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Wisconsin Cooperative Fishery Research Unit
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Wisconsin Cooperative Fishery Research Unit

Wisconsin Milfoil Weevil Project

Gilbert Lake Final Report

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ACKNOWLEDGEMENTS

We would like to thank all of the lake associations and other organizations that were involved with this study. Your financial support, generous donation of time, and high interest in this project were greatly appreciated! The study's success was in large-part due to your cooperation. In particular, we would like to thank: Beaver Dam Lake, Big Sand Lake, Eagle Lake, Gilbert Lake, Kangaroo Lake, Kusel Lake, Long-Trade Lake, Lorraine Lake, Lower Spring Lake, Nancy Lake, Pearl Lake, Waukesha County Parks System, and Whitewater Lake; the Wisconsin Department of Natural Resources especially Dick Lillie, Laura Herman, Frank Koshere, Jeff Kampa, Tim Rasman, Scott Szymanski, Deb Konkel, Jim Leverance and Jeff Bode; the University of Wisconsin – Stevens Point; the Wisconsin Cooperative Fishery Research Unit; the Midwest Aquatic Plant Management Society; and various "weevil researchers" around the country including Sallie Sheldon, Mariana Tamayo, Robert Creed, Robert Johnson, Bob Kirschner, Chip Welling, Ray Newman and John Madsen.

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Gilbert Lake Milfoil Weevil Project

An Assessment of Existing Weevil Populations and Experimental Weevil Stocking for Eurasian Water Milfoil Control

Project Objectives and Design

In 1996 information about a new biological control insect for Eurasian water milfoil (*Myriophyllum spicatum*) was publicized in a number of newspapers and scientific newsletters. A native weevil, *Euhrychiopsis lecontei*, commonly referred to as the milfoil weevil, was reported to be associated with Eurasian water milfoil declines in a number of Vermont Lakes. Closer to home, a story appeared in the Chicago Tribune about the sharp decline of the milfoil at McCullom Lake in northern Illinois which was also attributed to the weevil. And in Wisconsin, the weevil was attributed to unexplained milfoil declines in Fish and Wingra Lakes (Dane County) and Whitewater Lake in Walworth County. Together, these projects generated interest among both lake organizations and within the Wisconsin Department of Natural Resources (DNR) to investigate the milfoil weevil as a biological control agent for Eurasian water milfoil.

In consultation with three research scientists,

- Dr. Sallie Sheldon from Middlebury College in Vermont, who pioneered weevil research,
- Dr. Michael Bozek from the University of Wisconsin-Stevens Point, an aquatic ecologist, and
- Richard Lillie, a DNR aquatic insect and milfoil scientist,

a framework for the Wisconsin Milfoil Weevil Project was developed. Announcements were sent to candidate lakes, with Eurasian water milfoil problems, soliciting participation in a pilot weevil project. Early in the project design, it was clear there were more lakes wishing to participate than the project could accommodate. In the end, twelve lakes were selected from more than twenty interested in this study.

The project framework included answering three questions:

1) What is the geographic distribution of the milfoil weevil across the State?

Prior to 1996, only four locations of the weevil's occurrence were on record for the State. There was concern that stocking the weevil in areas of the state where it was not present might upset the ecological balance of other aquatic insects or native aquatic plants. It was clear that if weevil stocking was to occur, we first had to document the distribution of the species.

We searched for weevils in 46 lakes of the more than 200 lakes known to contain Eurasian water milfoil in Wisconsin. In each lake we spent up to 4 man-hours examining Eurasian water milfoil plants for adult weevils or weevil damage. The weevil distribution information was also supplemented by weevil samples collected by regional DNR employees. The results of our distribution monitoring are summarized in the Statewide Results section of this report.

2) Are there specific lake characteristics (geography, shoreline, water chemistry, etc.) that are correlated with weevil densities?

By monitoring weevil densities across a wide range of lakes in the State, we were able to examine some of the lake characteristics that are associated with naturally high weevil densities. In turn, we might expect lakes with these characteristics to have a greater potential for higher weevil densities and therefore a greater potential for Eurasian water milfoil control.

We sampled weevil densities in 31 lakes across Wisconsin between mid-July and mid-August in 1996 or 1997. In each lake we collected and examined 120 milfoil stems in order to obtain an accurate weevil density estimate (weevils per stem). The number of weevil adults, larvae, pupae, and eggs from inside and outside the stems were counted and preserved. In addition to weevil densities, information on a wide range of lake characteristics was also collected or gathered from existing data. These weevil densities and lake characteristics were examined for any patterns that might suggest what types of lakes produce higher weevil densities. The results of our weevil density and lake characteristics study are summarized in the Statewide Results section of this report.

3) Can stocking weevils in experimental plots increase natural weevil densities and cause a decrease in Eurasian water milfoil biomass?

Although the existing field and laboratory studies attribute many Eurasian water milfoil declines to the weevils, at the time we started this study there had been only one lake in Vermont where weevils had been stocked for potential milfoil control. The weevil stocking for our study was designed to provide an experimental test of the effectiveness of different levels of stocking in different types of lakes across a wide geographical range.

The original project design budgeted approximately $15,000 for the purchase of weevils to stock in experimental plots located within each of the 12 lakes. When the actual cost of the weevils was discovered to be approximately $0.40 each, we had to make a decision to 1) either substantially decrease the size of the experimental plots or 2) request additional funds from the lake organizations and expand the DNR grant amounts. In the end, the lakes organizations *"stepped up to the plate"* and we were able to purchase approximately 160,000 weevils for $45,000 from Dr. Sheldon's rearing facilities at Middlebury college in Vermont.

Weevils were stocked in three experimental plots in each study lake at one of three treatment levels: 1, 2, or 4 weevils per milfoil plant. Depending on the density of milfoil plants in the lake, and the treatment level assigned, lakes received between 100 and 12,000 weevils per plot.

Statewide Project Results

Weevil Distribution

The milfoil weevil was found to be widely distributed across Wisconsin in lakes that were infested with Eurasian water milfoil. From Vilas and Forest Counties in the north, to Polk and St. Croix Counties in the west, to Kenosha and Racine Counties in the southeast, a total of 45 new records of the weevil were established across Wisconsin (Figure 1). In fact, only Silver Lake in Waupaca County was found to be absent of weevils after four man-hours of searching. In most lakes weevils were found within the first 10-20 minutes of searching. While adults weevils were the easiest life stage to find, in three of the 45 lakes, adults were not found, but weevil damages and larval lifestages were recorded.

Weevil Density and Lake Characteristic Correlations

Weevil density (average number of weevils found on each milfoil stem) was sampled in 31of the lakes and varied from non-detectable densities to 2.5 weevils per stem (Figure 2). Only two of the 31 lakes had weevil densities greater than 2 per stem. Previous studies have indicated that densities greater than 2 weevils per stem are associated with Eurasian water milfoil declines. If that is correct, and our data is representative of the weevil densities across the state, weevil induced milfoil declines would rarely occur naturally. However, Robert Creed (1998) reports at least 10 naturally occurring Eurasian water milfoil declines in the state of Wisconsin in the past decades. Furthermore, 7 of these lakes are now known to harbor the milfoil weevil.

The evidence indicates that weevils can cause Eurasian water milfoil declines, but the density of weevils required to induce a milfoil decline seems to be highly lake specific. This leads us into the second part of the objective: are there lake specific characteristics that are correlated with weevil densities? For example, if there was a positive correlation between weevil density and lake size, our data would show, by more than a random chance, that a larger lake size would have a larger weevil density.

Based on the data from the 31 lakes, we found no correlation between weevil densities and the following lake characteristics:

- Geographic location (latitude)
- Time since Eurasian water milfoil first invaded the lake
- Lake depth, size or type (drainage or seepage)

Nor did weevil densities show a correlation with any of these water quality variables:

- Summer water temperatures
- Dissolved oxygen measurements
- Secchi disk measurements
- Nutrient concentrations (total phosphorus, nitrogen)
- Chlorophyll a
- Alkalinity, pH, conductivity

The lack of weevil density correlation with some of these parameters was surprising. Our data indicates that the productivity of a lake (i.e. nutrient levels) is not correlated to weevil densities. We also expected a positive relationship between water temperature and high weevil densities because temperature plays a large role in regulating aquatic insect reproduction and activity.

However, the percent of various weevil lifestages among all weevils collected per lake was significantly correlated with a few of the variables. For example,

- The percentage of eggs was positively correlated with summer water temperatures
- The percentage of larvae was negatively correlated with total phosphorus

Still, it is unclear if a correlation with a specific weevil lifestage might result in a direct correlation in weevil density. For instance, if warmer summer water temperatures are correlated with more weevil eggs, then we might expect more adults with warmer water temperatures. On the other hand, perhaps fish predation or motorboat impacts on the weevils also increase with warmer water temperatures so that weevil densities actually decrease. Certainly more information is needed about what controls the density of specific weevil lifestages and ultimately the weevil population itself.

Nonetheless, there were some variables that were significantly correlated with weevil densities. Weevil densities were positively correlated with the following variables:

- Distance from the middle of the milfoil bed to the shore
- Distance from the deep bed edge of the milfoil bed to the shore
- Percent of natural shoreline
- Number of apical tips (growing tips) per plant

And, weevil densities were *negatively* correlated with:

- Average depth of the milfoil bed

These correlations indicate that areas with natural shoreline have higher weevil densities than areas with rip-rap, sea walls, mown grass or sand at the shoreline. Knowing that weevils spend their winters in the leaf litter and mud along the shoreline, these results make sense. The data also suggest that there are higher numbers of weevils in large, shallow expanses of milfoil, and in milfoil with more apical tips or branches.

What Do Statewide Results Mean?

First, we found the weevil to be widely distributed across the State of Wisconsin. Therefore, stocking this insect for biological control of milfoil will not result in the introduction of an exotic insect species throughout Wisconsin. Second, a greater number of weevils are associated with large, shallow milfoil beds and areas of natural shoreline. Accordingly, this type of milfoil bed may potentially have the greatest vulnerability to weevil control.

For more information regarding weevil distribution and variable correlations see Laura Jester's M.S. Thesis (Jester 1998).

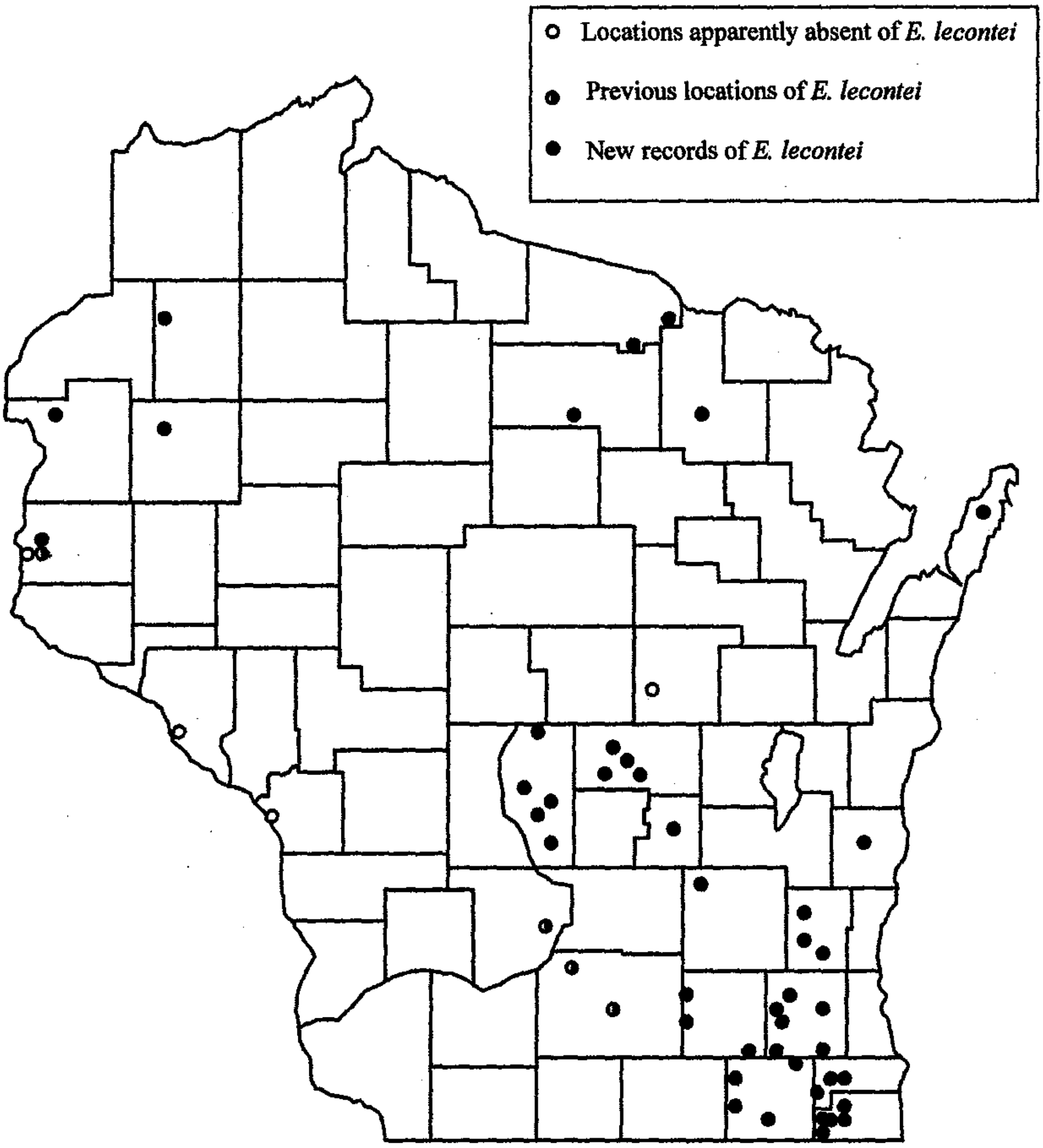


Figure 1. Known distribution of *E. lecontei* in Wisconsin. Previous locations referenced in Lillie (1991), Newman and Maher (1995), Lillie and Helsel (1997).

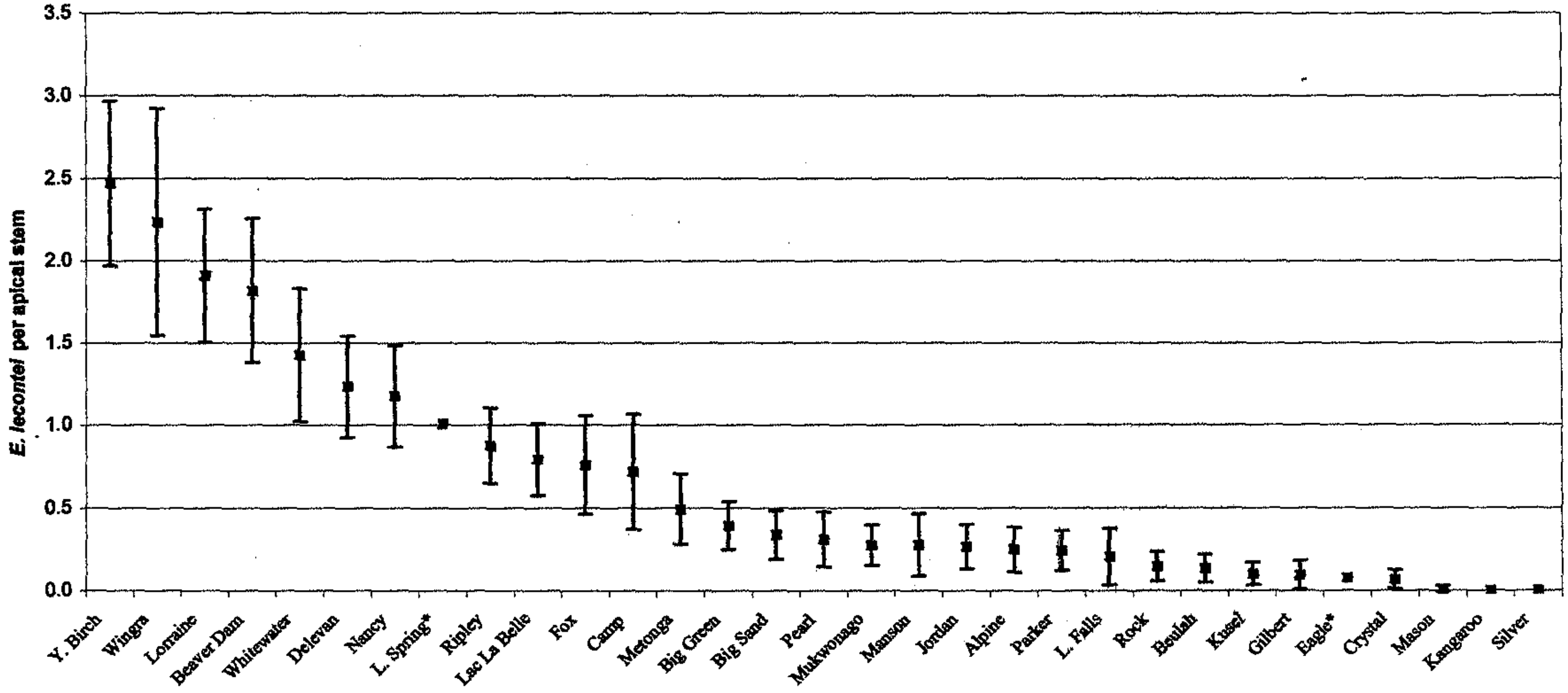


Figure 2. Density of milfoil weevils in Wisconsin lakes: all weevil lifestages combined. Values indicate the mean density of weevils per apical stem ± 95% confidence intervals.

Gilbert Lake Results

In Gilbert Lake, Eurasian water milfoil was found in a large bed just off the boat landing and in the northwestern corner in 1996. The Eurasian water milfoil appeared healthy with little or no weevil damage evident. Please see Table 1 for a log of research and sampling activity on Gilbert Lake.

Background Weevil Densities

Background weevil densities were sampled on July 29, 1996 in Gilbert Lake as part of the study's second objective. Samples were collected along 12 transects in the 2 bed areas to measure the density of weevils lake-wide. All weevil lifestages were counted in and on the stems in the laboratory. Background weevil densities in Gilbert Lake were less than 0.1 weevils per apical stem (Figure 2).

Weevil Stocking

On either side of the boat landing four plots, 2 meters x 6 meters each, were established and marked with a center buoy in early 1997. These plots were situated end to end, and parallel to shore, approximately 9 meters apart (Figure 3). Prior to stocking, weevil densities were collected on June 24, 1997 by snorkeling short transects between the plots to determine the number of weevils needed to bring populations up to a treatment level of 2 weevil per milfoil plant. Weevil densities were found to be 0.4 per apical stem and 0.14 per tip. These existing weevil densities were augmented to attain the desired treatment level. The treatment level of 2 weevil per plant was randomly selected among treatment levels. (See Table 2 for stocking calculations.) Weevil eggs and larvae for stocking were cultured at Middlebury College in Vermont from adults collected in Fish Lake, Dane County, Wisconsin. Adults were shipped to Vermont in coolers, on ice via overnight express; cultured eggs and larvae were returned in the same manner.

On June 26 and July 15, 1997, a total of 27,363 weevil eggs and larvae were stocked in plots 2, 3, and 4; plot 1 was left as a control or reference plot and was not stocked. Stocking was done by tying small bundles of Eurasian water milfoil containing the eggs and larvae onto existing milfoil plants in the plots. Although boat traffic was encouraged to stay away from the plots by yellow signs at the boat landing, neither enclosures nor exclosures were established. Therefore, weevils were allowed to move freely into the surrounding milfoil.

On August 22, 1997, approximately 5 weeks post-stocking, weevil density was measured again among the plots and was found to be 0 weevils per apical stem as no weevils were collected in the samples and no weevils were observed in the plots. Weevil densities were also measured a full year post-stocking on June 24 and August 24, 1998. June densities were very low at 0.03 weevils per apical stem in the plot areas, but by August, densities had dropped again to non-detectable levels (0 weevils collected or found) (Figure 4). *Note: Weevils were stocked at a rate of 2 per plant, however, weevil densities were measured as weevils per apical stem. Eurasian water milfoil often grows with more than one apical stem per plant.*

One explanation for this decline is the possibility that the weevils moved and became distributed throughout the milfoil beds during the weeks after stocking and did not return to the same plot areas after overwintering on shore. Additionally, there may have been unexpected mortality to the weevils during the stocking season and/or following seasons. Gilbert Lake milfoil also has a tremendous build-up of calcium carbonate deposits over the summer which may make the stems uninhabitable or less desirable for weevils. However, the low densities were probably due to a combination of many factors.

Changes in Eurasian Water Milfoil

Weevil densities are just part of the story. The key to successfully using the weevil for biocontrol of Eurasian water milfoil is documenting the correlation between increased weevil densities and decreased Eurasian water milfoil biomass. Accordingly, we also looked at the pre- and post-weevil stocking milfoil biomass or weight per area.

Plants were sampled in the plot areas to determine differences in Eurasian water milfoil variables between pre-stocking (1996) and post-stocking (1997 and 1998) and between reference and treatment plots. This was done using a 0.15 m^2 quadrat sampler and SCUBA. On August 22, 1996, the year before stocking, 8 samples were collected in the area where stocking plots would be placed the next year. On August 22, 1997, approximately 5 weeks post-stocking, three randomly selected samples were collected from each of the four plots for a total of 12 samples. Plants were collected again a full year post-stocking on August 24, 1998.

Overall, there were no changes in the Eurasian water milfoil in the plots and milfoil may still expanding into regions not previously invaded in Gilbert Lake. Although a few native plants still survive in the milfoil bed, (Table 3), Eurasian water milfoil dominates the littoral area near the boat landing.

It should be noted that there was little or no indication of weevil damage to the Eurasian water milfoil in Gilbert Lake over the course of the study. As stated earlier, this is probably due to a variety of factors, the most significant of which may be the heavily calcified condition of the milfoil. Eurasian water milfoil remained thick and healthy in the plots during the study although few plants grew completely to the surface and flowered.

Eurasian water milfoil biomass (or weight) decreased slightly in 1997 but rebounded again in 1998 for no overall effect (Figure 5). The same is true for the density of Eurasian water milfoil plants (plants per square meter) (Figure 6).

There was a slightly significant decrease in the length of Eurasian water milfoil stems from pre- to post-stocking years, although there was no difference between reference and treatment plots in 1997 (Figure 7).

The biomass of native plants decreased in the plots from pre- to post-stocking, although this change was not statistically significant (Figure 8, Table 3).

The percentage of broken milfoil tips did increase slightly after stocking possibly indicating weevil damage, however, this relationship was also not significant (Figure 9).

Table 1. Activity log and observations for Gilbert Lake during the Milfoil Weevil Project.

DATE	ACTIVITY[1]	RESEARCHERS	OBSERVATIONS[1]
6/10/96	Surveyed lake for weevil presence	L. Jester S. Sheldon	Found adult weevil at east end of lake off boat landing.
7/1/96	Surveyed lake for EWM	L. Jester M. Bozek	Found healthy EWM in 3 main areas: at boat landing and 2 smaller beds in northwestern bay.
7/29/96	Collected lake-wide background weevil density samples	L. Jester T. Johnson	Collected weevil density samples from 12 transects (3 transects in each of 4 beds around lake). Found healthy, thick EWM in northwestern bay and at boat landing. EWM was not surfacing and had no weevil damage evident.
8/22/96	Collected pre-stocking EWM samples	L. Jester T. Johnson	Collected 8 EWM samples from northwestern corner bed and 8 EWM samples from bed at boat landing. Most EWM was near the surface and healthy.
5/29/97	Placed one buoy in center of each plot (4)	L. Jester T. Johnson	Plots were situated in the EWM bed at the boat landing: 2 plots on each side of the landing. EWM was well below the surface but healthy.
6/24/97	Collected pre-stocking weevil density samples	L. Jester T. Johnson P. Jester	EWM was thick and healthy in the plot areas.
6/26/97	Stocked weevils in plots 2, 3, and 4	L. Jester T. Johnson P. Jester	Stocked ~ 5,255 weevils per plot. Approximately 30 EWM bundles with weevils were tied to EWM throughout each plot. EWM still well below the surface and healthy.
7/15/97	Stocked additional weevils in plots 2, 3, & 4	L. Jester T. Johnson	Stocked ~ 3,866 weevils per plot. Approximately 30 EWM bundles with weevils were tied to EWM throughout each plot. EWM still thick and healthy.
8/22/97	Collected post-stocking weevil densities and EWM samples in plots	L. Jester T. Johnson	Little or no weevil damage evident. EWM thick and healthy with much calcium carbonate build up on stems.
5/21/98	Re-placed buoys in center of plots (4)	L. Jester M. Bozek	EWM was thick and healthy in plot areas.
6/24/98	Collected weevil density samples in plots	L. Jester D. Kron	EWM was thick and healthy, at or near the surface with much calcium carbonate on stems.
8/24/98	Collected final weevil densities and EWM samples in plots	L. Jester R. Piette	EWM still very thick and healthy. Plants are "arching over" in water column probably due to weight calcium build-up and adventitious root development. No sign of weevils.

[1] EWM = Eurasian water milfoil

Table 2. Weevil stocking calculations for Gilbert Lake.

WEEVILS IN PLOTS PRIOR TO STOCKING:

Number of tips / EWM plant:		Number of weevils / EWM tip:		Number of weevils / EWM plant:
3.5 (Collected 8/22/96)	X	0.144 (Collected 6/24/97)	=	0.504 (Calculated)

Number of weevils / EWM plant:		EWM plants / square meter:		Number of weevils / square meter:
0.504 (From above)	X	384 (Collected 8/22/96)	=	194 (Calculated as pre-stocking level)

TOTAL WEEVILS NEEDED FOR TREATMENT LEVEL OF 2 PER PLANT:

No. of EWM plants / sq. meter:		No. of square meters / plot:		No. of EWM plants / plot:
384 (Collected 8/26/96)	X	12	=	4,608 (Calculated)

No. of weevils needed in each plot for treatment level of 1 per plant:		Treatment level assigned:		Total number of weevils needed per plot for 2 per plant:
4,608 (From above)	X	2	=	9,216 (Calculated)

STOCKING RATE PER PLOT FOR GILBERTLAKE:

Total number of weevils needed per plot for 2 per plant:		No. of weevils already in plots:		No. of weevils to stock per plot:
9,216 (From above)	-	2,328 (194 weevils x 12 m^2)	=	**6,888**

Table 3. Plants other than Eurasian water milfoil collected in Gilbert Lake during milfoil biomass sampling.

Aquatic Plant (common name)	Date(s) collected
Potamogeton alpinus	22 Aug 1997, 24 Aug 1998
Najas flexilis (Willd.) Rostk. & Schmidt. (bushy pondweed)	22 Aug 1996, 22 Aug 1997, 24 Aug 1998
Elodea canadensis G. (elodea)	22 Aug 1996
Myriophyllum sibiricum Komarov (northern watermilfoil)	22 Aug 1996
Potamogeton pectinatus L. (sago pondweed)	22 Aug 1996
Potamogeton zosteriformis Fernald. (flatstemmed pondweed)	22 Aug 1996
Chara sp.	22 Aug 1996, 24 Aug 1998
Potamogeton illinoensis Morong. (Illinois pondweed)	22 Aug 1996
Ceratophyllum demersum L. (coontail)	22 Aug 1996
Nitella sp.	22 Aug 1996

LAKE Gilbert
SECTION 10, 11, 14, 15
RANGE 11 E
TOWN Springwater
TOWNSHIP 20 N

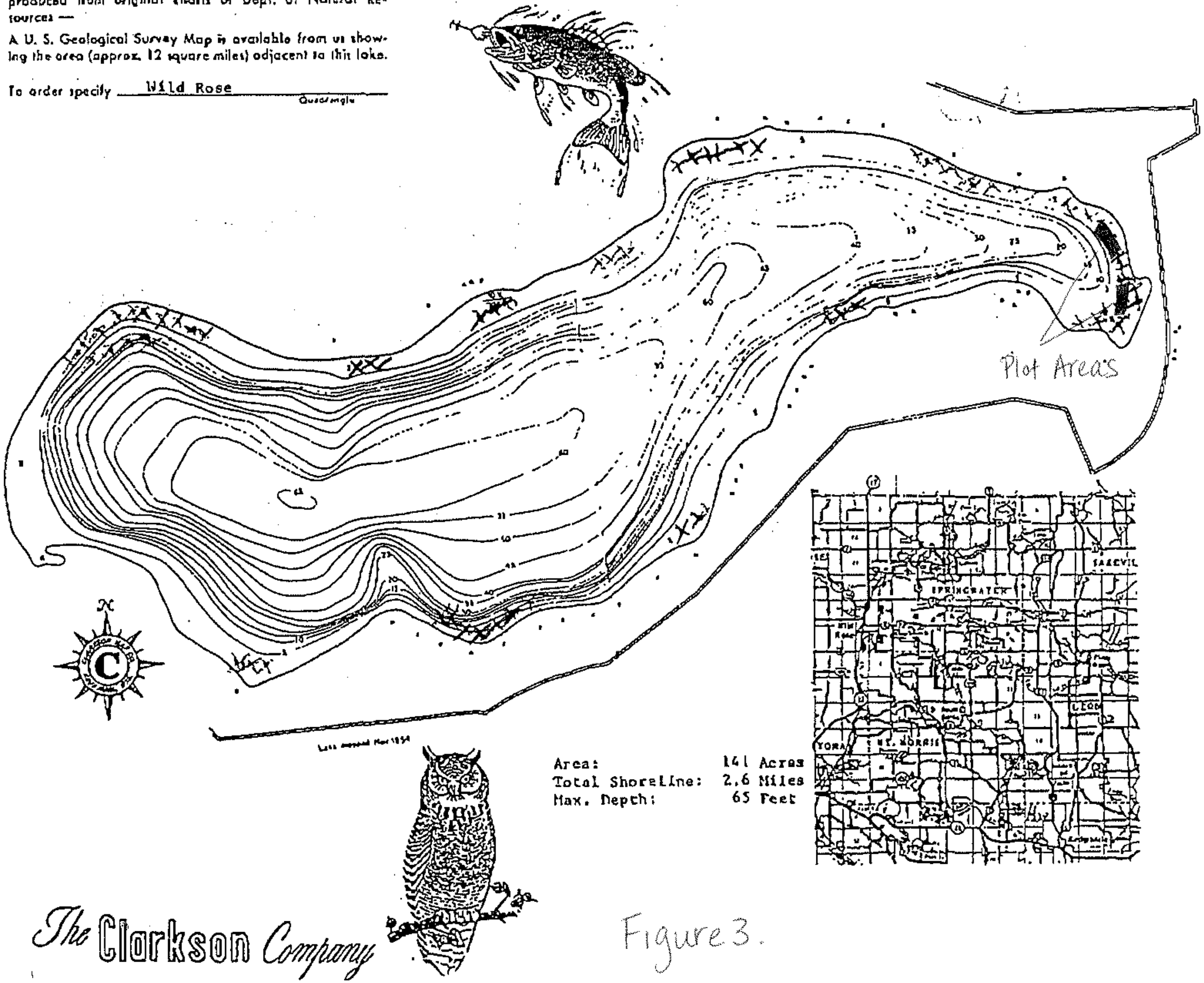
Map No. 2240

This is the only hydrographic map of this lake available, produced from original charts of Dept. of Natural Resources —

A U. S. Geological Survey Map is available from us showing the area (approx. 12 square miles) adjacent to this lake.

To order specify Wild Rose Quadrangle

WAUSHARA COUNTY



LEGEND

TOPOGRAPHIC SYMBOLS

STEEP SLOPE
SPRING
INTERMITTENT INLET
BRUSH
WOODED
PASTURED
CULTIVATED
ENCROACH. SHORE
PERMANENT INLET
PERMANENT OUTLET
MARSH
PARTIALLY WOODED — PW
CLEARED
BENCH MARK — B.M.

LAKE BOTTOM SYMBOLS

PULPY PEAT — P
MUCK — K
CLAY — C
SAND — S
RUBBLE — R
EMERGENT VEGET. — L
FIBROUS PEAT — F
DETRITUS — D
MARL — M
GRAVEL — G
BEDROCK — Br.
SUBMERGENT VEGET. — T

Area: 141 Acres
Total Shoreline: 2.6 Miles
Max. Depth: 65 Feet

The Clarkson Company
Kaukauna, Wisconsin 54130

Figure 3.

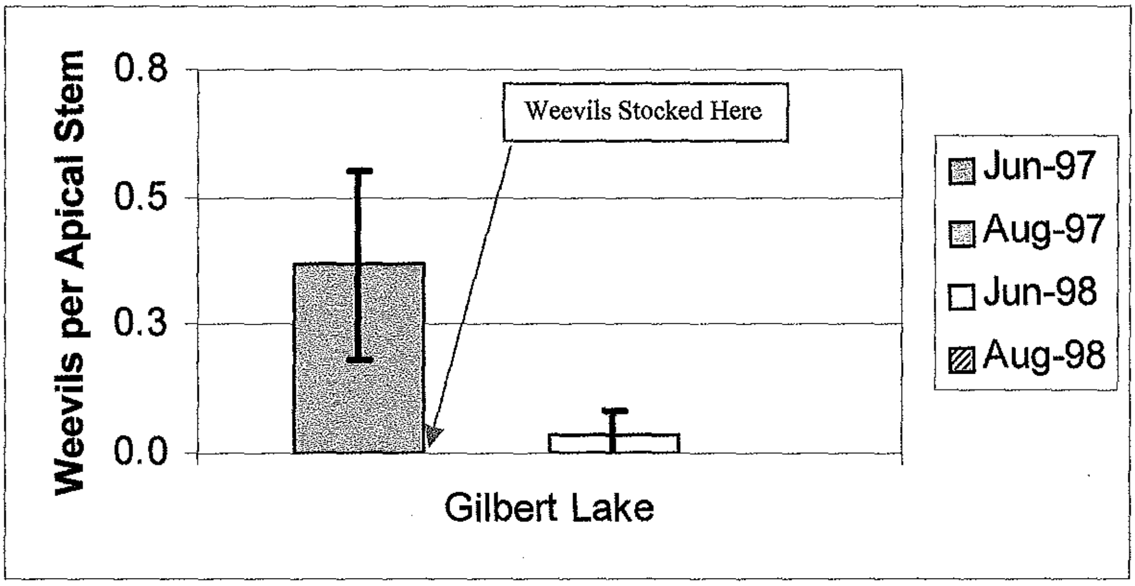


Figure 4. Weevil densities and 95% confidence intervals in plot areas pre-stocking (June 97) and post-stocking. *NOTE: Weevils were stocked at a rate of weevils per plant, however, weevil densities were measured as weevils per apical stem. Eurasian water milfoil often grows with more than one apical stem per plant.*

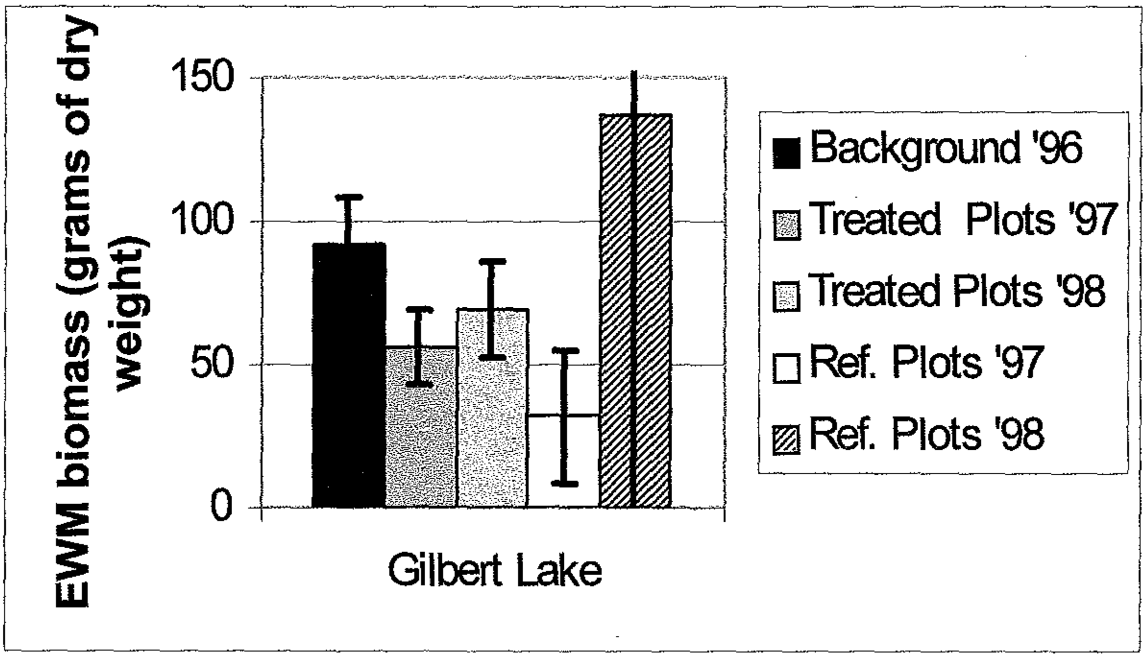


Figure 5. Average biomass of Eurasian water milfoil in plots and 95% confidence intervals.

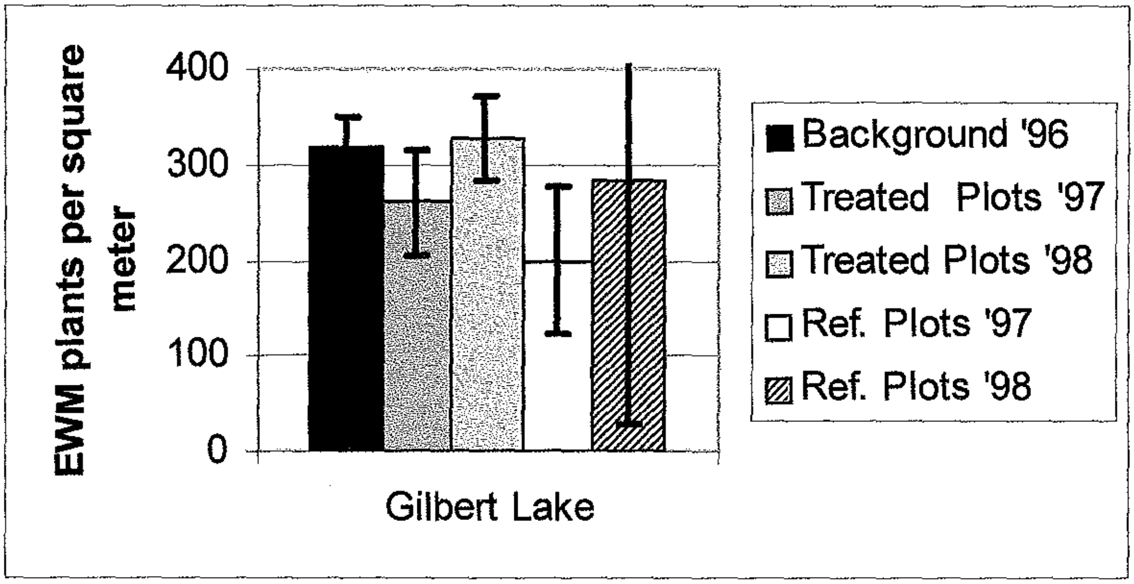


Figure 6. Average density of Eurasian water milfoil plants in plots and 95% confidence intervals.

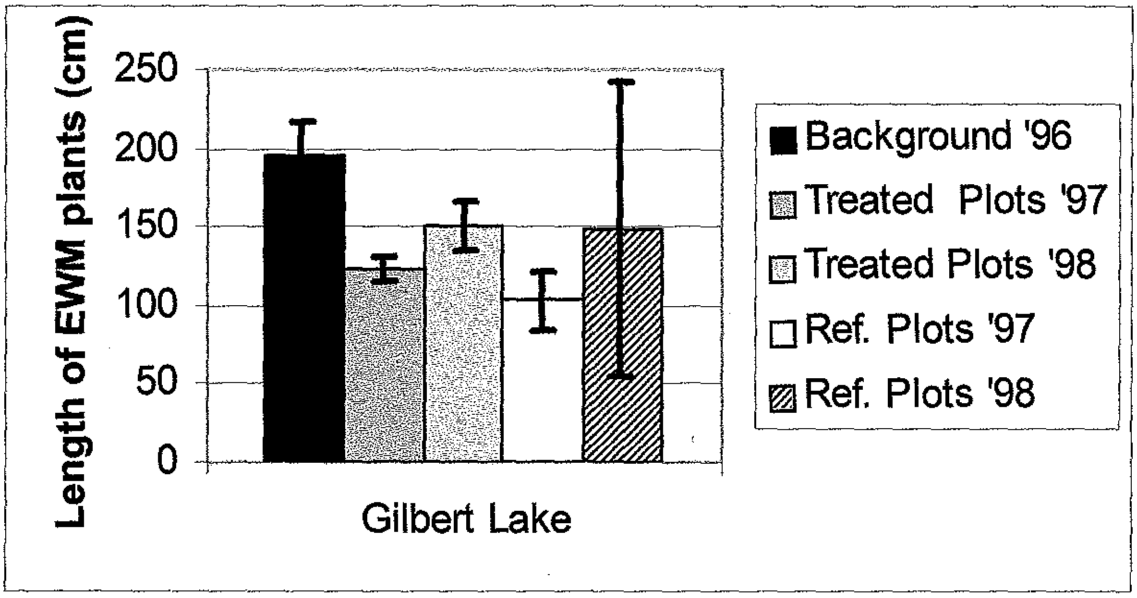


Figure 7. Average length of Eurasian water milfoil plants in plots and 95% confidence intervals.

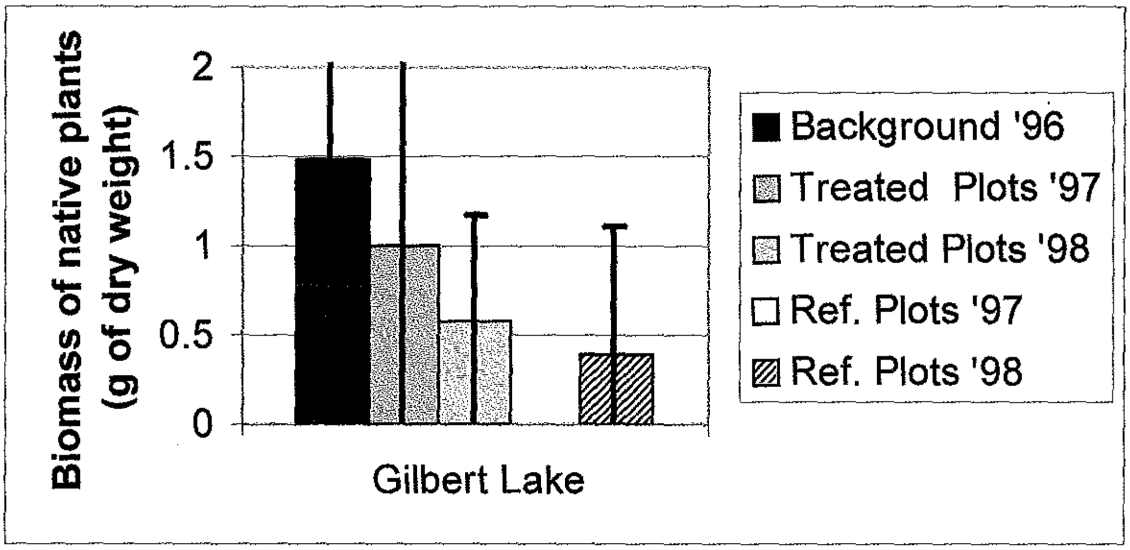


Figure 8. Average biomass of native aquatic plants in plots and 95% confidence intervals.

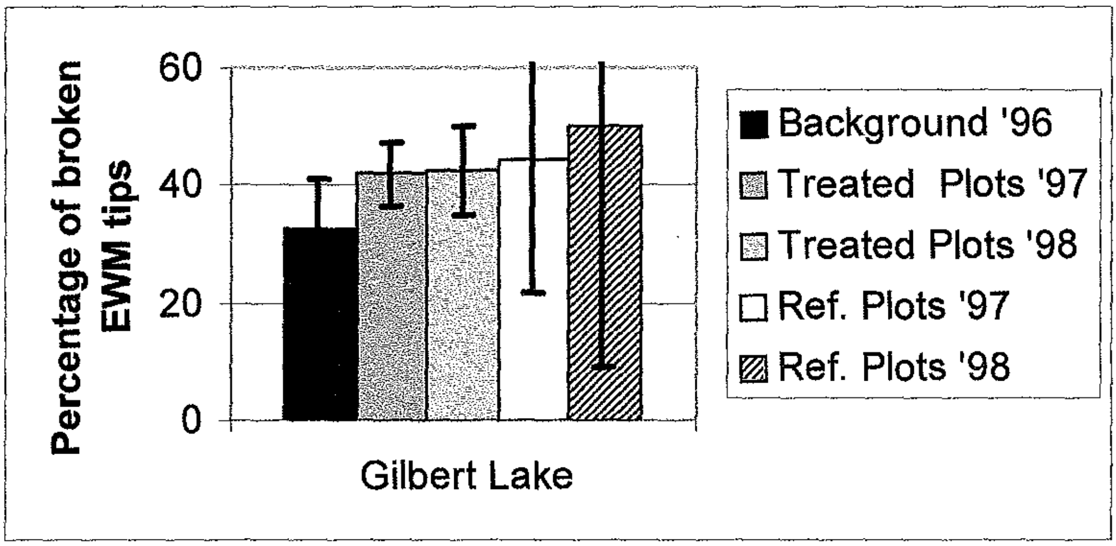


Figure 9. Average percentage of broken apical tips on Eurasian water milfoil plants in plots and 95% confidence intervals.

Wisconsin Study Lakes

Results of the weevil stocking among the 12 lakes were very similar across lakes, geographic regions and treatment levels. Weevil stocking in most lakes did not result in increased numbers of weevils. This could be due to weevil mortality in the lake, mortality in overwintering habitats, dispersal of weevils away from the plot areas, or a combination of many factors. Although there were some statistically significant declines in Eurasian water milfoil variables in many lakes from pre- to post-stocking, these declines were not often visually observed in the lakes. In most cases, the public and landowners did not notice a significant change in the milfoil and did not consider the stocking a success.

Kusel Lake, a study lake in central Wisconsin, did experience a large-scale decline in Eurasian water milfoil during the course of the study. Although we do not believe weevils played a major role in the initial decline, it appeared that weevils (both stocked and natural) were able to keep the small amount of returning milfoil from reaching nuisance levels in 1997 and 1998. It is unknown whether milfoil will again become a dominant part of the plant community in Kusel Lake in the future.

There were two observations made during this study might prove to be important in determining which lakes may experience a weevil-induced decline (either stocked or natural). First, weevils did not have a substantial negative effect in any lake where the milfoil itself was still expanding and claiming new territory within the lake. Perhaps weevil populations are not able to keep up with expanding milfoil beds fast enough to cause a decline. This would suggest that stocking weevils would be more effective in lakes where the milfoil had already reached a maximum distribution – and not in lakes with new milfoil infestations. Second, weevils did not establish populations of any size on milfoil that was heavily coated with calcium carbonate deposits. It is possible that the thick deposits make the milfoil unsuitable for weevil colonization.

Weevil Stocking Results and Recommendations

The results and observations made in Gilbert Lake were typical of most other lakes participating in the study. Although there was usually a slight localized effect on the Eurasian water milfoil among the plot areas, there was not a substantial decline in milfoil.

One common observation in many study lakes (unlike Gilbert Lake) was a high amount of damage in the top portions of the plants in the plots. Dr. Raymond Newman of the University of Minnesota hypothesized that plant vigor, health, and possible resistance to weevil predation may be directly related to sediment nutrients. Perhaps more nutrient-rich sediments are able to support plants which are strong enough to resist weevil predation. Along the same line, this study found that higher weevil densities are significantly and positively related to the number of branches or apical tips on the plant. It is possible that plants are responding to increased stress from herbivores by producing more branches from the lower portions of the shoots. Thus, weevils would have an effect at the top of the plant, but could not keep up with the increasing biomass being produced below.

Unfortunately, weevil populations were never reached a high enough density to have an effect on the milfoil in Gilbert Lake, even 5 weeks after stocking.

With the amount and condition of Eurasian water milfoil in Gilbert Lake and the fact that milfoil may be expanding in the lake, we do not believe that stocking weevils in the future can be a cost-effective method of control. However, it is possible that the calcified plants are not the major cause for the lack of weevils and natural populations of weevils may one day increase to higher and more effective levels; especially once the milfoil beds have stopped expanding. Gilbert Lake has much natural shoreline, which may aide in the weevil's overwintering survival.

The depth of Gilbert Lake still allows for a substantial boating area. If the milfoil becomes a nuisance along piers and landings, consideration might be made toward mechanically harvesting lanes to landowners' docks so that travel to open water is easier. Other alternatives include the use of selective herbicides to control the Eurasian water milfoil. Because native aquatic plants live among the milfoil beds, perhaps a selective herbicide could reduce milfoil enough to allow for native plant regrowth.

Commercially Available Weevil Stocking

Within the last year, EnviroScience, a company in Ohio, began to sell a commercial method of Eurasian water milfoil control involving weevil stocking. This process (marketed as the Middfoil™ process) involves weevil stocking planning, monitoring and stocking. Eagle Spring Lake (Southeast Wisconsin) contracted with EnviroScience for a project involved with the monitoring and stocking of approximately 5,000 weevils at a total cost of about $9,000. Since this is the first year of stocking, it is too soon to conclude whether this stocking was effective. We suggest carefully watching the results of weevil stocking efforts by EnviroScience in Wisconsin and other lakes across the mid-west. These stockings will provide additional case studies into the potential use of weevils to control milfoil and may begin to indicate what lake or milfoil characteristics are essential for successful control. Perhaps biological control with weevils will one day become cost-effective for Gilbert Lake, but at current market prices and unproved effectiveness, it is still a management tool which needs more research and development.

Alternative Management Options

Numerous methods are currently used in an attempt to control Eurasian water milfoil from spreading and creating nuisance conditions, or being transferred to additional waterbodies. Chemical herbicides (e.g. 2-4 D), large mechanical harvesters, bottom barriers, rototillers, suction dredges, drawdowns, ultrasound, and biological controls have been researched, tested, and in many cases, implemented to help control the growth of milfoil in lakes throughout North America (Bates et al. 1985, Maxnuk 1985, Rawson 1985, Soar 1985, Bode et al. 1993). Lake organizations and local governments continue to spend millions of dollars on harvesting, consulting fees, and chemicals in an attempt to control Eurasian water milfoil (Bode et al. 1993).

In addition to being costly, most control methods provide only short-term reductions in biomass (e.g., usually one season or just part of one season) (Aiken et al. 1979, Smith and Barko 1990, Bode et al. 1993) and often have drawbacks associated with their use. For instance, chemical treatment can kill both target and non-target species, promote oxygen loss from rapid plant decay, and suppress less resistant native species (Engel 1990a). Mechanical harvesting can impact ecosystems by disturbing sediments, creating drifting plant fragments, removing and dislodging macroinvertebrates and fish, and altering fish feeding behavior (Engel 1990a, Engel 1990b). Eurasian water milfoil can often recover from harvesting within a few weeks and can resurge to even greater densities following harvest (Engel 1990b).

Table 4 provides general information regarding the other EWM control methods. Please work with your local DNR Fisheries and Water Quality Biologists if you decide explore these methods of control.

TABLE 4 SUMMARY INFORMATION FOR EURASIAN WATER MILFOIL CONTROL METHODS				
Eurasian Water Milfoil Control Methodology	**Advantages**	**Limitations**	**Best Suited for**	**Estimated 1999 Cost**
Mechincal Harvesting	Instant Relief of Nuisance, Minimal Permitting Effort, Long-term (> 9 yrs) Harvesting may Reduce EWM	Increases plant fragmentation and spreading, Two or three cuts required each season, Disposal area required for weeds, Moderately nonselective, Can harvest fish and other aquatic life, Not useful around obstructions or in shallow water (< 2 feet)	Large infestations of EWM (> 5 acres) that spread throughout the lake and exceed 30-50% of the littoral zone. Cutting the top canopy of EWM leaving native understory unharvested	\$200 - \$400 per acres Cover 0.25-0.5 acre/hr New Harvester purchase = \$50,000 - \$200,000 plus operational costs of \$5,000 to \$10,000 per year (maintenance and manpower).
Chemical Herbicides	Treatment may be attempted selectively with 2,4-D or Fluridone, but results vary,	Introduction of potential toxic compounds into water, Requires extensive permitting and certification, Multiple treatments are usually required.	Small infestations (< 5 acres) within sheltered coves or shorelines where contact time of pesticide can be ensured.	2,4-D around \$300-\$350 per acre Fluridone around \$300 per acre but must treat larger than 5 acres.
Bottom Barriers or Sediment Blankets	Immediate control of milfoil after covering	Permit detailed through Chapter 30. Must be removed and cleaned semi-annually. Fabric can billow and cause obstruction	Optimal for high, use recreational area in greater than 3 feet of water like a public beach or boat launch	\$1.00 per square foot installed plus maintance \$10,000 per acre, but usually only used for areas less than 0.25 acres

Newly Emerging Technologies

Whole Lake Sonar® Treatments for the selective control of Eurasian water milfoil have been tried since the early 1990s, including treatments in some of our neighboring states. The Minnesota DNR has approved just one public whole lake treatment and have determined that too many native species are threatened by whole lake treatments. On the other hand, the Michigan DNR has permitted over 20 whole lake treatments and continues to require lower spring treatment fluridone concentrations approaching 5 parts per billion.

More recently, Wisconsin DNR approved the first whole lake treatment which was conducted in the fall (October 1997) at Potters Lake in Southeast Wisconsin. It was hypothesized that many of the natives plants would be dying back for the winter and would not be susceptible to the chemical active ingredients, while the milfoil would be actively growing and would be controlled. The first year results indicate excellent control of Eurasian water milfoil, but also little native plant regrowth. In Waushara County, two lakes used granular treatments of fluridone in the fall to try to selectively control Eurasian water milfoil using the same reasoning. For all of these treatments, another year or two of data is required before any final determination about their effectiveness and environmental impacts can be made.

Deep water mechanical harvesting has been recently tried in a number of southern lakes. A specially designed harvester was constructed by Dane County allowing the milfoil to be mechanically cut at depths approaching 20 feet. Although only narrow channels were cut to increase "the edge effect," preliminary results indicate that cutting the milfoil close to the bottom may provide longer-term harvesting control up to of 2 years. Conventional equipment is not available to undertake such aggressive harvesting of milfoil, but this is a strategy to consider if a lake organization is going to build their own harvester or if these deep water harvesters are commercially constructed in the future.

Although weevil stocking has not yet been proven to provide predictable control at a cost effective price, we have provided general information about other Eurasian water milfoil control methods so that you can continue to work on the Eurasian water milfoil problem in your lake. You should work with your local DNR Aquatic Plant Coordinator to develop a specific action plan to address the milfoil infestation at Gilbert Lake.

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Appendix A – Review of Eurasian Water Milfoil Problem

The submersed aquatic plant Eurasian water milfoil (*Myriophyllum spicatum* L.) was introduced into North American lakes in the early 20th century from Europe and Asia (Couch and Nelson 1985). Since that time, it has spread to lakes, ponds and rivers and has now been recorded in at least 40 states and three Canadian provinces (Sheldon and Creed 1995). Eurasian water milfoil was first found in Wisconsin in the 1960's and has since been reported in lakes located in 39 of Wisconsin's 72 counties and it continues to spread.

Historically, aquarium traders, worm farmers, and fishermen were known to use and transplant Eurasian water milfoil among lakes and ponds (Couch and Nelson 1985). Today, boaters and other recreationalists continue to inadvertently spread this exotic by transporting stem fragments on boat trailers, boat propellers, anchors, and other recreational equipment (Reed 1977, Johnstone et al. 1985, Newroth 1985, Engel 1994).

Physical characteristics of Eurasian water milfoil facilitate its rapid invasion and its ability to dominate plant beds in many lakes. One of the most significant means of milfoil dispersal throughout a lake is autofragmentation (Nichols and Shaw 1986, Madsen et al. 1988). Fragments naturally break away from the milfoil stem, develop rootlets and settle to the lake bottom to grow as independent plants (Kimbel 1982). Dispersal is augmented through wind and wave action that carry fragmented stems great distances to colonize new areas. Fragments can float in the water and stay viable for several weeks (Rawson 1985).

Eurasian water milfoil possesses other competitive adaptations, which make it an effective invader including overwintering under the ice as an entire plant, often with green shoots (Reed 1977, Kimbel 1982). As a result, in early spring, Eurasian water milfoil grows quickly before other species have had a chance to get started and the plants become well established by April (Aiken et al. 1979). In addition to an early start, growth is rapid and stands can be extremely dense. Reed (1977) reported that summer growth can reach a rate of 5-7 centimeters per day. Eurasian water milfoil grows at depths from 1-10 meters, often surfacing and forming a dense canopy of entangled branches on the water's surface.

The aggressive and competitive nature of Eurasian water milfoil alters aquatic communities. It can inhibit the growth of native plant species so that it dominates plant communities often within two to three years after introduction and can even colonize previously unvegetated areas (Aiken et al. 1979). The effect of Eurasian water milfoil on invertebrate communities has been equivocal. Hanson (1990) reported that plant beds composed of different plant species differ in the diversity and abundance of invertebrates inhabiting them. However, there is little evidence showing whether Eurasian water milfoil increases or decreases the diversity and abundance of invertebrates compared with other submersed plants.

Dense, monotypic stands of Eurasian water milfoil may also alter fish communities by changing the structure and density of plant beds, which influence predator-prey interactions (Crowder and Cooper 1982, Savino and Stein 1982, Diehl 1988, Dionne and Folt 1991). Dense Eurasian water milfoil beds can reduce the open-water areas between plants, which give larger fish access to prey within the macrophyte beds (Engel 1994). Engel (1994) suggested that with increasing Eurasian water milfoil biomass, fish production could shift from a few gamefish species, such as northern pike (*Esox lucius*) and walleyes (*Stizostedion vitreum*), to sunfish (Centrarchidae) and less "sporty" fish.

Appendix B – Review of Weevil Life History

The life history of the milfoil weevil has been studied in detail (Creed et al. 1992, Creed and Sheldon 1993, Solarz and Newman 1996, Newman et al. 1996a,b, Sheldon and O'Bryan 1996a). Adult weevils are 2 – 3 mm in length with black and yellow stripes along the back and a light under side. The adult female lays one, two or sometimes more tiny, yellow individual eggs in the leafy apical tips of a plant before moving onto another tip on the same plant or an adjacent plant to continue laying eggs. The larvae hatch after about four days and begin to eat the delicate tissues of the tip where they hatched. Later larval stages continue to burrow further down into the stem, eating the vascular tissues and occasionally making exit and entry holes along the way . The larval lifestage lasts approximately 10 - 13 d and duration is temperature dependent (Sheldon and O'Bryan 1996a, Newman et al.1997a). The majority of weevil damage comes from the destruction of the apical growing tip which suppresses the production of new plant biomass (Creed and Sheldon 1995), and the hollowing of the stem, which disrupts transport of carbohydrates and nutrients, suppresses root production, and reduces plant buoyancy (Creed and Sheldon 1995, Sheldon and Creed 1995).

Following the larval stage, the weevil pupates, or changes into an adult, inside the stem further down the plant stem (> 0.5 m) where the stem is thicker (Sheldon and O'Bryan 1996a, Newman et al. 1997a). Pupation lasts approximately 10 - 13 d and again, duration is temperature dependent (Sheldon and O'Bryan 1996a, Newman et al. 1997a). In Vermont, there are approximately three generations of weevils per summer and adult weevils live the entire season with females laying up to 1.9 eggs per day and a hatching rate of 87% (Sheldon and O'Bryan 1996a). As such, there is the potential for rapid population growth under optimal conditions. Newman et al. (1997b) reported that the entire life cycle is temperature dependent ranging from 60d at 15 °C to 17d at 27 – 31°C with 75% successful development above 15 °C.

Weevil adults move to shoreline overwintering habitat (the top 2.5 cm of soil/litter interface) between September and November (Newman et al. 1996b) and overwinter survival can be as high as 40% (Newman and Ragsdale 1995). These same adults emerge in the spring and move back to the milfoil beds.

Appendix C – Review of Weevil Biocontrol Effects

Biological control of Eurasian water milfoil using herbivores insects has gained attention in recent years (Newman and Ragsdale 1995). Natural declines of milfoil in various lakes, however, have corresponded with the presence of three herbivores: the naturalized moth *Acentria ephemerella* (Denis and Schiffermuller) (=*Acentria nivea* Oliver), the native midge *Cricotopus myriophylli* Oliver, and the native weevil *Euhrychiopsis lecontei* Dietz (or the milfoil weevil) (Sheldon 1994, Newman and Ragsdale 1995). Although all three species feed on Eurasian water milfoil, studies indicate that the weevil appeared to have the best potential for biological control (Creed and Sheldon 1995, Sheldon and Creed 1995). Studies quantifying the effects of the weevil on Eurasian water milfoil have been performed in New England and Minnesota in recent years. The work of Creed and Sheldon (1993, 1995, Creed et al. 1992, Sheldon and Creed 1995) showed that the weevil suppressed Eurasian water milfoil production, adversely affected its buoyancy, and lowered fragment viability both in the laboratory and in natural field conditions. Newman et al. (1996b) also found the weevil had a significant negative impact on Eurasian water milfoil in experimental tanks. Feeding by the weevil reduced the percentage of carbohydrates in both stems and roots (Newman et al. 1996b, Perry and Penner 1995). Newman et al. (1996b) speculated that plant injury by weevils may accumulate over several years by reducing root stocks and thus invoke longer term Eurasian water milfoil declines with more lasting effects than harvesting.

While the weevil negatively affects Eurasian water milfoil, its effects on native plants appear to be minimal. In experiments by Sheldon and Creed (1995) there was no evidence that weevils fed or reproduced on any native plants except northern water milfoil (*Myriophyllum sibiricum* Komarov) and in experiments by Solarz and Newman (1996), only 3 of 207 females did not lay eggs on Eurasian water milfoil. Although weevils fed and laid eggs on the northern water milfoil, the effects on this native plant were not significantly different from control treatments (those without weevils) (Sheldon and Creed 1995, Creed and Sheldon 1993). This suggests that northern water milfoil and the weevil may have co-evolved with northern water milfoil or other milfoil species as the original host plants. Solarz and Newman (1996) found that weevils raised on Eurasian water milfoil had a high specificity for Eurasian water milfoil, while weevils raised on northern water milfoil had no preference between Eurasian water milfoil and the native plant.

Recent studies also indicate that Eurasian water milfoil produces larger weevil adults and promotes a faster development time from egg to adult, thus making Eurasian water milfoil a superior host plant (Newman et al. 1997a, Newman et al. 1997b). Solarz and Newman (1996) reported that the weevil is unlikely to shift to non-water milfoil hosts and will have minimal damage on native plant species. However, if Eurasian water milfoil becomes rare, the weevil may likely use northern water milfoil until other Eurasian water milfoil becomes available.

Appendix D – Water quality measurements in Gilbert Lake

PARAMETER MEASURED	MEASUREMENT	DATE MEASURED
Surface water temperature	23.9 °C	July 29, 1996
Bottom water temperature	18.7 °C	July 29, 1996
Surface dissolved oxygen	10.65 mg/L	July 29, 1996
Bottom dissolved oxygen	9.46 mg/L	July 29, 1996
Surface water temperature	24.7 °C	August 22, 1996
Surface dissolved oxygen	10.05 mg/L	August 22, 1996
Secchi disk depth	17 ft	August 22, 1996
Surface water temperature	24.9 °C	June 26, 1997
Bottom water temperature	6.4 °C	June 26, 1997
Surface dissolved oxygen	8.78 mg/L	June 26, 1997
Bottom dissolved oxygen	6.8 mg/L	June 26, 1997
Secchi disk depth	28 ft	June 26, 1997
Surface water temperature	26.9 °C	August 24, 1998
Surface dissolved oxygen	9.46 mg/L	August 24, 1998
Secchi disk depth	15.5 ft	August 24, 1998