the impacts that this plant has on human uses, such as interfering with hydropower generation, flood control, and recreation. Therefore, it is important to identify and address these infestations before impacts to the native plant community occur. Effective control programs utilize extensive surveying to identify and monitor Eurasian watermilfoil populations both spatially and temporally. Data collected during surveys can be used directly for strategic planning and implementing control techniques while the populations are still small.

The use of auxin mimicking herbicides such as 2,4-D (butoxyethyl ester of (2,4-dichlorophenoxy) acetic acid), triclopyr (triethylamine (TEA) salt of [(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid), and the contact herbicide endothall (dipotassium salt of 7-oxabicyclo [2,2,1] heptane-2,3-dicarboxylic acid) have been used extensively for Eurasian watermilfoil control. The systemic herbicides 2,4-D and triclopyr are taken up by the plant and translocated throughout the plant via the symplastic pathway, accumulating in the growing points of shoots and roots (Senseman 2007). These herbicides mimic the auxin hormone in plants; which in Eurasian watermilfoil affects plant respiration and food reserves, causing excessive growth, cell division, and ultimately plant mortality (Christopher and Bird 1992). Endothall is considered a broad-spectrum, membrane active, contact herbicide that is effective on a wide range of aquatic plants including both monocotyledons and dicotolyledons (Madsen 1997, Senseman 2007). Endothall rapidly penetrates the leaf cuticle of Eurasian watermilfoil and causes cellular breakdown within two to five days (MacDonald et al. 1993). Symptoms associated with endothall exposure include plant defoliation and/or brown desiccated tissue (Senseman 2007). Endothall does not translocate throughout plants and therefore, multiple applications may be necessary to completely control Eurasian watermilfoil.

Control of Eurasian watermilfoil using 2,4-D, triclopyr, and endothall has been well documented. Microcosm studies have determined concentration and exposure times for endothall, 2,4-D, and triclopyr (Westerdahl and Hall 1983, Green and Westerdahl 1990, Netherland et al. 1991, Netherland and Getsinger 1992). Small plot and whole lake studies have documented the efficacy range for 2,4-D and triclopyr rates, as well as selectivity removing Eurasian watermilfoil populations with little to no harm to native plant communities (Getsinger et al. 1982, Sprecher and Stewart 1995, Getsinger et al. 1997, Getsinger et al. 2000, Parsons et al. 2001, Poovey et al. 2004). Additionally, The combination of 2,4-D or triclopyr with endothall may also reduce the exposure time needed to control Eurasian watermilfoil. In Lake Pend Oreille there are several areas in the river portion that experience high flow rates that would likely reduce efficacy of 2,4-D and triclopyr alone, therefore combining the systemic herbicide with endothall may offer greater efficacy in these situations. Moreover, the addition of endothall may also allow for the control of curlyleaf pondweed (*Potamogeton crispus* L.), a species that frequently co-exists with Eurasian watermilfoil and is not affected by either 2,4-D or triclopyr (Netherland et al. 2000, Poovey et al. 2002).

The economic and ecological threats posed by the presence of Eurasian watermilfoil as well the difficulties associated with controlling this species in such a large system (both in aerial coverage and volume) that is subject to high water flows requires a proactive and quantitative approach. The point intercept survey is a simple method that allows for rapid data collection during large multi-year studies, but most importantly it offers the ability to conduct a quantitative statistical assessment of control techniques. The purpose of these surveys is to determine the current distribution of Eurasian watermilfoil in Lake Pend Oreille and to evaluate treatment efficacy in areas of active Eurasian watermilfoil management. Intensive surveying has been cited as the only effective way to determine a program's success and when to terminate a management program (Simberloff 2003).

Objectives

The objectives of the herbicide assessment survey were to 1) evaluate the effectiveness of 2,4-D, 2,4-D in combination with endothall, triclopyr, and triclopyr in combination with endothall on Eurasian watermilfoil; and 2) evaluate the native plant community response to herbicide treatments.

Materials and Methods

Herbicide Assessment Surveys

A point intercept survey on a 100 meter grid was conducted in early September 2008 to assess herbicide treatments for control of Eurasian watermilfoil. Survey methods were similar to those used in the littoral survey as outlined by Madsen (1999) and Madsen and Wersal (2008). Areas that were treated in 2007 were sampled again in 2008 to make between year comparisons. Additional points were added, if necessary, in 2008 to areas that were previously untreated. A total of 1130 points were sampled during the 2008 assessment survey to assess the efficacy of 2,4-D applied as a granular (Navigate®) or liquid (Weedar 64), triclopyr applied as Ecotriclopyr, or combinations of 2,4-D (Weedar 64) or triclopyr with endothall (applied as Aquathol K®). Diquat was also applied as Reward® in 2008, however only 4 acres were treated which would not contain enough points to reliably assess herbicide efficacy. Therefore, diquat was not included in analyses. Granular 2,4-D was always applied alone to achieve a concentration of 0.75 to 1.5 mg ae L^{-1} (part per million). When triclopyr was applied alone the target concentration was 0.75 to 1.50 mg ae L^{-1}. The combination treatments were applied with 2,4-D (0.5 to 1.25 mg ae L^{-1})

and endothall (0.7 to 1.3 mg ae L^{-1}) or triclopyr (0.5 to 1.1 mg ae L^{-1}) and endothall (0.5 to 2.0 mg ae L^{-1}). A total of 1924 acres were treated in 2008.

It is important to note that the 2008 assessment survey was conducted in early September, however approximately 50% of herbicide treatments were made after this survey in late September and into October. These late treatment areas were not included in the analyses assessing a particular herbicide's efficacy. Data collected during the 2007 assessment survey were clipped using ArcMap software to the treatment boundaries of 2008, this ensured that all analyses and inferences were made for identical areas and points between years. Survey data were pooled according to year and herbicide for comparison. Plant species presence was averaged over all points sampled and multiplied by 100. Total species richness was calculated and presented as the mean (± 1 SE) of all species observed at each point. Native species richness was calculated in a similar fashion as species richness however, non-native species were removed from the calculations. Changes in the occurrence of plant species across all herbicides and within a given herbicide was determined using McNemar's Test to assess the differences in the correlated proportions within a given data set between variables that are not independent (Stokes et al. 2000, Wersal et al. 2006). A pairwise comparison of each species was made between years using the Cochran-Mantel-Haenszel statistic (Stokes et al. 2000, Wersal et al. 2006). Additionally, those sites that were treated after the assessment survey were used as an "untreated reference" for purposes of comparison to those treated before September. A Chi-square test was used to assess the overall effectiveness of herbicide treatment (sites treated before September) versus no treatment (sites treated after the survey). Total Species richness and native species richness for 2007 and 2008 were also compared using a paired T-test. All statistical analyses were conducted at the $p=0.05$ level of significance using SAS or Statistix 8.0 software (Analytical Software 2003).

Results and Discussion

Whole Lake Assessment (All Herbicides Combined)

The 2008 assessment survey included approximately 50% of the total areas that were to be treated, as treatments continued into late September and October after the survey had been completed. Large portions in the river had not been treated prior to the survey. Therefore, results and conclusions are based solely on areas treated prior to the assessment survey.

The presence of Eurasian watermilfoil during the post treatment assessment was 23.6% when all herbicide types were pooled. This represents a 63% reduction in Eurasian watermilfoil presence from the 2007 survey (64.5%) (Table 2.1). These results indicate that the applications of herbicides are having a significant effect on Eurasian watermilfoil. Overall, Eurasian watermilfoil has been selectively removed with little impact to the native plant community. However, the presence of northern watermilfoil (*Myriophyllum sibiricum* Komorov), whorled watermilfoil (*Myriophyllum verticillatum* L.), and white water-buttercup (*Ranunculus aquatilis* L.) decreased from 2007 to 2008. This is not surprising due to the fact that auxin mimicking herbicides have been used extensively in Lake Pend Oreille for several years. These species should recover from the propagule bank fairly rapidly. In a study conducted on the Pend Oreille

River, WA, it was reported that the dicotyledon community was impacted in the year of treatment however; these native species increased in abundance in the absence of Eurasian watermilfoil one and two years after treatment (Getsinger et al. 1997). This is further supported by differences in species richness between 2007 and 2008 where both native species richness and total species richness declined ($p < 0.01$) (Table 2.1). Again the decline can be attributed to removal of Eurasian watermilfoil and impacts to other species in the treatment areas. In most cases there will be some initial injury to some native species and this will depend upon the herbicides used as to which species are injured. However, the removal of the milfoil canopy will increase light penetration into the water column, increase available space for plant colonization and result in increased growth and competition of native species. The increased growth of natives may resist re-colonization by Eurasian watermilfoil in the future (Madsen 1997). The extensive use of auxin herbicides has removed Eurasian watermilfoil, but it is releasing curlyleaf pondweed (*Potamogeton crispus*) as shown by its increase ($p < 0.01$) from 6.2% in 2007 to 20.1% in 2008 within the same treatment areas. The increasing presence of curlyleaf pondweed will undoubtedly pose greater management problems as this species can root from fragments, but also produces turions for survival of adverse conditions, dispersal, and plant growth. There are fewer herbicides available for curlyleaf pondweed control and none that will offer selective removal of the plant.

Product Assessment

2,4-D Assessment: The use of 2,4-D in the areas that were evaluated did not result in a significant ($p = 0.14$) decrease in the presence of Eurasian watermilfoil (Table 2.2). However only 25% of all areas treated with 2,4-D were evaluated because treatments were made in mid to late September and into October following the assessment survey. The few areas that were evaluated were largely unprotected sites in the river. These areas were likely subject to increased flow and therefore adequate exposure time was not achieved. Similar to the whole lake assessment, curlyleaf pondweed increased ($p < 0.01$) in occurrence from 2007 (0.0%) to 2008 (32.3%). The presence of native species did not change from 2007 to 2008 in the areas evaluated with the exception of sago pondweed (*Stuckenia pectinata*) which decreased in occurrence. Also, native species richness was significantly less in 2008 than 2007 which is driven by the decrease in sago pondweed. The fact that the pondweeds typically are not affected by auxin mimicking herbicides (Sprecher and Stewart 1995, Sprecher et al. 1998) indicates that other factors may have influenced the growth the aquatic plants in 2008 which will be discussed later in this report.

2,4-D and Endothall Combination Assessment: The presence of Eurasian watermilfoil was reduced ($p < 0.01$) in areas where 2,4-D was combined with endothall in 2008 (Table 2.3). After the 2007 assessment survey, Eurasian watermilfoil was observed at 63% of all points at these sites. In 2008, the presence of Eurasian watermilfoil was 36.5%, approximately a 42% reduction in the occurrence. We have found that this combination has been efficacious on Eurasian watermilfoil at reduced contact times in controlled trials (Madsen et al. unpubl. data). Again, with the exception of coontail (*Ceratophyllum demersum* L.), whorled watermilfoil, and leafy pondweed (*Potamogeton foliosus* Raf.), the native plant community was not significantly impacted with respect to occurrence. Furthermore, mean native species richness did not change ($p = 0.10$) from 2007 to 2008 at these combination treatment sites. It has been documented in both small scale mesocosm studies and field studies that some species selectivity may be achieved when applying endothall (Skogerboe and Getsinger 2001, Skogerboe and Getsinger 2002, Parsons et al. 2004).

Triclopyr Assessment: The use of triclopyr resulted in a 72% reduction in the presence of Eursian watermilfoil in the sites evaluated. In 2007, Eursian watermilfoil was observed at 64% of points following the assessment survey. Occurrence of Eursian watermilfoil was reduced ($p < 0.01$) to 18.2% in 2008 (Table 2.4). Similar results were reported in 2007 for Lake Pend Oreille when triclopyr was used for Eurasian watermilfoil control (Madsen and Wersal 2008). Mean species richness decreased ($p = 0.01$) from 2007 and 2008, likely due to the removal of Eurasian watermilfoil. The native plant community, with the exception of white water-buttercup, was unaffected by triclopyr applications as the presence of native species did not change between years, and mean native species richness was similar ($p = 0.20$) between years. Curlyleaf pondweed increased in occurrence from 4.9% to 19% between 2007 and 2008 respectively. The use of triclopyr has been very effective in selectively controlling Eurasian watermilfoil in Lake Pend Oreille.

Triclopyr and Endothall Combination Assessment: There were a limited number of sites available for evaluation of this treatment combination. Although we offer a statistical analysis we strongly caution the inferences made from them as the number of points included in the analysis was 14. The presence of Eurasian watermilfoil decreased from 67% in 2007 to 0% in 2008. Similar to 2,4-D, the combination of triclopyr and endothall has shown promise in controlled trials for controlling Eurasian watermilfoil at reduced contact times (Madsen et al. unpubl. data). The only native species that changed from 2007 to 2008 is white water-buttercup, again however having only 14 points in the analysis greatly reduces the power of any statistical test.

Treated / Non-treated Areas Comparison: The areas that were treated prior to September were compared to areas treated after September (the assessment survey was completed prior to herbicide treatments made after September 5, therefore these sites can be used as an "untreated reference" for purpose of analysis). The use of herbicides resulted in significantly less ($p < 0.01$) Eurasian watermilfoil than if herbicides were not used (Table 2.6). Eurasian watermilfoil was observed at 23% of points in areas treated prior to September. In areas that were not treated before the survey, Eurasian watermilfoil was observed at 52.5% of points. The removal of Eurasian watermilfoil resulted in an increase in coontail, leafy pondweed, and white water-buttercup. There was probably some site specific impacts to white water-buttercup with respect to herbicide application, however based upon these data not treating Eurasian watermilfoil may have a greater impact on the native plant community than herbicide treatments. The suppression and displacement of native plants by Eurasian watermilfoil has been documented in New York lakes (Madsen et al. 1991a,b). Over a three-year period (1987 – 1989) in the northwest bay of Lake George, New York, Eurasian watermilfoil spread from 30% coverage to over 95% coverage at a monitoring site (Madsen et al. 1991b). At this same location it was reported that the native plant density was significantly reduced from 5.5 species per quadrat to 2 species (Madsen et al. 1991b). The occurrence of native species was also reduced in the presence of Eurasian watermilfoil in Waneta Lake and Lamoka Lake, New York (Madsen et al. 2008). Based on these analyses and other empirical evidence, it appears that there may be a tradeoff in short term impacts to the native plant community from using herbicides (Getsinger et al. 1997); or long term reductions in native species from the growth of Eurasian watermilfoil.

Eurasian watermilfoil Locations within Specific Treatment Areas

Maps produced for specific treatment areas were created from data provided by Clean Lakes Inc. Only areas treated prior to September are included in these maps. Areas are color coded by treatment type with red dots indicating Eurasian watermilfoil observed in 2008 and smaller yellow dots representing Eurasian watermilfoil observed during the 2007 post treatment assessment. The points represent locations of only Eurasian watermilfoil and not the total number of points surveyed and used for assessment of treatment techniques.

LeClede Area: The presence of Eurasian watermilfoil in the LeClede area is depicted in figures 2.1 to 2.4. The majority of treatments in this area at the time of assessment were 2,4-D or 2,4-D in combination with endothall. These treatments were made in late July, approximately 5 weeks prior to the assessment survey. As previously reported, the 2,4-D treatments resulted in poor control of Eurasian watermilfoil in this portion of the river. In general, if Eurasian watermilfoil was found at a given point in 2007 it was found again at the same point in 2008. The reduced efficacy is likely a result of plants not having adequate exposure to the herbicide due to water flow. Conversely, sites treated with 2,4-D combined with endothall resulted in good control of Eurasian watermilfoil. The use of triclopyr in the LeClede areas resulted in good control of Eurasian watermilfoil 5 weeks after treatment (WAT). There were no areas treated with triclopyr combined with endothall in the LeClede area.

Dover Area: The presence of Eurasian watermilfoil in the Dover area is depicted in figures 2.5 and 2.6. At 5 WAT the areas treated with 2,4-D resulted in poor control of Eurasian watermilfoil. Sites treated with 2,4-D combined with endothall resulted in fair control with larger areas having greater control than smaller areas. There were no triclopyr combination sites in the Dover area.

Sandpoint Area: The presence of Eurasian watermilfoil in the Sandpoint/Kootenai Bay areas is depicted in figure 2.7. The combination of 2,4-D and endothall resulted in fair control of Eurasian watermilfoil in the one plot that was treated. Of the 4 points sampled only on had Eurasian watermilfoil remaining. Triclopyr was applied on June 23-25, nine weeks after treatment. Of the 16 points sampled 10 had Eurasian watermilfoil. The Eurasian watermilfoil found 9 WAT was regrowth and therefore, additional treatments were scheduled for October.

Kootenai Bay Area: The presence of Eurasian watermilfoil in the Kootenai Bay area is depicted in figure 2.8. The combination of 2,4-D with endothall resulted in excellent control of Eurasian watermilfoil. These treatments were made between June 23 and 26 approximately nine weeks prior to the assessment survey. Therefore, these treatments were initially effective and able to maintain control for at least nine weeks.

Oden Bay Area: The presence of Eurasian watermilfoil in the Oden Bay area is depicted in figures 2.9 to 2.11. Triclopyr treatments in this area were generally ineffective in controlling Eurasian watermilfoil as indicated by the presence of this plant in 2007 and at the same points in

2008. The majority of points that we found Eurasian watermilfoil at in 2007 still had plants in 2008, approximately 5 WAT. This may be a good area for a combination of triclopyr and endothall treatment if exposure time is an issue.

Pack River Area: The presence of Eurasian watermilfoil in the Pack River area is depicted in figure 2.12. The use of triclopyr in this area resulted in excellent control of Eurasian watermilfoil. Of the 42 points sampled in the triclopyr treatment area, 39 had Eurasian watermilfoil in 2007 with only 3 points having Eurasian watermilfoil in 2008, 3 WAT. There was a large area in the southwest portion of the Pack River area that was not treated in 2008, based on the assessment survey we would recommend treating this area in 2009 due to the greater number of points with Eurasian watermilfoil.

Hope Area: The presence of Eurasian watermilfoil in the Hope area is depicted in figure 2.13. The use of triclopyr in the one small area did not result in control of Eurasian watermilfoil. In contrast, the combination of triclopyr and endothall resulted in excellent control of Eurasian watermilfoil in the area near Hope Marina. In 2007, 3 points had Eurasian watermilfoil following the assessment survey. In 2008, we did not find any Eurasian watermilfoil at this treatment site 9 WAT.

Bottle Bay Area: The presence of Eurasian watermilfoil in the Bottle Bay area is in depicted figure 2.14. This area was not assessed in 2007 because there was a benthic barrier in place, however during the 2007 littoral survey we did find Eurasian watermilfoil in this area. Triclopyr was applied on July 21, 2008 and at 5 WAT, resulted in fair control of Eurasian watermilfoil. Of the 12 points sampled in the treatment area, only five had Eurasian watermilfoil. This Eurasian watermilfoil population does not appear to be rapidly expanding, therefore additional herbicide applications should result in the eradication of Eurasian watermilfoil from this bay. With the high amount of boat traffic, monitoring should continue to ensure new plants are not brought in.

Aquatic Plant Population Dynamics

As in 2007, pondweeds (*Potamogeton* and *Stuckenia* spp.) comprised the majority of plant species observed in the lake. These species are generally not impacted by auxin mimicking herbicides (Sprecher and Stewart 1995, Sprecher et al. 1998). After the 2008 assessment survey, it appeared that the presence of leafy pondweed and sago pondweed were reduced in 2,4-D treated areas, as well as lake wide in herbicide treated areas. However, the presence of sago pondweed did not change between 2007 and 2008 when other herbicides were used, including the contact herbicide endothall, which suggests that some other factor or factors are influencing plant growth within Lake Pend Oreille. The effects that environmental factors have on the growth of aquatic plants have received considerable attention which has been reviewed by Barko et al. (1986), however temporal population dynamics of plant species as a result of changes in their growth environment are largely unknown.

In general, aquatic plant growth is often influenced by water depth, light availability, and temperature. The elevation and water temperature of Lake Pend Oreille for May to September of 2007 and 2008 is depicted in figure 2.15. The elevation changed little after June, but water flow was such that herbicide applications had to be postponed. The increases in water flow may have caused decreases in water transparency if sediment and debris were brought into the system. In a Minnesota system, maximum biomass of sago pondweed was inversely related to spring water transparency, meaning that if water was turbid during the early growing season (April and May) maximum biomass was reduced (Wersal et al. 2006). More importantly however, is the fact that water temperature in Lake Pend Oreille was on average 5° colder in 2008. In 2007, the growing season average was 65° compared to 60° in 2008. The lower temperatures in 2008 likely delayed or limited the growth of a number of native species. The temperature optimum for many submersed freshwater species is fairly high, often ranging from 28 to 32 C (82 to 89 F) (Barko and Smart 1981, Barko et al. 1982), so even small reductions in water temperature can have significant impacts to plant growth. Wersal et al. (2006) reported that seasonal biomass of sago pondweed was positively related to water temperature. Perturbations in the growing environment of 2008 likely caused some of the changes in species occurrences.

The herbicide assessment survey was conducted on a smaller scale than the littoral survey and therefore exhibits more detail and variability. The larger scale littoral survey provided data on the overall patterns across years, but lacked enough detail to detect individual species response in some cases. In natural systems each individual and each species experiences the environment on a unique range of scales, and responds to variability within the environment individualistically (Levin 1992). The individualistic response to environmental perturbations or variability leads to differences in species abundance and or distribution. Specific interactions can be intense on certain scales and not on others, because of the match or mismatch of species distributions (Wiens 1986, Wiens et al. 1986). At fine scales, systems are unpredictable with high variability (Jeffers 1989, Levin 1992). Research often focuses on larger scales or longer temporal scales to reduce this variability making the system more predictable which allows for easier generalizations. However, there is a trade off of detail for predictability as the scale broadens (Levin 1992). Small scales may reduce the ability to extrapolate and predict phenomenon at larger scales; while large scales may not result in enough detail to fully understand the mechanisms involved (Levin 1992). Therefore, the use of surveys on different spatial scales may offer further insights into not only how effective herbicide treatments are, but also patterns in species responses to changes in the system.

Literature Cited

Analytical Software 2003. Statistix 8.0. Analytical Software, Tallahassee, FL.

Barko, J.W., and R. M. Smart. 1981. Comparative influences of light and temperature on the growth and metabolism of selected submersed freshwater macrophytes. Ecological Monographs 51:219-235.

Barko, J. W., D. G. Hardin, and M.S. Matthews. 1982. Growth and morphology of submersed freshwater macrophytes in relation to light and temperature. Canadian Journal of Botany 60:877-887.

Barko, J.W., M.S. Adams, and N.S. Clesceri. 1986. Environmental factors and their consideration in the management of submersed aquatic vegetation: A review. Journal of Aquatic Plant Management 24:1-10.

Christopher, S. V. and K. T. Bird. 1992. The effects of herbicides on development of *Myriophyllum spicatum* L. cultured in vitro. Journal of Environmental Quality 21:203-207.

Engelhardt, K. A. M. and M. E. Ritchie. 2002. The effect of aquatic plant species richness on wetland ecosystem processes. Ecology 83:2911-2924.

Getsinger, K. D., G. J. Davis, and M. M. Brinson. 1982. Changes in a *Myriophyllum spicatum* L. community following 2,4-D treatment. Journal of Aquatic Plant Management 20:4-8.

Getsinger, K. D., E. G. Turner, J. D. Madsen, and M. D. Netherland. 1997. Restoring native vegetation in a Eurasian watermilfoil dominated plant community using the herbicide triclopyr. Regulated Rivers: Reservoir Management 13:357-375.

Getsinger, K. D., D. G. Petty, J. D. Madsen, J. G. Skogerboe, B. A. Houtman, W. T. Haller, and A. M. Fox. 2000. Aquatic dissipation of the herbicide triclopyr in Lake Minnetonka, Minnesota. Pest Management Science 56:388-400.

Green, W. R. and H. E. Westerdahl. 1990. Response of Eurasian watermilfoil to 2,4-D concentrations and exposure times. Journal of Aquatic Plant Management 28:27-32.

Jeffers, J.N.R. 1989. Statistical and mathematical approaches to issues of scale in ecology. Pages 47-56 *in* T. Rosswall, R.G. Woodmansee, and P.G. Risser. Scales and Global Change. John Wiley and Sons, New York, New York, USA.

Keast, A. 1984. The introduced macrophyte, *Myriophyllum spicatum*, as a habitat for fish and their invertebrate prey. Canadian Journal of Zoology 62:1289-1303.

Krull, J.N. 1970. Aquatic plant-invertebrate associations and waterfowl. Journal of Wildlife Management 34:707-718.

Levin, S.A. 1992. The problem of pattern and scale in ecology. Ecology 73:1943-1967.

Lillie, R.A., and J. Budd. 1992. Habitat architecture of *Myriophyllum spicatum* as an index to habitat quality for fish and macroinvertebrates. Journal of Freshwater Ecology 7:113-125.

MacDonald, G. E., D. G. Shilling, and T. A. Bewick. 1993. Effects of endothall and other aquatic herbicides on chlorophyll fluorescence, respiration and cellular integrity. Journal of Aquatic Plant Management 31:50-55.

Madsen, J.D. 1997. Methods for management of non-indigenous aquatic plants. P. 145-171. *In*: J.O Luken and J.W. Thieret (eds.). Assessment and Management of Plant Invasions. Springer-Verlag, NY.

Madsen, J.D. 1998. Predicting invasion success of Eurasian watermilfoil. Journal of Aquatic Plant Management 36:28-32.

Madsen, J.D. 1999. Point and line intercept methods for aquatic plant management. APCRP Technical Notes Collection (TN APCRP-M1-02), U.S. Army Engineer Research and Development Center, Vicksburg, MS. 16 pp.

Madsen, J.D., C.F. Hartleb and C.W. Boylen. 1991a. Photosynthetic characteristics of *Myriophyllum spicatum* and six submersed macrophyte species native to Lake George, New York. Freshwater Biology 26:233-240.

Madsen, J.D., J.W. Sutherland, J.A. Bloomfield, L.W. Eichler, and C.W. Boylen. 1991b. The decline of native vegetation under dense Eurasian watermilfoil canopies. Journal of Aquatic Plant Management 29:94-99.

Madsen, J.D., R.M. Stewart, K.D. Getsinger, R.L. Johnson and R.M. Wersal. 2008. Aquatic plant communities in Waneta Lake and Lamoka Lake, New York. Northeastern Naturalist 15:97-110.

Madsen, J.D. and R.M. Wersal. 2008. Assessment of Eurasian watermilfoil (*Myriophyllum spicatum* L.) populations in Lake Pend Oreille, Idaho for 2007. GRI #5028, GeoResources Institute, Mississippi State University.

Netherland, M. D., W. R. Green, and K. D. Getsinger. 1991. Endothall concentration and exposure time relationships for the control of Eurasian watermilfoil and hydrilla. Journal of Aquatic Plant Management 29:61-67.

Netherland, M. D. and K. D. Getsinger. 1992. Efficacy of triclopyr on Eurasian watermilfoil: Concentration and exposure time effects. Journal of Aquatic Plant Management 30:1-5.

Netherland, M.D., J.D. Skogerboe, C.S. Owens, and J.D. Madsen. 2000. Influence of water temperature on the efficacy of diquat and endothall versus curlyleaf pondweed. Journal of Aquatic Plant Management 38:25-32.

Parsons, J. K., K. S. Hamel, J. D. Madsen, and K. D. Getsinger. 2001. The use of 2,4-D for selective control of an early infestation of Eurasian watermilfoil in Loon Lake, Washington. Journal of Aquatic Plant Management 39:117-125.

Parsons, J. K., K. D. Hamel, S. L. O'Neal, and A. W. Moore. 2004. The impact of endothall on the aquatic plant community of Kress Lake, Washington. Journal of Aquatic Plant Management 42:109-114.

Poovey, A. G., J. G. Skogerboe, and C. S. Owens. 2002. Spring treatments of diquat and endothall for culyleaf pondweed control. Journal of Aquatic Plant Management 40:63-67.

Poovey, A. G., K. D. Getsinger, and J. G. Skogerboe. 2004. Small-plot, low-dose treatments of triclopyr for selective control of Eurasian watermilfoil. Lake and Reservoir Management 20:322-332.

Senseman, S. A. (ed.). 2007. Herbicide handbook. 9th ed. Weed Science Society of America, Lawrence, KS. 458 p.

Simberloff, D. 2003. Eradication-preventing the invasion at the outset. Weed Science 51:247-253.

Skogerboe, J. G. and K. D. Getsinger. 2001. Endothall species selectivity evaluation: Southern latitude aquatic plant community. Journal of Aquatic Plant Management 39:129-135.

Skogerboe, J. G. and K. D. Getsinger. 2002. Endothall species selectivity evaluation: Northern altitude aquatic plant community. Journal of Aquatic Plant Management 40:1-5.

Sprecher, S.L. and A.B. Stewart. 1995. Triclopyr effects on peroxidase activity in target and non-target aquatic plants. Journal of Aquatic Plant Management 33:43-48.

Sprecher, S.L., K.D. Getsinger and A.B. Stewart. 1998. Selective effects of aquatic herbicides on sago pondweed. Journal of Aquatic Plant Management 36:64-68.

Stokes, M. E., C. S. Davis, and G. G. Koch. 2000. Categorical Data Analysis Using the SAS® System, second edition. SAS Institute Inc., Cary, NC, USA.

Wersal, R.M., J.D. Madsen, B.R. McMillan, and P.D. Gerard. 2006. Environmental factors affecting the biomass and distribution of *Stuckenia pectinata* in the Heron Lake System, Jackson County, Minnesota, USA. *Wetlands* 26: 313-321.

Westerdahl, H. E. and J. F. Hall. 1983. Threshold 2,4-D concentrations for control of Eurasian watermilfoil and sago pondweed. Journal of Aquatic Plant Management 21:22-25.

Wiens, J.A. 1986. Spatial scale and temporal variation in studies of shrub steppe birds. Pages 154-172 *in* J. Diamond and T.J. Case, editors. Community ecology. Harper and Row, New York, New York, USA.

Wiens, J.A., J.T. Rotenberry, and B. Van Horne. 1986. A lesson in the limitations of field experiments: shrub steppe birds and habitat alteration. Ecology 67:365-376.

[GRI reports are available at the GRI Website: http//www.gri.msstate.edu, under the Resources tab]

Table 2.1. Aquatic plant occurrence following the 2008 post treatment herbicide assessment (all treatment areas) survey of Lake Pend Oreille. Comparisons were made with the 2007 post treatment herbicide assessment survey for the same areas. Only areas treated prior to September 2008 are included in the analyses. Differences between years were determined at a p = 0.05 significance level using a Cochran Mantel Haenszel test.

Species	Common Name	% Occurrence 2007	% Occurrence 2008	p-value (n=624)
***Butomus umbellatus* L.**	Flowering rush	0.0	0.0	**-**
***Callitriche* sp.**	Water-starwort	0.0	0.0	**-**
***Ceratophyllum demersum* L.**	Coontail	14.8	11.3	**0.18**
***Chara* sp.**	Muskgrass	20.2	18.3	**0.55**
***Elatine minima* (Nutt.) Fisch. & Mey.**	Waterwort	0.0	0.0	-
***Elodea canadensis* Michx.**	Elodea	31.4	33.0	**0.68**
***Heteranthera dubia* (Jacq.) Small**	Water stargrass	0.41	0.52	**0.84**
***Hippuris vulgaris* L.**	Mare's tail	0.0	0.0	-
***Isoetes macrospora* Dur.**	Lake quillwort	0.0	0.0	-
***Juncus pelocarpus* Mey.**	Rush	0.0	0.0	-
***Lemna minor* L.**	Common duckweed	0.0	0.0	-
***Myriophyllum hippuroides* Torrey & Grey**	Western watermilfoil	0.0	0.0	-
***Myriophyllum sibiricum* Komarov**	Northern watermilfoil	10.7	3.9	**< 0.01**
***Myriophyllum spicatum* L.**	Eurasian watermilfoil	64.5	23.6	**< 0.01**
***Myriophyllum verticillatum* L.**	Whorled watermilfoil	3.3	0.5	**< 0.01**
***Najas flexilis* (Willd.) Rostk. & Schmidt**	Slender naiad, bushy pondweed	4.5	4.1	**0.83**
***Nitella* sp.**	Nitella	1.6	1.0	**0.51**
***Phalaris arundinacea* L.**	Reed canary grass	0.0	0.4	**0.24**
***Polygonum amphibium* L.**	Water smartweed	0.0	0.0	-
***Potamogeton amplifolius* Tuckerm.**	Large-leaved pondweed	0.0	0.0	-
***Potamogeton crispus* L.**	Curlyleaf pondweed	6.2	20.1	**< 0.01**
***Potamogeton diversifolius* Raf.**	Waterthread pondweed	0.0	0.0	-
***Potamogeton epihydrus* Raf.**	Ribbonleaf pondweed	0.0	0.0	-
***Potamogeton foliosus* Raf.**	Leafy pondweed	26.0	26.7	**0.85**
***Potamogeton gramineus* L.**	Variableleaf pondweed	5.3	5.5	**0.94**
***Potamogeton illinoensis* Morong**	Illinois pondweed	0.0	0.0	-
***Potamogeton natans* L.**	Floating-leaved pondweed	0.4	0.5	**0.84**
***Potamogeton nodosus* Poir.**	American pondweed	1.6	0.0	**0.01**
***Potamogeton praelongus* Wulf.**	Whitestem pondweed	0.4	0.0	**0.20**
***Potamogeton pusillus* L.**	Narrowleaf pondweed	0.0	0.2	**0.42**
***Potamogeton richardsonii* (Ar. Benn.) Rydb.**	Clasping-leaved pondweed	6.2	10.0	**0.10**
***Potamogeton robbinsii* Oakes**	Robbins' pondweed	0.0	0.0	-
***Potamogeton zosteriformis* Fern.**	Flat-stemmed pondweed	3.7	2.1	**0.22**
***Ranunculus aquatilis* L.**	White water-buttercup	8.6	3.0	**< 0.01**
***Ranunculus reptans* L.**	Creeping spearwort	0.0	0.0	**0.22**
***Sagittaria cuneata* Sheldon**	Arumleaf arrowhead	0.0	0.0	**-**
***Sagittaria graminea* Michx.**	Grassy arrowhead	0.0	0.0	-
***Sparganium angustifolium* Michx.**	Narrowleaf burreed	0.0	0.0	-
***Stuckenia pectinata* (L.) Börner**	Sago pondweed	14.8	9.4	**0.03**
***Typha latifolia* L.**	Common cattail	0.0	0.0	**-**
***Utricularia vulgaris* L.**	Common bladderwort	0.0	0.0	-
***Zannichellia palustris* L.**	Horned pondweed	0.0	0.0	-
Native Species Richness (per point)		1.5 ± 0.08	1.3 ± 0.04	**< 0.01**
Mean Species Richness (per point)		2.2 ± 0.08	1.7 ± 0.05	**< 0.01**

Table 2.2. Aquatic plant occurrence following the 2008 post treatment herbicide assessment of 2,4-D treated areas in Lake Pend Oreille. Comparisons were made with the 2007 post treatment herbicide assessment survey for the same areas. Only areas treated prior to September 2008 are included in the analyses. Differences between years were determined at a p = 0.05 significance level using a Cochran Mantel Haenszel test.

Species	Common Name	% Occurrence 2007	% Occurrence 2008	p-value (n=61)
***Butomus umbellatus* L.**	Flowering rush	0.0	0.0	-
***Callitriche* sp.**	Water-starwort	0.0	0.0	-
***Ceratophyllum demersum* L.**	Coontail	10.0	16.1	**0.48**
***Chara* sp.**	Muskgrass	13.3	9.7	**0.65**
***Elatine minima* (Nutt.) Fisch. & Mey.**	Waterwort	0.0	0.0	-
***Elodea canadensis* Michx.**	Elodea	30.0	29.0	**0.93**
***Heteranthera dubia* (Jacq.) Small**	Water stargrass	0.0	0.0	-
***Hippuris vulgaris* L.**	Mare's tail	0.0	0.0	-
***Isoetes macrospora* Dur.**	Lake quillwort	0.0	0.0	-
***Juncus pelocarpus* Mey.**	Rush	0.0	0.0	-
***Lemna minor* L.**	Common duckweed	0.0	0.0	-
***Myriophyllum hippuroides* Torrey & Grey**	Western watermilfoil	0.0	0.0	-
***Myriophyllum sibiricum* Komarov**	Northern watermilfoil	10.0	6.5	**0.61**
***Myriophyllum spicatum* L.**	Eurasian watermilfoil	70.0	51.6	**0.14**
***Myriophyllum verticillatum* L.**	Whorled watermilfoil	3.33	3.23	**0.98**
***Najas flexilis* (Willd.) Rostk. & Schmidt**	Slender naiad, bushy pondweed	6.6	0.0	**0.14**
***Nitella* sp.**	Nitella	3.3	0.0	**0.31**
***Phalaris arundinacea* L.**	Reed canary grass	0.0	0.0	-
***Polygonum amphibium* L.**	Water smartweed	0.0	0.0	-
***Potamogeton amplifolius* Tuckerm.**	Large-leaved pondweed	0.0	0.0	-
***Potamogeton crispus* L.**	Curlyleaf pondweed	0.0	32.3	**< 0.01**
***Potamogeton diversifolius* Raf.**	Waterthread pondweed	0.0	0.0	-
***Potamogeton epihydrus* Raf.**	Ribbonleaf pondweed	0.0	0.0	-
***Potamogeton foliosus* Raf.**	Leafy pondweed	23.3	22.6	**0.94**
***Potamogeton gramineus* L.**	Variableleaf pondweed	3.3	0.0	**0.31**
***Potamogeton illinoensis* Morong**	Illinois pondweed	0.0	0.0	-
***Potamogeton natans* L.**	Floating-leaved pondweed	3.3	0.0	**0.31**
***Potamogeton nodosus* Poir.**	American pondweed	3.3	0.0	**0.31**
***Potamogeton praelongus* Wulf.**	Whitestem pondweed	0.0	0.0	-
***Potamogeton pusillus* L.**	Narrowleaf pondweed	0.0	0.0	-
***Potamogeton richardsonii* (Ar. Benn.) Rydb.**	Clasping-leaved pondweed	6.6	0.0	**0.14**
***Potamogeton robbinsii* Oakes**	Robbins' pondweed	0.0	0.0	-
***Potamogeton zosteriformis* Fern.**	Flat-stemmed pondweed	6.6	6.5	**0.97**
***Ranunculus aquatilis* L.**	White water-buttercup	16.6	6.5	**0.21**
***Ranunculus reptans* L.**	Creeping spearwort	0.0	0.0	-
***Sagittaria cuneata* Sheldon**	Arumleaf arrowhead	0.0	0.0	-
***Sagittaria graminea* Michx.**	Grassy arrowhead	0.0	0.0	-
***Sparganium angustifolium* Michx.**	Narrowleaf burreed	0.0	0.0	-
***Stuckenia pectinata* (L.) Börner**	Sago pondweed	26.6	0.0	**< 0.01**
***Typha latifolia* L.**	Common cattail	0.0	0.0	-
***Utricularia vulgaris* L.**	Common bladderwort	0.0	0.0	-
***Zannichellia palustris* L.**	Horned pondweed	0.0	0.0	-
Native Species Richness (per point)		1.6 ± 0.2	1.0 ± 0.1	**0.03**
Mean Species Richness (per point)		2.3 ± 0.2	1.8 ± 0.2	**0.12**

Table 2.3. Aquatic plant occurrence following the 2008 post treatment herbicide assessment of 2,4-D and endothall combination areas in Lake Pend Oreille. Comparisons were made with the 2007 post treatment herbicide assessment survey for the same areas. Only areas treated prior to September 2008 are included in the analyses. Differences between years were determined at a p = 0.05 significance level using a Cochran Mantel Haenszel test.

Species	Common Name	% Occurrence 2007	% Occurrence 2008	p-value (n=125)
***Butomus umbellatus* L.**	Flowering rush	0.0	0.0	-
***Callitriche* sp.**	Water-starwort	0.0	0.0	-
***Ceratophyllum demersum* L.**	Coontail	22.5	9.5	**0.05**
***Chara* sp.**	Muskgrass	17.7	22.2	**0.53**
***Elatine minima* (Nutt.) Fisch. & Mey.**	Waterwort	0.0	0.0	-
***Elodea canadensis* Michx.**	Elodea	40.3	47.6	**0.41**
***Heteranthera dubia* (Jacq.) Small**	Water stargrass	1.6	0.0	**0.31**
***Hippuris vulgaris* L.**	Mare's tail	0.0	0.0	-
***Isoetes macrospora* Dur.**	Lake quillwort	0.0	0.0	-
***Juncus pelocarpus* Mey.**	Rush	0.0	0.0	-
***Lemna minor* L.**	Common duckweed	0.0	0.0	-
***Myriophyllum hippuroides* Torrey & Grey**	Western watermilfoil	0.0	0.0	-
***Myriophyllum sibiricum* Komarov**	Northern watermilfoil	4.8	4.8	**0.98**
***Myriophyllum spicatum* L.**	Eurasian watermilfoil	63.0	36.5	**< 0.01**
***Myriophyllum verticillatum* L.**	Whorled watermilfoil	6.4	0.0	**0.04**
***Najas flexilis* (Willd.) Rostk. & Schmidt**	Slender naiad, bushy pondweed	6.4	6.4	**0.98**
***Nitella* sp.**	Nitella	0.0	1.5	**0.32**
***Phalaris arundinacea* L.**	Reed canary grass	0.0	0.0	-
***Polygonum amphibium* L.**	Water smartweed	0.0	0.0	-
***Potamogeton amplifolius* Tuckerm.**	Large-leaved pondweed	0.0	0.0	-
***Potamogeton crispus* L.**	Curlyleaf pondweed	11.3	22.2	**0.10**
***Potamogeton diversifolius* Raf.**	Waterthread pondweed	0.0	0.0	-
***Potamogeton epihydrus* Raf.**	Ribbonleaf pondweed	0.0	0.0	-
***Potamogeton foliosus* Raf.**	Leafy pondweed	17.7	3.1	**< 0.01**
***Potamogeton gramineus* L.**	Variableleaf pondweed	8.1	6.4	**0.71**
***Potamogeton illinoensis* Morong**	Illinois pondweed	0.0	0.0	-
***Potamogeton natans* L.**	Floating-leaved pondweed	0.0	0.0	-
***Potamogeton nodosus* Poir.**	American pondweed	3.2	0.0	**0.15**
***Potamogeton praelongus* Wulf.**	Whitestem pondweed	1.6	0.0	**0.31**
***Potamogeton pusillus* L.**	Narrowleaf pondweed	0.0	0.0	-
***Potamogeton richardsonii* (Ar. Benn.) Rydb.**	Clasping-leaved pondweed	1.6	6.4	**0.17**
***Potamogeton robbinsii* Oakes**	Robbins' pondweed	0.0	0.0	-
***Potamogeton zosteriformis* Fern.**	Flat-stemmed pondweed	4.8	1.6	**0.30**
***Ranunculus aquatilis* L.**	White water-buttercup	4.8	3.2	**0.63**
***Ranunculus reptans* L.**	Creeping spearwort	0.0	0.0	-
***Sagittaria cuneata* Sheldon**	Arumleaf arrowhead	0.0	0.0	-
***Sagittaria graminea* Michx.**	Grassy arrowhead	0.0	0.0	-
***Sparganium angustifolium* Michx.**	Narrowleaf burreed	0.0	0.0	-
***Stuckenia pectinata* (L.) Börner**	Sago pondweed	6.4	3.2	**0.39**
***Typha latifolia* L.**	Common cattail	0.0	0.0	-
***Utricularia vulgaris* L.**	Common bladderwort	0.0	0.0	-
***Zannichellia palustris* L.**	Horned pondweed	0.0	0.0	-
Native Species Richness (per point)		1.4 ± 0.1	1.2 ± 0.1	**0.10**
Mean Species Richness (per point)		2.1 ± 0.2	1.7 ± 0.1	**0.03**

Table 2.4. Aquatic plant occurrence following the 2008 post treatment herbicide assessment of triclopyr treated areas in Lake Pend Oreille. Comparisons were made with the 2007 post treatment herbicide assessment survey for the same areas. Only areas treated prior to September 2008 are included in the analyses. Differences between years were determined at a p = 0.05 significance level using a Cochran Mantel Haenszel test.

Species	Common Name	% Occurrence 2007	% Occurrence 2008	p-value (n=424)
***Butomus umbellatus* L.**	Flowering rush	0.0	0.0	**-**
***Callitriche* sp.**	Water-starwort	0.0	0.0	-
***Ceratophyllum demersum* L.**	Coontail	13.1	11.4	**0.59**
***Chara* sp.**	Muskgrass	21.5	17.8	**0.36**
***Elatine minima* (Nutt.) Fisch. & Mey.**	Waterwort	0.0	0.0	-
***Elodea canadensis* Michx.**	Elodea	27.7	30.36	**0.58**
***Heteranthera dubia* (Jacq.) Small**	Water stargrass	0.0	0.7	**0.30**
***Hippuris vulgaris* L.**	Mare's tail	0.0	0.0	**-**
***Isoetes macrospora* Dur.**	Lake quillwort	0.0	0.0	**-**
***Juncus pelocarpus* Mey.**	Rush	0.0	0.0	**-**
***Lemna minor* L.**	Common duckweed	0.0	0.0	-
***Myriophyllum hippuroides* Torrey & Grey**	Western watermilfoil	0.0	0.0	-
***Myriophyllum sibiricum* Komarov**	Northern watermilfoil	13.8	3.5	**< 0.01**
***Myriophyllum spicatum* L.**	Eurasian watermilfoil	64.0	18.2	**< 0.01**
***Myriophyllum verticillatum* L.**	Whorled watermilfoil	2.1	0.4	**0.08**
***Najas flexilis* (Willd.) Rostk. & Schmidt**	Slender naiad, bushy pondweed	3.5	3.6	**0.98**
***Nitella* sp.**	Nitella	2.1	0.7	**0.21**
***Phalaris arundinacea* L.**	Reed canary grass	0.0	0.0	**-**
***Polygonum amphibium* L.**	Water smartweed	0.0	0.0	-
***Potamogeton amplifolius* Tuckerm.**	Large-leaved pondweed	0.0	0.0	-
***Potamogeton crispus* L.**	Curlyleaf pondweed	4.9	19.0	**< 0.01**
***Potamogeton diversifolius* Raf.**	Waterthread pondweed	0.0	0.0	**-**
***Potamogeton epihydrus* Raf.**	Ribbonleaf pondweed	0.0	0.0	**-**
***Potamogeton foliosus* Raf.**	Leafy pondweed	29.8	33.2	**0.48**
***Potamogeton gramineus* L.**	Variableleaf pondweed	4.1	6.1	**0.41**
***Potamogeton illinoensis* Morong**	Illinois pondweed	0.0	0.0	**-**
***Potamogeton natans* L.**	Floating-leaved pondweed	0.0	0.7	**0.31**
***Potamogeton nodosus* Poir.**	American pondweed	0.6	0.0	**0.16**
***Potamogeton praelongus* Wulf.**	Whitestem pondweed	1.6	0.0	**0.31**
***Potamogeton pusillus* L.**	Narrowleaf pondweed	0.0	0.36	**0.47**
***Potamogeton richardsonii* (Ar. Benn.) Rydb.**	Clasping-leaved pondweed	8.3	11.8	**0.27**
***Potamogeton robbinsii* Oakes**	Robbins' pondweed	0.0	0.0	-
***Potamogeton zosteriformis* Fern.**	Flat-stemmed pondweed	2.7	1.8	**0.50**
***Ranunculus aquatilis* L.**	White water-buttercup	9.0	2.5	**< 0.01**
***Ranunculus reptans* L.**	Creeping spearwort	0.0	0.0	**-**
***Sagittaria cuneata* Sheldon**	Arumleaf arrowhead	0.0	0.0	**-**
***Sagittaria graminea* Michx.**	Grassy arrowhead	0.0	0.0	-
***Sparganium angustifolium* Michx.**	Narrowleaf burreed	0.0	0.0	-
***Stuckenia pectinata* (L.) Börner**	Sago pondweed	15.9	11.8	**0.22**
***Typha latifolia* L.**	Common cattail	0.0	0.0	**-**
***Utricularia vulgaris* L.**	Common bladderwort	0.0	0.0	-
***Zannichellia palustris* L.**	Horned pondweed	0.0	0.0	**-**
Native Species Richness (per point)		1.5 ± 0.1	1.4 ± 0.1	**0.20**
Mean Species Richness (per point)		2.2 ± 0.1	1.7 ± 0.1	**0.01**

Table 2.5. Aquatic plant occurrence following the 2008 post treatment herbicide assessment of triclopyr and endothall combination areas in Lake Pend Oreille. Comparisons were made with the 2007 post treatment herbicide assessment survey for the same areas. Only areas treated prior to September 2008 are included in the analyses. Differences between years were determined at a p = 0.05 significance level using a Cochran Mantel Haenszel test.

Species	Common Name	% Occurrence 2007	% Occurrence 2008	p-value (n=14)
***Butomus umbellatus* L.**	Flowering rush	0.0	0.0	-
***Callitriche* sp.**	Water-starwort	0.0	0.0	-
***Ceratophyllum demersum* L.**	Coontail	0.0	0.0	-
***Chara* sp.**	Muskgrass	50.0	37.5	**0.65**
***Elatine minima* (Nutt.) Fisch. & Mey.**	Waterwort	0.0	0.0	-
***Elodea canadensis* Michx.**	Elodea	33.3	25.0	**0.74**
***Heteranthera dubia* (Jacq.) Small**	Water stargrass	0.0	0.0	-
***Hippuris vulgaris* L.**	Mare's tail	0.0	0.0	-
***Isoetes macrospora* Dur.**	Lake quillwort	0.0	0.0	-
***Juncus pelocarpus* Mey.**	Rush	0.0	0.0	-
***Lemna minor* L.**	Common duckweed	0.0	0.0	-
***Myriophyllum hippuroides* Torrey & Grey**	Western watermilfoil	0.0	0.0	-
***Myriophyllum sibiricum* Komarov**	Northern watermilfoil	0.0	0.0	-
***Myriophyllum spicatum* L.**	Eurasian watermilfoil	67.0	0.0	**< 0.01**
***Myriophyllum verticillatum* L.**	Whorled watermilfoil	2.1	0.4	**0.08**
***Najas flexilis* (Willd.) Rostk. & Schmidt**	Slender naiad, bushy pondweed	0.0	25.0	**0.20**
***Nitella* sp.**	Nitella	0.0	12.5	**0.38**
***Phalaris arundinacea* L.**	Reed canary grass	0.0	0.0	-
***Polygonum amphibium* L.**	Water smartweed	0.0	0.0	-
***Potamogeton amplifolius* Tuckerm.**	Large-leaved pondweed	0.0	0.0	-
***Potamogeton crispus* L.**	Curlyleaf pondweed	16.6	0.0	**0.24**
***Potamogeton diversifolius* Raf.**	Waterthread pondweed	0.0	0.0	-
***Potamogeton epihydrus* Raf.**	Ribbonleaf pondweed	0.0	0.0	-
***Potamogeton foliosus* Raf.**	Leafy pondweed	33.0	0.0	**0.08**
***Potamogeton gramineus* L.**	Variableleaf pondweed	16.6	0.0	**0.24**
***Potamogeton illinoensis* Morong**	Illinois pondweed	0.0	0.0	-
***Potamogeton natans* L.**	Floating-leaved pondweed	0.0	0.0	-
***Potamogeton nodosus* Poir.**	American pondweed	0.0	0.0	-
***Potamogeton praelongus* Wulf.**	Whitestem pondweed	0.0	0.0	-
***Potamogeton pusillus* L.**	Narrowleaf pondweed	0.0	0.0	-
***Potamogeton richardsonii* (Ar. Benn.) Rydb.**	Clasping-leaved pondweed	0.0	12.5	**0.38**
***Potamogeton robbinsii* Oakes**	Robbins' pondweed	0.0	0.0	-
***Potamogeton zosteriformis* Fern.**	Flat-stemmed pondweed	2.7	1.8	**0.50**
***Ranunculus aquatilis* L.**	White water-buttercup	9.0	2.5	**< 0.01**
***Ranunculus reptans* L.**	Creeping spearwort	0.0	0.0	-
***Sagittaria cuneata* Sheldon**	Arumleaf arrowhead	0.0	0.0	-
***Sagittaria graminea* Michx.**	Grassy arrowhead	0.0	0.0	-
***Sparganium angustifolium* Michx.**	Narrowleaf burreed	0.0	0.0	-
***Stuckenia pectinata* (L.) Börner**	Sago pondweed	16.6	12.5	**0.83**
***Typha latifolia* L.**	Common cattail	0.0	0.0	-
***Utricularia vulgaris* L.**	Common bladderwort	0.0	0.0	-
***Zannichellia palustris* L.**	Horned pondweed	0.0	0.0	-

Table 2.6. Comparison of sites treated before September 2008 and sites treated after September 2008. Those areas treated after September served as an "untreated reference" for the purposes of analyses. Differences between treatment times were determined using a Chi-square analysis. Differences in species richness were determined using a Wilcoxin Rank Sum Test. All analyses were conducted at p = 0.05 level of significance.

Species	Common Name	Sites Treated Before September % Occurrence	Sites Treated After September % Occurrence	p-value
***Butomus umbellatus* L.**	Flowering rush	0.0	0.0	-
***Callitriche* sp.**	Water-starwort	0.0	0.0	-
***Ceratophyllum demersum* L.**	Coontail	10.5	18.3	**0.04**
***Chara* sp.**	Muskgrass	19.4	15.8	**0.42**
***Elatine minima* (Nutt.) Fisch. & Mey.**	Waterwort	0.0	0.8	**0.21**
***Elodea canadensis* Michx.**	Elodea	34.0	35.0	**0.86**
***Heteranthera dubia* (Jacq.) Small**	Water stargrass	0.0	0.0	-
***Hippuris vulgaris* L.**	Mare's tail	0.0	0.0	-
***Isoetes macrospora* Dur.**	Lake quillwort	0.0	0.0	-
***Juncus pelocarpus* Mey.**	Rush	0.0	0.0	-
***Lemna minor* L.**	Common duckweed	0.0	0.0	-
***Myriophyllum hippuroides* Torrey & Grey**	Western watermilfoil	0.0	0.0	-
***Myriophyllum sibiricum* Komarov**	Northern watermilfoil	3.1	6.6	**0.14**
***Myriophyllum spicatum* L.**	Eurasian watermilfoil	23.0	52.5	**< 0.01**
***Myriophyllum verticillatum* L.**	Whorled watermilfoil	0.5	0.8	**0.73**
***Najas flexilis* (Willd.) Rostk. & Schmidt**	Slender naiad, bushy pondweed	4.2	1.6	**0.21**
***Nitella* sp.**	Nitella	0.0	0.0	**0.38**
***Phalaris arundinacea* L.**	Reed canary grass	0.0	0.0	-
***Polygonum amphibium* L.**	Water smartweed	0.0	0.0	-
***Potamogeton amplifolius* Tuckerm.**	Large-leaved pondweed	0.0	0.0	-
***Potamogeton crispus* L.**	Curlyleaf pondweed	18.9	25.0	**0.19**
***Potamogeton diversifolius* Raf.**	Waterthread pondweed	0.0	0.0	-
***Potamogeton epihydrus* Raf.**	Ribbonleaf pondweed	0.0	0.0	-
***Potamogeton foliosus* Raf.**	Leafy pondweed	24.6	14.1	**0.02**
***Potamogeton gramineus* L.**	Variableleaf pondweed	6.8	6.6	**0.96**
***Potamogeton illinoensis* Morong**	Illinois pondweed	0.0	0.0	-
***Potamogeton natans* L.**	Floating-leaved pondweed	0.0	0.8	**0.20**
***Potamogeton nodosus* Poir.**	American pondweed	0.0	0.0	-
***Potamogeton praelongus* Wulf.**	Whitestem pondweed	0.0	0.0	-
***Potamogeton pusillus* L.**	Narrowleaf pondweed	0.0	0.0	-
***Potamogeton richardsonii* (Ar. Benn.) Rydb.**	Clasping-leaved pondweed	7.8	8.3	**0.87**
***Potamogeton robbinsii* Oakes**	Robbins' pondweed	0.0	0.0	-
***Potamogeton zosteriformis* Fern.**	Flat-stemmed pondweed	2.6	8.3	**0.02**
***Ranunculus aquatilis* L.**	White water-buttercup	4.2	14.1	**< 0.01**
***Ranunculus reptans* L.**	Creeping spearwort	0.0	0.0	-
***Sagittaria cuneata* Sheldon**	Arumleaf arrowhead	0.0	0.0	-
***Sagittaria graminea* Michx.**	Grassy arrowhead	0.0	0.0	-
***Sparganium angustifolium* Michx.**	Narrowleaf burreed	0.0	0.0	-
***Stuckenia pectinata* (L.) Börner**	Sago pondweed	10.9	5.0	**0.06**
***Typha latifolia* L.**	Common cattail	0.0	0.0	-
***Utricularia vulgaris* L.**	Common bladderwort	0.0	0.0	-
***Zannichellia palustris* L.**	Horned pondweed	0.0	0.0	-
Native Species Richness (per point)		1.3 ± 0.1	1.3 ± 0.1	**0.65**
Mean Species Richness (per point)		1.7 ± 0.1	2.0 ± 0.1	**< 0.01**

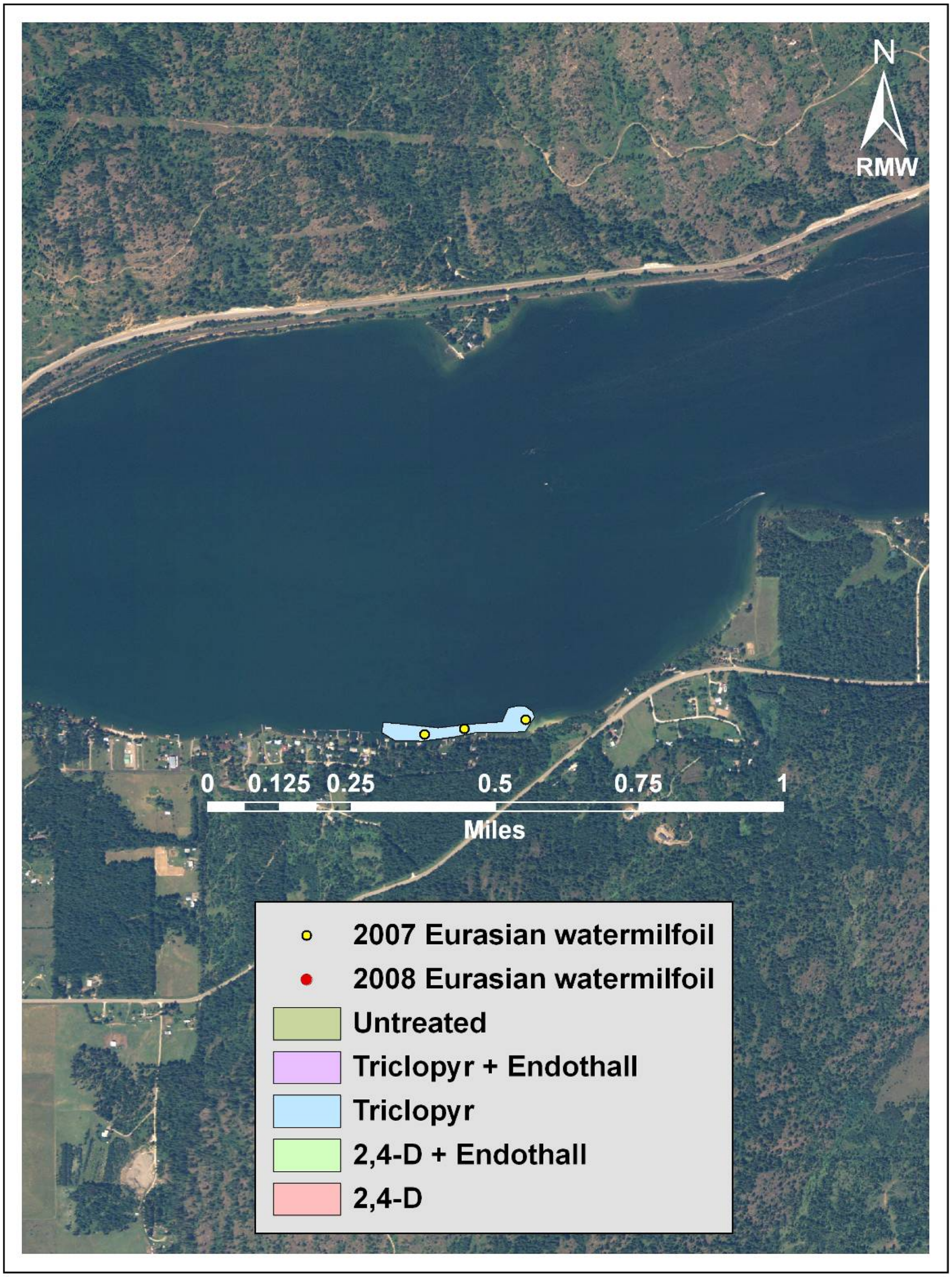

Figure 2.1. The presence of Eurasian watermilfoil west of the LeClede area, September 2008.

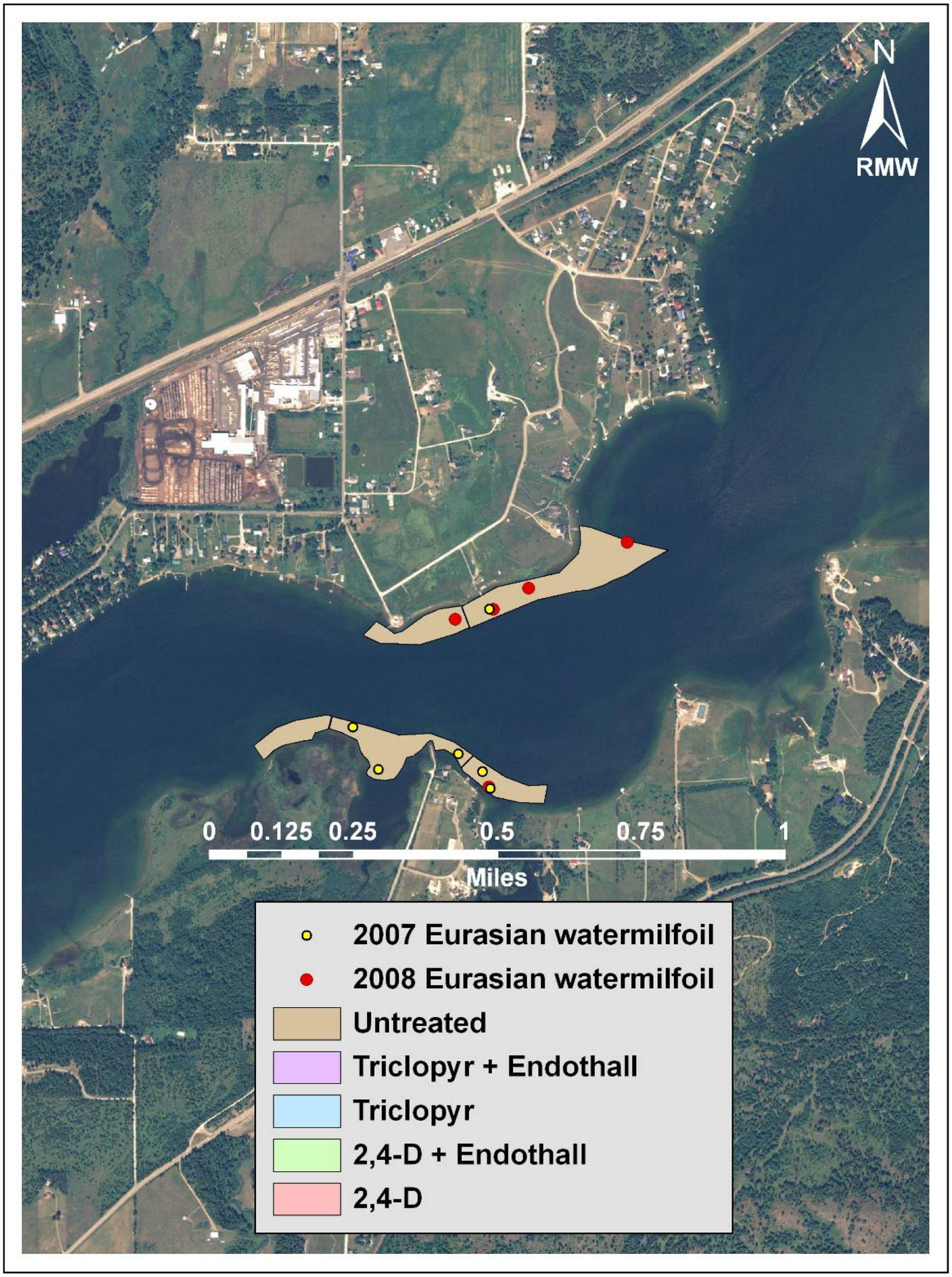

Figure 2.2. The presence of Eurasian watermilfoil in the LeClede Area, September 2008.

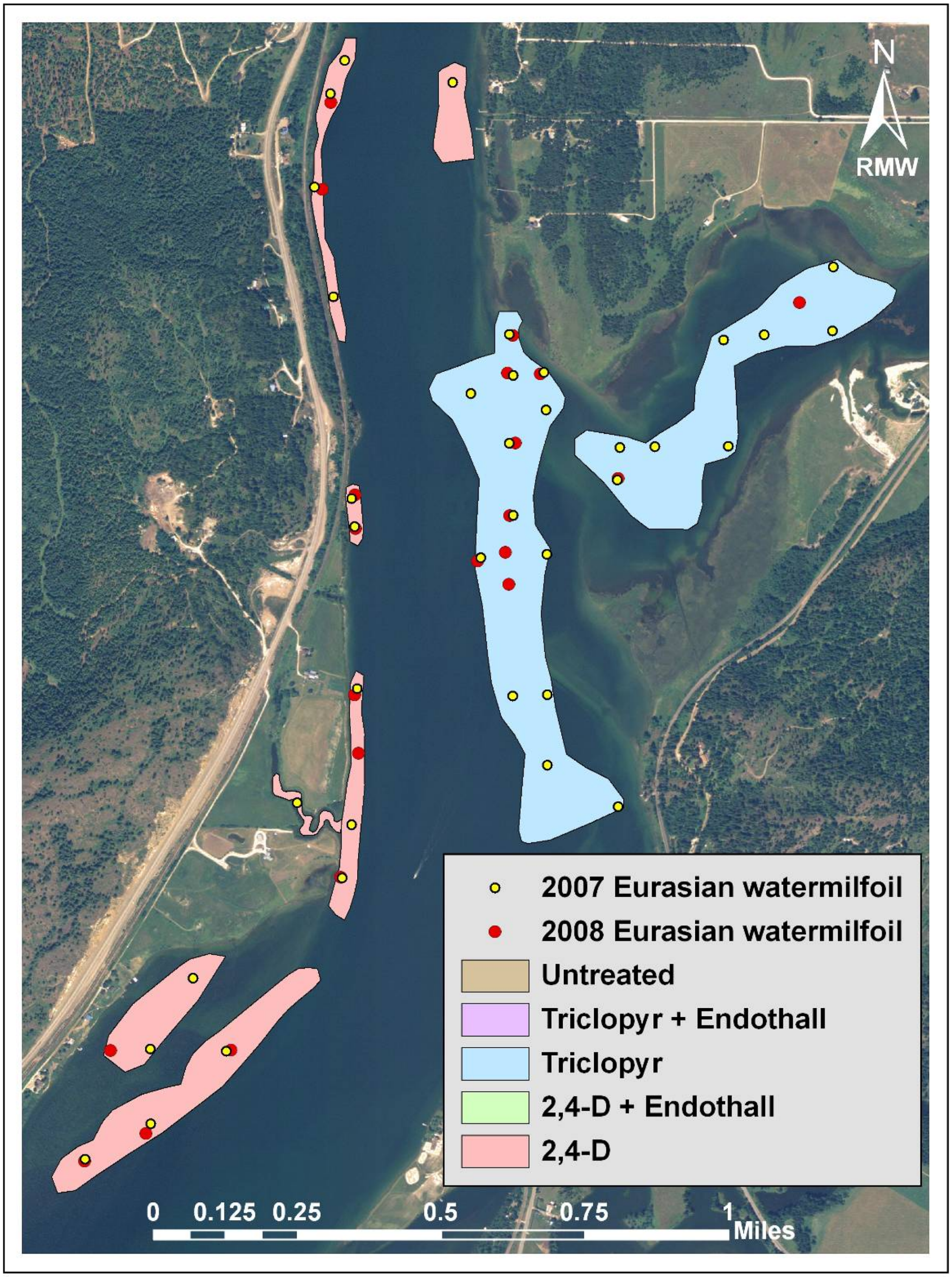

Figure 2.3. The presence of Eurasian watermilfoil north of the LeClede area, September 2008.

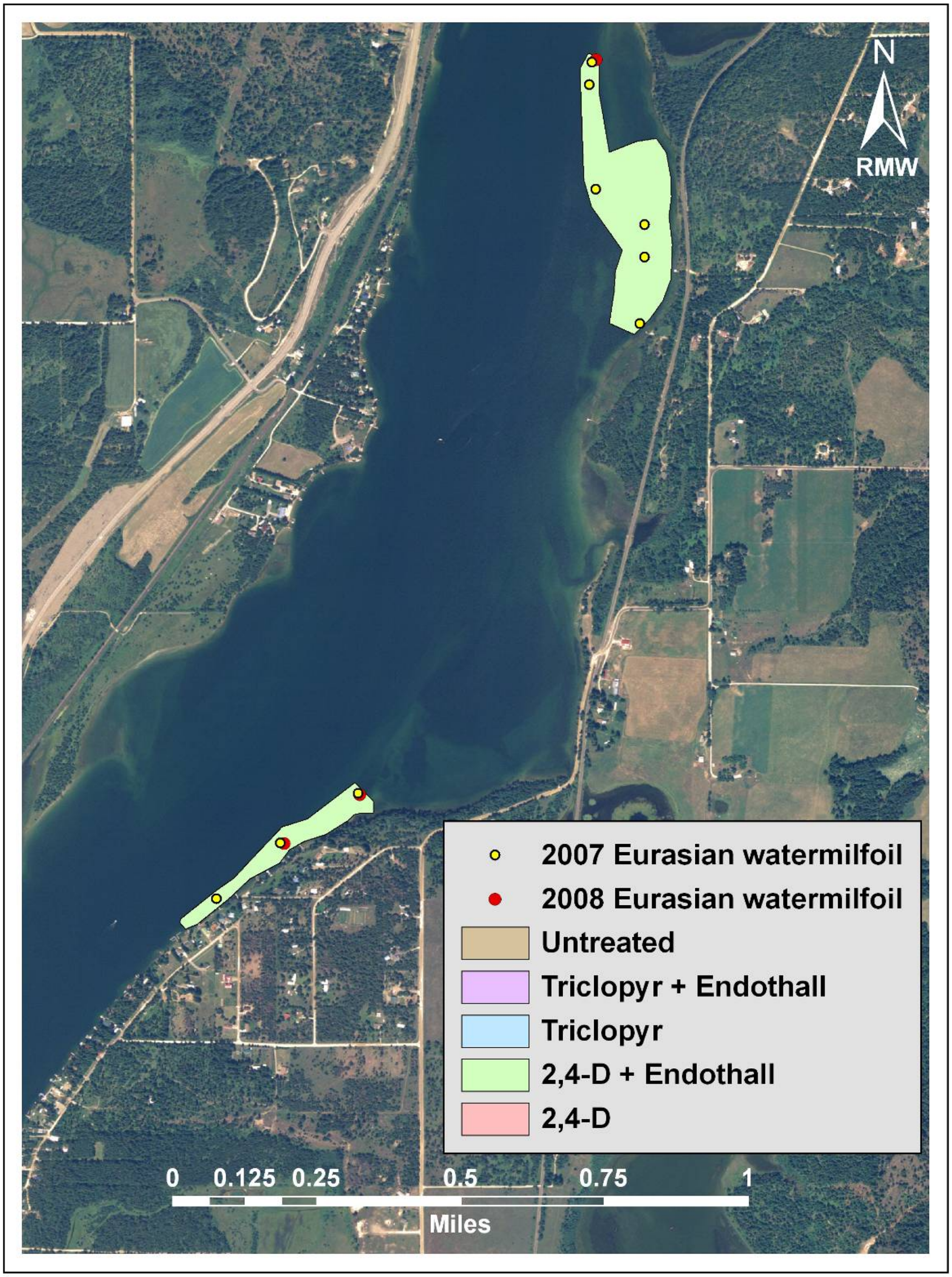

Figure 2.4. The presence of Eurasian watermilfoil west of Dover area, September 2008.

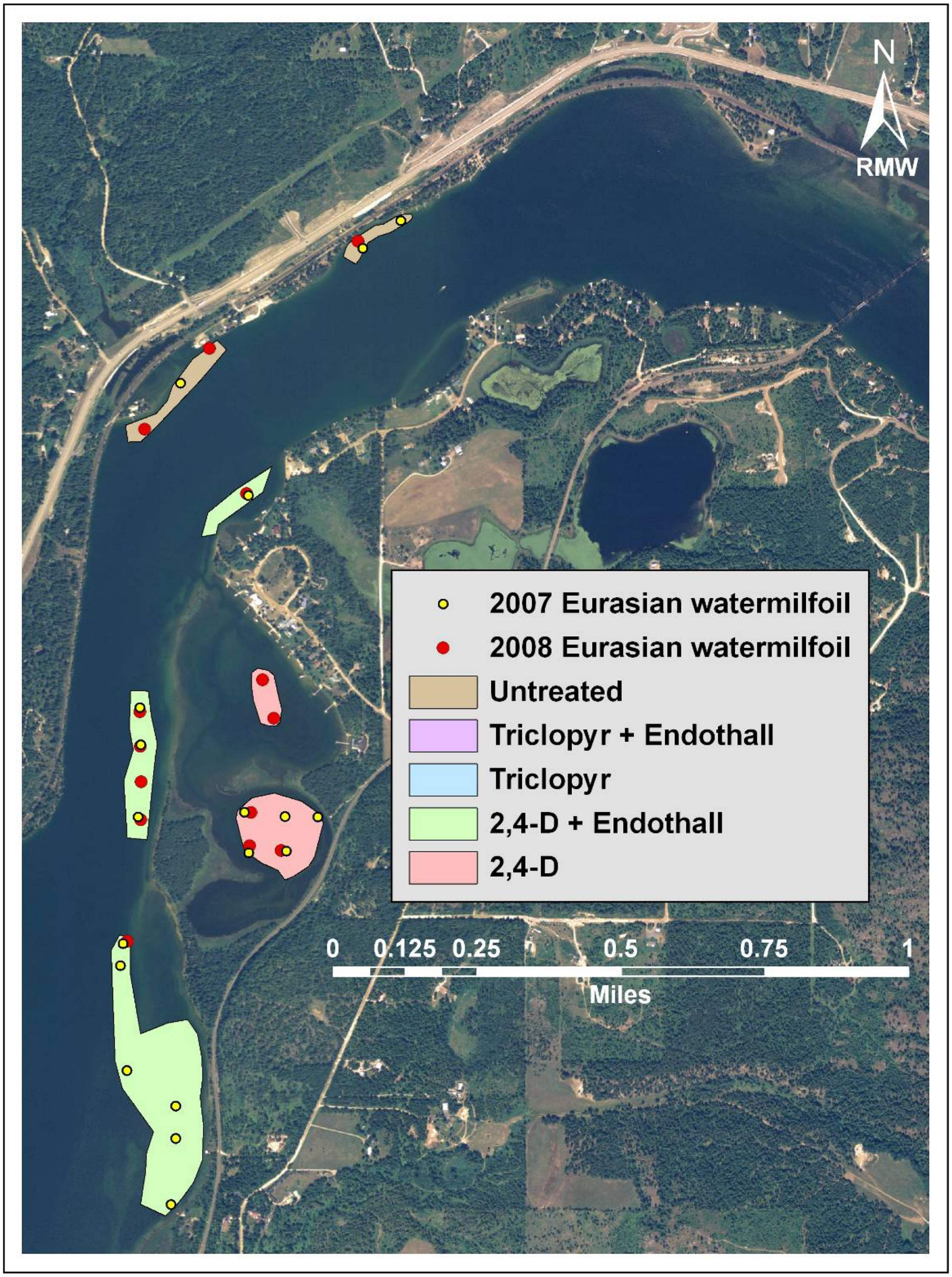

Figure 2.5. Additional locations of Eurasian watermilfoil west of Dover area, September 2008.

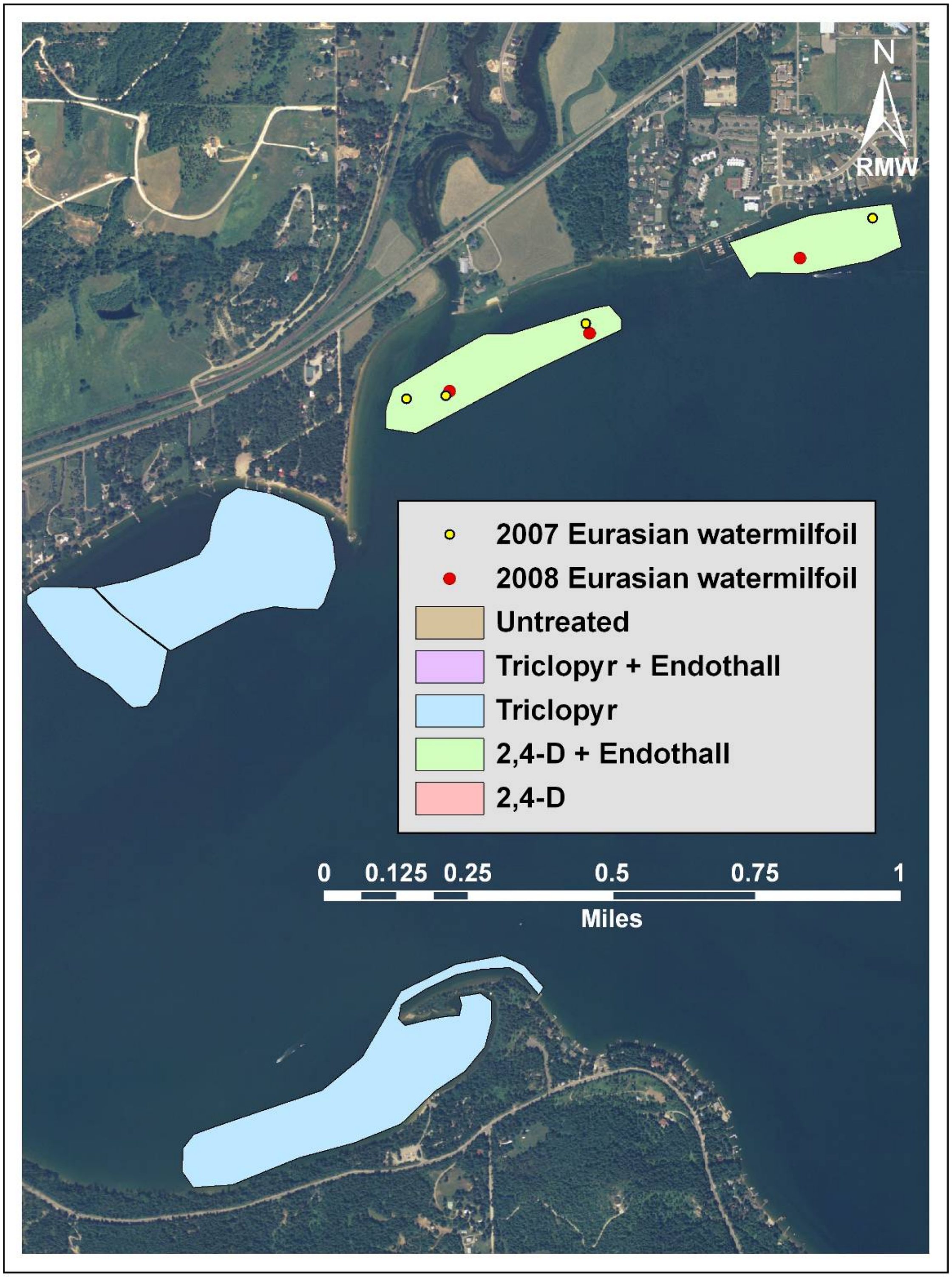

Figure 2.6. The presence of Eurasian watermilfoil in the Dover/Sandpoint area, September 2008.

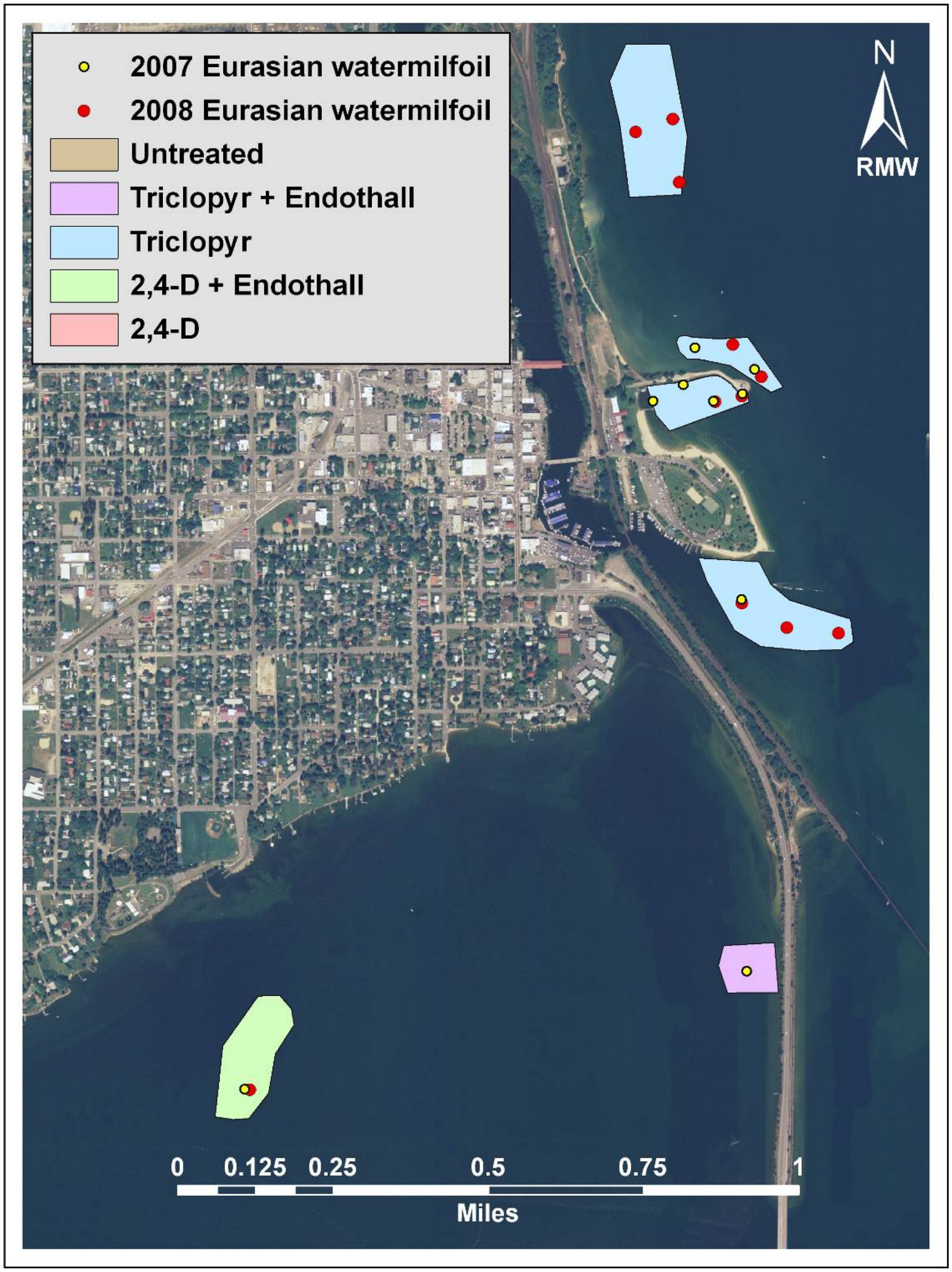

Figure 2.7. The presence of Eurasian watermilfoil in Sandpoint/Kootenai Bay area, September 2008.

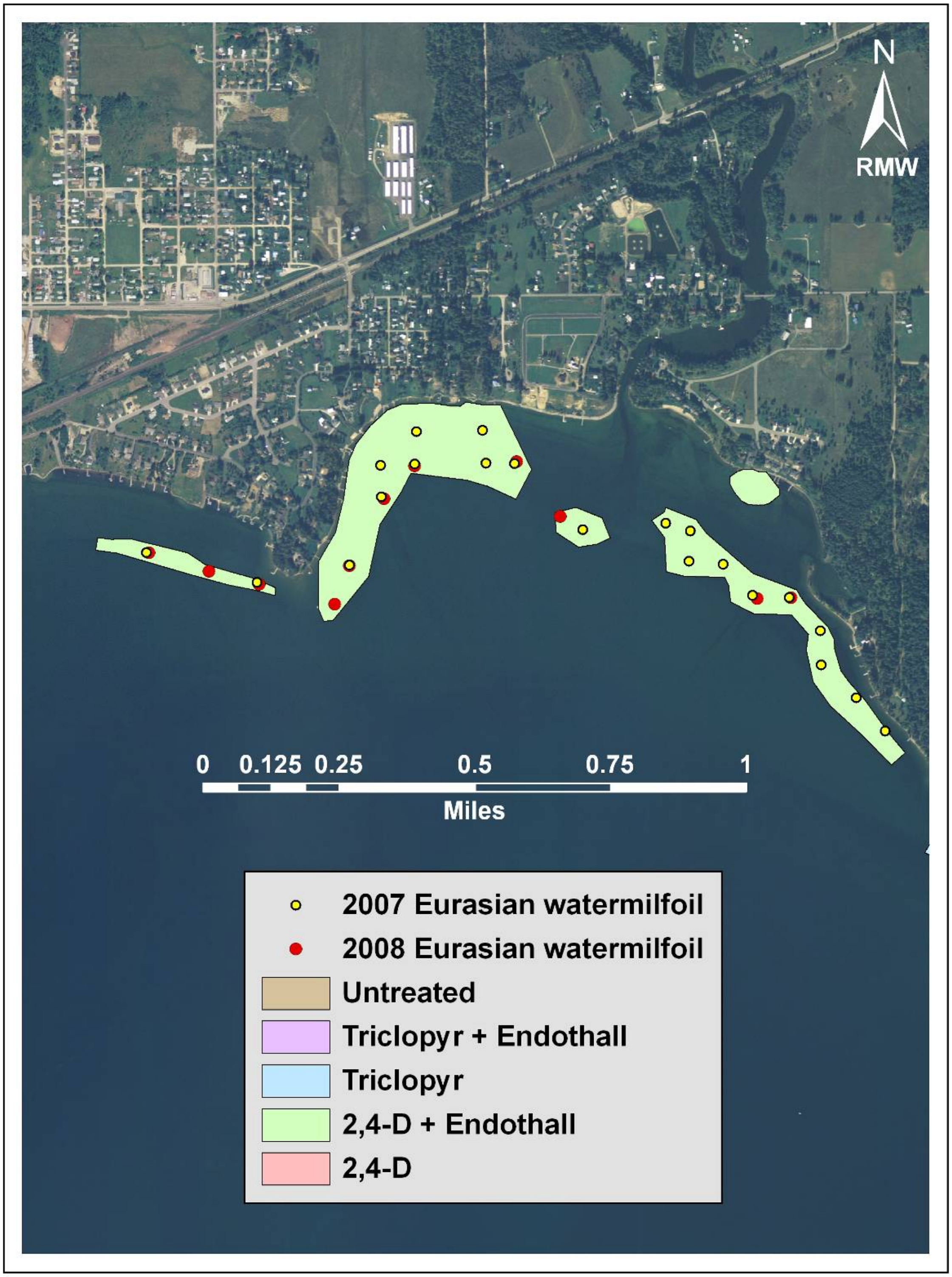

Figure 2.8. The presence of Eurasian watermilfoil in the Kootenai Bay area, September 2008.

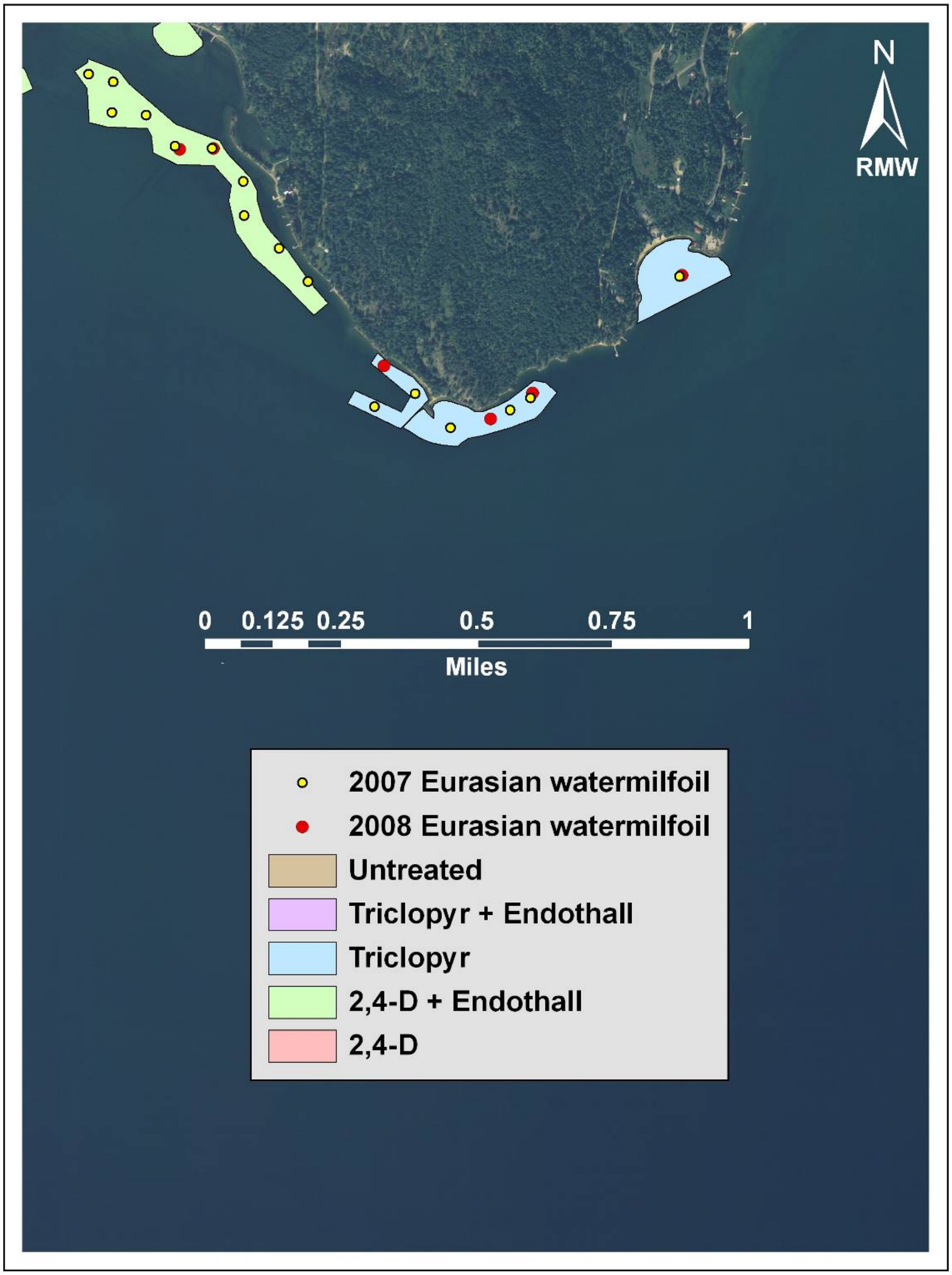

Figure 2.9. The presence of Eurasian watermilfoil in Kootenai Bay/Oden Bay area, September 2008.

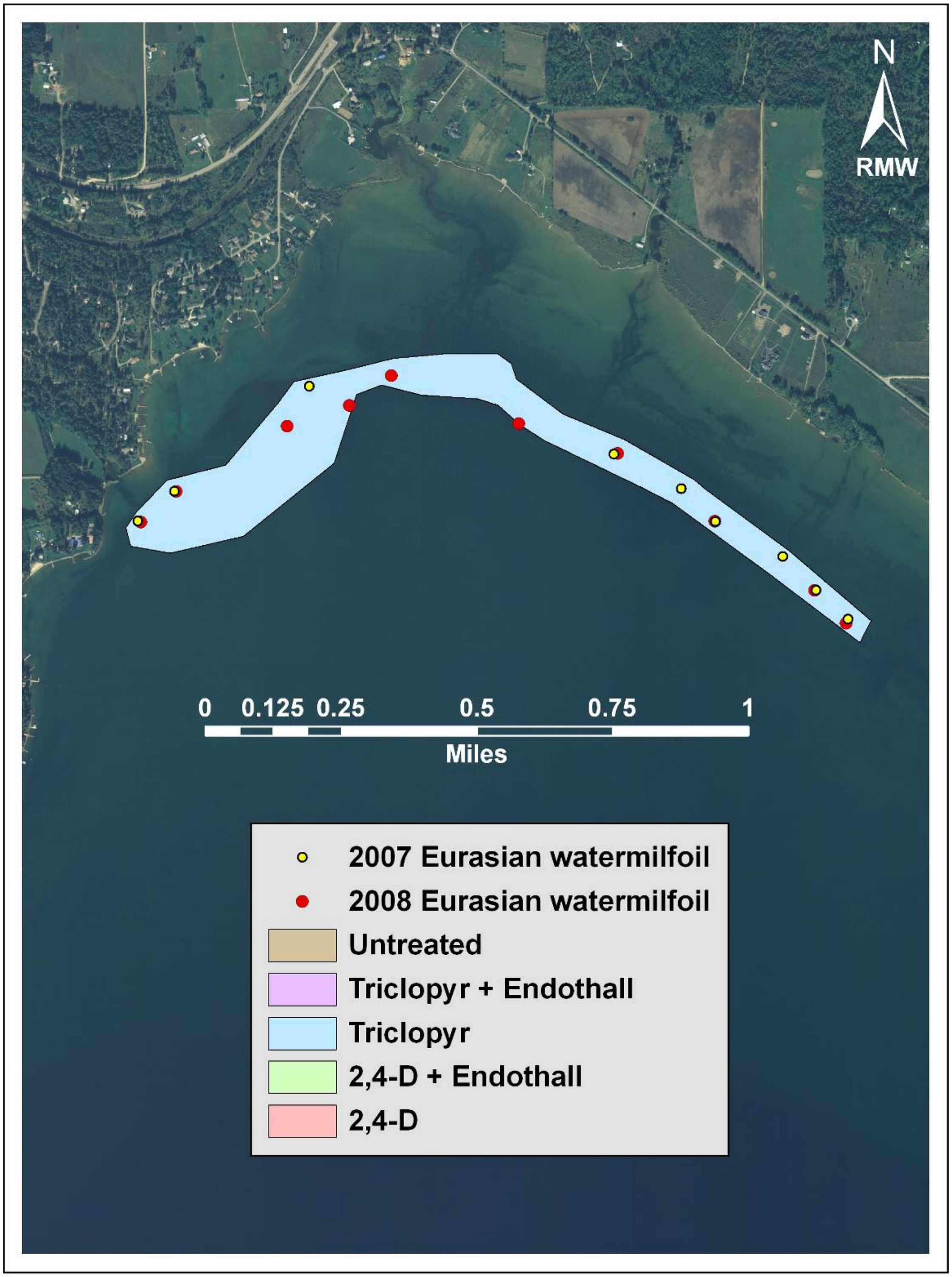

Figure 2.10. The presence of Eurasian watermilfoil in the Oden Bay area, September 2008.

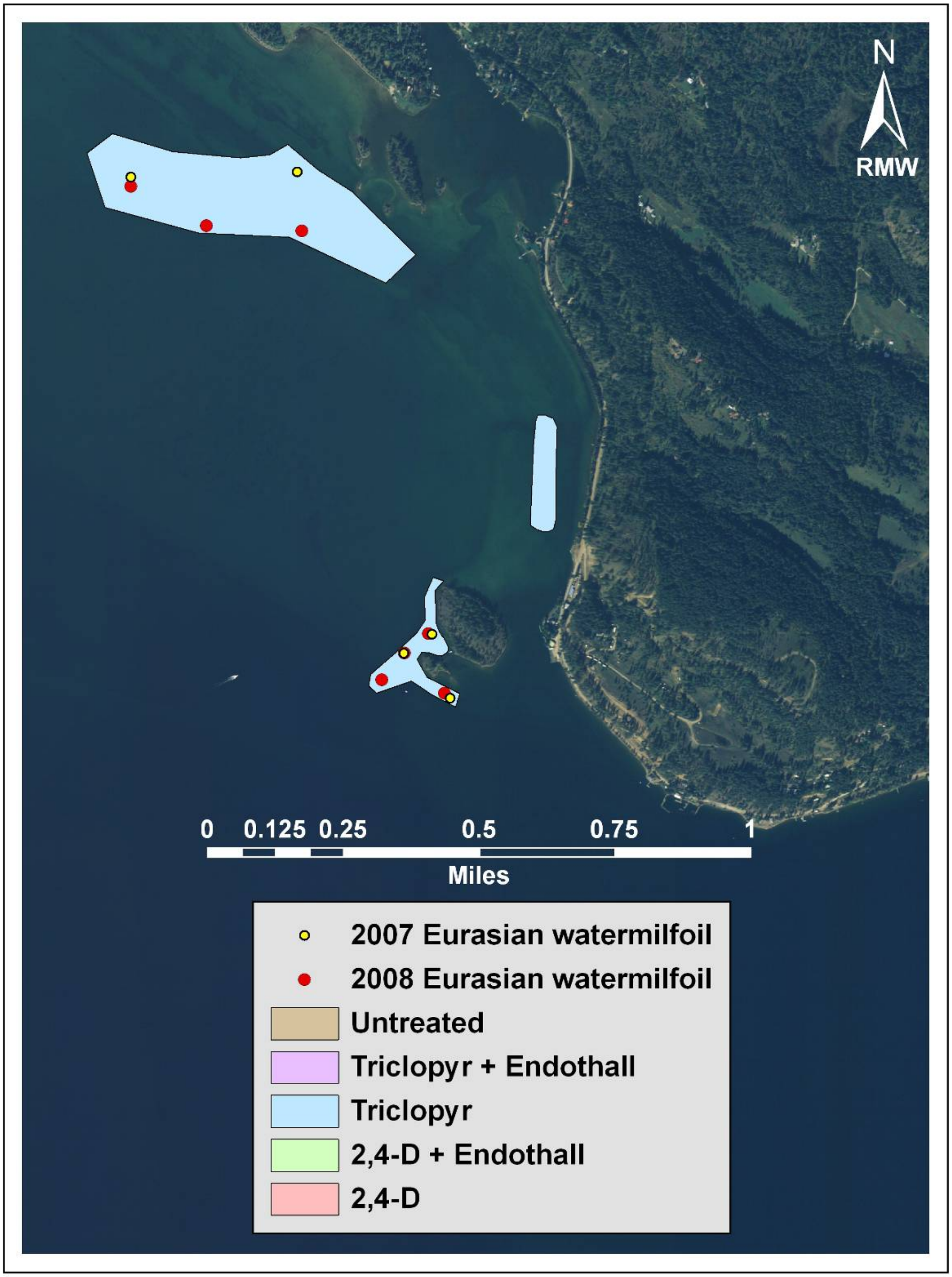

Figure 2.11. The presence of Eurasian watermilfoil in Southeast Oden Bay, September 2008.

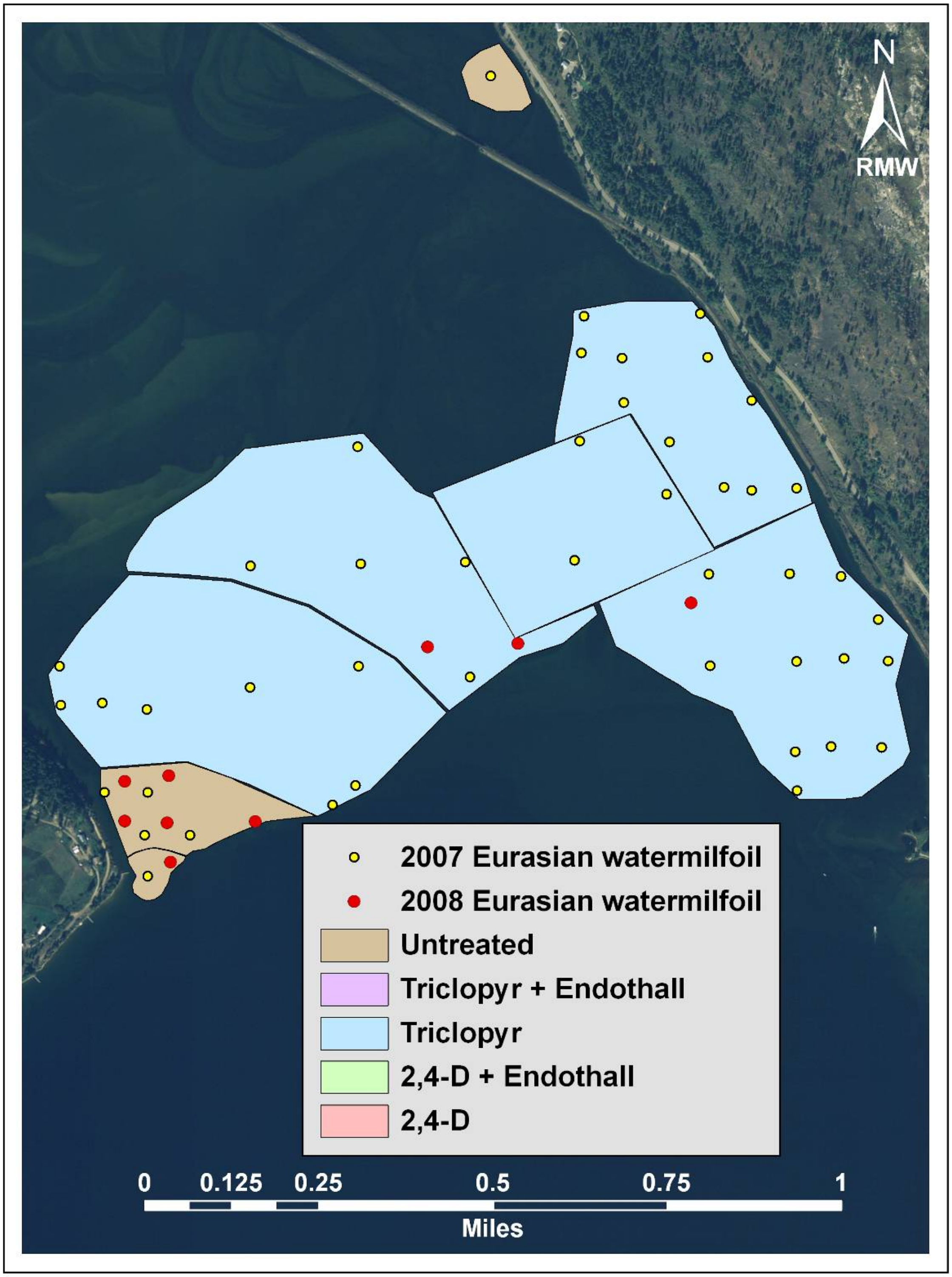

Figure 2.12. The presence of Eurasian watermilfoil in the Pack River area, September 2008.

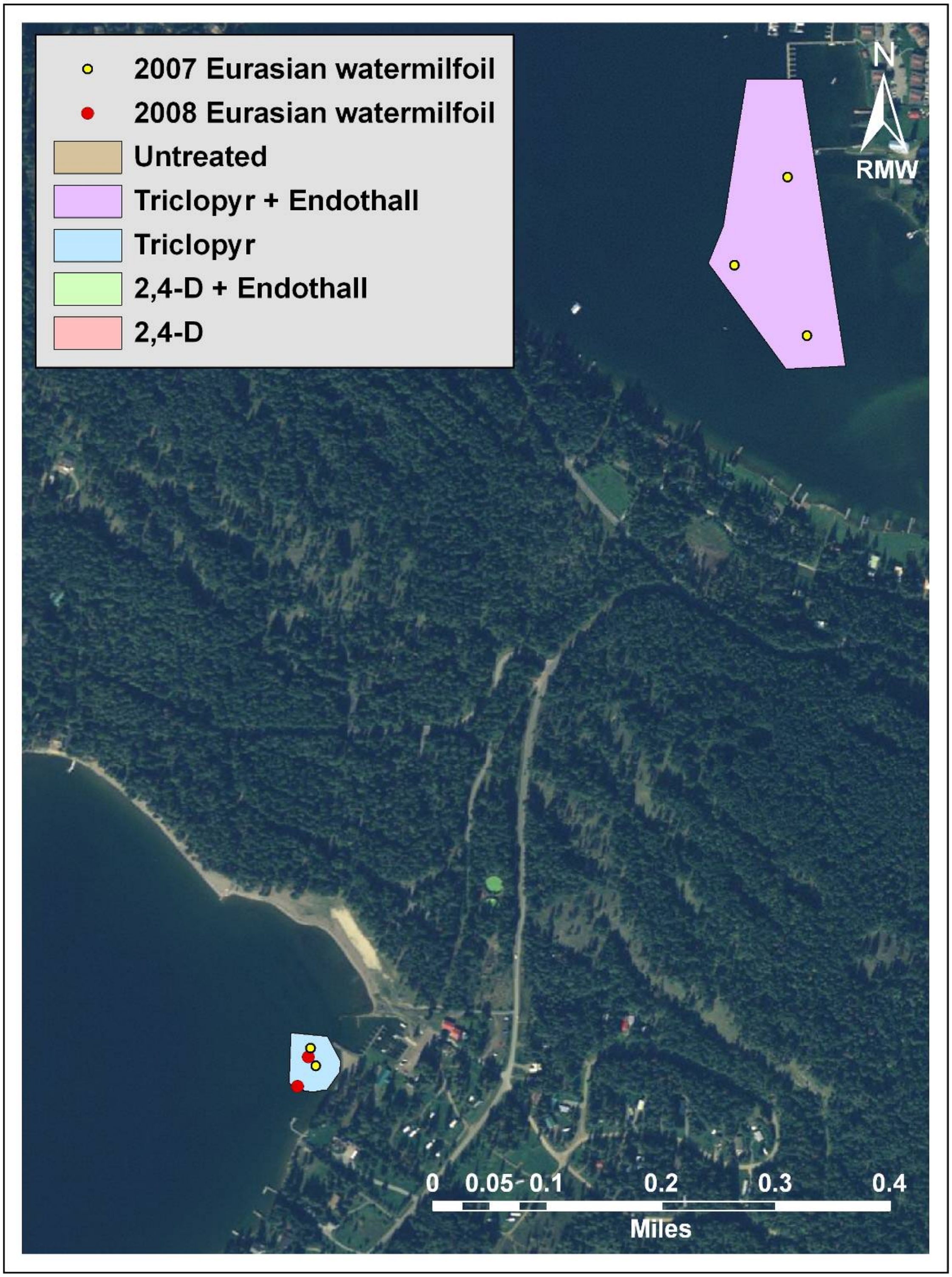

Figure 2.13. The presence of Eurasian watermilfoil in the Hope area, September 2008.

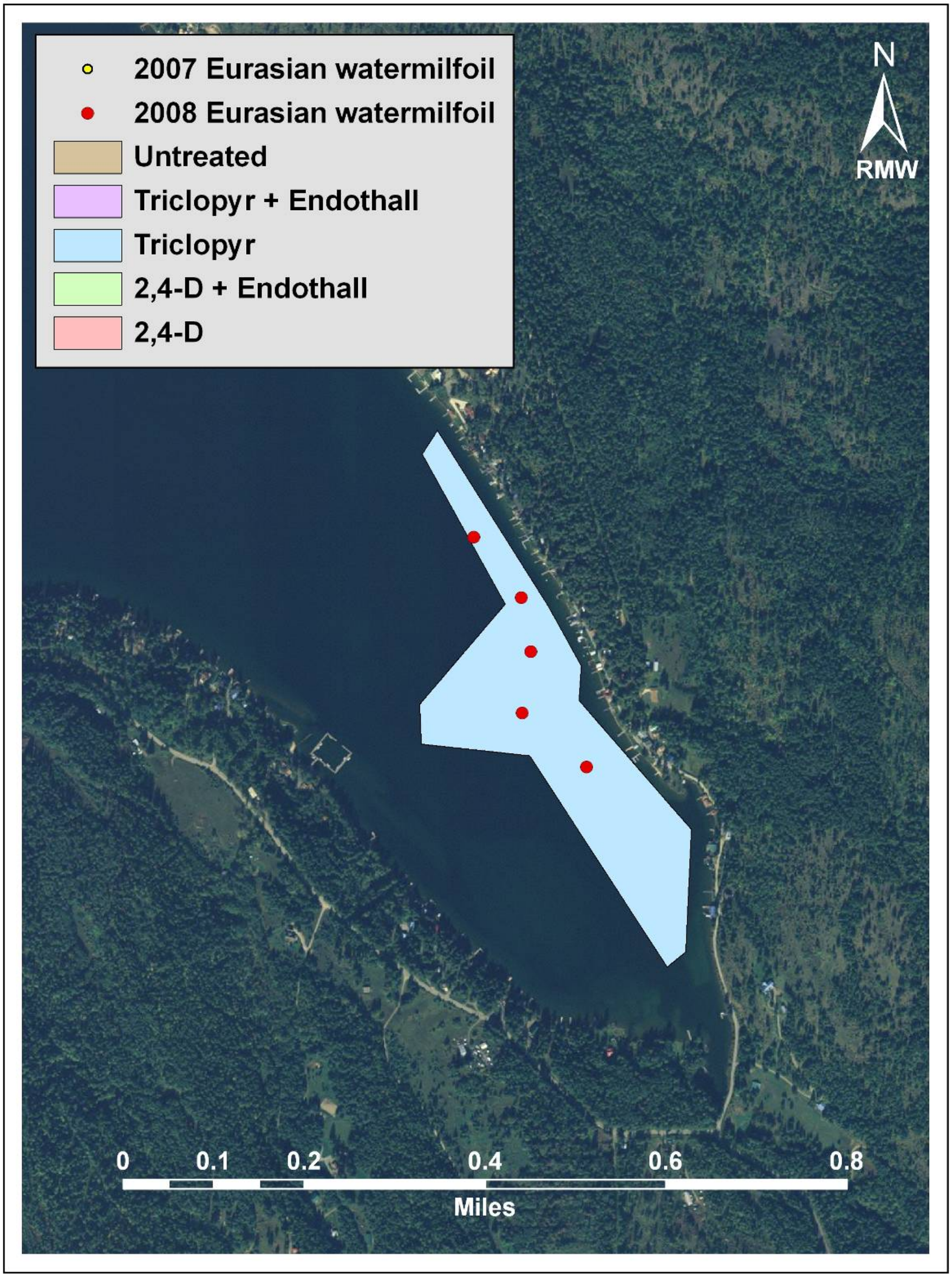

Figure 2.14. The presence of Eurasian watermilfoil in Bottle Bay, September 2008.

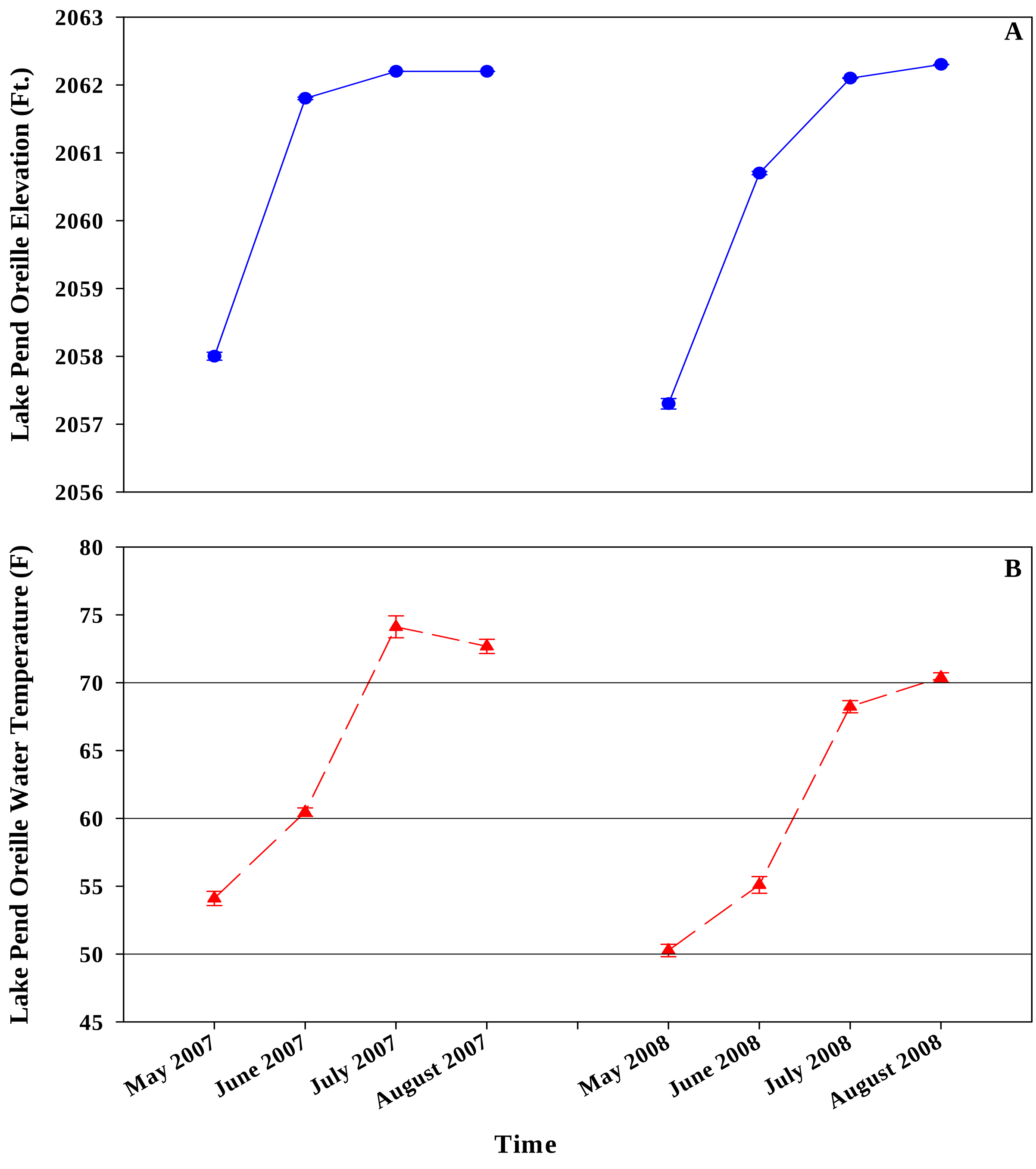

Figure 2.15. Mean lake elevation (± 1 SE) (A) and mean water temperature (± 1 SE) (B) for Lake Pend Oreille form May to August 2007 and 2008. Elevation data were retrieved from the US Army Corp. of Engineers gauge near the Hope Area (48° 15' 0" N 116° 19' 12" W), water temperature data were retrieved from the Albeni Falls Dam (48° 10' 48" N 117° 1' 48" W) gauge.

Chapter 3

One Year Re-assessment of Fluridone-Treated Areas in Lake Pend Oreille

Introduction

The use of fluridone (1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4(1H)-pyridinone) for Eurasian watermilfoil (*Myriophyllum spicatum* L.) control has been examined in other Northern tier lakes with good results (Getsinger et al. 2002, Madsen et al. 2002, Crowell et al. 2006, Valley et al. 2006). Fluridone is classified as a systemic herbicide and some selectivity has been reported if fluridone concentrations remain between 5 to 8 part per billion (ppb), or if native plants produce tubers or turions to recover from the herbicide application (Madsen et al. 2002, Crowell et al. 2006, Pedlow et al. 2006). Fluridone often requires a long contact time with target plants, typically 60 to 90 days has been the recommendation (Netherland et al. 1993). Depending upon the specific site characteristics and concentration used the contact time may be shorter.

In general, previous studies were conducted in smaller, often times shallower lakes that had potentially less water movement. In the case of partial lake or plot treatments, these were typically done in an embayment or other area where water exchange was minimized. Madsen and Wersal (2008) reported no significant reductions in the presence of Eurasian watermilfoil in Lake Pend Oreille, Idaho between a pre and post treatment survey in fluridone treated areas. The authors concluded that the fluridone applications made in Lake Pend Oreille were made in deeper waters with increased water movement and dilution of the herbicide, ultimately resulting in reduced exposure of plants to fluridone. In 2007, fluridone was used near drinking water intakes because it was the only approved herbicide for use in these areas, severely restricting herbicide choice. Drinking water intakes were typically in open areas with either high dissipation or current flow, which likely contributed to the reduced efficacy reported in 2007 (Madsen and Wersal 2008). Eurasian watermilfoil plants treated with fluridone in Lake Pend Oreille did not show fluridone exposure symptoms during the time of the post treatment survey. During the 2007 survey it was also noted that native species were minimally impacted by the fluridone treatments, overall, species richness increased between the pre-treatment and post treatment surveys as well as native plant species biomass.

However, the assessment survey conducted in 2007 was done approximately 4 weeks after herbicide applications, meaning that the majority of fluridone treatments only had 30-35 days contact time (Madsen and Wersal 2008). This time period may have been too soon for an accurate assessment of fluridone efficacy, given some of the deeper areas that were treated. Therefore as part of the 2008 survey we re-visited areas that were treated with fluridone in 2007 and were not re- treated in 2008, to see if in fact control of Eurasian watermilfoil was achieved in the year following treatment. Only areas that were not treated in 2008 were used for analyses.

Objectives

The objective was to conduct a one year after treatment assessment of the fluridone plots that were treated in 2007 to determine if control was achieved in the year following treatment.

The survey will also serve to further understand some site characteristics in Lake Pend Oreille that might contribute to the relative effectiveness of the fluridone treatment.

Materials and Methods

A one year after treatment (YAT) assessment was conducted in 2008 in areas that were treated with fluridone in 2007. The assessment consisted of a point intercept survey following those methods outlined in Madsen and Wersal (2008). Only areas that were not to be treated in 2008 were included in the analyses with the exception of the Pack River Delta. The points that were used for the assessment of the Pack River Delta in 2007 were based upon the 2007 littoral survey, therefore these same points were revisited in 2008 prior to any herbicide applications.

Survey data were pooled according to year and differences in Eurasian watermilfoil presence was determined using McNemar's Test to assess the differences in the correlated proportions within a given data set between variables that are not independent (Stokes et al. 2000, Wersal et al. 2006). Additionally, a pairwise comparison between years was made using the Cochran-Mantel-Haenszel statistic (Stokes et al. 2000, Wersal et al. 2006). Following this analysis, the fluridone sites were divided into "protected" and "unprotected" sites base upon their orientation to the main body of the lake and potential influence of water flow. The only site we considered protected was Cocolalla Creek, all other sites were considered unprotected. A similar analysis was then conducted to determine if the presence of Eurasian watermilfoil changed between 2007 and 2008 in the protected and unprotected sites. All analyses were conducted a $p = 0.05$ level of significance. Analyses and conclusions were made across areas (i.e. protected vs. unprotected) not within specific sites. We did not have sufficient points in each plot to perform a site-by-site statistical analysis.

Results and Discussion

The presence of Eurasian watermilfoil significantly ($p < 0.01$) decreased between 2007 and 2008 when all sites were analyzed together. Eurasian watermilfoil was observed at 40.1% of the sample points during the 2007 assessment. In 2008, Eurasian watermilfoil was found at only 25% of the sample points. This difference is being driven by the effectiveness of fluridone in the protected site (Cocolalla Creek). The presence of Eurasian watermilfoil decreased ($p < 0.01$) from 36.6% (2007) to 2.1% (2008), a 93% reduction in the presence of Eurasian watermilfoil from 2007 to 2008. Conversely, there was no difference ($p = 0.13$) in the presence of Eurasian watermilfoil between 2007 and 2008 in the unprotected sites. Eurasian watermilfoil was observed at 41.6% and 32.8% of sampled points in 2007 and 2008 respectively. The maps indicate where Eurasian watermilfoil was observed for 2007 and 2008 and not the total number of points surveyed in a given area.

Protected Sites

Cocolalla Creek: The presence of Eurasian watermilfoil in Cocolalla Creek is depicted in figure 3.1. There were 22 points that had Eurasian watermilfoil in 2007. In 2008, Eurasian watermilfoil was only found at 1 point. It was unclear if this observation was regrowth, but the point was on the western most portion of the treatment area closest to the inlet from Lake Pend Oreille so it may have been a re-infestation brought in with water movement.

Unprotected Sites

LeClede Area: The presence of Eurasian watermilfoil in the LeClede area is depicted in figure 3.2. Eurasian watermilfoil was found at 18 and 13 sample points in 2007 and 2008 respectively. Some of the Eurasian watermilfoil that was found was in new locations within the treatment area.

Dover Area: The presence of Eurasian watermilfoil in the Dover area is depicted in figure 3.3. Eurasian watermilfoil was found at 4 sample points in both 2007 and 2008, of which some were new locations for 2008.

Oden Bay: The presence of Eurasian watermilfoil in Oden Bay is depicted in figure 3.4. We found Eurasian watermilfoil in the same location both years.

Pack River Delta: The presence of Eurasian watermilfoil in the Pack River Delta is depicted in figure 3.5. In 2007, Eurasian watermilfoil was found at 34 and 28 sample points in 2007 and 2008 respectively. In general, plants were found at the same points in both years.

Based on data from the re-assessment, the use of fluridone resulted in excellent control of Eurasian watermilfoil in Cocolalla Creek. Once Lake Pend Oreille returns to full pool this area generally remains fairly stable with little water flow. Therefore, fluridone treatments in Cocolalla Creek and other areas like it should be efficacious. The other areas that were assessed were along the main channel of the river or in bays of the lake that frequently experience increased water flow or wave action. This would have resulted in herbicide dilution or movement off target resulting in no control of Eurasian watermilfoil.

Conclusion

As with all aquatic herbicides, much of our knowledge on how to use fluridone is built on controlled experiments that then allow us to predict the behavior of the herbicide and treated plants at larger scales. Ultimately, our knowledge of how to use these products is based on trial and error, field demonstrations, and careful monitoring of both herbicide residues and plant responses. Further research on the use of fluridone, and all other approved aquatic herbicides, should examine varying rates, different formulations, plot size, dissipation rate, and movement of the herbicide into sediment pore water. Reporting on both apparent successes and failures will build our knowledge base to improve future management of Eurasian watermilfoil and other invasive aquatic plants.

Literature Cited

Crowell, W.J, N.A. Proulx and C.H. Welling. 2006. Effects of repeated fluridone treatments over nine years to control Eurasian watermilfoil in a mesotrophic lake. Journal of Aquatic Plant Management 44:133-136.

Getsinger, K.D., J.D. Madsen, T.J. Koschnick and M.D. Netherland. 2002. Whole lake fluridone treatments for selective control of Eurasian watermilfoil: I. Application strategy and herbicide residues. Lake and Reservoir Management 18:181-190.

Madsen, J.D., K.D. Getsinger, R.M. Stewart and C.S. Owens. 2002. Whole lake fluridone treatments for selective control of Eurasian watermilfoil: II. Impacts on submersed plant communities. Lake and Reservoir Management 18:191-200.

Madsen, J.D. and R.M. Wersal. 2008. Assessment of Eurasian watermilfoil (*Myriophyllum spicatum* L.) populations in Lake Pend Oreille, Idaho for 2007. GRI #5028, GeoResources Institute, Mississippi State University.

Netherland, M.D., K.D. Getsinger and E.G. Turner. 1993. Fluridone concentrations and exposure time requirements for control of Eurasian watermilfoil and hydrilla. Journal of Aquatic Plant Management 31:189-194.

Pedlow, C.L., E.D. Dibble and K.D. Getsinger. 2006. Littoral habitat heterogeneity and shifts in plant composition relative to a fall whole-lake fluridone application in Perch Lake, Michigan. Journal of Aquatic Plant Management 44:26-31.

Stokes, M. E., C. S. Davis, and G. G. Koch. 2000. Categorical Data Analysis Using the SAS® System, second edition. SAS Institute Inc., Cary, NC, USA.

Valley, R.D., W.J. Crowell, C.H. Welling and N.A. Proulx. 2006. Effects of a low dose fluridone treatment on submersed aquatic vegetation in a eutrophic Minnesota lake dominated by Eurasian watermilfoil and coontail. Journal of Aquatic Plant Management 44:19-25.

Wersal, R.M., J.D. Madsen, B.R. McMillan, and P.D. Gerard. 2006. Environmental factors affecting the biomass and distribution of *Stuckenia pectinata* in the Heron Lake System, Jackson County, Minnesota, USA. *Wetlands* 26: 313-321.

[GRI reports are available at the GRI Website: http//www.gri.msstate.edu, under the Resources tab]

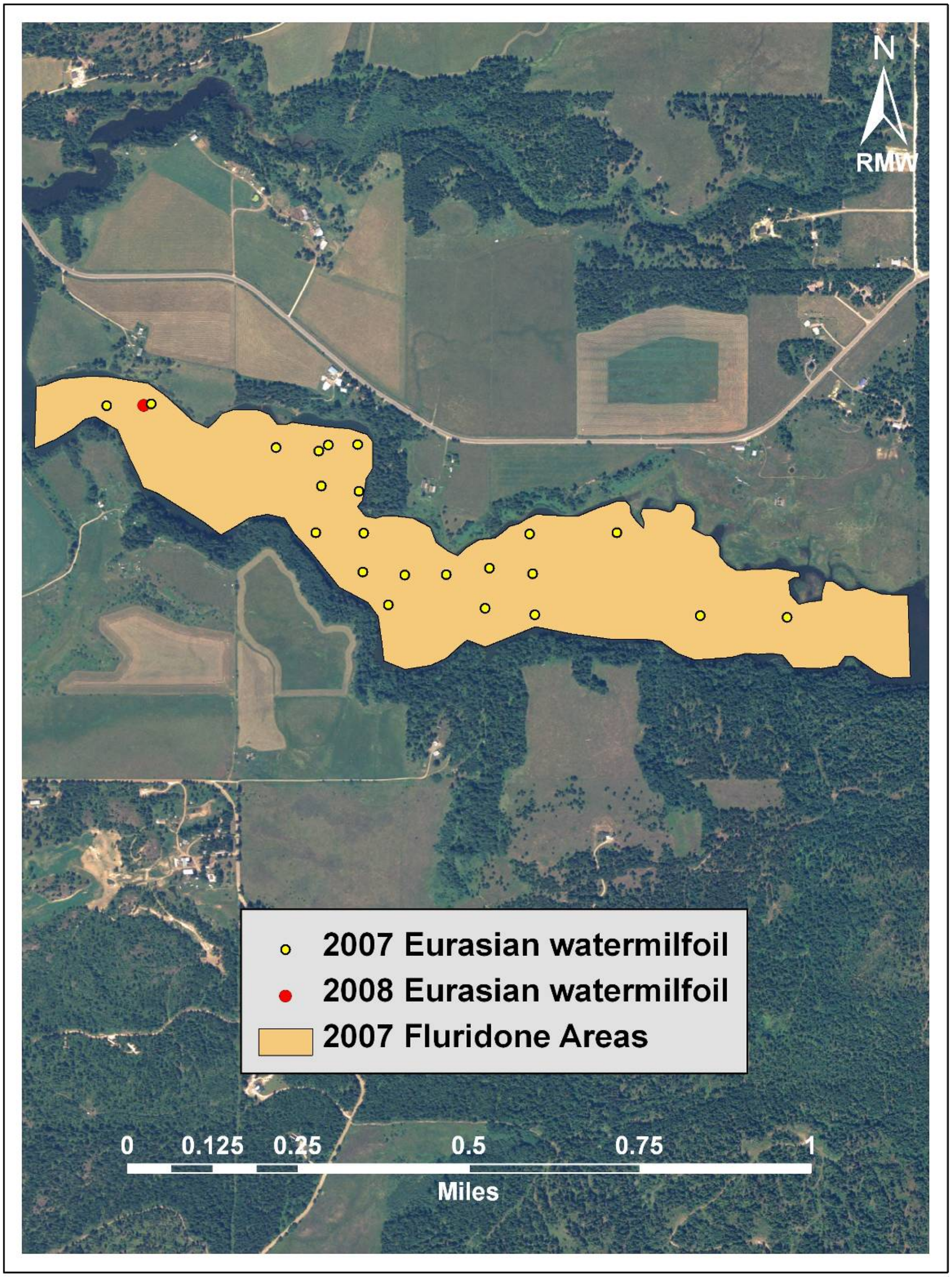

Figure 3.1. The presence of Eurasian watermilfoil in Cocolalla Creek from 2007 to 2008.

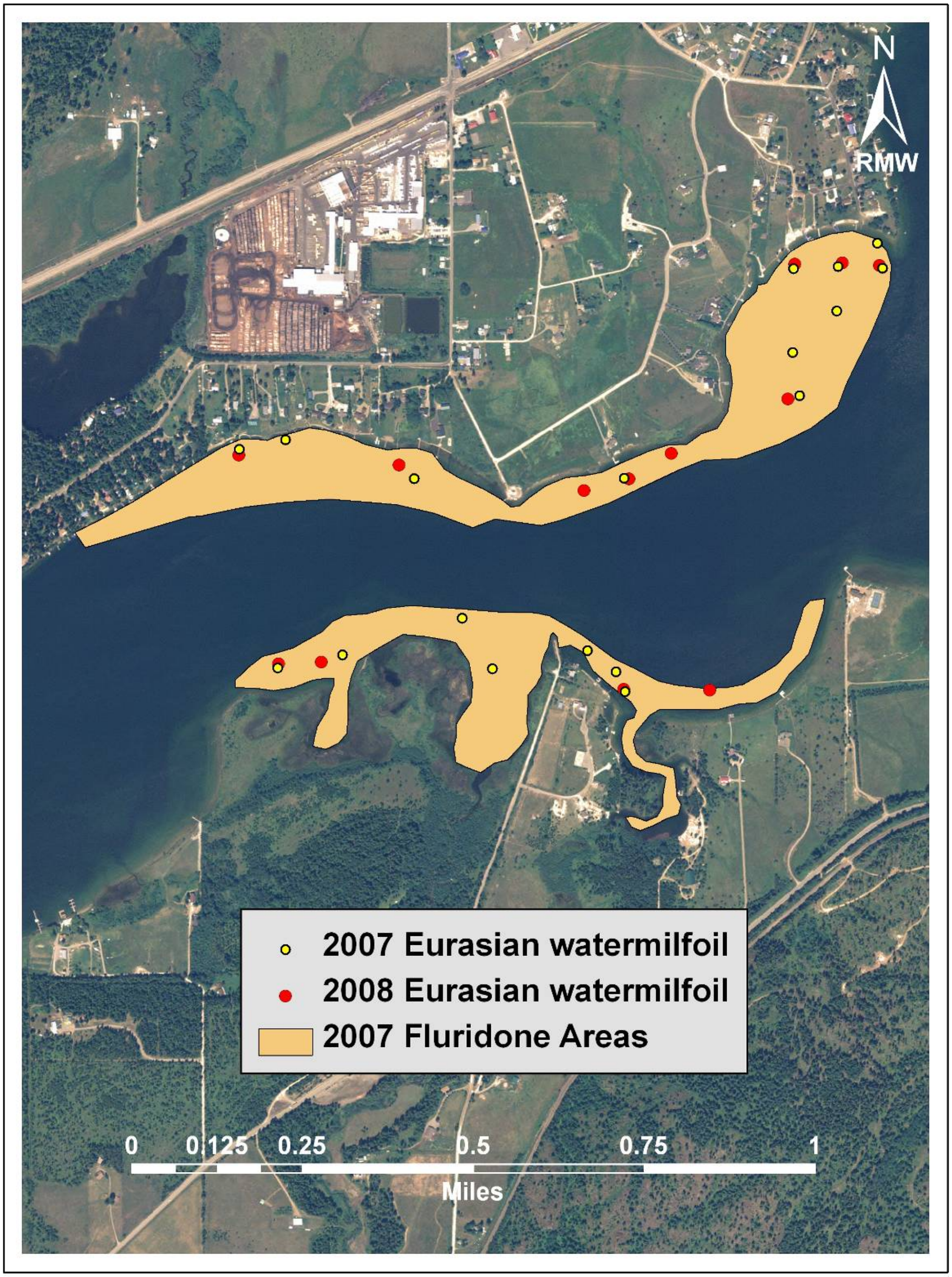

Figure 3.2. The presence of Eurasian watermilfoil in the LeClede area from 2007 to 2008.

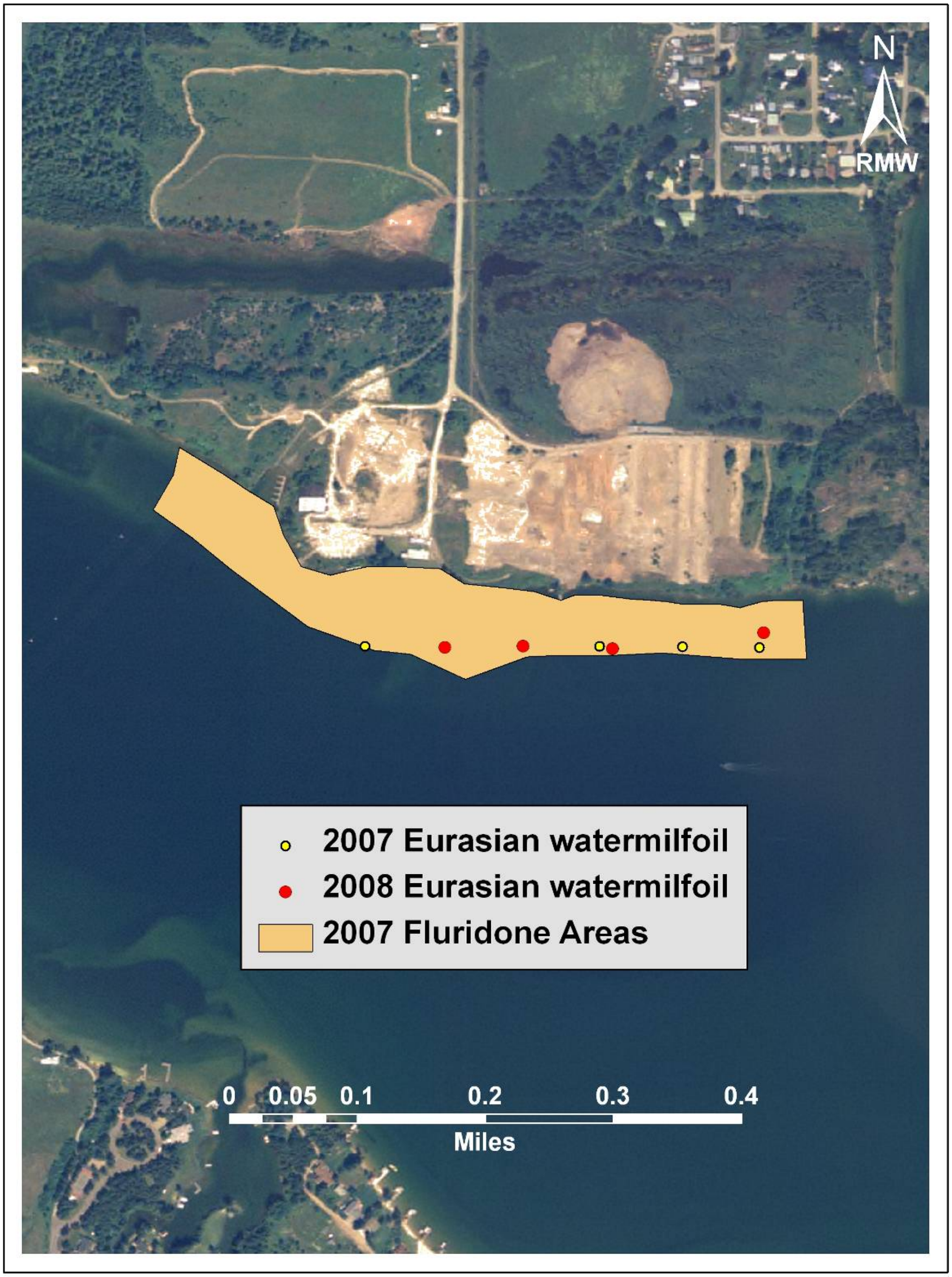

Figure 3.3. The presence of Eurasian watermilfoil in the Dover area from 2007 to 2008.

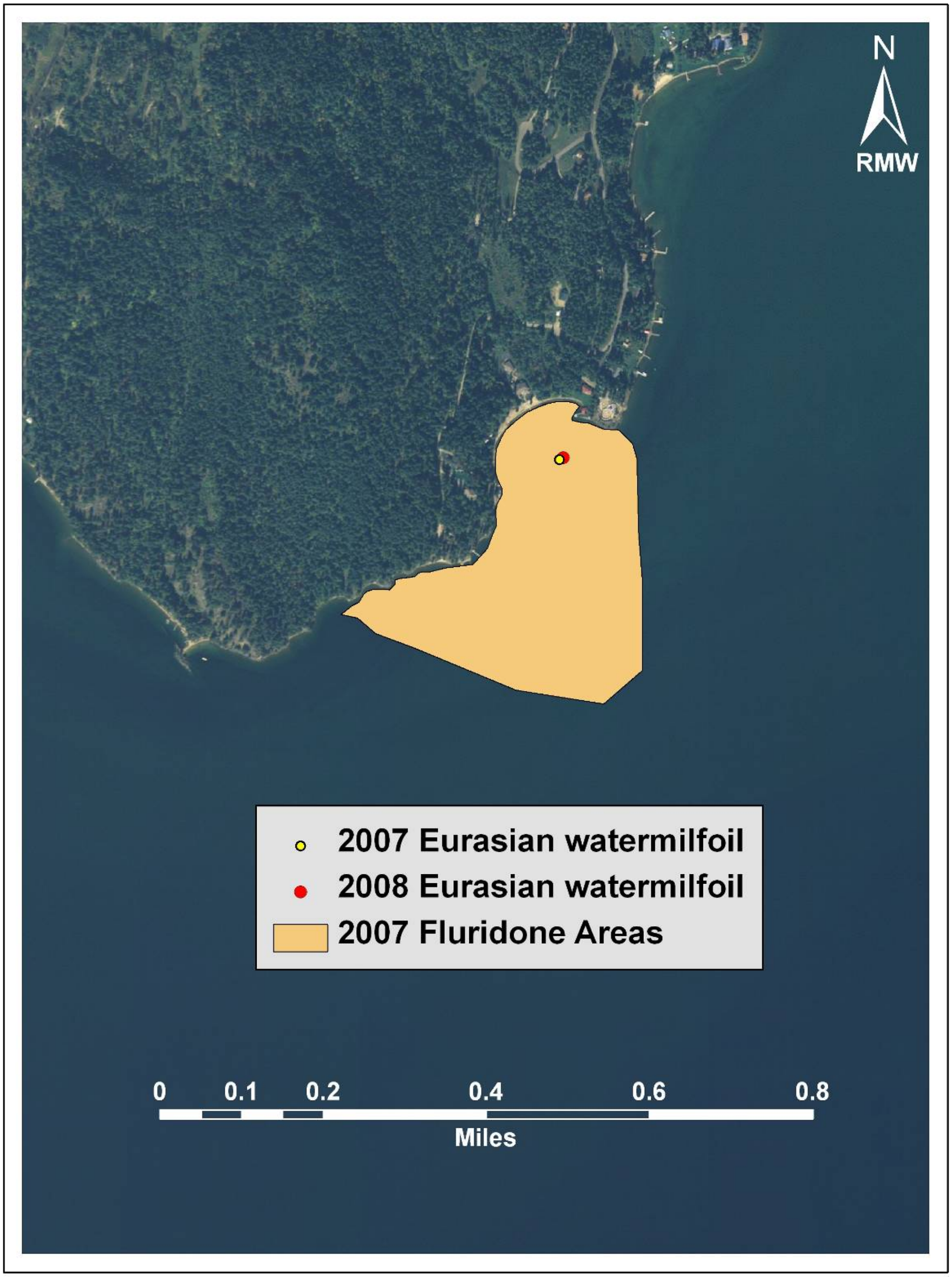

Figure 3.4. The presence of Eurasian watermilfoil in Oden Bay from 2008 to 2008

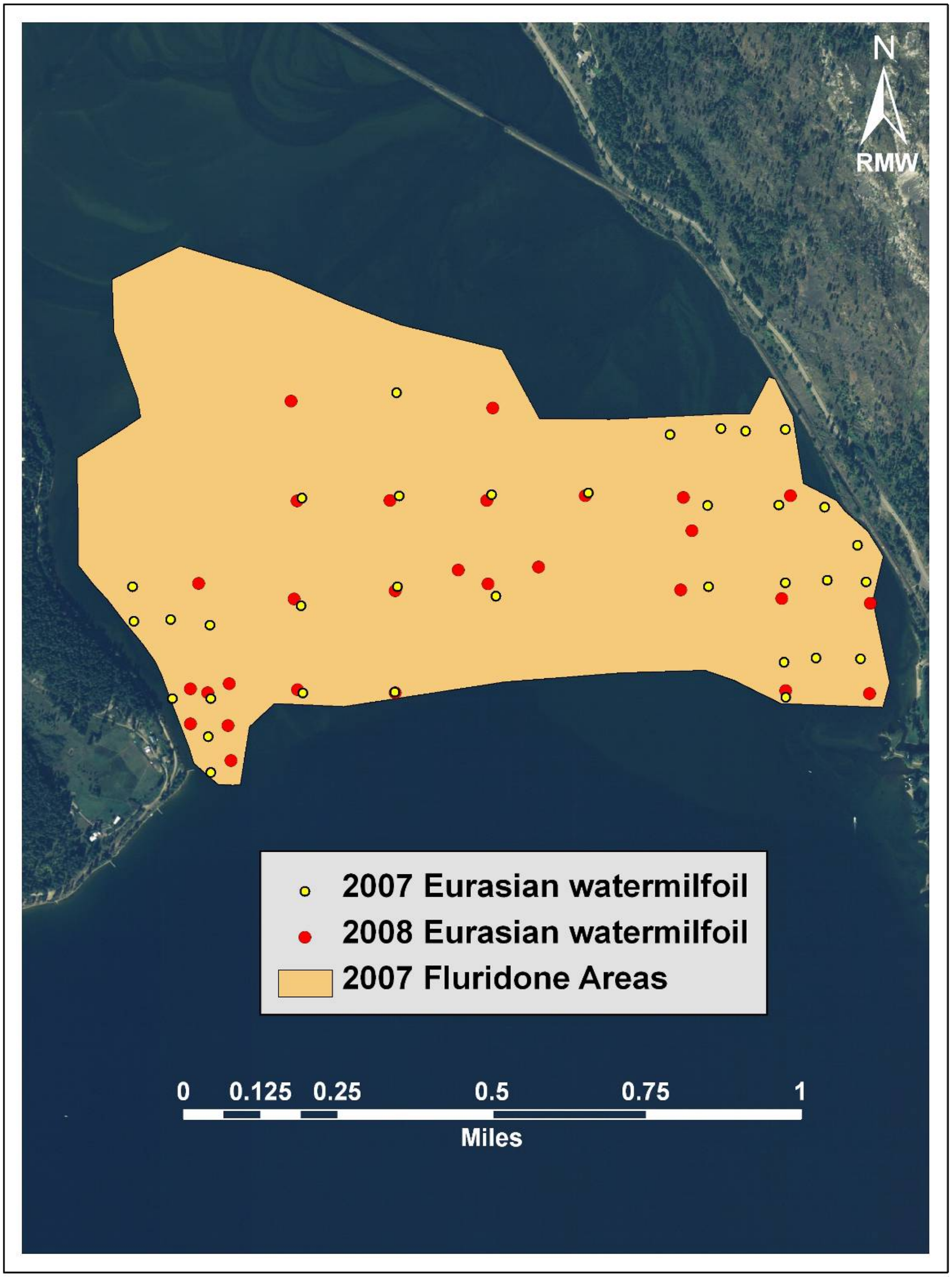

Figure 3.5. The presence of Eurasian watermilfoil in the Pack River Delta from 2007 to 2008.

Chapter 4

Conclusions

- Similar to the 2007 littoral zone surveys, the 2008 survey found a species-rich lake system. There does appear to be a shift from early to late season species as well as a changing plant community from mud flat annuals in shallow area early in the spring to submersed species when the lake returns to full pool.

- The native aquatic plant community has remained fairly stable from 2007 to 2008 despite herbicide applications.

- The removal of Eurasian watermilfoil to promote dense native plant growth may in fact aid in resisting future re-infestation.

- Overall, the herbicide applications that were evaluated were effective in controlling Eurasian watermilfoil, with the exception of 2,4-D alone. Eurasian watermilfoil was reduced by 63% at sites treated before September 2008.

- Since the majority of 2,4-D was applied after the assessment survey (late September and October) there were few areas to evaluate. The areas that were evaluated were largely unprotected sites in the river. These areas were likely subject to increased flow and therefore adequate exposure time was not achieved, therefore, it was probably not an accurate assessment of 2,4-D efficacy.

- The combination of 2,4-D and endothall resulted in significant control of Eurasian watermilfoil. The addition of a contact herbicide may have resulted in non-target injury to some of the native watermilfoils and coontail. However, other studies have documented that this injury is transient and species recover and growth increases in the absent of Eurasian watermilfoil.

- Similar to the 2007 applications, the use of triclopyr resulted in excellent control of Eurasian watermilfoil. There were reductions in the presence of whorled watermilfoil and white water-buttercup in the sites evaluated.

- The combination of triclopyr and endothall initially looks very promising. However there were a very limited number of sites where this combination was utilized, which reduced the ability to accurately assess this treatment.

- The combination treatments may be a good choice in areas of the river or high water flow to reduce the contact time needed for acceptable control.

- Overall, the use of herbicides was more effective than not treating the Eurasian watermilfoil. Based on our analyses the presence of Eurasian watermilfoil was more detrimental to the native plant community than the herbicide treatments.

- There was likely some site-specific injury to native plants, however environmental factors can also cause reductions in plant growth. The water temperature in 2008 was on average 5° colder than in 2008. The colder temperatures, especially in the early part of the growing season, can impede or limit the growth of aquatic plants.

- In general, the population and community dynamics of submersed aquatic plants is unclear. This is especially the case in a system as large as Lake Pend Oreille, but the native plant community is responding well to the herbicide applications based on the 2007 and 2008 surveys.

- Fluridone treatments in Cocolalla Creek were very effective in controlling Eurasian watermilfoil as indicated by a 1 YAT survey. This area is protected and therefore adequate contact and exposure was likely achieved. Apparent control was greater 1 YAT than we observed during the year of treatment.

- The other fluridone sites surveyed from treatments that were done in 2007 were in unprotected areas and control of Eurasian watermilfoil was not achieved; results achieved 1 YAT were no better than those observed during the year of treatment.

- The effectiveness of fluridone on Eurasian watermilfoil is fairly well documented in the scientific literature. The use of fluridone in Lake Pend Oreille should be reconsidered in areas that would permit adequate contact time. If there are questions regarding contact time then dye studies should be conducted prior to herbicide applications, and evaluation of different use-patterns may be assessed to optimize efficacy.

- While we believe that surveys targeted to assess the effectiveness of herbicide treatments are indispensible in evaluating management efforts, we recognize that it is difficult at best to apply a single monitoring technique and timing to different herbicides applied at different times. During 2008, fully half of the treatments were done after our posttreatment assessment. We encourage follow-on assessments of these treatments during 2009. Data interpretation should consider not only the time of treatment, but the response time of the target plant to each individual herbicide applied. The full plant response may not be seen until the following season. That being said, consistent evaluation properly and conservatively interpreted will provide a guide for which treatments are effective, and which are not.

- We encourage the continued monitoring of plant populations and assessment of all management techniques utilizing independent third parties, whether that be a state or county agency, university, or consultants.