Paradise Lake Management Plan

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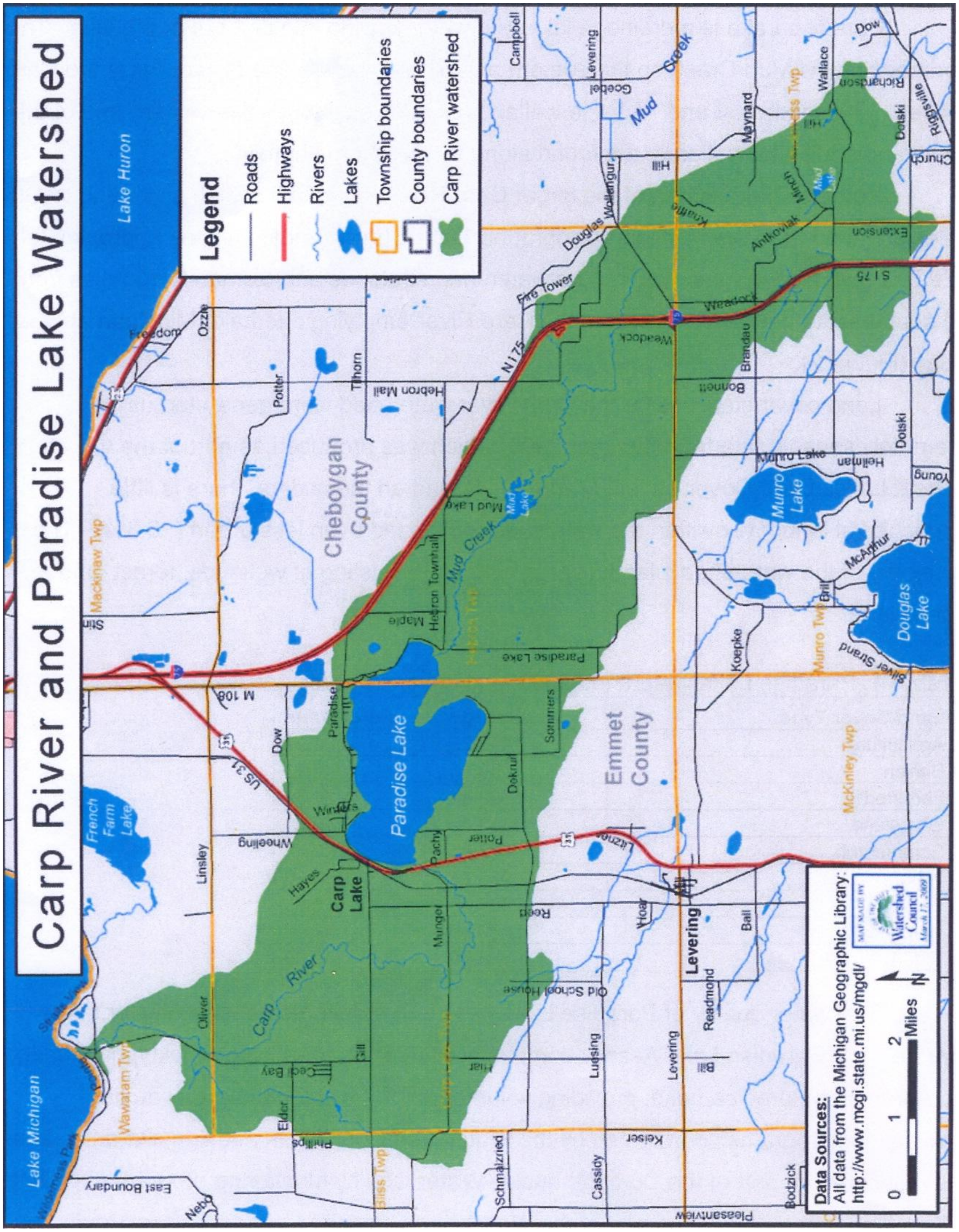

Figure 1: Map of Carp River Watershed courtesy of Tip of the Mitt Watershed Council.

INTRODUCTION

Paradise Lake in Northern Michigan is a mesotrophic lake currently faced with three major threats to the intended recreational use and health of the lake. These threats are unusual nutrient levels as well as the invasion of Eurasian watermilfoil and zebra mussels. This management plan is a dynamic 10-20 year guideline for managing these threats and maintaining the ecological integrity of Paradise Lake.

Hydrology

Paradise Lake is a part of the Carp River watershed and is a relatively shallow lake—a majority of the lake area is less than 3 meters deep—reaching a maximum depth around 5 meters. As a drainage lake, water from Mud Creek and Carp Lake River flows in and out of the lake, respectively. The discharge of water entering Paradise Lake from Mud Creek was 0.18 meters/second (as calculated in late July of 2009). The outflow, through the Carp Lake River, was 0.05 meters/second (again, taken in late July of 2009). Given these levels of inflow and outflow together with the estimated volume of water in the lake, retention time was calculated to be 110 years. This is a common retention time for the size of Paradise Lake in Northern Michigan. Other lakes in Northern Michigan of similar size display approximately the same retention time with Burt Lake having a retention time of 80 years and Douglas Lake of 90 years.

Categorized as a mesotrophic lake, Paradise Lake has a moderate level of productivity. The productivity of the lake occurs in both a large population of aquatic plants as well as a population of algae in the water column. This abundance of aquatic plants is due to the shallow nature of the lake which allows for light penetration to the benthos. This in-lake productivity serves as an important food source for organisms as well as nursery habitat for the local fish population.

Sample Site	Nitrate (µg/L)	Ammonia (µg/L)	Phosphate (µg/L)	Total Nitrogen (mg/L)	Total Phosphorus (µg/L)	Chloride (mg/L)
1	0.8	12.7	2.6	0.704	29.6	12.3
2	2.9	64.3	1.7	1.021	61.4	12.3
3	0.8	5.7	ND	0.861	98.7	12.6
4	1.1	16.6	4	0.493	29.6	12.6

Table 1: Paradise Lake nutrient sample results from July 2009. Nitrogen and phosphorus levels are consistent with data from surrounding watersheds. Chloride levels show continued elevation.

Watershed Uses

The Paradise Lake watershed is predominantly undeveloped forest, wetland, and grassland, with developed land use making up approximately ten percent of the current land use in the entire watershed (See Table 1). Paradise Lake is classified by the DNR as an all-purpose recreational lake, which includes boating, water sports, and fishing.

Land Cover Type	Acreage	Percentage
Agriculture	2446.29	8.27
Barren	39.15	0.13
Forested	6329.48	21.39

Grassland	3153.35	10.66
Scrub/shrub	627.01	2.12
Urban	975.35	3.30
Water	2057.48	6.95
Wetlands	13960.19	47.18
Total	29588.29	100.00

Table 2: Paradise Lake watershed 2000 land cover statistics from Tip of the Mitt Watershed Council. The vast majority of land use in the Carp River Watershed is undeveloped, leading to relatively natural lake conditions.

Threats

Nutrients

Appropriate levels of nutrients like phosphorous and nitrogen are essential for a healthy, functioning lake ecosystem. These nutrients are the basis for primary productivity within the aquatic habitat. Problematic changes in ecosystem function can arise, however, when the ratios of the concentration of these nutrients are change within the water body. In many lake systems, one of these two nutrients is limiting or controlling primary productivity and in Northern Michigan ecosystems, the limiting nutrient is often phosphorous. In essence, this means that the amount of production by primary producers is dependent on the amount of phosphorous present in the lake. High ammonia and phosphorus levels strongly indicate an anthropogenic source for the increase in productivity, namely aquatic plant growth, which is a major concern to boaters and swimmers who routinely use Paradise Lake for recreation and for homeowners who call the lake home for part or all of the year. If primary productivity increases without being checked, the lake system can become eutrophic (ultraproductive) which could lead to the lake becoming anoxic which would cause fish kill. Most of the phosphorous in Paradise Lake enters from a terrestrial source, i.e., old septic systems, fertilizers, or even from pet waste. Because of phosphorus mainly enters aquatic ecosystems through a terrestrial source, phosphorous levels in Paradise Lake have the ability to be controlled. Solutions to potential increases in phosphorus include replacing old septic systems, planting/letting grow a greenbelt close to the shore, creating a roadside rain garden, or limiting fertilizer use.

Unlike phosphorous, most of the nitrogen in lakes enters the aquatic ecosystem through atmospheric processes. However, nitrogen input can also be augmented through groundwater inputs and storm water runoff. Conveniently, many of the same preventative strategies for limiting and controlling phosphorous work just as well for limiting and controlling nitrogen input.

Chloride is a naturally occurring ion present in low concentrations throughout bodies of water in Northern Michigan due to the geology of the area. Water erodes limestone, which releases the chloride ions into the water. However, unnatural increases in chloride can occur through leaky septic systems, increased use of road deicers, and agriculture uses of salted organic compounds. Chloride is an important ion to monitor within aquatic ecosystems due to the direct connection with human impacts on aquatic ecosystems. An important difference between nutrients, such as phosphorous and nitrogen, and chloride is that nitrogen and phosphorus are naturally cycled within the aquatic ecosystem such that the compounds change their structure as the biology uses different forms of these nutrients. In addition, nitrogen and phosphorus can cycle out of an aquatic ecosystem through natural processes. Chloride is not cycled within or outside of the ecosystem, but stays within the ecosystem once its enters. As a result of this difference, over time, unless there is treatment, chloride levels will increase.

Plants

Eurasian watermilfoil, *Myriophyllum spicatum* L., exists on every continent except Antarctica, and is native to Europe, Asia, and Northern Africa. Milfoil is a submersed, perennial aquatic herb that typically grows where water is one to four meters deep but is found in water up to10 m in depth. Watermilfoil obtains most of its nutrients from the sediment through an adventitious root system. Reproduction is both sexual and asexual, but dispersal occurs primarily by fragments. Milfoil fragments are created both by auto-fragmentation after flowering, and by disturbances such as water turbulence and human activities. Interlake fragment transport may be caused by several dispersal mechanisms, including wind, waterfowl, water flow between connected water bodies, and human-related activities. Motorboats and boat trailers, however, are the dispersal mechanisms most often cited for inter-lake transport of milfoil fragments (Buchan and Padilla, 2000).

Invasive zoology

Zebra mussels are a freshwater mollusk originating from the Caspian Sea. They first appeared in the Great Lakes area in the 1980s. Larval zebra mussels are microscopic and free-floating, making them easily transportable. Adult zebra mussels usually range in length from 0.5 cm to 3.5 cm and have a lifespan of 3 to 5 years. They prefer habitats where summer temperatures are between 10 and 25°C with a salinity less than 4 parts per thousand and pH values between 7.9 and 9.0. Natural predators of the zebra mussel include lake sturgeon, yellow perch, freshwater drum, catfish, and sunfish, as well as diving ducks. Zebra mussels are detrimental to existing habitats because they filter feed particles, filtering a quart of water a day, and directly competing for food with some species of fish, thereby altering the food web interactions. Mussels attach to substrates using tough byssal threads, fouling intake pipes and boat motors.

Management Plan Goals

Problem	Goal
Nutrient levels	To maintain current levels of nitrogen, phosphorus, and chloride; stop nutrient increase from anthropogenic sources
Eurasian watermilfoil	To reduce and maintain populations of watermilfoil at low levels that do not impede recreational use of the lake while preserving the natural plant biomass
Zebra mussels	To control population growth and prevent mass colonization by adults

Table 3: Goals of the Paradise Lake Management Plan.

Nutrients

Nitrogen and Phosphorus

In lakes, anthropogenic influx of nitrogen and phosphorous leads to a primary productivity blooms, which are defined by an increase algae and more aquatic plants. Excessive algal blooms that result from an excess nutrient load can lead to eutrophication and ultimately, potential anoxia within a lake. If the algae blooms are consistently large, a long term detriment to the lake ecosystem can occur with the loss of native benthic primary productivity and loss of native fish populations.

Human habitation around ecosystems has the potential to induce an increase in nutrient inputs into the aquatic ecosystem through increased levels of sewage, refuse, fertilized agriculture, and deforestation. This accelerated rate of primary productivity associated with increased urbanization of land use leads to eutrophication.

Much of the data on nitrogen is found in its reduced form, ammonia. This may be attributed to either anthropogenic influx through fertilizer or the high productivity of primary producers including algae and aquatic plants. Phosphate makes up only a fraction of total phosphorus, suggesting a higher frequency of dissolved and particulate organic phosphorus. This may be due, again, to anthropogenic forces (fertilizer) or to the accumulation of detritus. Compared to the nearby Maple River Watershed, these levels of nitrogen and phosphorus are within a normal range for the hydrology of the area. Though these levels are not currently a concern, should some of the undeveloped land become developed, there may be an influx of nitrogen and phosphorus into the system. Because of this possibility, it is advisable to put in place control measures in order to capture the nutrients before they reach the water.

Establishment of a perimeter around the lake where growth of plants and trees is allowed to progress without major interference allows for the uptake of nutrients before they are washed into the lake. Independent initiation on the part of homeowners or the establishment of an easement could both promote the greenbelt. This solution is free of cost.

Decreasing runoff to the bodies of water could also decrease the influx of nutrients. A rain garden is a roadside depression that traps water and allows it to percolate through the soil. Implementation is troublesome due to the location of the rain gardens falling in state jurisdiction, and high start-up costs are associated with this solution.

Possibly the most effective method for reducing the total nitrogen and phosphorus being brought into the system is to reduce widespread fertilizer use. This solution is also free of cost.

Treatment	Advantages	Disadvantages
Greenbelt	Low cost, natural	Inconvenience, aesthetic concerns, effectiveness
Rain Garden	Natural, decreases runoff	Aesthetic concerns, jurisdiction, effectiveness, mosquitoes
Decreased Fertilizer Use	Halting addition of nutrients to the system	Aesthetic concerns

Table 4: Possible solutions for controlling nutrients in Paradise Lake.

Chloride

The chloride levels present in Paradise Lake had remained fairly constant until the year 2000, and in the past nine years, levels of chloride have nearly doubled. A rise of this magnitude is a potential cause for concern given the long retention time for Paradise Lake. In addition, since chloride is not cycled through the ecosystem, chloride will remain in the lake ecosystem until it is removed either through sedimentation out of the water column or through human intervention.

The EPA Secondary Drinking Water Regulations advocate a maximum chloride concentration of no more than 250 mg/L. Though current Paradise Lake levels are not approaching this level, the unknown reason for the increase in chloride makes future predictions of lake water levels nearly impossible. At high concentrations, chloride can bond readily with compounds present in decaying material and may form carcinogenic materials (need reference for this statement).

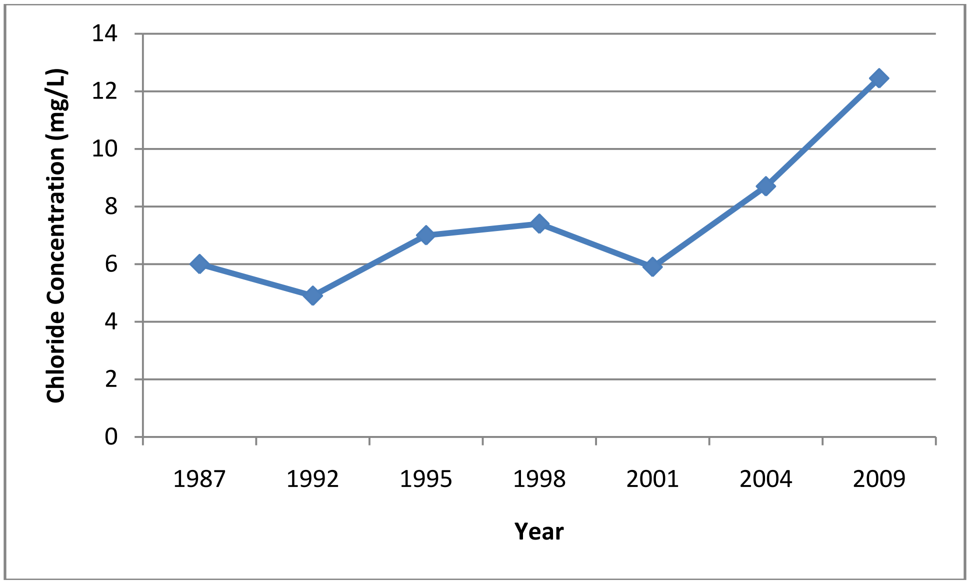

Figure 2: Chloride concentrations in Paradise Lake, Michigan. The levels of chloride ions present in the water column have nearly doubled in the last nine years.

Potential sources of chloride contamination within Paradise Lake may include leaky septic systems. Although we could not determine a point source for chloride during our sampling intervals, it is possible that due to the seasonal nature of the community of Paradise Lake, there is a possible influx of chloride during the summer months due to more heavy septic use. Michigan is one of the few states that does not currently have a state-wide regulation of septic systems. Currently, the Department of Environmental Quality is considering ameliorating the problem by instating further regulation.

Another possible source of chloride influx into the lake is the nearby presence of two major highways, US-31 and I-75, cutting through the Carp River Watershed. The use of road salt to make the roadways navigable may contribute to the influx of chloride. Groundwater recharge of watershed levels occurs in early spring when the previous winter's precipitation melts. If there is significant use of road salt in a previous winter, then there may be additional spikes in the chloride concentration for lake water..

The solutions for the reducing the growth of chloride in the lake ecosystem vary. The suggested first step is determining the exact causes for the chloride influx. In a survey of the salinity around the perimeter of the lake, no definite spikes in chloride concentration were observed. If, in early spring during the snow melt, increases in salinity occur mainly near culverts, it can be deduced that road salt contributes a large amount of chloride ions per year. If this is the case, writing to the Emmet County and Cheboygan County Road Commissions may prove effective in reducing the amount of salts used or possibly switching instead to sand or gravel application.

Treatment	Advantages	Disadvantages
Septic Review	Stop further watershed detriment	Cost, invasiveness
Decreased Deicer Use	Prevent further addition of nutrients	Effectiveness of alternatives

Table 5: Possible solutions for controlling chloride concentrations in Paradise Lake.

EURASIAN WATERMILFOIL

The geography of Paradise Lake makes it an ideal ecosystem for the invasion and growth of Eurasian watermilfoil. Paradise Lake is a very large, shallow lake with a maximum depth of 5.2 meters (17 feet). Large portions of the lake are very shallow resulting in vast areas where plants can grow easily (Kevern, et al 1989). The Eurasian watermilfoil has been identified as a problem and has been treated as such in Paradise Lake from 1998.

There are many different options for managing aquatic macrophytes. Madsen (2000) places them into three major categories, which are; biological management, chemical management and mechanical/physical management techniques.

Previously, Paradise Lake has chosen weevils as a biological control agent for the Eurasian watermilfoil. In 1998, approximately 10,000 weevils were placed in Paradise Lake. Five thousand weevils were placed in the lake in 1999. Members of the Paradise Lake Association report that the density of the Eurasian watermilfoil decreases after these applications of the weevil. According to members of the lake association, the density of the population appeared to be reduced until a resurgence of the macrophyte was noted in 2005. A new shipment of 17,000 weevils was applied to patches throughout Paradise Lake in late summer 2009.

The use of *E. lecontei* appears to be a viable option for the management of Eurasian watermilfoil in Paradise Lake. We recommend that the applications of the weevils occur in spring. We also counsel periodic applications of lower quantities of weevils to maintain lower watermilfoil numbers and sustain the weevil population. Eurasian watermilfoil tends to begin its growth cycle in early spring when little light is available. We hypothesize that if the milfoil is controlled early it may provide an opportunity for other macrophytes to become established later in the season when more light becomes available. (please explain why the lower numbers and continued application should be used instead of major doses).

We also suggest using a multifaceted approach to managing Eurasian watermilfoil (See Table 6). According to Madsen 2000, “There is no single cure-all solution to aquatic plant problems, no single "best choice.” Madsen states that “it is up to each management group to select the most appropriate techniques for their situation given a set of social, political, economic and environmental conditions.” When deciding what management techniques to use the Paradise Lake Association needs to take into consideration availability of funding, intended uses of the lake and how little of an impact they would like to have on the biodiversity of the lake ecosystem.

Each of these treatment methods has their advantages and disadvantages. None are 100% effective in eradicating Eurasian watermilfoil but may be more effective when used in conjunction with other techniques. Hand – cutting is very effective if volunteerss are adequately trained to identify the plant and removing athe entire the plant. This is a good effort for volunteer groups that want to make a small localized impact. Diver-operated suction harvesting is another mechanical form of control. However, this method requires costly equipment and is a slow process. It is best for small populations of watermilfoil but there is typically re-growth of Eurasian watermilfoil (Madsen 2000).

Chemical controls can also be considered in the management of Eurasian water milfoil. One such chemical is Endothall. It works rapidly but does not affect the underground portion of the plant. This treatment would result in the regrowth of milfoil because it does not impact the root system of these plants. 2,4-D is another potential treatment method for milfoil. This chemical is not selective to the Eurasian watermilfoil. It is selective to dicots, plants that are rare, but do occur in aquatic ecosystems. There are non-target dicots in Paradise Lake that would be impacted by non-selective herbicides. Chemical by-products, as a result of the breakdown of 2,4-D have half-lives of 333 days within the anoxic soils that occur at the bottom of Paradise Lake as well as the 110 year residence time within the lake. Finally, non-selective chemical treatments ofr dicot plants could destroy the larval nursery habitats of the sport fish present in the lake.

Biological control agents include *E. lecontei* and restoring native plant communities. Weevils are specific to watermilfoil. Native plant community restoration may help natives outcompete the invasive species. It also provides habitat for fauna within the lake.

Management Method	Description	Advantages	Disadvantages	Reference
Hand-Cutting/Pulling	Direct hand pulling or use of hand tools	Low-technology, affordable, can be selective	Labor-Intensive, cost is labor based	Madsen 2000
Diver-Operated Suction Harvester	Vacuum lift used to remove plant stems, roots, leaves, sediment left in place	Moderately selective (based on visibility and operator), longer term	Slow and cost intensive	Madsen 2000
2,4-D	Absorbed by roots and leaves; translocates to and accumulates mainly in the growing points of shoots and roots	Does not affect monocots Inexpensive	May impact other aquatic dicots (including *Utricularia* vulgaris, Common bladderwort) Requires constant application	Schardt and Ludlow 2003. Madsen 2000

Endothall	Afast-acting contact herbicide that is believed to disrupt the plant biochemical processes at the cellular level	Rapid action, limited drift	Does not affect underground portions	Madsen 2000
Euhrychiopsis lecontei	Weevil-natural or naturalized	Already established in U.S.	Works in some lakes and not others	Madsen 2000
Native Plant Community Restoration	Planting of desirable native plant species or community	Provides habitat, may slow reinvasion or initial invasion	Expensive, techniques still under development	Madsen 2000

Table 6: Management methods for reducing patches of Eurasian watermilfoil.

Zebra mussels

Zebra mussels were most likely introduced to Paradise Lake through the transport of boats from zebra mussel populated waters. The larval stage of the zebra mussel is microscopic and can easily be transported in bait buckets and bilge water as well as the hulls of boats.

There are two main approaches to zebra mussel control: the first, a continuous approach, disallows any colonization by mussels. The second approach, periodic, allows some mussels to colonize but keeps numbers relatively low in order to minimize impact. Zebra mussels exist in relatively low densities in Paradise Lake. The majority of the zebra mussel population reside on Stony Point. Eurasian water milfoil also provides an attachment point for zebra mussels and control of the milfoil may eliminate some sites for attachment. A brief survey of adult zebra mussels per stem of watermilfoil yielded numbers around 20 mussels. Studies in the St. Croix waterways of Wisconsin have reported densities of as high as 2000 adult mussels per meter^2.

Because zebra mussels do not yet pose a significant barrier to the desired use of Paradise Lake as a recreational body, periodic control measures are recommended as opposed to eradication measures. In order to prevent further spread of zebra mussels, the establishment of a boat-washing protocol is advisable. All boats entering and leaving Paradise Lake should be washed, preferably with hot water (above 104°F) at high pressures, though cold water at high pressures is also effective at removing larval zebra mussels. If boats are unable to withstand the pressure washing, they should be allowed to dry out in the sun for at least five days in order to kill the larval mussels. All water from motor, bilge, and transom should be drained before entering Paradise Lake. Zebra mussel contaminated water should flow away from the lake.

The placement of removable substrate may also prove effective in the control of zebra mussels. PVC plates, cement blocks, and/or lengths of rope may be placed in high zebra mussel density areas and the mussels should be allowed to colonize the substrate. Periodically (about every three or four months), the substrate should be removed and the zebra mussels should be scraped into an area where they will dry out effectively and there is little chance of the mussels finding their way back to a body of water.

If zebra mussels should pose a more significant threat in the future, several experimental treatments are currently being developed. The most promising treatment appears to be Zequanox (developed by Marrone Bio Innovations), a strain of bacteria that, even when dead cells are applied, destroys the digestive tract of the zebra mussels but does not affect other aquatic inhabitants. Though this treatment may prove expensive, its application following the establishment of a well-enforced boat washing protocol may greatly reduce zebra mussel populations. The product is anticipated to be approved in the United States in 2010.

Treatment	Advantages	Disadvantages
Boat Wash Station	Prevents the spread of larval forms to/from the lake	Hard to enforce
Removable Substrate	Keeps number of adults low	Time consuming
Zequanox	Eliminates zebra mussels, not harmful to other organisms	Expensive, pending approval

Table 7: Possible solutions for controlling zebra mussel populations in Paradise Lake.

BEST MANAGEMENT PRACTICES

Concern	Treatment	Approximate Cost	Duration
Nutrients	Greenbelt	Free!	Forever
Eurasian watermilfoil	Weevils	$15,000 per treatment	Every 3-4 years
Zebra Mussels	Establish boat wash station	$500	1 time, + enforcement
Zebra Mussels	Removable substrate	$100 + Time	Every 3-4 months

Table 8: Best management practices for controlling nutrient levels and invasive species.

EVALUATION PROCESS

Nutrient measurements taken by Tip of the Mitt Watershed Council should be forwarded to the Paradise Lake Association in order to stay informed of current nutrient levels and trends in cycling. Revisions should occur if nutrient levels are unnatural or if trends in nutrients continue to rise.

Aerial photographs every five years can help to track the prevalence of Eurasian watermilfoil and the effectiveness of watermilfoil reduction treatment. If densities become higher, more frequent applications of weevils or the use of chemicals should be investigated in order to return watermilfoil to a manageable level.

Word of mouth information can be spread regarding the incidence of zebra mussels throughout the lake. If densities should become larger, alternatives should be considered to bring the numbers back down. Updates on Zequanox should be reported; approval should occur in the spring or summer of 2010. Paradise Lake Association members should stay updated on new zebra mussel management technologies.