A

APPENDIX A

Public Participation Materials

"Lost Lake Study Year 1 Analysis In" Lakeland Times Article – Beckie Gaskill 2/9/2018

"Lost Lake Curly-Leaf Pondweed Treatment at Risk" Lakeland Times Article – Beckie Gaskill 4/20/2019

Planning Meeting I Presentation

The LAKELAND TIMES Minocqua, Wisconsin
Online edition
2016 Newspaper of the Year
"The Voice of the Northwoods since 1891"
Serving the greater Oneida, Vilas and Iron counties of Northern Wisconsin

COLDWELL BANKER MULLEADY, INC., REALTORS
CLICK HERE TO FIND YOUR NEW PROPERTY!
MULLEADY, INC., REALTORS
Northern Wisconsin's #1 Real Estate Professionals
6 Locations to serve you • Rhinelander, Minocqua, Woodruff, Eagle River, Manitowish Waters and Land O'Lakes

search sponsored by
Woodruff APPLIANCE & T.V.
Over 70 Years of Experience!
715-356-2107

2/9/2018 7:27:00 AM

Lost Lake study Year 1 analysis in

Lost Lake seems to be winning the fight against CLP

Beckie Gaskill
Outdoors Writer

Lost Lake in Vilas County has had a curly leaf pondweed (CLP) problem for several years. Last April members of the Long Lake Protection and Rehabilitation District (LLPRD) met with members of the DNR and environmental consultants, Onterra, to create a plan to deal with the CLP problem on the lake. While Eurasian watermilfoil (EWM) chemical treatments are well documented and research has been done regarding collateral damage to other species of aquatic plants, less was known about the effects of chemically treating CLP. Onterra was hired to put together a summary report, and then proposed a CLP treatment on the lake. Much like EWM, CLP does not always create the worst case scenario in a lake. Indeed, in some lakes it has died off on its own. On other lakes, it continues to grow and expand. CLP had been mapped since it was found in 2014, and it became obvious it was not going to wane in this case, but continue to grow and take over. In the end, it was decided CLP would continue to be a problem in Lost Lake, and it was already impeding recreation and pushing out native species of plants.

The summary report went through some changes as a result of that meeting in April, and tentative plans to chemically treat the CLP, based on that report, were put into place.There was some concern about collateral damage and how the rest of the plant community may respond.

"If we kick people out of the apartments, other people can move in," said Tim Hoyman from Onterra in that meeting as an analogy to help others understand how the plant community might respond to CLP being knocked down in the bay where it has taken hold.

"We might just have to accept some collateral damage," Marv Anderson of LLPRD had countered. "We have to take that because, 30 acres, you can't go through it with a kayak. I go back and say, OK, the collateral damage is going to happen. How much does that play into the decision to treat the curly leaf pondweed and maybe we just have to take our lumps?" Together, the LLPRD, the DNR and Onterra ultimately decided it was time to chemically treat the CLP with endothall, which is commonly used to fight the invasive.

Point intercept surveys have been done on Lost Lake in 2007, 2010, and 2017. Both invasive and native plants were taken into consideration. It was found, in the western bay, where the CLP had taken hold, there were five native species present: flat-stemmed pondweed, coontail, common waterweed, northern watermilfoil and fern-leaf pondweed. In Onterra's experience they knew flat-stemmed pondweed, northern watermilfoil and fern-lead pondweed are particularly susceptible to early season endothall treatments. Coontail, they said, is somewhat more resilient. It was expected common waterweed would be unimpacted. In some cases, common waterweed populations had even increased with early-season endothall treatments.

In the pre-treatment survey in May of last year, Onterra found CLP in 84 percent sample locations in the treatment area. The plan was to manipulate the dam in such a way to keep the herbicide treatment from being flushed downstream before it could have its full affect on the CLP and also to minimize impacts downstream. However, heavy amounts of rain shortly after treatment made for less than optimal conditions in that respect.

After treatment, endothall concentrations in the treatment area were lower than target, but were sustained for at least 72 hours, according to a recent report prepared by Onterra entitled the 2017 AIS Monitoring and Control Strategy Assessment Report for the Lost Lake Protection and Rehabilitation District. It was thought the extended duration of exposure would offset the lower than optimal concentrations and still be effective in controlling the CLP.

Three days after treatment, the center of the lake was tested for endothall concentrations. They were at 0.009 ppm, almost immeasurable. Onterra, from their experience, said three days after treatment, the lake likely had an equilibrium concentration throughout the lake. Due to the low concentration levels, it was deduced the spot treatment was likely confined to the treatment area and would not have lake-wide impacts.

In late June, another survey of the treatment area took place. No CLP was found in the western bay of Lost Lake, pointing to a highly effective treatment. The CLP, which was noted at 84 percent of points in the previous

Marshfield Clinic
Sick?
Download the Care My Way app for a virtual visit.
GET TREATED NOW

We know the Northwoods!
FirstWeber.com
The human side of real estate.
FIRSTWEBER REALTORS

survey, was not found at any of the 101 sample points during the late June survey. In the August survey, however, nine sampling locations contained CLP, with the majority of those locations being in the western bay, the area of treatment. CLP regrows from turions that fall off the mature plants and can stay dormant in the substrate for years. Seed banks can build up in the soil and grow in subsequent years after treatment. For that reason, multiple-year treatments are usually necessary to push back the CLP and keep it from regrowing. The CLP found in August, this suggests, sprouted from turions after the last survey in late June.

The study also looked at the impact on native plant populations. Point-intercept data was collected and complied and validated anecdotal reports stating the submergent aquatic plant population of Lost Lake was much lower than previous years. Different plants reacted differently during the time of treatment. A lake-wide decline in white-stem pondweed and fern-leaf pondweed as seen from 2014 to 2017, but the decline was higher in the treatment area. Lake-wide, coontail, which is not normally affected by early-season endothall treatments, experienced a decline from 38.7 percent in 2014 to 13.2 percent in 2017, and the decrease in the treatment area was greater than that lake-wide. Lake-wide common waterweed was basically unchanged from 2014 to 2017, but had experienced a sharp decline in 2014 from 2010 surveys.

Slender naiad, which Onterra said is very susceptible to large-scale 2,4-D treatments, saw an uptick after the endothall treatment. Wild celery increased lake-wide, but at a smaller rate in the treatment area. Clasping-leaf pondweed indicated a decline within the treatment area.

Water quality was also included in the recent report, but early season rains washing nutrients and organic acids into the lake greatly impacted water clarity in 2017. Further examination of the water quality parameters will be included in future lake management project planning, according to the report.

The main conclusions were summarized at the end of the report. It stated for plant species in decline, the decline was consistent over time and were present not only after treatment or only within the treatment area. Also, with the heavy rains, the dam was open at its highest level for 10 consecutive days in an attempt to control water levels within Lost Lake.

It is thought more herbicide dissipated out of the lake in that direction rather than to the east into the main body of the lake. Herbicide concentrations in Lost Creek, the report said, were similar to those in the treatment area when tested. It was also said if the herbicide applied to the treatment area were to be spread out across the entire lake, concentrations would be far too low to have an impact on the plant community.

Lastly, three days after treatment, herbicide concentration monitoring showed an almost undetectable amount of the chemical endothall in the center of the lake. The endothall treatment was considered a success in the western bay of Lost Lake. However, with turions likely still in the soil from previous years, CLP will again grow in 2018, as was evidenced by the mid-August survey.

In January of this year, the LLPRD directors voted unanimously to conduct another endothall spot treatment in the same treatment area this year. This treatment, which is done before plants shed their turions for the season, will likely need to take place for at least two more years to ensure any turions left in the soil are gone.

Aquatic plant monitoring is also planned for 2018 and the LLPRD will be looking to the DNR for funding assistance. Water sampling for herbicide concentrations will also continue this year, to be done by volunteers on the lake. At some point in March or April, the Lost Lake Planning Committee and Onterra will meet again to discuss project results thus far and to further review and refine management goals for both Eurasian watermilfoil and CLP.

Beckie Gaskill may be reached via email at bgaskill@lakelandtimes.com.

American Investigator

twitter

SmugMug

facebook

Today's Circulars

Online Coupons

Classifieds

Links

Public Documents

Advertising Promos

Today's Weather

Article Comment Submission Form

Please feel free to submit your comments.

Article comments are not posted immediately to the Web site. Each submission must be approved by the Web site editor, who may edit content for appropriateness. There may be a delay of 24-48 hours for any submission while the web site editor reviews and approves it.

Note: All information on this form is required. Your telephone number is for our use only, and will not be attached to your comment.

Submit an Article Comment

First Name:
Required

Last Name:
Required

Telephone:
Required

Email:
Required

The LAKELAND TIMES
Minocqua, Wisconsin
Online edition
2016 Newspaper of the Year
"The Voice of the Northwoods since 1891"
Serving the greater Oneida, Vilas and Iron counties of Northern Wisconsin

COLDWELL BANKER MULLEADY, INC., REALTORS
CLICK HERE TO FIND YOUR NEW PROPERTY!
MULLEADY, INC., REALTORS
Northern Wisconsin's #1 Real Estate Professionals
6 Locations to serve you • Rhinelander, Minocqua, Woodruff, Eagle River, Manitowish Waters and Land O'Lakes

search sponsored by
Woodruff APPLIANCE & T.V.
Over 70 Years of Experience!
715-356-2107

4/20/2018 7:29:00 AM

Lost Lake curly leaf pondweed treatment at risk

DNR now reluctant to follow through with treatment

Beckie Gaskill
Outdoors Writer

Last year, the Lost Lake Protection and Rehabilitation District (LLPRD) met with members of environmental consulting firm Onterra, the Department of Natural Resources and other plant specialists to discuss how to proceed with a problem invasive, curly leaf pondweed, which was all but choking off one entire bay in the lake.

At this meeting, the groups all agreed what made attempting to deal with the CLP problem on Lost Lake more difficult was it is an invasive about which not much is known. Eurasian watermilfoil, for example, is an invasive which there has been much research about. That is not the case of CLP. So, going in, there were a number of questions, but also the opportunity to learn a great deal about its control.

Treatment a better option?

One of the things that makes CLP difficult to control or attempt to eradicate is the fact it produces turions which can lie dormant in the soil for a long period of time. Those turions, then, when conditions are right, will take hold and shoot up new plants, sometimes years late.

For that reason, it would be necessary to treat the CLP in the affected bay for several years. A big unknown was how the plant community might respond to the CLP being gone from the lake.

"If we kick people our of the apartments, other people can move in," Tim Hoyman of Onterra had told the group at that meeting, as an analogy to the plant community response. In an area conducive to plant growth, if the CLP was removed, it would be likely other plants would take over. Whether or not those would be native plants could not be said, of course.

Native plant populations were also discussed at last year's meeting. There was some concern whether the chemical treatment for CLP would affect native plants as well. The chemical does not differentiate between natives and invasives. Susan Knight from UW-Madison Trout Lake Station said in other treatment scenarios, native plants have come back after treatment, but there was no clear timeline for their reemergence, and each lake would react differently.

"We might just have to accept collateral damage," Marv Anderson from LLPRD had said at that meeting. "We have to take that because, 30 acres, you can't go through it with a kayak. I go back and say, OK, the collateral damage is going to happen. How much does that play into the decision to treat the curly leaf pondweed and maybe we just have to take our lumps?"

"Just because we aren't measuring certain biota doesn't mean they aren't being affected, either," DNR water resource management specialist Kevin Gauthier had said at the time. "We try to manage what risks are out there."

All agreed that using a herbicide always comes with risks. In this case, however, Onterra firmly believed the risks that may be associated with treatment were such that treatment of the CLP was a better option than non-treatment. Members of the lake district agreed.

According to District chairman Jim Ulett, members of the lake district are still behind the idea and are willing to commit more dollars through a tax levy to continue to combat this overbearing invasive.

Marshfield Clinic
Sick?
Download the Care My Way app for a virtual visit.
GET TREATED NOW

DELTA CONNECTION
is now booking flights into and out of Rhinelander...
FLY Rhinelander
SkyWest
CLICK HERE FOR MORE INFORMATION

WALDMANN Construction, Inc.
Design / Build General Contractor
715-479-3132
P.O. Box 159 · 6221 Hwy. 70 East · St. Germain, WI 54558
Celebrating 25 Years of Building in the Northwoods

This year, however, it seems as though there may be a problem with that plan. Although all parties went into the endeavor knowing there would be multiple treatment years needed and there may be collateral damage, they believed the option of doing nothing was no longer viable and that treatment should begin.

However, in March of this year, Gauthier sent an email to stakeholders reviewing the annual report sent by Onterra as well as some recommendations. It was found native plant populations in the lake were at a lower level than previous. However, no point intercept survey had been completed since 2014, so the reasons for, and timing of, those declines was uncertain. Two recommendations came from Knight and DNR fisheries biologist Hadley Boehm. Boehm had a number of questions after reviewing the report.

"My thoughts:," she wrote in her response, "Is it a good idea to proceed with chemical treatment given there is a lakewide decline in veg? Would it be better to do more monitoring first? Would it be wiser to put funds into figuring out the reason for the decline?"

She also wondered about effects on fish. With less vegetation, she said, there is less habitat. She questioned the effect of endothall, the chemical used in CLP treatment, on fish at various stages of their life cycle.

In Knight's response she pointed to the fact that no point intercept survey had been done since 2014, so it was impossible to know if the native plant populations were in decline before the treatment or if the populations were as low as what they had been in 2014. She said regardless of where the populations were, it was apparent they were in decline.

"With respect to treating again in 2018, there are two ways to look at this," she said. "A justification for another treatment in 2018 is that the lack of native plants could give room for the CLP expansion that was already underway. Onterra gave good reasons of why the drop in native aquatic plants was not due to the treatment. On the other hand, the lack of native plants suggests something is on in the lake that is having a negative effect on the natives, and we should further investigate, and try to mitigate this, before we use anymore herbicides."

She stated the lack of water clarity could be having a negative effect on natives, but CLP could be more tolerant of lower clarities. She went on to say that despite Onterra's reasoning that the herbicide treatment was not responsible for the decline, it was "extremely worrisome." She felt strongly there should be no further herbicide treatment until native plants were shown to be clearly recovering.

Onterra responds

Tim Hoyman of Onterra weighed in on an email chain in regards to these recommendations given by Knight and Boehm. Herbicide data collected posttreatment showed the achieved concentrations were in fact lower than what Onterra aimed for.

Hoyman said Onterra was also "concerned and a bit baffled" by the decline in native plant communities, but based on their experience and other data collected, they did not believe the proposed treatment would have lake-wide affects on those communities. There was evidence, he said, that native plant communities were already in decline.

"To be clear, when someone we respect as much as Susan (Knight) states, 'I feel strongly there should be no herbicide treatments until it is clear the native plants are recovering,' we take note. Still, as described in last year's and this year's report, we believe that because this is a new infestation of curly-leaf pondweed, that there is a greater chance of success at reducing the population by completing the annual treatments. That is our primary reason for disagreeing with the department not supporting the treatment." Hoyman said. While all parties were looking to protect Lost Lake, it was apparent to him there was a disagreement on how that should be handled.

After all of this discussion, it was up to the LLPRD as to whether or not to apply for a permit. It was brought up at an LLPRD meeting last week and district members were unanimously in favor of treating the CLP with endothall again. Jim Ulett, LLPRD chairman stated the district would apply for a permit for the treatment in 2018. In a response email, Ulett gave the district's reasoning.

"The local DNR has made it clear to the district and other area lake groups that they are against the use of herbicide in all instances, even when trying to manage an aquatic invasive species. This makes us question the objectivity of the comments the DNR has made within this email chain."

He said statements made in the email chain between the groups made it clear neither Knight or Gauthier felt as though a permit should be sought.

"There is a feeling of prejudice by DNR official Kevin Gauthier when it comes to Lost Lake and any treatment of this kind," Ulett said. "Kevin and DNR officials knew that the treatment on Lost Lake was a three or more year process. Not moving forward with the plan of treating this area for at least 3 consecutive years would waste the $40,000 cost of last year's treatment by the home owners on Lost Lake have supported this process by vote and a strong financial investment."

Ulett said home owners continue to support treatments and had again voted yes to a tax levy that would allow for enough money to continue to treat the problem. The decision was made by the LLPRD to apply for a permit for endothall treatment of their CLP for 2018. Whether that permit is granted or not is now in the hands of the DNR.

American Investigator

twitter

SmugMug

facebook

Today's Circulars

Online Coupons

Classifieds

Links

Public Documents

Advertising Promos

Today's Weather

Presentation Outline

- **Lake Management Planning Project Overview**
- **Study Results**
  - Aquatic Plants
    - Native Plants
    - Non-Native Plants (EWM & CLP)
  - Water Quality
  - Watershed
  - Shoreland
  - Fisheries (Next Discussion)

Onterra LLC
Lake Management Planning

Management Planning Project Overview

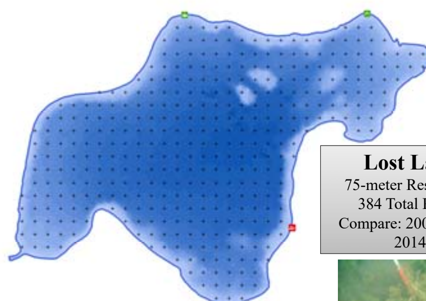
- Foster holistic understanding of Horsehead Lake ecosystem
- Collect & analyze data
  - Technical & sociological
- Construct long-term & useable plan

Onterra LLC
Lake Management Planning

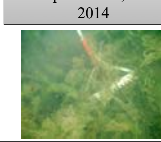
Aquatic Plant Surveys

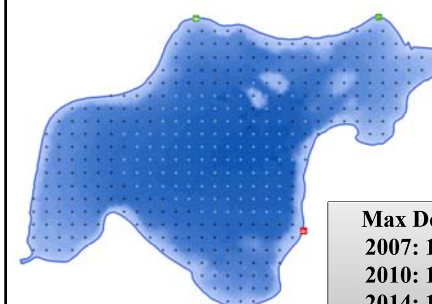
- Determine changes in plant community from past surveys
- Assess both native and non-native populations
- Numerous surveys completed in 2017
  - Early-Season AIS Survey
  - Whole-Lake Point-Intercept Survey
  - Emergent/Floating-Leaf Community Mapping Survey
  - EWM Peak-Biomass Survey

Onterra LLC
Lake Management Planning

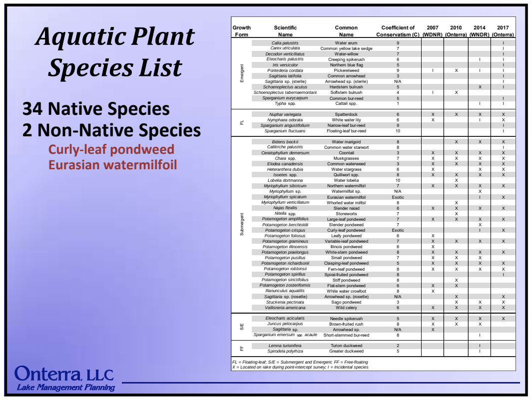


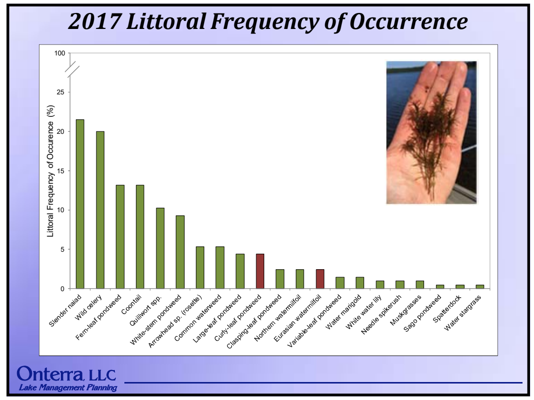
Lost Lake
75-meter Resolution
384 Total Points
Compare: 2007, 2010, 2014

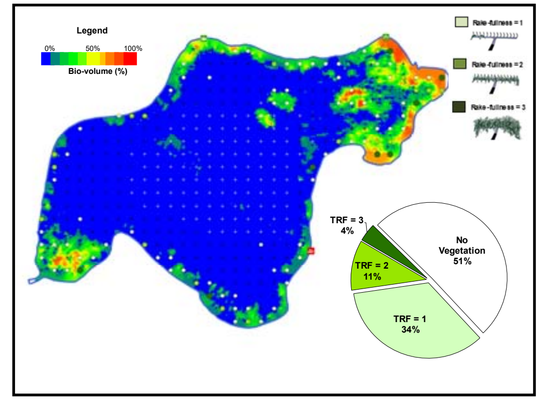


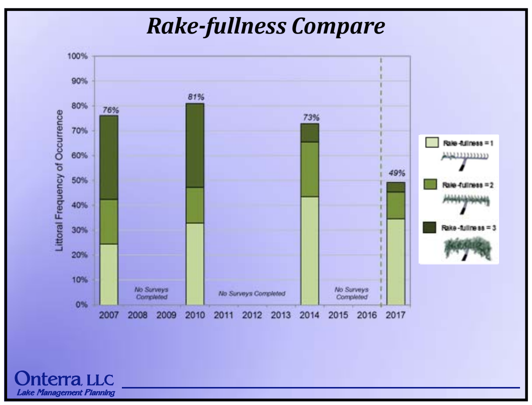


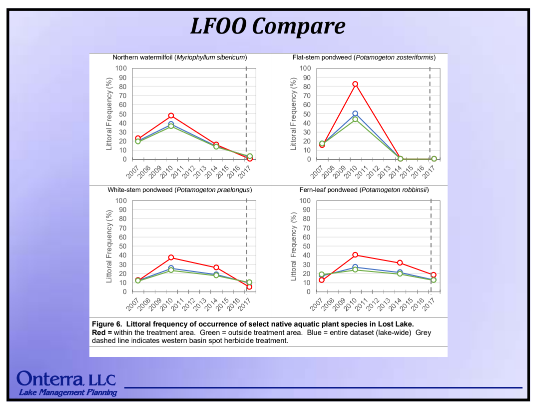
Max Depth
2007: 15 ft
2010: 15 ft
2014: 15 ft
2017: 13 ft

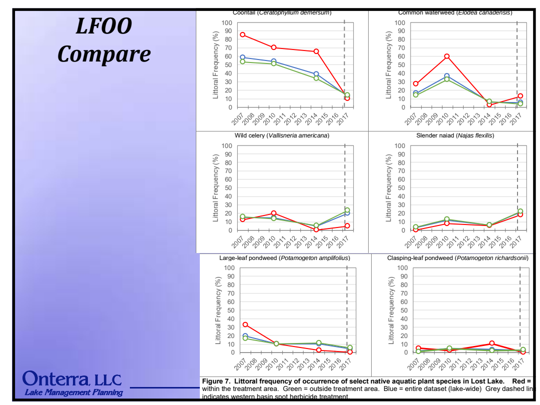

Aquatic Plant Species List
34 Native Species
2 Non-Native Species
Curly-leaf pondweed
Eurasian watermilfoil
Onterra LLC
Lake Management Planning

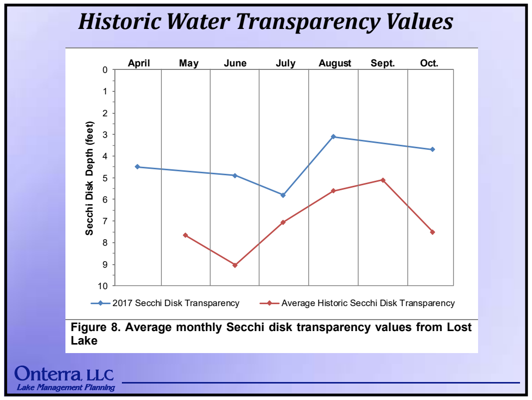

2017 Littoral Frequency of Occurrence
Littoral Frequency of Occurrence (%)
Slender naiad
Wild celery
Fern-leaf pondweed
Coontail
Quillwort spp.
White-stem pondweed
Arrowhead sp. (rosette)
Common waterweed
Large-leaf pondweed
Curly-leaf pondweed
Clasping-leaf pondweed
Northern watermilfoil
Eurasian watermilfoil
Variable-leaf pondweed
Water marigold
White water lily
Needle spikerush
Muskgrasses
Sago pondweed
Spatterdock
Water stargrass
Onterra LLC
Lake Management Planning


Legend
0%
50%
100%
Bio-volume (%)
Rake-fullness = 1
Rake-fullness = 2
Rake-fullness = 3
TRF = 3
4%
TRF = 2
11%
TRF = 1
34%
No Vegetation
51%

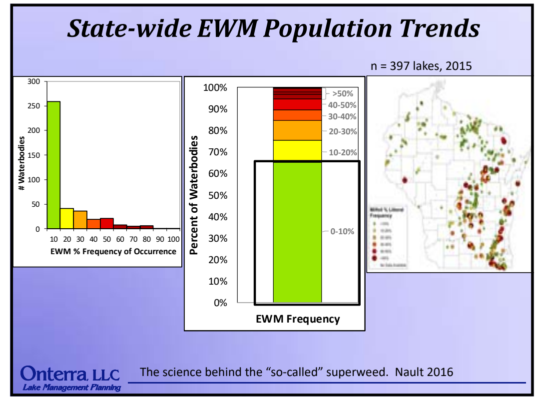

Rake-fullness Compare
Littoral Frequency of Occurrence
76%
81%
73%
49%
No Surveys Completed
No Surveys Completed
No Surveys Completed
2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
Rake-fullness = 1
Rake-fullness = 2
Rake-fullness = 3
Onterra LLC
Lake Management Planning

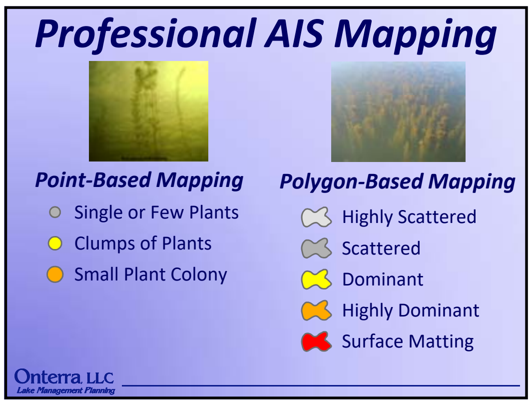

LFOO Compare
Northern watermilfoil (Myriophyllum sibericum)
Flat-stem pondweed (Potamogeton zosteriformis)
White-stem pondweed (Potamogeton praelongus)
Fern-leaf pondweed (Potamogeton robbinsii)
Littoral Frequency (%)
Figure 6. Littoral frequency of occurrence of select native aquatic plant species in Lost Lake. Red = within the treatment area. Green = outside treatment area. Blue = entire dataset (lake-wide) Grey dashed line indicates western basin spot herbicide treatment.
Onterra LLC
Lake Management Planning

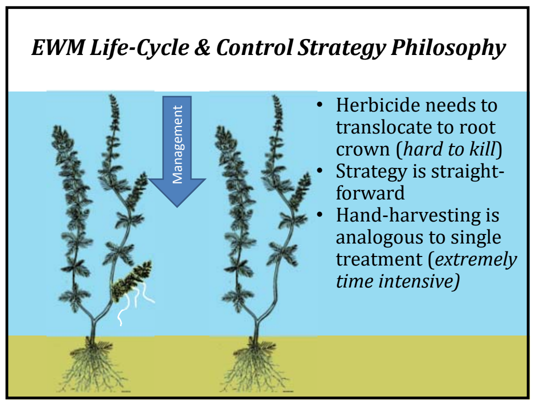

LFOO Compare
Coontail (Ceratophyllum demersum)
Common waterweed (Elodea canadensis)
Wild celery (Vallisneria americana)
Slender naiad (Najas flexilis)
Large-leaf pondweed (Potamogeton amplifolius)
Clasping-leaf pondweed (Potamogeton richardsonii)
Littoral Frequency (%)
Figure 7. Littoral frequency of occurrence of select native aquatic plant species in Lost Lake. Red = within the treatment area. Green = outside treatment area. Blue = entire dataset (lake-wide) Grey dashed line indicates western basin spot herbicide treatment.
Onterra LLC
Lake Management Planning

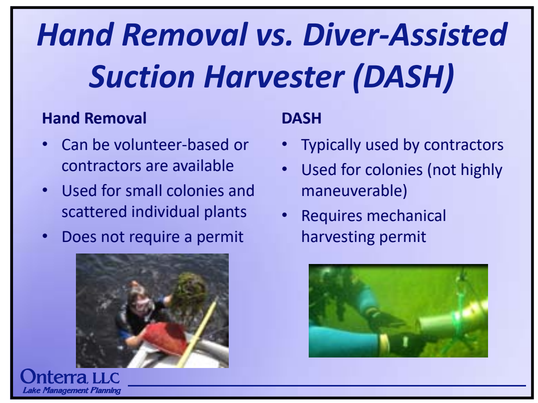

Historic Water Transparency Values
April
May
June
July
August
Sept.
Oct.
Secchi Disk Depth (feet)
2017 Secchi Disk Transparency
Average Historic Secchi Disk Transparency
Figure 8. Average monthly Secchi disk transparency values from Lost Lake
Onterra LLC
Lake Management Planning

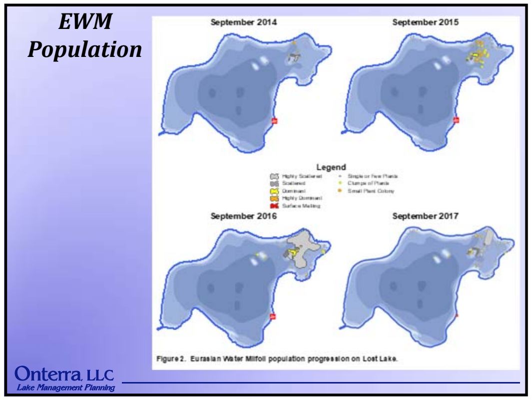

Non-Native Aquatic Plants
Eurasian Water Milfoil
• First "officially" documented in 2013
• 2017 PI – 2.4% LFOO

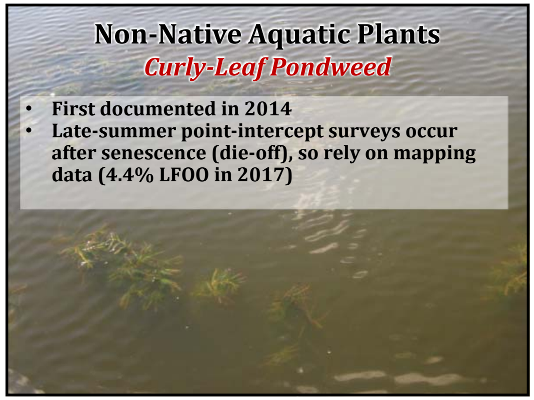

State-wide EWM Population Trends
n = 397 lakes, 2015
# Waterbodies
EWM % Frequency of Occurrence
Percent of Waterbodies
EWM Frequency
>50%
40-50%
30-40%
20-30%
10-20%
0-10%
Onterra LLC
Lake Management Planning
The science behind the "so-called" superweed. Nault 2016

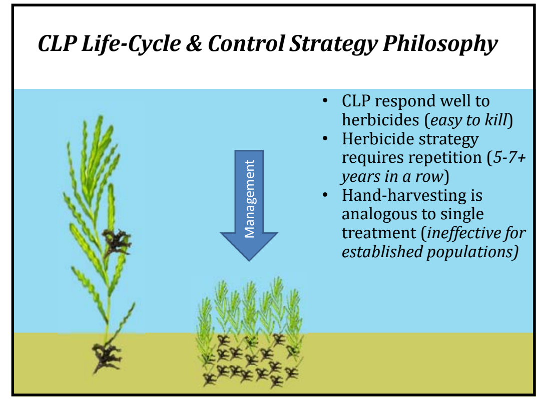

Professional AIS Mapping
Point-Based Mapping
Single or Few Plants
Clumps of Plants
Small Plant Colony
Polygon-Based Mapping
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting
Onterra LLC
Lake Management Planning

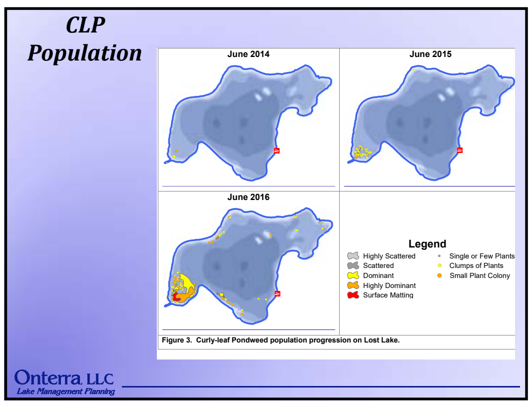

EWM Life-Cycle & Control Strategy Philosophy
Management
• Herbicide needs to translocate to root crown (hard to kill)
• Strategy is straight-forward
• Hand-harvesting is analogous to single treatment (extremely time intensive)

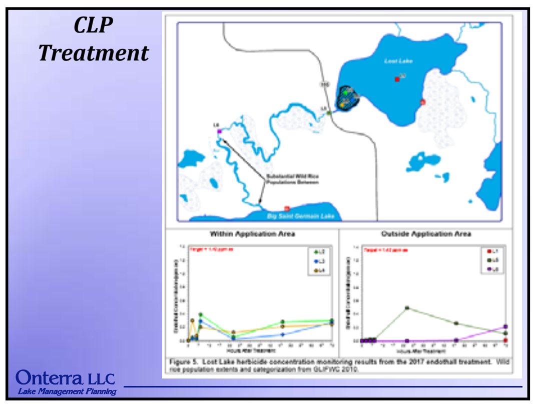

Hand Removal vs. Diver-Assisted Suction Harvester (DASH)
Hand Removal
• Can be volunteer-based or contractors are available
• Used for small colonies and scattered individual plants
• Does not require a permit
DASH
• Typically used by contractors
• Used for colonies (not highly maneuverable)
• Requires mechanical harvesting permit
Onterra LLC
Lake Management Planning

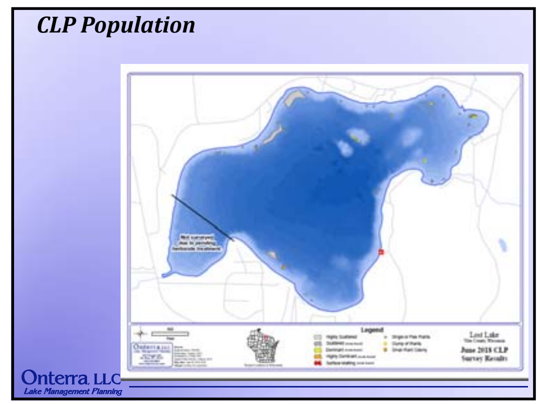

EWM Population
September 2014
September 2015
Legend
September 2016
September 2017
Figure 2. Eurasian Water Milfoil population progression on Lost Lake.
Onterra LLC
Lake Management Planning


Non-Native Aquatic Plants
Curly-Leaf Pondweed
• First documented in 2014
• Late-summer point-intercept surveys occur after senescence (die-off), so rely on mapping data (4.4% LFOO in 2017)


CLP Life-Cycle & Control Strategy Philosophy
Management
• CLP respond well to herbicides (easy to kill)
• Herbicide strategy requires repetition (5-7+ years in a row)
• Hand-harvesting is analogous to single treatment (ineffective for established populations)


CLP Population
June 2014
June 2015
June 2016
Legend
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting
Single or Few Plants
Clumps of Plants
Small Plant Colony
Figure 3. Curly-leaf Pondweed population progression on Lost Lake.
Onterra LLC
Lake Management Planning


CLP Treatment
Within Application Area
Outside Application Area
Figure 5. Lost Lake herbicide concentration monitoring results from the 2017 endothall treatment. Wild rice population extents and categorization from GLIFWC 2010.
Onterra LLC
Lake Management Planning

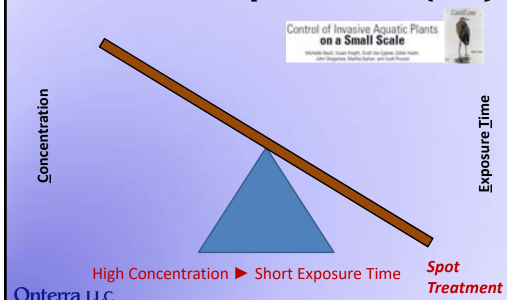

CLP Population
Legend
Lost Lake
June 2018 CLP Survey Results
Onterra LLC
Lake Management Planning

AIS Management Options

1. **Let Nature Take its Course - No Coordinated Active Management**
   - Onterra recommends periodic monitoring
   - Onterra recommends education on manual removal by property owners
2. **Reduce AIS Population on a lake-wide level - Ecosystem Restoration Approach**
   - Requires monitoring before, during, and after
   - Would rely on herbicide treatment strategies (risk assessment)
   - Will not "eradicate" AIS
3. **Improve ability for some riparians to navigate to deeper waters – Improve Cultural Ecosystem Services**
   - Onterra recommends periodic monitoring
   - Onterra recommends professional hand-harvesting of areas or lanes
   - Hand-harvesting may not be able to reach this goal and herbicides or small mechanical harvester may be alternatives worth considering

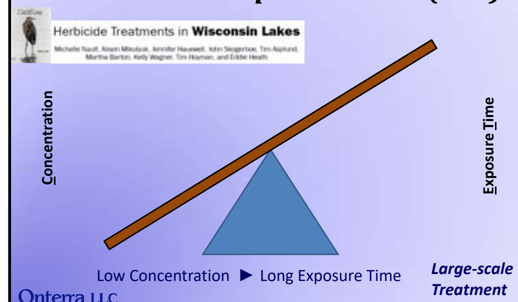
Onterra LLC
Lake Management Planning

Herbicide Use Patterns Concentration Exposure Time (CET)



Onterra LLC
Lake Management Planning

Herbicide Use Patterns Concentration Exposure Time (CET)



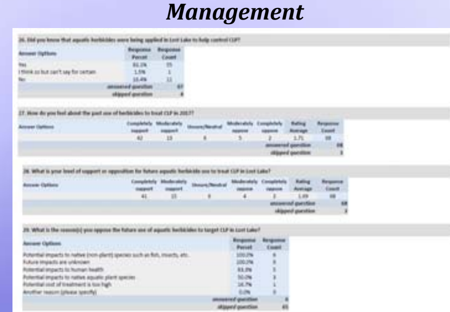
Onterra LLC
Lake Management Planning

Are herbicides "safe?"

- Registration by the EPA does not mean that the use of the herbicide poses no risk to humans or the environment, only that the benefits have been determined to outweigh the risks .
- Because product use is not without risk, the EPA does not define any pesticide as "safe."
- Risk-Risk factors must be considered in determining treatment strategy
- Strategy objective must be to effectively control target species with minimal impact to native habitat

Onterra LLC
Lake Management Planning

Lost Lake Stakeholder Perceptions of CLP Management

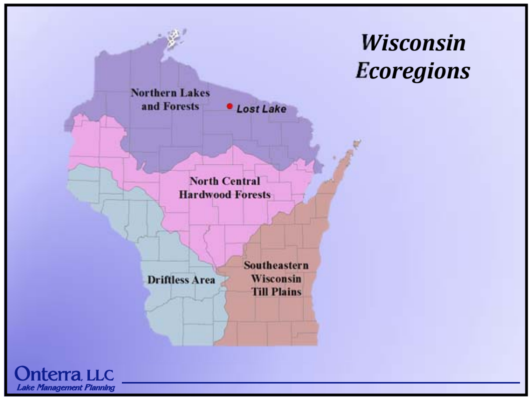


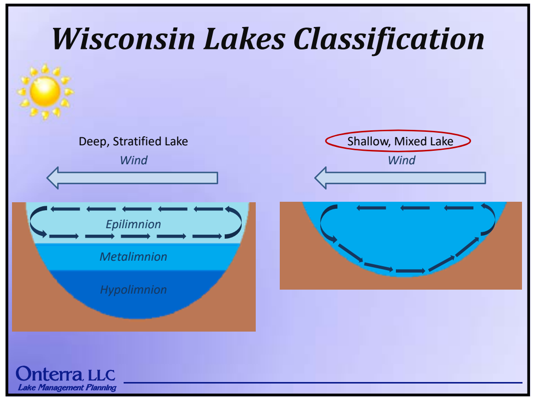
Onterra LLC
Lake Management Planning

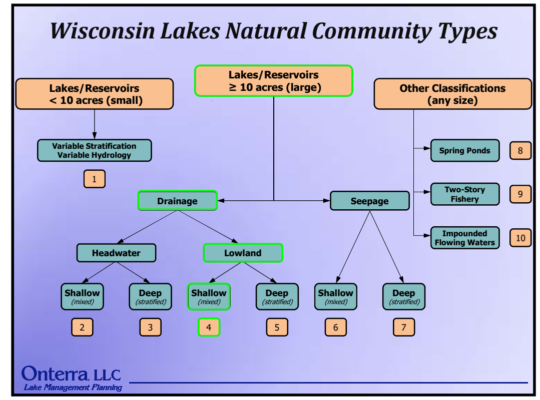
Looking Past AIS Management

- Important that in parallel with AIS management, district is conducting other lake stewardship activities to keep Lost Lake healthy

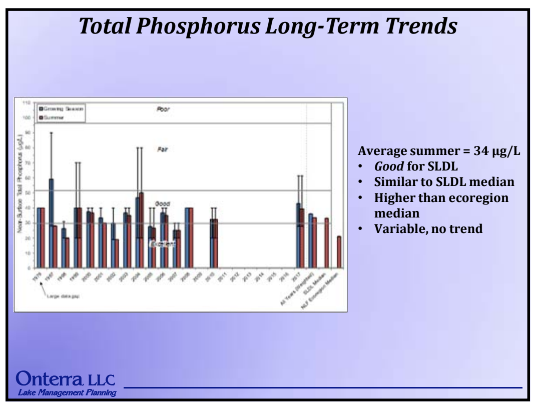
Onterra LLC
Lake Management Planning

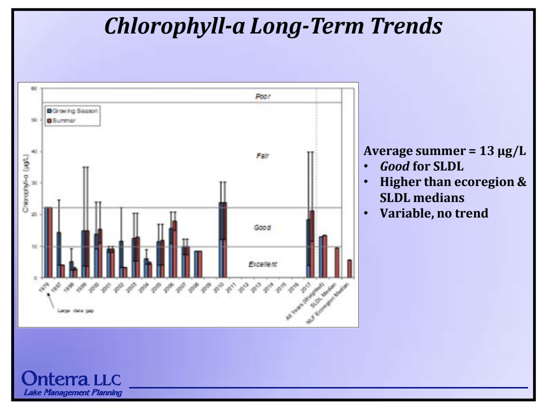

Wisconsin Ecoregions
Northern Lakes and Forests
Lost Lake
North Central Hardwood Forests
Driftless Area
Southeastern Wisconsin Till Plains
Onterra LLC
Lake Management Planning

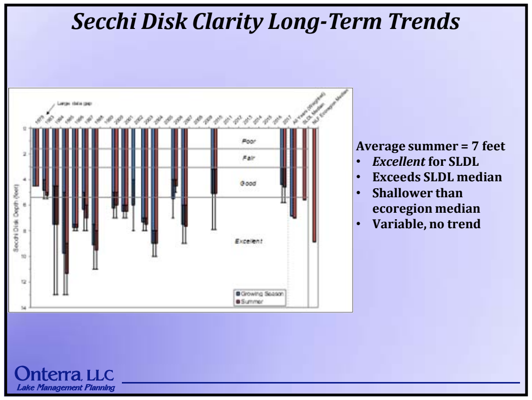

Wisconsin Lakes Classification
Deep, Stratified Lake
Wind
Epilimnion
Metalimnion
Hypolimnion
Shallow, Mixed Lake
Wind
Onterra LLC
Lake Management Planning

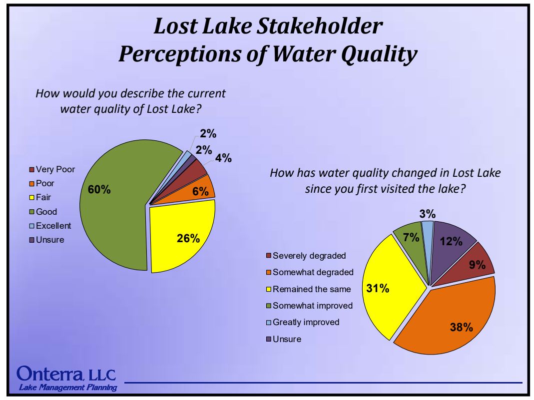

Wisconsin Lakes Natural Community Types
Lakes/Reservoirs < 10 acres (small)
Lakes/Reservoirs ≥ 10 acres (large)
Other Classifications (any size)
Variable Stratification Variable Hydrology
1
Drainage
Seepage
Spring Ponds
8
Two-Story Fishery
9
Impounded Flowing Waters
10
Headwater
Lowland
Shallow (mixed)
Deep (stratified)
Shallow (mixed)
Deep (stratified)
Shallow (mixed)
Deep (stratified)
2
3
4
5
6
7
Onterra LLC
Lake Management Planning


Introduction to Lake Water Quality
Phosphorus
Naturally occurring & essential for all life
Regulates phytoplankton biomass in most WI lakes
Most often 'limiting plant nutrient' (shortest supply)
Human activity often increases P delivery to lakes
Chlorophyll-a
Pigment used in photosynthesis
Used as surrogate for phytoplankton biomass
Secchi Disk Transparency
Measure of water clarity
Measured using a Secchi disk
Onterra LLC
Lake Management Planning


Total Phosphorus Long-Term Trends
Poor
Fair
Good
Average summer = 34 µg/L
• Good for SLDL
• Similar to SLDL median
• Higher than ecoregion median
• Variable, no trend
Onterra LLC
Lake Management Planning

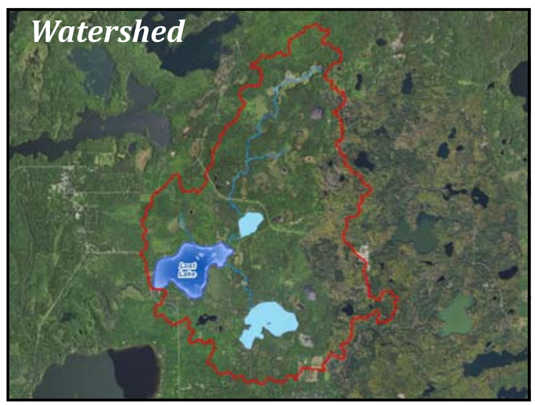

Chlorophyll-a Long-Term Trends
Poor
Fair
Good
Excellent
Average summer = 13 µg/L
• Good for SLDL
• Higher than ecoregion & SLDL medians
• Variable, no trend
Onterra LLC
Lake Management Planning

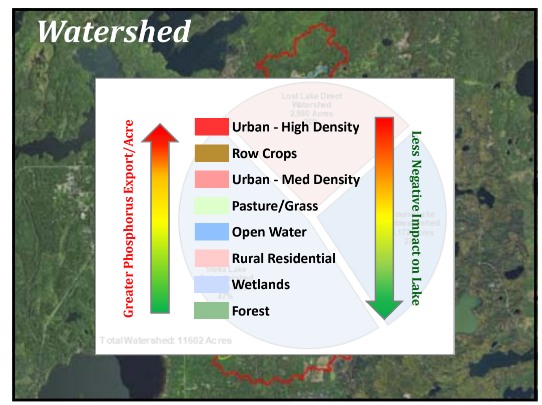

Secchi Disk Clarity Long-Term Trends
Poor
Fair
Good
Excellent
Average summer = 7 feet
• Excellent for SLDL
• Exceeds SLDL median
• Shallower than ecoregion median
• Variable, no trend
Onterra LLC
Lake Management Planning

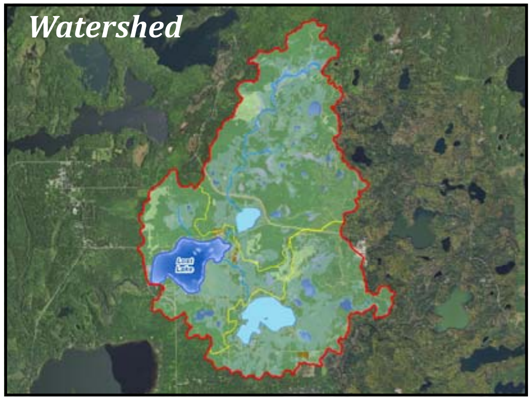

Lost Lake Stakeholder Perceptions of Water Quality
How would you describe the current water quality of Lost Lake?
Very Poor
Poor
Fair
Good
Excellent
Unsure
60%
26%
6%
4%
2%
2%
How has water quality changed in Lost Lake since you first visited the lake?
Severely degraded
Somewhat degraded
Remained the same
Somewhat improved
Greatly improved
Unsure
3%
7%
12%
9%
31%
38%
Onterra LLC
Lake Management Planning

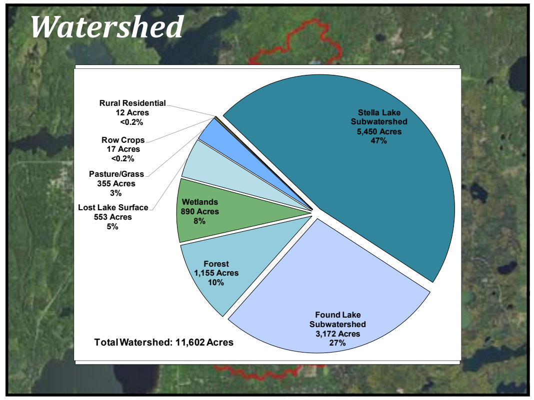

Management Goal:
Maintain Current Water Quality Conditions
Possible Management Actions
1. Monitor water quality through WDNR Citizens Lake Monitoring Network.
Continuation of current effort
Requires refreshed volunteer commitment
Onterra LLC
Lake Management Planning

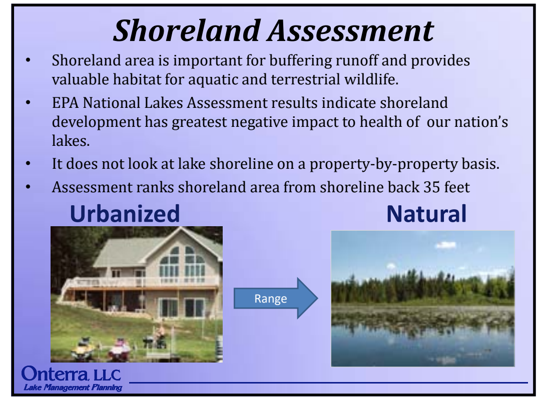

Watershed
11,602 acres
WS:LA = 20:1
Residence Time: 0.49 yr
Flushing Rate: 2.04/yr
Lost Lake

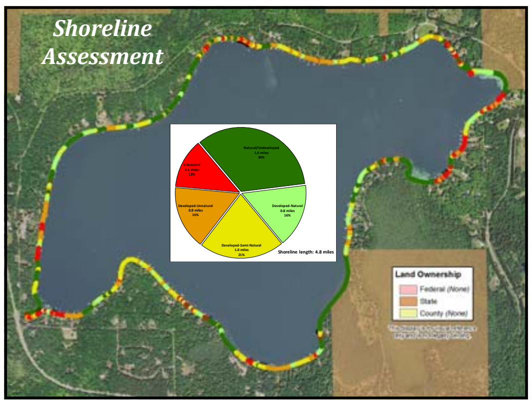

Watershed
Lost Lake

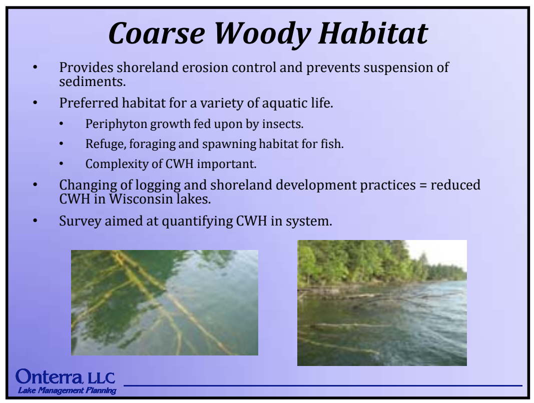

Watershed
Greater Phosphorus Export/Acre
Urban - High Density
Row Crops
Urban - Med Density
Pasture/Grass
Open Water
Rural Residential
Wetlands
Forest
Less Negative Impact on Lake

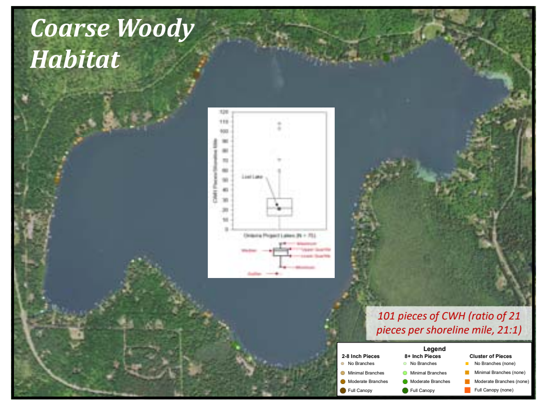

Watershed
Lost Lake


Watershed
Rural Residential
12 Acres
<0.2%
Row Crops
17 Acres
<0.2%
Pasture/Grass
355 Acres
3%
Lost Lake Surface
553 Acres
5%
Wetlands
890 Acres
8%
Forest
1,155 Acres
10%
Stella Lake
Subwatershed
5,450 Acres
47%
Found Lake
Subwatershed
3,172 Acres
27%
Total Watershed: 11,602 Acres


Shoreland Assessment
• Shoreland area is important for buffering runoff and provides valuable habitat for aquatic and terrestrial wildlife.
• EPA National Lakes Assessment results indicate shoreland development has greatest negative impact to health of our nation's lakes.
• It does not look at lake shoreline on a property-by-property basis.
• Assessment ranks shoreland area from shoreline back 35 feet
Urbanized
Natural
Range
Onterra LLC
Lake Management Planning


Shoreline
Assessment
Shoreline length: 4.8 miles
Land Ownership
Federal (None)
State
County (None)


Coarse Woody Habitat
• Provides shoreland erosion control and prevents suspension of sediments.
• Preferred habitat for a variety of aquatic life.
• Periphyton growth fed upon by insects.
• Refuge, foraging and spawning habitat for fish.
• Complexity of CWH important.
• Changing of logging and shoreland development practices = reduced CWH in Wisconsin lakes.
• Survey aimed at quantifying CWH in system.
Onterra LLC
Lake Management Planning


Coarse Woody
Habitat
Lost Lake
101 pieces of CWH (ratio of 21 pieces per shoreline mile, 21:1)
Legend
2-8 Inch Pieces
8+ Inch Pieces
Cluster of Pieces

Management Goal:
Maintain and Improve Lake Resource of Lost Lake

Possible Management Actions

1. **Educate Stakeholders on the Importance of Shoreland Condition, Shoreland Restoration, and Coarse Woody Habitat (Fish Sticks Program)**
2. **Protect natural shoreland zones**

Onterra LLC
Lake Management Planning

Conclusions

Water Quality & Watershed

- Overall good for shallow lowland drainage
- Data gaps make it difficult to to conduct trend analysis
- Water clarity may be slightly decreased in recent years (precipitation)
- Watershed is in great shape and supports the great water quality
- Attention should be paid to shoreland areas to increase habitat value

Onterra LLC
Lake Management Planning

Conclusions

Aquatic Plants

- EWM hand-harvesting was early response approach
  - This plan will have to outline future management strategy
- CLP response was wait-and-see followed by herbicide spot treatment
  - This plan will have to outline future management strategy
- Native plant community is healthy, but reduced in recent years

Onterra LLC
Lake Management Planning

Next Steps – Planning Meeting II/Teleconf

- More on aquatic plant management
  - WDNR discussions
  - Tribal discussions
- Fisheries data integration
  - WDNR is in charge of fisheries management goals, but discussion of how district interacts and provides feedback on these goals
- Solid draft of full plan to WDNR by Dec 1, 2018 to satisfy base eligibility requirements to apply for Feb 1, 2019 AIS-EPC Grant

Onterra LLC
Lake Management Planning

B

APPENDIX B

Riparian Stakeholder Survey Response Charts & Comments

Lost Lake - Anonymous Stakeholder Survey

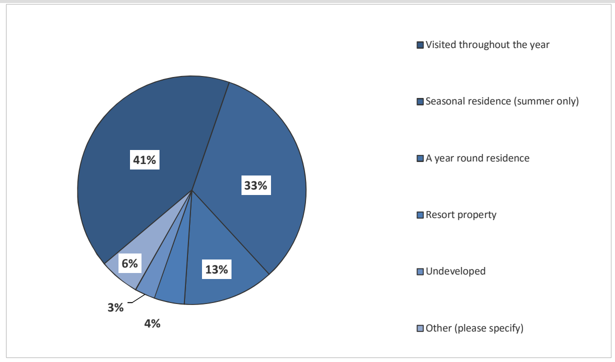
Surveys Distributed: 189
Surveys Returned: 71
Response Rate: 38%

Lost Lake Property

1. How is your property on Lost Lake utilized?

Answer Options	Response Percent	Response Count
Visited throughout the year	41.4%	29
Seasonal residence (summer only)	32.9%	23
A year round residence	12.9%	9
Resort property	4.3%	3
Undeveloped	2.9%	2
Other (please specify)	5.7%	4
	answered question	**70**
	skipped question	**1**

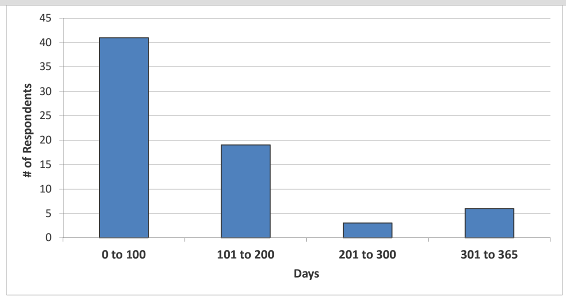
Number	Other (please specify)
1	5/1 - Columbus Day 11/?
2	vacation summer/winter
3	has been seasonal in past but about to retire and expect
4	Seasonal Rental



2. How many days each year is your property used by you or others?

Answer Options	Response Count
	69
answered question	**69**
skipped question	**2**

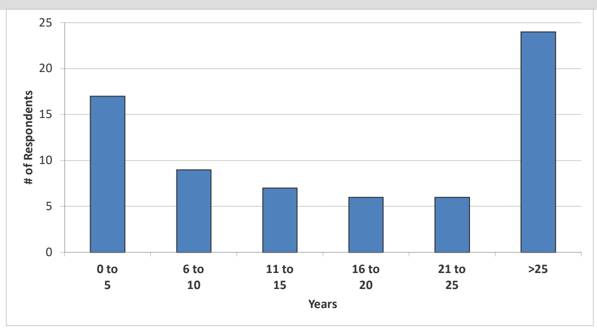
Category (# of days)	Responses	
0 to 100	**41**	**59%**
101 to 200	**19**	**28%**
201 to 300	**3**	**4%**
301 to 365	**6**	**9%**



3. How long have you owned your property on Lost Lake?

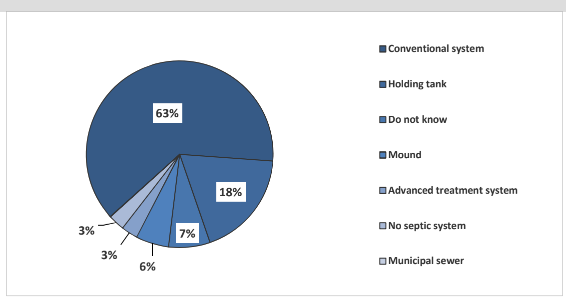
Answer Options	Response Count
	69
answered question	**69**
skipped question	**2**

Category (# of years)	Responses	% Response
0 to 5	**17**	**25%**
6 to 10	**9**	**13%**
11 to 15	**7**	**10%**
16 to 20	**6**	**9%**
21 to 25	**6**	**9%**
>25	**24**	**35%**



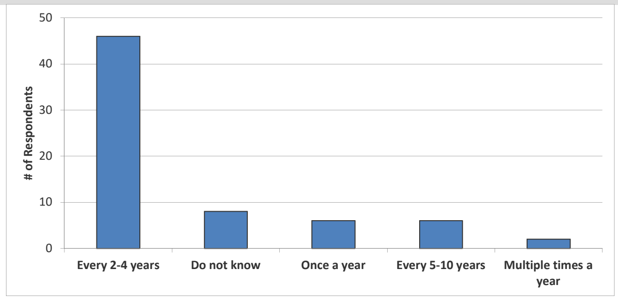
4. What type of septic system does your property utilize?

Answer Options	Response Percent	Response Count
Conventional system	62.9%	44
Holding tank	18.6%	13
Do not know	7.1%	5
Mound	5.7%	4
Advanced treatment system	2.9%	2
No septic system	2.9%	2
Municipal sewer	0.0%	0
	answered question	**70**
	skipped question	**1**



5. How often is the septic system on your property pumped?

Answer Options	Response Percent	Response Count
Every 2-4 years	67.7%	46
Do not know	11.8%	8
Once a year	8.8%	6
Every 5-10 years	8.8%	6
Multiple times a year	2.9%	2
	answered question	**68**
	skipped question	**3**

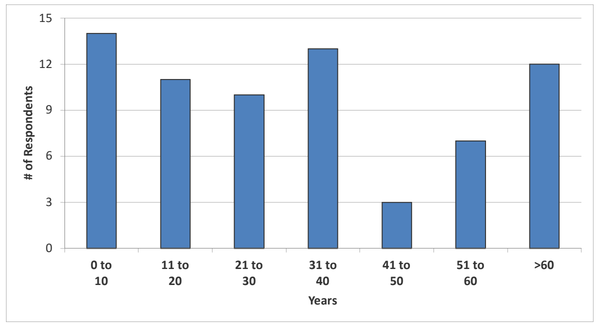


Recreational Activity on Lost Lake

6. How many years ago did you first visit Lost Lake?

Answer Options	Response Count
	70
answered question	**70**
skipped question	**1**

Category (# of days)	Responses	% Response
0 to 10	14	**20%**
11 to 20	11	**16%**
21 to 30	10	**14%**
31 to 40	13	**19%**
41 to 50	3	**4%**
51 to 60	7	**10%**
>60	12	**17%**



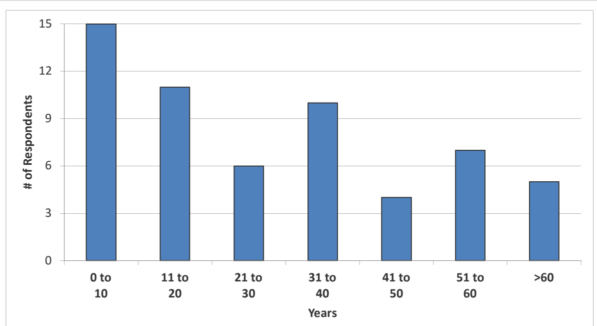
7. Have you personally fished on Lost Lake in the past three years?

Answer Options	Response Percent	Response Count
Yes	82.6%	57
No	17.4%	12
	answered question	**69**
	skipped question	**2**

8. For how many years have you fished Lost Lake?

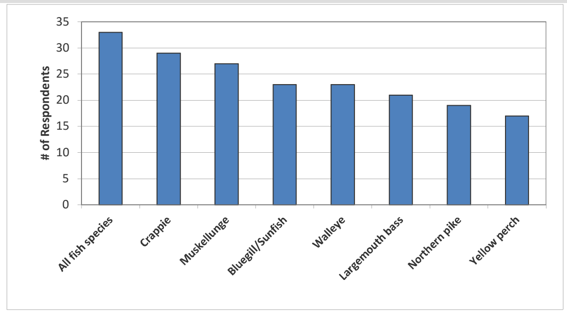
Answer Options	Response Count
	58
answered question	**58**
skipped question	**13**

Category (# of years)	Responses	% Response
0 to 10	15	**26%**
11 to 20	11	**19%**
21 to 30	6	**10%**
31 to 40	10	**17%**
41 to 50	4	**7%**
51 to 60	7	**12%**
>60	5	**9%**



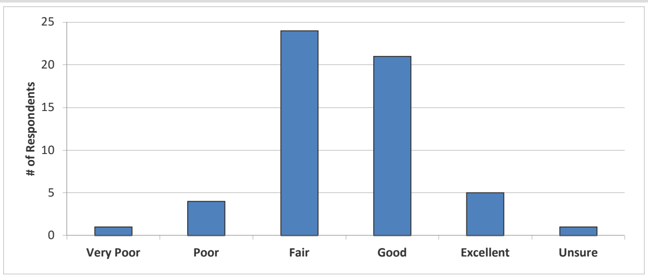
9. What species of fish do you like to catch on Lost Lake?

Answer Options	Response Percent	Response Count
All fish species	57.9%	33
Crappie	50.9%	29
Muskellunge	47.4%	27
Bluegill/Sunfish	40.4%	23
Walleye	40.4%	23
Largemouth bass	36.8%	21
Northern pike	33.3%	19
Yellow perch	29.8%	17
Other (please specify)	0.0%	0
	answered question	57
	skipped question	14



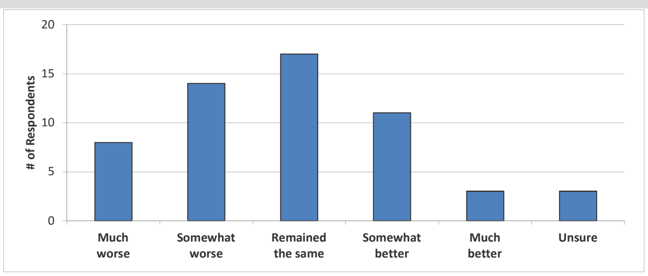
10. How would you describe the current quality of fishing on Lost Lake?

Answer Options	Very Poor	Poor	Fair	Good	Excellent	Unsure	Response Count
	1	4	24	21	5	1	56
						answered question	56
						skipped question	15



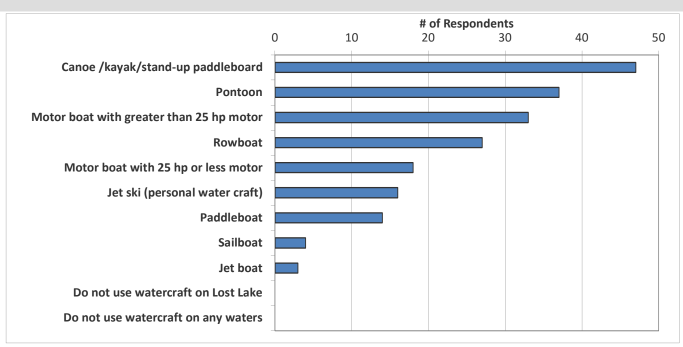
11. How has the quality of fishing changed on Lost Lake since you have started fishing the lake?

Answer Options	Much worse	Somewhat worse	Remained the same	Somewhat better	Much better	Unsure	Response Count
	8	14	17	11	3	3	56
						answered question	56
						skipped question	15



12. What types of watercraft do you currently use on Lost Lake?

Answer Options	Response Percent	Response Count
Canoe /kayak/stand-up paddleboard	69.1%	47
Pontoon	54.4%	37
Motor boat with greater than 25 hp motor	48.5%	33
Rowboat	39.7%	27
Motor boat with 25 hp or less motor	26.5%	18
Jet ski (personal water craft)	23.5%	16
Paddleboat	20.6%	14
Sailboat	5.9%	4
Jet boat	4.4%	3
Do not use watercraft on Lost Lake	0.0%	0
Do not use watercraft on any waters	0.0%	0
	answered question	68
	skipped question	3



13. Do you use your watercraft on waters other than Lost Lake?

Answer Options	Response Percent	Response Count
Yes	32.4%	22
No	67.7%	46
	answered question	68
	skipped question	3

14. What is your typical cleaning routine after using your watercraft on waters other than Lost Lake?

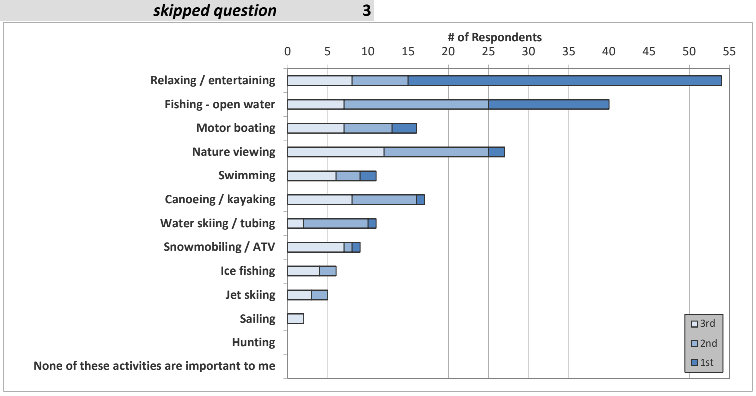
Answer Options	Response Percent	Response Count
Remove aquatic hitch-hikers (ex. - plant material, clams, mussels)	91.3%	21
Drain bilge	65.2%	15
Rinse boat	30.4%	7
Power wash boat	4.4%	1
Do not clean boat	4.4%	1
Apply bleach	0.0%	0
Other (please specify)	0.0%	1
	answered question	23
	skipped question	48

Number	Other (please specify)
1	hand dry when removed

15. For the list below, rank up to three activities that are important reasons for owning your property on Lost Lake, with 1 being the most important.

Answer Options	1st	2nd	3rd	Rating Average	Response Count
Relaxing / entertaining	39	7	8	1.43	54
Fishing - open water	15	18	7	1.8	40
Motor boating	3	6	7	2.25	16
Nature viewing	2	13	12	2.37	27
Swimming	2	3	6	2.36	11
Canoeing / kayaking	1	8	8	2.41	17
Water skiing / tubing	1	8	2	2.09	11
Snowmobiling / ATV	1	1	7	2.67	9
Ice fishing	0	2	4	2.67	6
Jet skiing	0	2	3	2.6	5
Sailing	0	0	2	3	2
Hunting	0	0	0	0	0
None of these activities are important to me	0	0	0	0	0
Other (please specify below)	3	0	1	1.5	4
				answered question	68
				skipped question	3

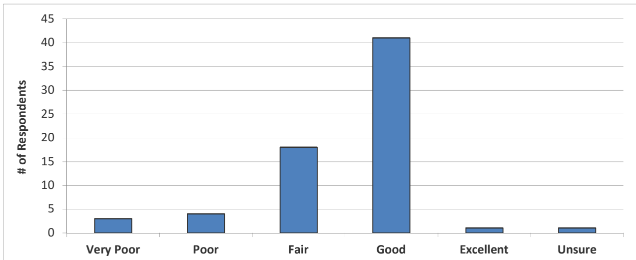
Number	"Other" responses
1	Golf
2	Just enjoy living by the lake
3	pontoon cruising
4	nature
5	Our retirement residence
6	Pontoon boating



Lost Lake Current and Historic Condition, Health and Management

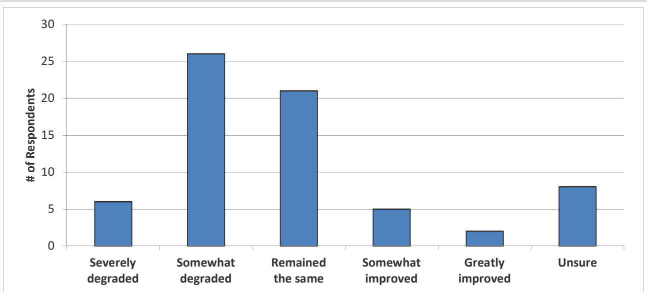
16. How would you describe the current water quality of Lost Lake?

Answer Options	Very Poor	Poor	Fair	Good	Excellent	Unsure	Response Count
	3	4	18	41	1	1	68
						answered question	**68**
						skipped question	**3**



17. How has the current water quality changed in Lost Lake since you first visited the lake?

Answer Options	Severely degraded	Somewhat degraded	Remained the same	Somewhat improved	Greatly improved	Unsure	Response Count
	6	26	21	5	2	8	68
						answered question	**68**
						skipped question	**3**



18. Before reading the statement above, had you ever heard of aquatic invasive species?

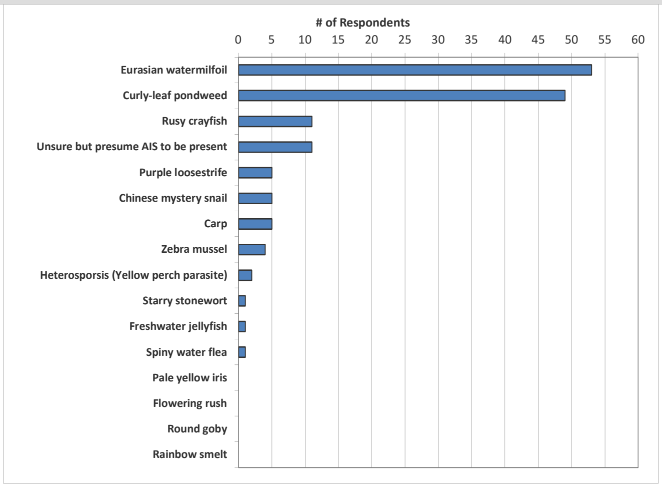
Answer Options	Response Percent	Response Count
Yes	100.0%	67
No	0.0%	0
	answered question	**67**
	skipped question	**4**

19. Do you believe aquatic invasive species are present within Lost Lake?

Answer Options	Response Percent	Response Count
Yes	94.0%	63
I think so but am not certain	6.0%	4
No	0.0%	0
	answered question	**67**
	skipped question	**4**

20. Which aquatic invasive species do you believe are in Lost Lake?

Answer Options	Response Percent	Response Count
Eurasian watermilfoil	80.3%	53
Curly-leaf pondweed	74.2%	49
Rusy crayfish	16.7%	11
Unsure but presume AIS to be present	16.7%	11
Purple loosestrife	7.6%	5
Chinese mystery snail	7.6%	5
Carp	7.6%	5
Zebra mussel	6.1%	4
Heterosporsis (Yellow perch parasite)	3.0%	2
Starry stonewort	1.5%	1
Freshwater jellyfish	1.5%	1
Spiny water flea	1.5%	1
Pale yellow iris	0.0%	0
Flowering rush	0.0%	0
Round goby	0.0%	0
Rainbow smelt	0.0%	0
Other (please specify)	3.0%	2
	answered question	66
	skipped question	5

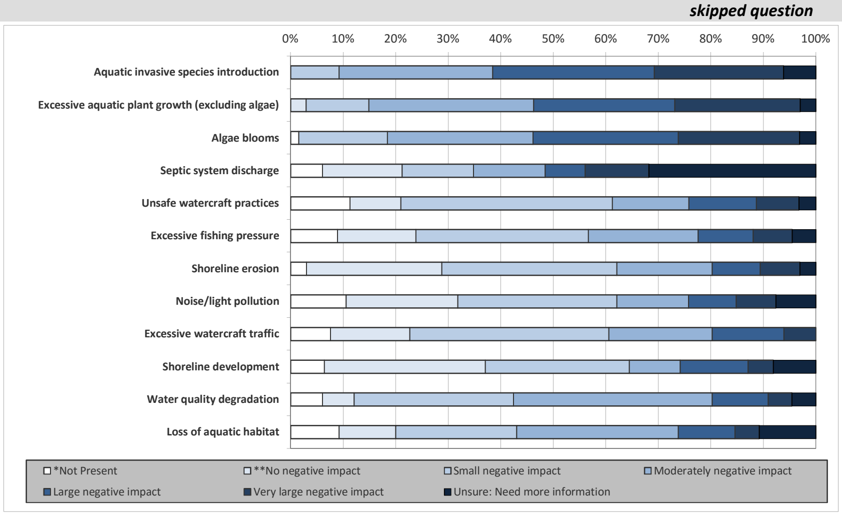


Number	"Other" responses
1	Spatterdock or White Water Lily
2	not an expert on this. agree that invasive species are in the lake because the lake district news letters talk about it

21. To what level do you believe each of the following factors may currently be negatively impacting Lost Lake?
*** Not Present means that you believe the issue does not exist on Lost Lake.**
**** No Impact means that the issue may exist on Lost Lake but it is not negatively impacting the lake.**

Answer Options	*Not Present	**No negative impact	Small negative impact	Moderately negative impact	Large negative impact	Very large negative impact	Unsure: Need more information	Rating Average	Response Count
Aquatic invasive species introduction	0	0	6	19	20	16	4	2.58	65
Excessive aquatic plant growth (excluding algae)	0	2	8	21	18	16	2	2.51	67
Algae blooms	1	0	11	18	18	15	2	2.48	65
Septic system discharge	4	10	9	9	5	8	21	1.12	66
Unsafe watercraft practices	7	6	25	9	8	5	2	1.40	62
Excessive fishing pressure	6	10	22	14	7	5	3	1.36	67
Shoreline erosion	2	17	22	12	6	5	2	1.27	66
Noise/light pollution	7	14	20	9	6	5	5	1.15	66
Excessive watercraft traffic	5	10	25	13	9	4	0	1.42	66
Shoreline development	4	19	17	6	8	3	5	1.05	62
Water quality degradation	4	4	20	25	7	3	3	1.56	66
Loss of aquatic habitat	6	7	15	20	7	3	7	1.35	65
Other (please specify)									4
								answered question	67
								skipped question	4

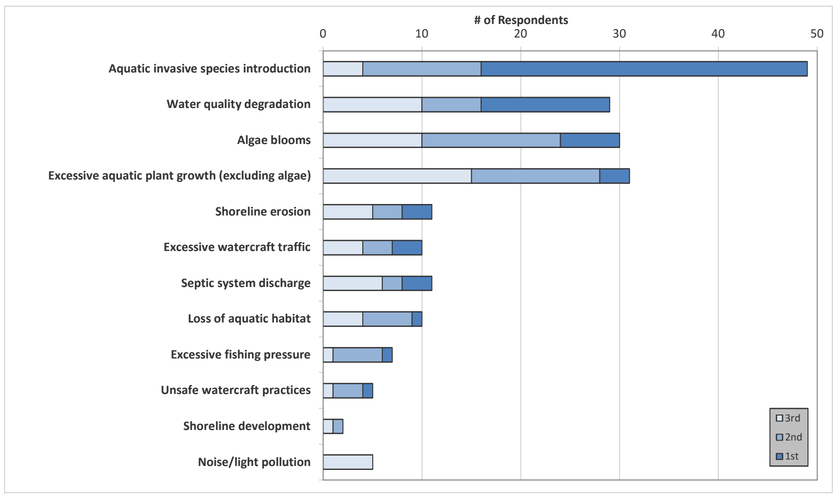
Number	Other (please specify)
1	the lake weeds are out of control and then turn to muck on the lake bottom
2	Excessive number of jet skis in the summer time negatively impacts fishing.
3	herbacide monitoring a must!!
4	Lack of adequate stocking of walleye (poor walley management)



22. From the list below, please rank your top three concerns regarding Lost Lake, with 1 being your greatest concern.

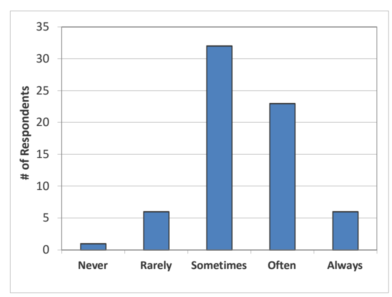
Answer Options	1st	2nd	3rd	Response Count
Aquatic invasive species introduction	33	12	4	49
Water quality degradation	13	6	10	29
Algae blooms	6	14	10	30
Excessive aquatic plant growth (excluding algae)	3	13	15	31
Shoreline erosion	3	3	5	11
Excessive watercraft traffic	3	3	4	10
Septic system discharge	3	2	6	11
Loss of aquatic habitat	1	5	4	10
Excessive fishing pressure	1	5	1	7
Unsafe watercraft practices	1	3	1	5
Shoreline development	0	1	1	2
Noise/light pollution	0	0	5	5
Other (please specify)	0	1	1	2
Please specify "Other" response here				4
			answered question	68
			skipped question	3

Number	"Other" responses
1	out of control weed growth, then the weeds turn to muck walleye population has no rocky bottom to spawn
2	Walleye Fishing non existent/very poor
3	chemical treatment of the lake may be hazard
4	Lack of adequate walleye stocking (poor walleye management...have the DNR help stock extended growth walleyes or ask them to set the bag limit to one walleye over 24 inches until walleye population recovers)



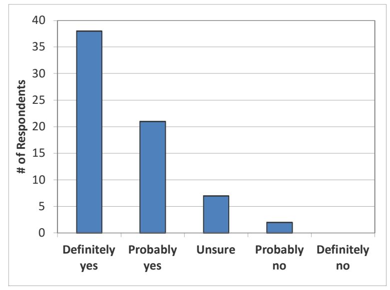
23. During open water season how often does aquatic plant growth, including algae, negatively impact your enjoyment of Lost Lake?

Answer Options	Never	Rarely	Sometimes	Often	Always	Response Count
	1	6	32	23	6	68
					answered question	68
					skipped question	3



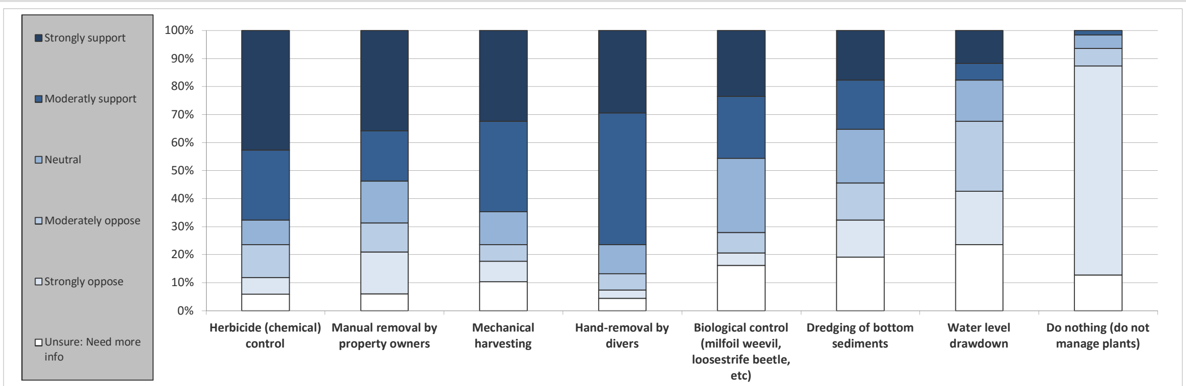
24. Considering your answer to the question above, do you believe aquatic plant control is needed on Lost Lake?

Answer Options	Definitely yes	Probably yes	Unsure	Probably no	Definitely no	Response Count
	38	21	7	2	0	68
					answered question	**68**
					skipped question	**3**



25. Aquatic plants can be managed using many techniques. What is your level of support for the responsible use of the following techniques on Lost Lake?

Answer Options	Strongly oppose	Moderately oppose	Neutral	Moderatly support	Strongly support	Unsure: Need more info	Rating Average	Response Count
Herbicide (chemical) control	4	8	6	17	29	4	3.69	68
Manual removal by property owners	10	7	10	12	24	4	3.31	67
Mechanical harvesting	5	4	8	22	22	7	3.46	68
Hand-removal by divers	2	4	7	32	20	3	3.81	68
Biological control (milfoil weevil, loosestrife beetle, etc)	3	5	18	15	16	11	3.04	68
Dredging of bottom sediments	9	9	13	12	12	13	2.56	68
Water level drawdown	13	17	10	4	8	16	1.96	68
Do nothing (do not manage plants)	47	4	3	1	0	8	1.08	63
							answered question	**68**
							skipped question	**3**



26. Did you know that aquatic herbicides were being applied in Lost Lake to help control CLP?

Answer Options	Response Percet	Response Count
Yes	82.1%	55
I think so but can't say for certain	1.5%	1
No	16.4%	11
	answered question	**67**
	skipped question	**4**

27. How do you feel about the past use of herbicides to treat CLP in 2017?

Answer Options	Completely support	Moderately support	Unsure/Neutral	Moderately oppose	Completely oppose	Rating Average	Response Count
	42	13	6	5	2	1.71	68
						answered question	**68**
						skipped question	**3**

28. What is your level of support or opposition for future aquatic herbicide use to treat CLP in Lost Lake?

Answer Options	Completely support	Moderately support	Unsure/Neutral	Moderately oppose	Completely oppose	Rating Average	Response Count
	41	15	6	4	2	1.69	68
						answered question	68
						skipped question	3

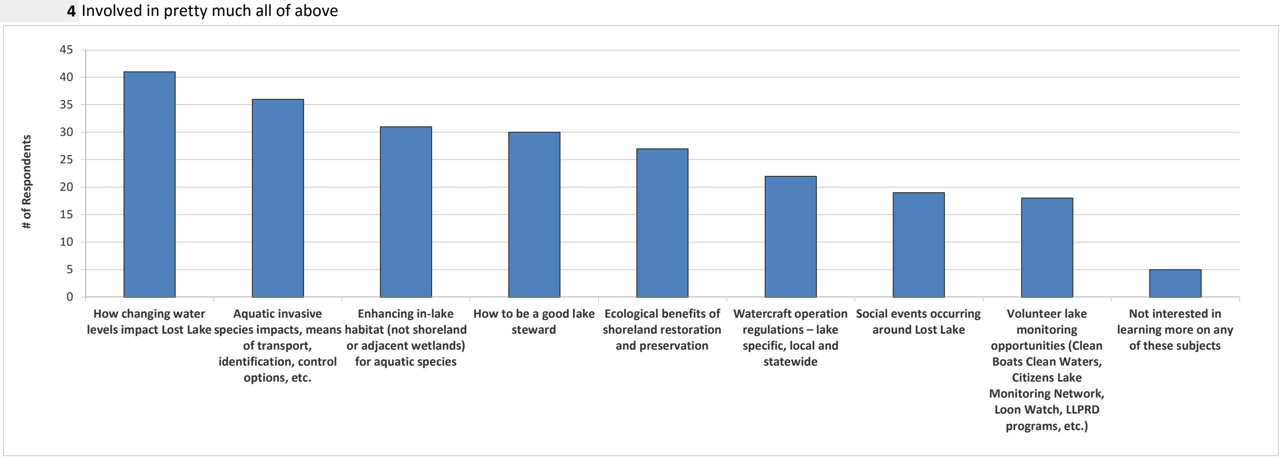
29. What is the reason(s) you oppose the future use of aquatic herbicides to target CLP in Lost Lake?

Answer Options	Response Percent	Response Count
Potential impacts to native (non-plant) species such as fish, insects, etc.	100.0%	6
Future impacts are unknown	100.0%	6
Potential impacts to human health	83.3%	5
Potential impacts to native aquatic plant species	50.0%	3
Potential cost of treatment is too high	16.7%	1
Another reason (please specify)	0.0%	0
	answered question	6
	skipped question	65

30. Stakeholder education is an important component of every lake management planning effort. Which of these subjects would you like to learn more about?

Answer Options	Response Percent	Response Count
How changing water levels impact Lost Lake	64.1%	41
Aquatic invasive species impacts, means of transport, identification, control options, etc.	56.3%	36
Enhancing in-lake habitat (not shoreland or adjacent wetlands) for aquatic species	48.4%	31
How to be a good lake steward	46.9%	30
Ecological benefits of shoreland restoration and preservation	42.2%	27
Watercraft operation regulations – lake specific, local and statewide	34.4%	22
Social events occurring around Lost Lake	29.7%	19
Volunteer lake monitoring opportunities (Clean Boats Clean Waters, Citizens Lake Monitoring Network, Loon Watch, LLPRD programs, etc.)	28.1%	18
Not interested in learning more on any of these subjects	7.8%	5
Other (please specify)	6.3%	4
	answered question	64
	skipped question	7

Number	Other (please specify)
1	species specific herbacide vs.broad spectrum
2	details regarding the results of the CLP herbacide used - I think it affected a larger area than planned???
3	how to prevent shore line erosion
4	Involved in pretty much all of above



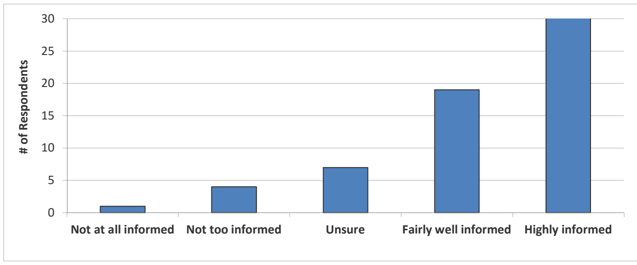
Lost Lake Protection & Rehabilitation District (LLPRD)

31. Before receiving this mailing, have you ever heard of the LLPRD?

Answer Options	Response Percent	Response Count
Yes	95.6%	65
No	4.4%	3
	answered question	68
	skipped question	3

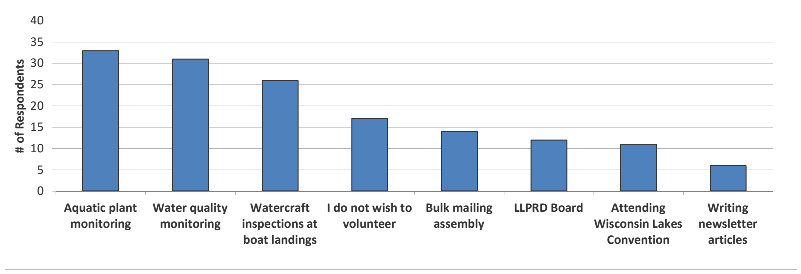
32. How informed has the LLPRD kept you regarding issues with Lost Lake and its management since the recent formation of the district?

Answer Options	Not at all informed	Not too informed	Unsure	Fairly well informed	Highly informed	Response Count
	1	4	7	19	34	65
					answered question	**65**
					skipped question	**6**



33. The effective management of your lake will require the cooperative efforts of numerous volunteers. Please circle the activities you would be willing to participate in if the LLPRD requires additional assistance.

Answer Options	Response Percent	Response Count
Aquatic plant monitoring	49.3%	33
Water quality monitoring	46.3%	31
Watercraft inspections at boat landings	38.8%	26
I do not wish to volunteer	25.4%	17
Bulk mailing assembly	20.9%	14
LLPRD Board	17.9%	12
Attending Wisconsin Lakes Convention	16.4%	11
Writing newsletter articles	9.0%	6
	answered question	**67**
	skipped question	**4**



34. Please feel free to provide written comments concerning Lost Lake, its current and/or historic condition and its management.

Answer Options	Response Count
	37
answered question	**37**
skipped question	**34**

Number	Response Text
1	Georgie Southwick did a great job with her book on Lost Lake. The Lost Lake Group Association has many social activities thanks to hard working volunteers. We think Lost Lake is a great place to enjoy wonderful summers. Those who live there are beautiful people. The Heelers add so much to the lake with their weekly ballgames. Pontoon Parties each week are so wonderful for our social life. Even the gatherings at Patti's on Sunday evenings keep us together as a group. Lost Lake is a wonderful place to meet your future spouse and fill your summers with fun and activities and finally retire enjoying a beautiful lake, wonderful friends, a fantastic place to entertain grandchildren. We Love Lost Lake! Thank you to all who make it so fantastic.
2	A big thank you to the board and all others who help keep Lost Lake healthy and beautiful.
3	OVER THE LAST 25 YEARS THE LAKE HAS BECOME VERY POLLUTED, I DO NOT LET MY DOGS SWIMM IN THE LAKE ANY MORE.
4	We are thankful that the LLPRD was formed and that it is performing at a high degree of care and responsibility on our behalf.
5	The formation of the LLPRD is a great plus for all Lost Lake property owners. The current board is doing a great job.
6	I believe current management is doing a great job. More grants are needed.
7	I think the LLPRD are taking the necessary steps in controlling the invasive species. Folks told me it was one of the best years for fishing. For the most part the lake seemed clear. We like to kayak and the algae blooms were bothersome. Usually they appeared around Labor Day & beyond, however in mid August they were occurring. I like flowers but I don't think it's necessary to leave them on piers. People fertilize them which I believe adds to the algae blooms. I enjoy star gazing and some folks leave very bright lights on their properties which diminishes the heavenly display. Thank you.
8	We feel that the LLPRD has done a masterful job in taking care of the health of Lost Lake. More needs to be done and we are thankful for this hard working group.
9	This past summer broad swaths of native vegatation were noticably absent, presumably from broad spectrum herbacide application. What can be done to assure a species specific herbacide is used to control only the unwanted vegitation in the proper concentrations. The east bay got wiped out, and although it may have enhanced property values for a select few, its impact on the health of the lake is suspect. Please publish who is responsible for the oversight of these types of projects,The outcomes affect ALL property owners! Thank you
10	Thank you for putting this survey together. I am interested to learn more. Thanks!!
11	The WDNR or LLPRD needs to do something to control weed growth and muck on the lake bottom
12	The lake is improving. The AIS treatment this past year seemed to be very effective.
13	Thank you for your work in preserving beautiful Lost Lake. I am concerned with the increased jet ski traffic on the lake. I wish there were some restricted hours for this kind of watercraft. Since the lake is smaller, it only takes a few jet skis to impact others on the lake.
14	thank you to all for conscientious efforts to make improvements.

15	I've been fishing on Lost Lake for over 40 years and I'm extremely disappointed with how the evasive weeds have taken over the lake. Scary times now that I'm a homeowner on the lake. My kids will never know how fantastic this lake used to be for fishing. Also since the permanent dam was installed decades ago to raise the water level on Stella Lake, the fishing on Lost Lake as never been the same. I'm so glad that the half of dozen residents on Stella Lake now have higher water levels for the past 30 years while the fishing on Lost Lake has steadily declined. Maybe the Stella Lake residents should of learned to trap beavers and remove all the dams on the creek that flows into their lake on the north side. When Stella Creek was allowed to flow freely into Lost Lake, I witnessed first hand on numerous occasions before the dam was built, large groups of 25"+ walleyes running up into the creek to spawn in the early spring. Now our lake has very little walleyes. Any correlation? I believe 100% YES!!!....On a more positive note, I'm happy to hear that the lake association purchased and released 1,500 five to seven inch walleyes in the lake this fall. This makes me very happy and should be done every year until the walleye population returns to historic levels. I'm glad to see the ballpark is still being maintained for the local kids to enjoy during the summer and please NEVER make any parking improvements and/or upgrades to the boat landing. The day this happens is the day I put my cabin up for sale. Less people on the lake the better!!!
16	.
17	30 years ago Lost lake was a weedy lake and a great fishery for Walleye and Muskie. It is not that way today. Walleye fishing is horrible and Muskie fish isn't as good as it once was.
18	Will not eat the fish due to the herbicide
19	we need more monitoring of lake boating laws
20	We feel that Lost Lake is a true Up North gem that needs to be protected and quality monitored for the benefit of all its lake users.
21	We love it here!
22	Found that over the 20 yrs,.all owners are not treated equally, when trying to restore their shoreline.or building distances from the lake..seems some owners are able to do what they want but others are held to permits etc. Some new cabins are 33 ft. from lake .Really!!
23	Management is doing a good job trying to improve and control the water quality. The invasive species appear to be spreading around the lake.
24	Weed growth and algae bloom have increased over the years. Last year due to weather weed growth exception. Fishing has continued to decline. Small panfish, few Walleye
25	I may be interested in being more involved if I were living at my property year round. I feel strongly about the need to actively pursue the recovery of the walleye population and would be willing to donate specifically to another future extended growth planting of walleyes in Lost lake. I also believe that it would be beneficial to seek the help of the DNR to change the limit for walleyes on our Lake to one fish over 24 inches allowing anyone who would want to keep a "trophy". We need more mature spawning walleyes to survive in our lake until the natural reproduction of walleyes can help sustain other efforts.
26	LLPRD Board has been very pro-active on issues concerning AIS problems.
27	Fighting invasives seems like an expensive no win battle.
28	I and others are willing to contribute to yearly stocking of the larger walleyes similar to what was stocked in 2017.
29	We have two properties on Lost Lake, one has been in the family for 40 years. There seems to now be quite a bit more American Lotus and or White Water Lily that have taken over certain areas on the North, East and SE parts of the lake. We plan on living on our property in 5-8 years and want a great lake and habitat for ourselves, as well as our children. I spent every summer up north for 50 years now and want our area a clean and welcoming place for others. Thank you.
30	Currently be actively and well managed
31	Too many city slickers with their outdoor yard lights and barking dogs!
32	The LLPRD is doing a great job managing AIS and keeping us informed of events on the lake. Keep up the good work!
33	We have a very active community on Lost that I am appreciative of that has been at the core of the Lost Lake Community Club and LLPRD. Thank you all who have donated your time. We have struggled to participate in the past because our time that we get to spend up is fairly limited and we want to spend with family when we are up. We will look for more opportunities for us to participate to ensure long term health of Lost Lake.
34	We are highly interested in and support the preservation and ongoing efforts of the LLPRD as we plan on becoming permanent residents of the lake in the coming years.
35	Nice work this year controlling the invasive species.
36	This was an interesting/informative survey. Clearly, protecting and maintaining Lost Lake is important, and we appreciate all of the effort going toward it.
37	I feel the Lost Lake District has, and continues to do a good job of dealing with lake problems.

C

APPENDIX C

Water Quality Data

	Secchi (feet)				Chlorophyll-*a* (µg/L)				Total Phosphorus (µg/L)			
	Growing Season		Summer		Growing Season		Summer		Growing Season		Summer	
Year	**Count**	**Mean**	**Count**	**Mean**	**Count**	**Mean**	**Count**	**Mean**	**Count**	**Mean**	**Count**	**Mean**
1979	1	4.5	1	4.5	1	22.2	1	22.2	1	40.0	1.0	40.0
1993	3	4.8	2	5.3								
1994	5	7.5	5	7.5								
1995	4	9.8	3	11.3								
1996	2	7.8	2	7.8								
1997	3	6.3	2	7.0	2	14.3	1	4.0	2	57.0	1.0	28.0
1998	5	9.1	2	9.5	4	5.0	2	2.8	5	26.0	2.0	20.0
1999					3	14.8	3	14.8	3	41.3	3.0	41.3
2000	4	6.3	3	6.0	4	13.8	3	15.3	4	37.3	3.0	37.3
2001	5	6.5	3	6.5	3	9.0	2	9.0	3	35.7	2.0	32.0
2002	2	6.0			3	11.5	1	3.2	3	29.7	1.0	19.0
2003	3	7.3	2	7.5	3	12.5	2	12.9	3	36.0	2.0	34.5
2004	3	9.0	2	9.0	3	6.0	2	4.6	3	49.3	2.0	53.5
2005					4	11.4	3	11.8	4	29.8	3.0	28.3
2006	4	5.5	2	4.5	3	15.6	2	17.9	3	35.0	2.0	35.0
2007	4	7.5	3	7.7	2	9.8	2	9.8	2	25.0	2.0	25.0
2008					1	8.4	1	8.4	1	36.0	1.0	36.0
2009							0					
2010	3	5.1	3	5.1	3	23.8	3	23.8	3	31.3	3.0	31.3
2011												
2012												
2013												
2014												
2015												
2016												
2017	5	4.4	3	4.6	5	18.4	3	21.2	5	43.0	3.0	39.5
All Years (Weighted)		6.8		7.0		13.0		13.3		36.2		34.1
SLDL Median				5.6				9.4				33.0
NLF Ecoregion Median				8.9				5.6				21.0

D

APPENDIX D

Point-Intercept Aquatic Macrophyte Survey Data

	Scientific Name	Common Name	LFOO (%) 2007	2010	2014	2017	2018
Dicots	*Myriophyllum spicatum*	Eurasian watermilfoil	0.0	0.0	0.0	2.4	8.8
	Ceratophyllum demersum	Coontail	58.8	54.0	38.7	13.2	11.3
	Myriophyllum sibiricum	Northern watermilfoil	20.2	38.1	14.0	2.4	0.6
	Bidens beckii	Water marigold	0.0	2.4	0.9	1.5	2.5
	Nuphar variegata	Spatterdock	1.7	0.8	0.4	0.5	1.3
	Nymphaea odorata	White water lily	0.8	0.0	0.0	1.0	1.3
	Utricularia vulgaris	Common bladderwort	0.0	0.0	0.0	0.0	0.6
	Myriophyllum tenellum	Dwarf watermilfoil	0.0	0.0	0.0	0.0	0.6
	Ranunculus aquatilis	White water crowfoot	0.4	0.0	0.0	0.0	0.0
	Myriophyllum verticillatum	Whorled watermilfoil	0.0	0.4	0.0	0.0	0.0
Non-dicots	*Potamogeton crispus*	Curly-leaf pondweed	0.0	0.0	0.0	4.4	4.4
	Potamogeton robbinsii	Fern-leaf pondweed	17.6	26.6	21.3	13.2	2.5
	Elodea canadensis	Common waterweed	16.4	36.9	6.0	5.4	7.5
	Potamogeton praelongus	White-stem pondweed	12.2	25.8	18.7	9.3	4.4
	Potamogeton zosteriformis	Flat-stem pondweed	16.8	50.0	0.0	0.0	0.6
	Vallisneria americana	Wild celery	15.5	14.7	4.7	20.0	11.9
	Najas flexilis	Slender naiad	3.4	11.9	6.0	21.5	11.9
	Potamogeton pusillus, P. berchtoldii, & P. strictifolius	Thin-leaved pondweed spp.	0.4	13.9	38.7	0.0	0.0
	Isoetes spp.	Quillwort spp.	8.4	4.4	3.8	10.2	15.1
	Potamogeton amplifolius	Large-leaf pondweed	19.3	9.9	9.8	4.4	1.3
	Potamogeton pusillus	Small pondweed	0.4	2.8	27.2	0.0	0.0
	Chara spp.	Muskgrasses	3.8	2.0	0.9	1.0	12.6
	Potamogeton berchtoldii	Slender pondweed	0.0	0.0	17.9	0.0	0.0
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	0.0	4.8	0.0	5.4	3.8
	Potamogeton richardsonii	Clasping-leaf pondweed	1.7	4.4	3.4	2.4	1.9
	Potamogeton strictifolius	Stiff pondweed	0.0	12.7	0.0	0.0	0.0
	Potamogeton gramineus	Variable-leaf pondweed	4.2	4.0	3.4	1.5	0.0
	Filamentous algae	Filamentous algae	2.1	0.0	5.5	4.4	1.3
	Eleocharis acicularis	Needle spikerush	3.4	1.2	0.9	1.0	1.3
	Heteranthera dubia	Water stargrass	0.8	0.0	0.4	0.5	3.1
	Stuckenia pectinata	Sago pondweed	0.0	0.8	1.3	0.5	0.0
	Juncus pelocarpus	Brown-fruited rush	0.8	0.8	0.4	0.0	0.0
	Eriocaulon aquaticum	Pipewort	0.0	0.0	0.0	0.0	1.3
	Schoenoplectus acutus	Hardstem bulrush	0.0	0.0	0.4	0.0	0.6
	Nitella spp.	Stoneworts	0.0	0.8	0.0	0.0	0.0
	Lemna turionifera	Turion duckweed	0.0	0.0	0.0	0.0	0.6
	Lemna trisulca	Forked duckweed	0.0	0.0	0.0	0.0	0.6
	Schoenoplectus tabernaemontani	Softstem bulrush	0.0	0.4	0.0	0.0	0.0
	Potamogeton illinoensis	Illinois pondweed	0.4	0.0	0.0	0.0	0.0
	Potamogeton foliosus	Leafy pondweed	0.4	0.0	0.0	0.0	0.0
	Pontederia cordata	Pickerelweed	0.0	0.4	0.0	0.0	0.0
	Lobelia dortmanna	Water lobelia	0.0	0.4	0.0	0.0	0.0
	Fissidens spp. & Fontinalis spp.	Aquatic Moss	0.0	0.0	0.0	0.5	0.0

Surveys By:
WDNR: 2007, 2014
Onterra: 2010, 2017, 2018

E

APPENDIX E

WDNR Fisheries Information Sheet for Lost Lake, 2011

WISCONSIN DNR
FISHERIES INFORMATION SHEET

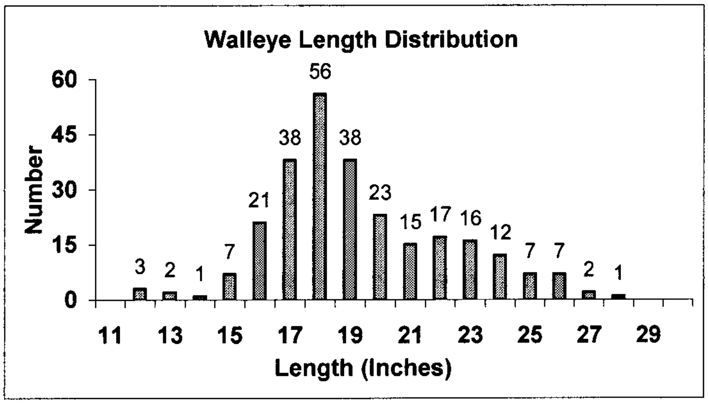
LAKE: Lost **COUNTY:** Vilas **YEAR:** 2011

The Department of Natural Resources surveyed Lost Lake, Vilas County, from April 23 through May 17, 2011, to determine the health of its fishery. The survey was primarily focused on estimating the abundance of the lake's gamefish. Lost Lake is a drainage lake with predominately sand, gravel and muck substrate. This lake has a surface area of 544 acres, 4.6 miles of shoreline, and a maximum depth of 20 feet.

Walleye

We conducted a mark-recapture survey of Lost Lake to make an estimate of the number of adult* walleye present. We captured and marked (fin clipped) 246 adult walleye in 6 days of netting and captured 52 adult walleyes during one night of electrofishing.

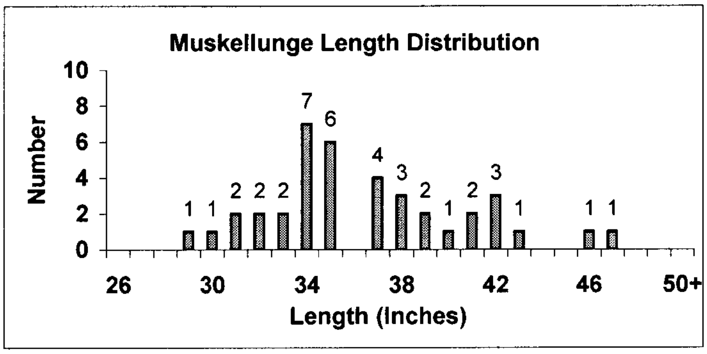
Based on these results, we calculated that Lost Lake is home to 497 adult walleye (0.9/acre). Approximately 97% of the adult walleye were legal-size, 15 inches long or larger. The average size for walleyes in Lost Lake was 19.4 inches long and the largest walleye we captured was 28.0 inches long.



Muskellunge

We captured and marked (fin clipped) 39 adult muskellunge in 11 days of sampling. Netting in spring of 2012 will be used to recapture muskellunge marked this year to estimate the adult muskellunge population.

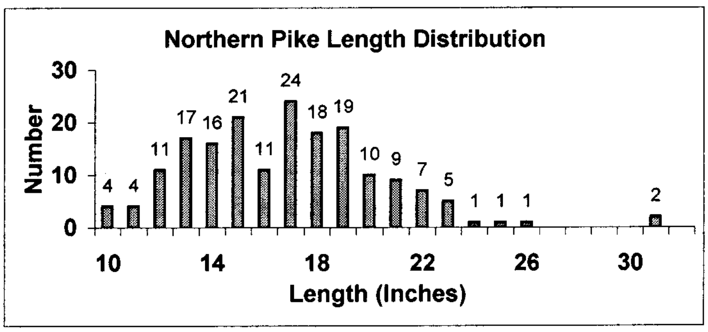
Approximately 79% of the adult muskellunge were 34 inches long or larger and 23% were 40 inches long or larger. The largest muskellunge we captured was a 47.0 inch long female that weighed 29.9 pounds.



Northern Pike

We captured and marked (fin clipped) 181 adult northern pike in 11 days of sampling.

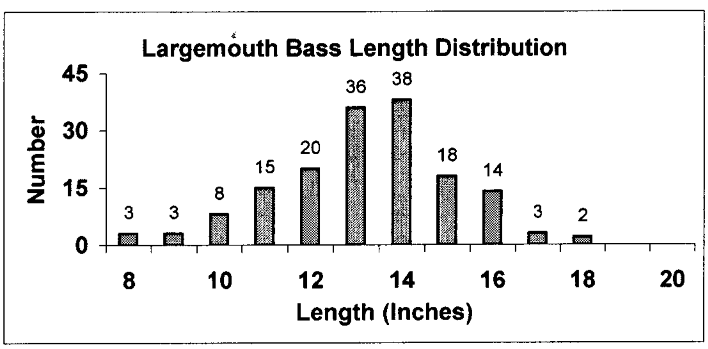
The average length of the northern pike captured was 16.8 inches long. The largest pike we captured was a 31.9 inch female.



Largemouth and Smallmouth Bass

We captured 160 largemouth bass in 11 days of sampling. The average size of the largemouth bass captured was 13.3 inches long and the biggest largemouth bass we captured was 18.0 inches long.

Smallmouth bass abundance was very low; only 11 were captured during the survey work. The smallmouth bass captured ranged in size from 8.6 to 19.2 inches long.

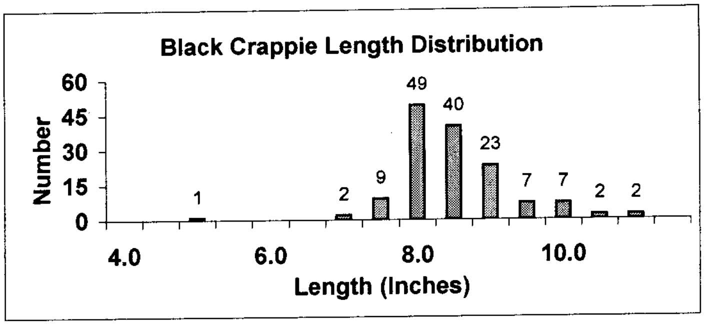


Drafted: May 19, 2011
By: Aaron Nelson

File: Lost Summary 11.xls

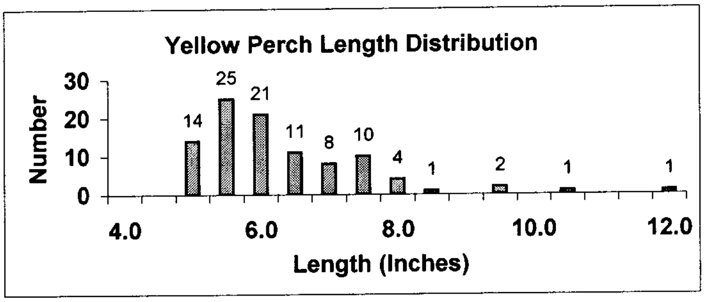
Black Crappie

Black crappie were considered to be moderately abundant based on the number captured in our nets. A random sample of 142 black crappies was measured and the average size of crappies in Lost Lake was 8.4 inches long. The largest crappie captured during the survey measured 11.9 inches long.



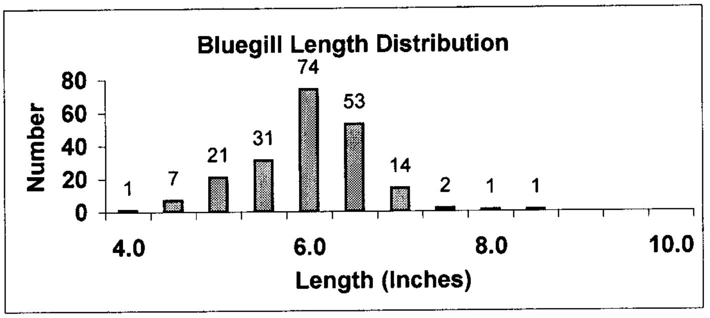
Yellow Perch

Yellow perch were considered to be moderately abundant based on the number captured in our nets. A random sample of 98 yellow perch was measured and the average size of perch in Lost Lake was 6.3 inches long. The largest perch captured during the survey measured 12.0 inches long.



Bluegill

Bluegill were considered to be abundant based on the number captured in our nets. From a random sample of 205 bluegills measured, the average size of bluegills in Lost Lake was 6.0 inches long. The largest bluegill captured during the survey measured 9.4 inches long.



Other Fish Species

All the catch per effort data present here should be viewed as minimum estimates of abundance. Other fish species captured or observed during this survey but in lower numbers were: pumpkinseed, rock bass, white sucker, burbot, yellow and black bullheads, creek chub, silver redhorse, golden shiner, common shiner, and bluntnose minnow.

Table 1. General Fishing Regulations for Lost Lake, Vilas County, 2011

FISH SPECIES	OPEN SEASON	DAILY LIMIT	MINIMUM LENGTH
Walleye	May 7 - March 4	5	15 inches
Largemouth and Smallmouth Bass	May 7 - June 17 (C&R) June 18 - March 4 (Harvest)	None 5	14 inches
Muskellunge	May 28 - Nov. 30	1	34 inches
Northern Pike	May 7 - March 4	5	No minimum length

A brief summary of selected fishing regulations for Lost Lake is included above (Table 1). While the regulatory information provided was current at the time the surveys were conducted, it is not comprehensive and should not be used as a substitute for the current fishing regulation pamphlet. You may obtain a copy of current fishing regulations when you purchase your fishing license, or download a copy from our web site at:

http://www.dnr.state.wi.us/fish/regulations

For answers to questions about fisheries management activities and plans for Lost Lake, Vilas County, contact:

Steve Gilbert, Fisheries Biologist
Wisconsin Department of Natural Resources
8770 Highway J
Woodruff, WI 54568
Phone: (715) 356-5211 Ext 229
Email: Stephen.Gilbert@Wisconsin.gov

Drafted: May 19, 2011
By: Aaron Nelson

File: Lost Summary 11.xls

F

APPENDIX F

Extracted Relevant Chapters from Aquatic Plant Management in Wisconsin: Draft Strategic Analysis – Draft December 2018

The WDNR is in the process of conducting a Strategy Analysis which will ultimately mold policies and approaches. The strategy the WDNR is following is outlined on the WDNR's APM Strategic Analysis Webpage:

https://dnr.wi.gov/topic/eia/apmsa.html

Below is a table of contents for the extracted materials for use in risk assessment of the discussed management tools within this project. Please refer to the WDNR's full text document cited above for Literature Cited.

Extracted Table of Contents

S.3.3. Herbicide Treatment

Herbicides are the most commonly employed method for controlling aquatic plants in Wisconsin. They are extremely useful tools for accomplishing aquatic plant management (APM) goals, like controlling invasive species, providing waterbody access, and ecosystem restoration. This Chapter includes basic information about herbicides and herbicide formulations, how herbicides are assessed for ecological and human health risks and registered for use, and some important considerations for the use of herbicides in aquatic environments.

A pesticide is a substance used to either directly kill pests or to prevent or reduce pest damage; herbicides are pesticides that are used to kill plants. Only a certain component of a pesticide product is intended to have pesticidal effects and this is called the active ingredient. The active ingredient is listed near the top of the first page on an herbicide product label. Any product claiming to have pesticidal properties must be registered with the U.S. EPA and regulated as a pesticide.

Inert ingredients often make up the majority of a pesticide formulation and are not intended to have pesticidal activity, although they may enhance the pesticidal activity of the active ingredient. These ingredients, such as carriers and solvents, are often added to the active ingredient by manufacturers, or by an herbicide applicator during use, in order to allow mixing of the active ingredient into water, make it more chemically stable, or aid in storage and transport. Manufacturers are not required to identify the specific inert ingredients on the pesticide label. In addition to inert ingredients included in manufactured pesticide formulations, adjuvants are inert ingredient products that may be added to pesticide formulations before they are applied to modify the properties or enhance pesticide performance. Adjuvants are typically not intended to have pesticidal properties and are not regulated as pesticides under the Federal Insecticide, Fungicide and Rodenticide Act. However, research has shown that inert ingredients can increase the efficacy and toxicity of pesticides especially if the appropriate label uses aren't followed (Mesnage et al. 2013; Defarge et al. 2016).

The combination of active ingredients and inert ingredients is what makes up a pesticide formulation. There are often many formulations of each active ingredient and pesticide manufacturers typically give a unique product or trade name to each specific formulation of an active ingredient. For instance, "Sculpin G" is a solid, granular 2,4-D amine product, while "DMA IV" is a liquid amine 2,4-D product, and the inert ingredients in these formulations are different, but both have the same active ingredient. Care should always be taken to read the herbicide product label as this will give information about which pests and ecosystems the product is allowed to be used for. Some formulations (i.e., non-aquatic formulations of glyphosate such as "Roundup") are not allowed for aquatic use and could lead to environmental degradation even if used on shorelines near the water. There are some studies which indaicate that the combination of two chemicals (e.g., 2,4-D and endothall) applied together produces syngerinstic efficacy results that are greater than if each product was applied alone (Skogerboe et al. 2012). Conversely, there are studies which indicate the the combination of two chemicals (i.e. diquat and penxosulam) which result in an antagonistic response between the herbicides, and resulted in reduced efficacy than when applying penoxsulam alone (Wersal and Madsen 2010b).

The U.S. EPA is responsible for registering pesticide products before they may be sold. In order to have their product registered, pesticide manufacturers must submit toxicity test data to the EPA that shows that the intended pesticide use(s) will not create unreasonable risks. "Unreasonable" in this context means that the risks of use outweigh the potential benefits. Once registered, the EPA must re-evaluate each pesticide and new information related to its use every 15 years. The current cycle of registration review will end in 2022, with a new cycle and review schedule starting then. In addition, EPA may decide to only register certain uses of any given pesticide product and can also require that only trained personnel can apply a pesticide before the risks outweigh the benefits. Products requiring training before application are called Restricted Use Pesticides.

As part of their risk assessments, EPA reviews information related to pesticide toxicity. Following laboratory testing, ecotoxicity rankings are given for different organismal groups based on the dosage that would cause harmful ecological effects (e.g., death, reduction in growth, reproductive impairment, and others). For example, the ecotoxicity ranking for 2,4-D ranges from "practically non-toxic" to "slightly toxic" for freshwater invertebrates, meaning tests have shown that doses of >100 ppm and 10-100 ppm are needed to cause 50% mortality or immobilization in the test population, respectively. Different dose ranges and indicators of "harm" are used to assess toxicity depending on the organisms being tested. More information can be found on the EPA's website.

Beyond selecting herbicide formulations approved for use in aquatic environments, there are additional factors to consider supporting appropriate and effective herbicide use in those environments. Herbicide treatments are often used in terrestrial restorations, so they are also often requested in the management and restoration of aquatic plant communities. However, unlike applications in a terrestrial environment, the fluid environment of freshwater systems presents a set of unique challenges. Some general best practices for addressing challenges associated with herbicide dilution, migration, persistence, and non-target impacts are described in Chapter 7.4. More detailed documentation of these challenges is described below and in discussions on individual herbicides in Supplemental Chapter S.3.3 (Herbicide Treatment).

As described in Chapter 7.4, when herbicide is applied to waters, it can quickly migrate offsite and dilute to below the target concentrations needed to provide control (Hoeppel and Westerdal 1983; Madsen et al. 2015; Nault et al. 2015). Successful plant control with herbicide is dependent on concentration exposure time (CET) relationships. In order to examine actual observed CET relationships following herbicide applications in Wisconsin lakes, a study of herbicide CET and Eurasian watermilfoil (*Myriophyllum spicatum*) control efficacy was conducted on 98 small-scale (0.1-10 acres) 2,4-D treatment areas across 22 lakes. In the vast majority of cases, initial observed 2,4-D concentrations within treatment areas were far below the applied target concentration, and then dropped below detectable limits within a few hours after treatment (Nault et al. 2015). These results indicate the rapid dissipation of herbicide off of the small treatment areas resulted in water column concentrations which were much lower than those recommended by previous laboratory CET studies for effective Eurasian watermilfoil control. Concentrations in protected treatment areas (e.g., bays, channels) were initially higher than those in areas more exposed to wind and waves, although concentrations quickly dissipated to below detectable limits within hours after treatment regardless of spatial location. Beyond confining small-scale treatments to protected areas, utilizing or integrating faster-acting herbicides with shorter CET requirements may also help to compensate for reductions in plant control due to dissipation (Madsen et al. 2015). The use of chemical curtains or adjuvants (weighting or sticking agents) may also help to maintain adequate CET, however more research is needed in this area.

This rapid dissipation of herbicide off of treatment areas is important for resource managers to consider in planning, as treating numerous targeted areas at a 'localized' scale may actually result in low-concentrations capable of having lakewide impacts as the herbicide dissipates off of the individual treatment sites. In general, if the percentage of treated areas to overall lake surface area is >5% and targeted areas are treated at relatively high 2,4-D concentrations (e.g., 2.0-4.0 ppm), then anticipated lakewide concentrations after dissipation should be calculated to determine the likelihood of lakewide effects (Nault et al. 2018).

Aquatic-use herbicides are commercially available in both liquid and granular forms. Successful target species control has been reported with both granular and liquid formulations. While there has been a commonly held belief that granular products are able to 'hold' the herbicide on site for longer periods of time, actual field comparisons between granular and liquid 2,4-D forms revealed that they dissipated similarly when applied at small-scale sites (Nault et al. 2015). In fact, liquid 2,4-D had higher initial observed water column concentrations than the granular form, but in the majority of cases concentrations of both forms decreased rapidly to below detection limits within several hours after treatment Nault et al. 2015). Likewise, according to United Phosphorus, Inc. (UPI), the sole manufacturer of endothall, the granular formulation of endothall does not hold the product in a specific area significantly longer than the liquid form (Jacob Meganck [UPI], *personal communication*).

In addition, the stratification of water and the formation of a thermal density gradient can confine the majority of applied herbicides in the upper, warmer water layer of deep lakes. In some instances, the entire lake water volume is used to calculate how much active ingredient should be applied to achieve a specific lakewide target concentration. However, if the volume of the entire lake is used to calculate application rates for stratified lakes, but the chemical only readily mixes into the upper water layer, the achieved lakewide concentration is likely to be much higher than the target concentration, potentially resulting in unanticipated adverse ecological impacts.

Because herbicides cannot be applied directly to specific submersed target plants, the dissipation of herbicide over the treatment area can lead to direct contact with non-target plants and animals. No herbicide is completely selective (i.e., effective specifically on only a single target species). Some plant species may be more susceptible to a given herbicide than others, highlighting the importance of choosing the appropriate herbicide, or other non-chemical management approach, to minimize potential non-target effects of treatment. There are many herbicides and plant species for which the CET relationship that would negatively affect the plant is unknown. This is particularly important in the case of rare, special concern, or threatened and endangered species. Additionally, loss of habitat following any herbicide treatment or other management technique may cause indirect reductions in populations of invertebrates or other organisms. Some organisms will only recolonize the managed areas as aquatic plants become re-established.

Below are reviews for the most commonly used herbicides for APM in Wisconsin. Much of the information here was pulled directly from DNR's APM factsheets (http://dnr.wi.gov/lakes/plants/factsheets/), which were compiled in 2012 using U.S. EPA herbicide product labels, U.S. Army Corps of Engineers reports, and communications with natural resource agencies in other northern, lake-rich states. These have been supplemented with more recent information from primary research publications.

Each pesticide has at least one mode of action which is the specific mechanism by which the active ingredient exerts a toxic effect. For example, some herbicides inhibit production of the pigments needed for photosynthesis while others mimic plant growth hormones and cause uncontrolled and unsustainable growth. Herbicides are often classified as either systemic or contact in mode of action, although some herbicides are able to function under various modes of action depending on environmental variables such as water temperature. Systemic pesticides are those that are absorbed by organisms and can be moved or translocated within the organism. Contact pesticides are those that exert toxic effects on the part(s) of an organism that they come in contact with. The amount of exposure time needed to kill an organism is based on the specific mode of action and the concentration of any given pesticide. In the descriptions below herbicides are generally categorized into which environment (above or below water) they are primarily used and a relative assessment of how quickly they impact plants. Herbicides can be applied in many ways. In lakes, they are usually applied to the water's surface (or below the water's surface) through controlled release by equipment including spreaders, sprayers, and underwater hoses. In wetland environments, spraying by helicopter, backpack sprayer, or application by cut-stem dabbing, wicking, injection, or basal bark application are also used.

S.3.3.1. Submersed or Floating, Relatively Fast-Acting Herbicides

Diquat

Registration and Formulations

Diquat (or diquat dibromide) initially received Federal registration for control of submersed and floating aquatic plants in 1962. It was initially registered with the U.S. EPA in 1986, evaluated for reregistration in 1995, and is currently under registration review. A registration review decision was expected in 2015 but has not been released (EPA Diquat Plan 2011). The active ingredient is 6,7-dihydrodipyrido[1,2-α:2',1'-c] pyrazinediium dibromide, and is commercially sold as liquid formulations for aquatic use.

Mode of Action and Degradation

Diquat is a fast-acting herbicide that works through contact with plant foliage by disrupting electron flow in photosystem I of the photosynthetic reaction, ultimately causing the destruction of cell membranes (Hess 2000; WSSA 2007). Plant tissues in contact with diquat become impacted within several hours after application, and within one to three days the plant tissue will become necrotic. Diquat is considered a non-selective herbicide and will rapidly kill a wide variety of plants on contact. Because diquat is a fast-acting herbicide, it is oftentimes used for managing plants growing in areas where water exchange is anticipated to limit herbicide exposure times, such as small-scale treatments.

Due to rapid vegetation decomposition after treatment, only partial treatments of a waterbody should be conducted to minimize dissolved oxygen depletion and associated negative impacts on fish and other aquatic organisms. Untreated areas can be treated with diquat 14 days after the first application.

Diquat is strongly attracted to silt and clay particles in the water and may not be very effective under highly turbid water conditions or where plants are covered with silt (Clayton and Matheson 2010).

The half-life of diquat in water generally ranges from a few hours to two days depending on water quality and other environmental conditions. Diquat has been detected in the water column from less than a day up towards 38 DAT, and remains in the water column longer when treating waterbodies with sandy sediments with lower organic matter and clay content (Coats et al. 1964; Grzenda et al. 1966; Yeo 1967; Sewell et al. 1970; Langeland and Warner 1986; Langeland et al. 1994; Poovey and Getsinger 2002; Parsons et al. 2007; Gorzerino et al. 2009; Robb et al. 2014). One study reported that diquat is chemically stable within a pH range of 3 to 8 (Florêncio et al. 2004). Due to the tendency of diquat to be rapidly adsorbed to suspended clays and particulates, long exposure periods are oftentimes not possible to achieve in the field. Studies conducted by Wersal et al. (2010a) did not observe differences in target species efficacy between daytime versus night-time applications of diquat. While large-scale diquat treatments are typically not implemented, a study by Parsons et al. (2007), observed declines in both dissolved oxygen and water clarity following the herbicide treatment.
Diquat binds indefinitely to organic matter, allowing it to accumulate and persist in the sediments over time (Frank and Comes 1967; Simsiman and Chesters 1976). It has been reported to have a very long-lived half-life (1000 days) in sediment because of extremely tight soil sorption, as well as an extremely low rate of degradation after association with sediment (Wauchope et al. 1992; Peterson et al. 1994). Both photolysis and microbial degradation are thought to play minor roles in degradation (Smith and Grove 1969; Emmett 2002). Diquat is not known to leach into groundwater due to its very high affinity to bind to soils.

One study reported that combinations of diquat and penoxsulam resulted in an antagonistic response between the herbicides when applied to water hyacinth (*Eichhornia crassipes*) and resulted in reduced efficacy than when applying penoxsulam alone. The antagonistic response is likely due to the rapid cell destruction by diquat that limits the translocation and efficacy of the slower acting enzyme inhibiting herbicides (Wersal and Madsen 2010b).
Toxicology

There are no restrictions on swimming or eating fish from waterbodies treated with diquat. Depending on the concentration applied, there is a 1-3 day waiting period after treatment for drinking water. However, in one study, diquat persisted in the water at levels above the EPA drinking water standard for at least 3 DAT, suggesting that the current 3-day drinking water restriction may not be sufficient under all application scenarios (Parsons et al. 2007). Water treated with diquat should not be used for pet or livestock drinking water for one day following treatment. The irrigation restriction for food crops is five days, and for ornamental plants or lawn/turf, it varies from one to three days depending on the concentration used. A study by Mudge et al. (2007) on the effects of diquat on five popular ornamental plant species (begonia, dianthus, impatiens, petunia, and snapdragon) found minimal risks associated with irrigating these species with water treated with diquat up to the maximum use rate of 0.37 ppm.

Ethylene dibromide (EDB) is a trace contaminant in diquat products which originates from the manufacturing process. EDB is a documented carcinogen, and the EPA has evaluated the health risk of its presence in formulated diquat products. The maximum level of EDB in diquat dibromide is 0.01 ppm (10 ppb). EBD degrades over time, and it does not persist as an impurity.

Diquat does not have any apparent short-term effects on most aquatic organisms that have been tested at label application rates (EPA Diquat RED 1995). Diquat is not known to bioconcentrate in fish tissues. A study using field scenarios and well as computer modelling to examine the potential ecological risks posed by diquat determined that diquat poses a minimal ecological impact to benthic invertebrates and fish (Campbell et al. 2000). Laboratory studies indicate that walleye (*Sander vitreus*) are more sensitive to diquat than some other fish species, such as smallmouth bass (*Micropterus dolomieu),* largemouth bass (*Micropterus salmoides*), and bluegills (*Lepomis macrochirus*), with individuals becoming less sensitive with age (Gilderhus 1967; Paul et al. 1994; Shaw and Hamer 1995). Maximum application rates were lowered in response to these studies, such that applying diquat at recommended label rates is not expected to result in toxic effects on fish (EPA Diquat RED 1995). Sublethal effects such as respiratory stress or reduced swimming capacity have been observed in studies where certain fish species (e.g., yellow perch (*Perca flavescens*), rainbow trout (*Oncorhynchus mykiss*), and fathead minnows (*Pimephales promelas*)) have been exposed to diquat concentrations (Bimber et al. 1976; Dodson and Mayfield 1979; de Peyster and Long 1993). Another study showed no observable effects on eastern spiny softshell turtles (*Apalone spinifera spinifera*; Paul and Simonin 2007). Reduced size and pigmentation or increased mortality have been shown in some amphibians but at above recommended label rates (Anderson and Prahlad 1976; Bimber and Mitchell 1978; Dial and Bauer-Dial 1987). Toxicity data on invertebrates are scarce and diquat is considered not toxic to most of them. While diquat is not highly toxic to most invertebrates, significant mortality has been observed in some species at concentrations below the maximum label use rate for diquat, such as the amphipod *Hyalella azteca* (Wilson and Bond 1969; Williams et al. 1984), water fleas (*Daphnia* spp.). Reductions in habitat following treatment may also contribute to reductions of *Hyalella azteca*. For more information, a thorough risk assessment for diquat was compiled by the Washington State Department of Ecology Water Quality Program (WSDE 2002). Available toxicity data for fish, invertebrates, and aquatic plants is summarized in tabular format by Campbell et al. (2000).
Species Susceptibility

Diquat has been shown to control a variety of invasive submerged and floating aquatic plants, including Eurasian watermilfoil (*Myriophyllum spicatum*), curly-leaf pondweed (*Potamogeton crispus*), parrot feather (*Myriophyllum aquaticum*), Brazilian waterweed (*Egeria densa*), water hyacinth, water lettuce (*Pistia stratiotes*), flowering rush (*Butomus umbellatus*), and giant salvinia (*Salvinia molesta*; Netherland et al. 2000; Nelson et al. 2001; Poovey et al. 2002; Langeland et al. 2002; Skogerboe et al. 2006; Martins et al. 2007, 2008; Wersal et al. 2010a; Wersal and Madsen 2010a; Wersal and Madsen 2012; Poovey et al. 2012; Madsen et al. 2016). Studies conducted on the use of diquat for hydrilla (*Hydrilla verticillata*) and fanwort (*Cabomba caroliniana*) control have resulted in mixed reports of efficacy (Van et al. 1987; Langeland et al. 2002; Glomski et al.

2005; Skogerboe et al. 2006; Bultemeier et al. 2009; Turnage et al. 2015). Non-native phragmites (*Phragmites australis* subsp. *australis*) has been shown to not be significantly reduced by diquat (Cheshier et al. 2012).

Skogerboe et al. 2006 reported on the efficacy of diquat (0.185 and 0.37 ppm) under flow-through conditions (observed half-lives of 2.5 and 4.5 hours, respectively). All diquat treatments reduced Eurasian watermilfoil biomass by 97 to 100% compared to the untreated reference, indicating that this species is highly susceptible to diquat. Netherland et al. (2000) examined the role of various water temperatures (10, 12.5, 15, 20, and 25°C) on the efficacy of diquat applications for controlling curly-leaf pondweed. Diquat was applied at rates of 0.16-0.50 ppm, with exposure times of 9-12 hours. Diquat efficacy on curly-leaf pondweed was inhibited as water temperature decreased, although treatments at all temperatures were observed to significantly reduce biomass and turion formation. While the most efficacious curly-leaf pondweed treatments were conducted at 25°C, waiting until water warms to this temperature limits the potential for reducing turion production. Diquat applied at 0.37 ppm (with a 6 to 12-hour exposure time) or at 0.19 ppm (with a 72-hour exposure time) was effective at reducing biomass of flowering rush (Poovey et al. 2012; Madsen et al. 2016).

Native species that have been shown to be affected by diquat include: American lotus (*Nelumbo lutea*), common bladderwort (*Utricularia vulgaris*), coontail (*Ceratophyllum demersum*), common waterweed (*Elodea canadensis*), needle spikerush (*Eleocharis acicularis*), Illinois pondweed (*Potamogeton illinoensis*), leafy pondweed (*P. foliosus*), clasping-leaf pondweed (*P. richardsonii*), fern pondweed (*P. robbinsii*), sago pondweed (*Stuckenia pectinata*), and slender naiad (*Najas flexilis*) (Hofstra et al. 2001; Glomski et al. 2005; Skogerboe et al. 2006; Mudge 2013; Bugbee et al. 2015; Turnage et al. 2015). Diquat is particularly toxic to duckweeds (*Landoltia punctata* and *Lemna* spp.), although certain populations of dotted duckweed (*Landoltia punctata*) have developed resistance of diquat in waterbodies with a long history (20-30 years) of repeated diquat treatments (Peterson et al. 1997; Koschnick et al. 2006). Variable effects have been observed for water celery (*Vallisneria americana*), long-leaf pondweed (*Potamogeton nodosus*), and variable-leaf watermilfoil (*Myriophyllum heterophyllum*; Skogerboe et al. 2006; Glomski and Netherland 2007; Mudge 2013).

Flumioxazin

Registration and Formulations

Flumioxazin (2-[7-fluoro-3,4-dihydro-3-oxo-4-(2-propynyl)-2H-1,4-benzoxazin-6-yl]-4,5,6,7-tetrahydro-1H-isoindole-1,3(2H)-dione) was registered with the U.S. EPA for agricultural use in 2001 and registered for aquatic use in 2010. The first registration review of flumioxazin is expected to be completed in 2017 (EPA Flumioxazin Plan 2011). Granular and liquid formulations are available for aquatic use.

Mode of Action and Degradation

The mode of action of flumioxazin is through disruption of the cell membrane by inhibiting protoporphyrinogen oxidase which blocks production of heme and chlorophyll. The efficacy of this mode of action is dependent on both light intensity and water pH (Mudge et al. 2012a; Mudge and Haller 2010; Mudge et al. 2010), with herbicide degradation increasing with pH and efficacy decreasing as light intensity declines.

Flumioxazin is broken down by water (hydrolysis), light (photolysis) and microbes. The half-life ranges from approximately 4 days at pH 5 to 18 minutes at pH 9 (EPA Flumioxazin 2003). In the majority of Wisconsin lakes half-life should be less than 1 day.

Flumioxazin degrades into APF (6-amino-7-fluro-4-(2-propynyl)-1,4,-benzoxazin-3(2H)-one) and THPA (3,4,5,6-tetrahydrophthalic acid). Flumioxazin has a low potential to leach into groundwater due to the very quick hydrolysis and photolysis. APF and THPA have a high potential to leach through soil and could be persistent.

Toxicology

Tests on warm and cold-water fishes indicate that flumioxazin is "slightly to moderately toxic" to fish on an acute basis, with possible effects on larval growth below the maximum label rate of 0.4 ppm (400 ppb). Flumioxazin is moderately to highly toxic to aquatic invertebrates, with possible impacts below the maximum label rate. The potential for bioaccumulation is low since degradation in water is so rapid. The metabolites APF and THPA have not been assessed for toxicity or bioaccumulation.

The risk of acute exposure is primarily to chemical applicators. Concentrated flumioxazin doesn't pose an inhalation risk but can cause skin and eye irritation. Recreational water users would not be exposed to concentrated flumioxazin.

Acute exposure studies show that flumioxazin is "practically non-toxic" to birds and small mammals. Chronic exposure studies indicate that flumioxazin is non-carcinogenic. However, flumioxazin may be an endocrine disrupting compound in mammals (EPA Flumioxazin 2003), as some studies on small mammals did show effects on reproduction and larval development, including reduced offspring viability, cardiac and skeletal malformations, and anemia. It does not bioaccumulate in mammals, with the majority excreted in a week.

Species Susceptibility

The maximum target concentration of flumioxazin is 0.4 ppm (400 ppb). At least one study has shown that flumioxazin (at or below the maximum label rate) will control the invasive species fanwort (*Cabomba caroliniana*), hydrilla (*Hydrilla verticillata*), Japanese stiltgrass (*Microstegium vimineum*), Eurasian watermilfoil (*Myriophyllum spicatum*), water lettuce (*Pistia stratiotes*), curly-leaf pondweed (*Potamogeton crispus*), and giant salvinia (*Salvinia molesta*), while water hyacinth (*Eichhornia crassipes*) and water pennyworts (*Hydrocotyle* spp.) do not show significant impacts (Bultemeier et al. 2009; Glomski and Netherland 2013a; Glomski and Netherland 2013b; Mudge 2013; Mudge and Netherland 2014; Mudge and Haller 2012; Mudge and Haller 2010). Flowering rush (*Butomus umbellatus*; submersed form) showed mixed success in herbicide trials (Poovey et al. 2012; Poovey et al. 2013). Native species that were significantly impacted (in at least one study) include coontail (*Ceratophyllum demersum*), water stargrass (*Heteranthera* *dubia*), variable-leaf watermilfoil (*Myriophyllum heterophyllum*), America lotus (*Nelumbo lutea*), pond-lilies (*Nuphar* spp.), white waterlily (*Nymphaea odorata*), white water crowfoot (*Ranunculus aquatilis*), and broadleaf cattail (*Typha latifolia*), while common waterweed (*Elodea canadensis*), squarestem spikerush (*Eleocharis quadrangulate*), horsetail (*Equisetum hyemale*), southern naiad (*Najas guadalupensis*), pickerelweed (*Pontederia cordata*), Illinois pondweed (*Potamogeton illinoensis*), long-leaf pondweed (*P. nodosus*), broadleaf arrowhead (*Sagittaria latifolia*), hardstem bulrush (*Schoenoplectus acutus*), common three-square bulrush (*S. pungens*), softstem bulrush (*S. tabernaemontani*), sago pondweed (*Stuckenia pectinata*), and water celery (*Vallisneria americana*) were not impacted relative to controls. Other species are likely to be susceptible, for which the effects of flumioxazin have not yet been evaluated.

S.3.3.2. Submersed, Relatively Slow-Acting Herbicides

2,4-D

Registration and Formulations

2,4-D is an herbicide that is widely used as a household weed-killer, agricultural herbicide, and aquatic herbicide. It has been in use since 1946 and was registered with the U.S. EPA in 1986 and evaluated and reregistered in 2005. It is currently being evaluated for reregistration, and the estimated registration review decision date was in 2017 (EPA 2,4-D Plan 2013). The active ingredient is 2,4-dichloro-phenoxyacetic acid. There are two types of 2,4-D used as aquatic herbicides: dimethyl amine salt (DMA) and butoxyethyl ester (BEE). The ester formulations are toxic to fish and some important invertebrates such as water fleas (*Daphnia* spp.) and midges at application rates. 2,4-D is commercially sold as a liquid amine as well as ester and amine granular products for control of submerged, emergent, and floating-leaf vegetation. Only 2,4-D products labeled for use in aquatic environments may be used to control aquatic plants.

Mode of Action and Degradation

Although the exact mode of action of 2,4-D is not fully understood, the herbicide is traditionally believed to target broad-leaf dicotyledon species with minimal effects generally observed on numerous monocotyledon species, especially in terrestrial applications (WSSA 2007). 2,4-D is a systemic herbicide which affects plant cell growth and division. Upon application, it mimics the natural plant hormone auxin, resulting in bending and twisting of stems and petioles followed by growth inhibition, chlorosis (reduced coloration) at growing points, and necrosis or death of sensitive species (WSSA 2007). Following treatment, 2,4-D is taken up by the plant and translocated through the roots, stems and leaves, and plants begin to die within one to two weeks after application, but can take several weeks to decompose. The total length of target plant roots can be an important in determining the response of an aquatic plant to 2,4-D (Belgers et al. 2007). Treatments should be made when plants are growing. After treatment, the 2,4-D concentration in the water is reduced primarily through microbial activity, off-site movement by water, or adsorption to small particles in silty water.

Previous studies have indicated that 2,4-D degradation in water is highly variable depending on numerous factors such as microbial presence, temperature, nutrients, light, oxygen, organic content of substrate, pH, and whether or not the water has been previously exposed to 2,4-D or other phenoxyacetic acids (Howard et al. 1991). Once in contact with water, both the ester and amine formulations dissociate to the acid form of 2,4-D, with a faster dissociation to the acid form under more alkaline conditions. 2,4-D degradation products include 1,2,4-benzenetriol, 2,4-dichlorophenol, 2,4-dichloroanisole, chlorohydroquinone (CHQ), 4-chlorophenol, and volatile organics.

The half-life of 2,4-D has a wide range depending on water conditions. Half-lives have been reported to range from 12.9 to 40 days, while in anaerobic lab conditions the half-life has been measured at 333 days (EPA RED 2,4-D 2005). In large-scale low-concentration 2,4-D treatments monitored across numerous Wisconsin lakes, estimated half-lives ranged from 4-76 days, and the rate of herbicide degradation was generally observed to be slower in oligotrophic seepage lakes. Of these large-scale 2,4-D treatments, the threshold for irrigation of plants which are not labeled for direct treatment with 2,4-D (<0.1 ppm (100 ppb) by 21 DAT) was exceeded the majority of the treatments (Nault et al. 2018). Previous historical use of 2,4-D may also be an important variable to consider, as microbial communities which are responsible for the breakdown of 2,4-D may potentially exhibit changes in community composition over time with repeated use (de Lipthay et al. 2003; Macur et al. 2007). Additional detailed information on the environmental fate of 2,4-D is compiled by Walters 1999.

There have been some preliminary investigations into the concentration of primarily granular 2,4-D in water-saturated sediments, or pore-water. Initial results suggest the concentration of 2,4-D in the pore-water varies widely from site to site following a chemical treatment, although in some locations the concentration in the pore-water was observed to be 2-3 times greater than the application rate (Jim Kreitlow [DNR], *personal communication*). Further research and additional studies are needed to assess the implications of this finding for target species control and non-target impacts on a variety of organisms.

<u>Toxicology</u>

There are no restrictions on eating fish from treated waterbodies, human drinking water, or pet/livestock drinking water. Based upon 2,4-D ester (BEE) product labels, there is a 24-hour waiting period after treatment for swimming. Before treated water can be used for irrigation, the concentration must be below 0.1 ppm (100 ppb), or at least 21 days must pass. Adverse health effects can be produced by acute and chronic exposure to 2,4-D. Those who mix or apply 2,4-D need to protect their skin and eyes from contact with 2,4-D products to minimize irritation and avoid inhaling the spray. In its consideration of exposure risks, the EPA believes no significant risks will occur to recreational users of water treated with 2,4-D.

There are differences in toxicity of 2,4-D depending on whether the formulation is an amine (DMA) or ester (BEE), with the BEE formulation shown to be more toxic in aquatic environments. BEE formulations are considered toxic to fish and invertebrates such as water fleas and midges at operational application rates. DMA formulations are not considered toxic to fish or invertebrates at operational application rates. Available data indicate 2,4-D does not accumulate at significant levels in the tissues of fish. Although fish exposed to 2,4-D may take up very small amounts of its breakdown products to then be metabolized, the vast majority of these products are rapidly excreted in urine (Ghassemi et al. 1981).

On an acute basis, EPA assessment considers 2,4-D to be "practically non-toxic" to honeybees and tadpoles. Dietary tests (substance administered in the diet for five consecutive days) have shown 2,4-D to be "practically non-toxic" to birds, with some species being more sensitive than others (when 2,4-D was orally and directly administered to birds by capsule or gavage, the substance was "moderately toxic" to some species). For freshwater invertebrates, EPA considers 2,4-D amine to be "practically non-toxic" to "slightly toxic" (EPA RED 2,4-D 2005). Field studies on the potential impact of 2,4-D on benthic macroinvertebrate communities have generally not observed significant changes, although at least one study conducted in Wisconsin observed negative correlations in macroinvertebrate richness and abundance following treatment, and further studies are likely warranted (Stephenson and Mackie 1986; Siemering et al. 2008; Harrahy et al. 2014). Additionally, sublethal effects such as mouthpart deformities and change in sex ratio have been observed in the midge *Chironomus riparius* (Park et al. 2010).

While there is some published literature available looking at short-term acute exposure of various aquatic organisms to 2,4-D, there is limited literature is available on the effects of low-concentration chronic exposure to commercially available 2,4-D formulations (EPA RED 2,4-D 2005). The department recently funded several projects related to increasing our understanding of the potential impacts of chronic exposure to low-concentrations of 2,4-D through AIS research and development grants. One of these studies observed that fathead minnows (*Pimephales promelas*) exposed under laboratory conditions for 28 days to 0.05 ppm (50 ppb) of two different commercial formulations of 2,4-D (DMA® 4 IVM and Weedestroy® AM40) had decreases in larval survival and tubercle presence in males, suggesting that these formulations may exert some degree of chronic toxicity or endocrine-disruption which has not been previously observed when testing pure compound 2,4-D (DeQuattro and Karasov 2016). However, another follow-up study determined that fathead minnow larval survival (30 days post hatch) was decreased following exposure of eggs and larvae to pure 2,4-D, as well as to the two commercial formulations (DMA® 4 IVM and Weedestroy® AM40), and also identified a critical window of exposure for effects on survival to the period between fertilization and 14 days post hatch (Dehnert et al. 2018).

Another related follow-up laboratory study is currently being conducted to examine the effects of 2,4-D exposure on embryos and larvae of several Wisconsin native fish species. Preliminary results indicate that negative impacts of embryo survival were observed for 4 of the 9 native species tested (e.g., walleye, northern pike, white crappie, and largemouth bass), and negative impacts of larval survival were observed for 4 of 7 natives species tested (e.g., walleye, yellow perch, fathead minnows, and white suckers; Dehnert and Karasov, *in progress*).

A controlled field study was conducted on six northern Wisconsin lakes to understand the potential impacts of early season large-scale, low-dose 2,4-D on fish and zooplankton (Rydell et al. 2018). Three lakes were treated with early season low-dose liquid 2,4-D (lakewide epilimnetic target rate: 0.3 ppm (300 ppb)), while the other three lakes served as reference without treatment. Zooplankton densities were similar within lakes during the pre-treatment year and year of treatment, but different trends in several zooplankton species were observed in treatment lakes during the year following treatment. Peak abundance of larval yellow perch (*Perca flavescens*) was lower in the year following treatment, and while this finding was not statistically significant, decreased larval yellow perch abundance was not observed in reference lakes. The observed declines in larval yellow perch abundance and changes in zooplankton trends within treatment lakes in the year after treatment may be a result of changes in aquatic plant communities and not a direct effect of treatment. No significant effect was observed on peak abundance of larval largemouth bass (*Micropterus salmoides*), minnows, black crappie (*Pomoxis nigromaculatus*), bluegill (*Lepomis macrochirus*), or juvenile yellow perch. Larval black crappie showed no detectable response in growth or feeding success. Net pen trials for juvenile bluegill indicated no significant difference in survival between treatment and reference trials, indicating that no direct mortality was associated with the herbicide treatments. Detection of the level of larval fish mortality found in the lab studies would not have been possible in the field study given large variability in larval fish abundance among lakes and over time.

Concerns have been raised about exposure to 2,4-D and elevated cancer risk. Some epidemiological studies have found associations between 2,4-D and increased risk of non-Hodgkin lymphoma in high exposure populations, while other studies have shown that increased cancer risk may be caused by other factors (Hoar et al. 1986; Hardell and Eriksson 1999; Goodman et al. 2015). The EPA determined in 2005 that there is not sufficient evidence to classify 2,4-D as a human carcinogen (EPA RED 2,4-D 2005).

Another chronic health concern with 2,4-D is the potential for endocrine disruption. There is some evidence that 2,4-D may have effects on reproductive development, though other studies suggest the findings may have had other causes (Garry et al. 1996; Coady et al. 2013; Goldner et al. 2013; Neal et al. 2017). The extent and implications of this are not clear and it is an area of ongoing research.

Detailed literature reviews of 2,4-D toxicology have been compiled by Garabrant and Philbert (2002), Jervais et al. (2008), and Burns and Swaen (2012).

Species Susceptibility

With appropriate concentration and exposure, 2,4-D is capable of reducing abundance of the invasive plant species Eurasian watermilfoil (*Myriophyllum spicatum*), parrot feather (*M. aquaticum*), water chestnut (*Trapa natans*), water hyacinth (*Eichhornia crassipes*), and water lettuce (*Pistia stratiotes*; Elliston and Steward 1972; Westerdahl et al. 1983; Green and Westerdahl 1990; Helsel et al. 1996, Poovey and Getsinger 2007; Wersal et al. 2010b; Cason and Roost 2011; Robles et al. 2011; Mudge and Netherland 2014). Perennial pepperweed (*Lepidium latifolium)* and fanwort (*Cabomba caroliniana*) have been shown to be somewhat tolerant of 2,4-D (Bultemeier et al. 2009; Whitcraft and Grewell 2012).

Efficacy and selectivity of 2,4-D is a function of concentration and exposure time (CET) relationships, and rates of 0.5-2.0 ppm coupled with exposure times ranging from 12 to 72 hours have been effective at achieving Eurasian watermilfoil control under laboratory settings (Green and Westerdahl 1990). In addition, long exposure times (>14 days) to low-concentrations of 2,4-D (0.1-0.25 ppm) have also been documented to achieve milfoil control (Hall et al. 1982; Glomski and Netherland 2010).

According to product labels, desirable native species that may be affected include native milfoils (*Myriophyllum* spp.), coontail (*Ceratophyllum demersum*), common waterweed (*Elodea canadensis*), naiads (*Najas* spp.), waterlilies (*Nymphaea* spp. and *Nuphar* spp.), bladderworts (*Utricularia* spp.), and duckweeds (*Lemna* spp.). While it may affect softstem bulrush (*Schoenoplectus tabernaemontani*), other species such as American bulrush (*Schoenoplectus americanus*) and muskgrasses (*Chara* spp.) have been shown to be somewhat tolerant of 2,4-D (Miller and Trout 1985; Glomski et al. 2009; Nault et al. 2014; Nault et al. 2018).

In large-scale, low-dose (0.073-0.5 ppm) 2,4-D treatments evaluated by Nault et al. (2018), milfoil exhibited statistically significant lakewide decreases in posttreatment frequency across 23 of the 28 (82%) of the treatments monitored. In lakes where year of treatment milfoil control was achieved, the longevity of control ranged from 2–8 years. However, it is important to note that milfoil was not 'eradicated' from any of these lakes and is still present even in those lakes which have sustained very low frequencies over time. While good year of treatment control was achieved in all lakes with pure Eurasian watermilfoil populations, significantly reduced control was observed in the majority of lakes with hybrid watermilfoil (*Myriophyllum spicatum* x *sibiricum*) populations. Eurasian watermilfoil control was correlated with the mean concentration of 2,4-D measured during the first two weeks of treatment, with increasing lakewide concentrations resulting in increased Eurasian watermilfoil control. In contrast, there was no significant relationship observed between Eurasian watermilfoil control and mean concentration of 2,4-D. In lakes where good (>60%) year of treatment control of hybrid watermilfoil was achieved, 2,4-D degradation was slow, and measured lakewide concentrations were sustained at >0.1 ppm (>100 ppb) for longer than 31 days. In addition to reduced year of treatment efficacy, the longevity of control was generally shorter in lakes that contained hybrid watermilfoil versus Eurasian watermilfoil, suggesting that hybrid watermilfoil may have the ability to rebound quicker after large-scale treatments than pure Eurasian watermilfoil populations. However, it is important to keep in mind that hybrid watermilfoil is broad term for multiple different strains, and variation in herbicide response and growth between specific genotypes of hybrid watermilfoil has been documented (Taylor et al. 2017).

In addition, the study by Nault et al. (2018) documented several native monocotyledon and dicotyledon species that exhibited significant declines posttreatment. Specifically, northern watermilfoil (*Myriophyllum sibiricum*), slender naiad (*Najas flexilis*), water marigold (*Bidens beckii*), and several thin-leaved pondweeds (*Potamogeton pusillus*, *P. strictifolius*, *P. friesii* and *P. foliosus*) showed highly significant declines in the majority of the lakes monitored. In addition, variable/Illinois pondweed (*P. gramineus*/*P. illinoensis*), flat-stem pondweed (*P. zosteriformis*), fern pondweed (*P. robbinsii*), and sago pondweed (*Stuckenia pectinata*) also declined in many lakes. Ribbon-leaf pondweed (*P. epihydrus*) and water stargrass (*Heteranthera dubia*) declined in the lakes where they were found. Mixed effects of treatment were observed with water celery (*Vallisneria americana*) and southern naiad (*Najas guadalupensis*), with some lakes showing significant declines posttreatment and other lakes showing increases.

Since milfoil hybridity is a relatively new documented phenomenon (Moody and Les 2002), many of the early lab studies examining CET for milfoil control did not determine if they were examining pure Eurasian watermilfoil or hybrid watermilfoil (*M. spicatum* x *sibiricum*) strains. More recent laboratory and mesocosm studies have shown that certain strains of hybrid watermilfoil exhibit more aggressive growth and are less affected by 2,4-D (Glomski and Netherland 2010; LaRue et al. 2013; Netherland and Willey 2017; Taylor et al. 2017), while other studies have not seen differences in overall growth patterns or treatment efficacy when compared to pure Eurasian watermilfoil (Poovey et al. 2007). Differences between Eurasian and hybrid watermilfoil control following 2,4-D applications have also been documented in the field, with lower efficacy and shorter longevity of hybrid watermilfoil control when compared to pure Eurasian watermilfoil populations (Nault et al. 2018). Field studies conducted in the Menominee River Drainage in northeastern Wisconsin and upper peninsula of Michigan observed hybrid milfoil genotypes more frequently in lakes that had previous 2,4-D treatments, suggesting possible selection of more tolerant hybrid strains over time (LaRue 2012).

Fluridone

Registration and Formulations

Fluridone is an aquatic herbicide that was initially registered with the U.S. EPA in 1986. It is currently being evaluated for reregistration. The estimated registration review decision date was in 2014 (EPA Fluridone Plan 2010). The active ingredient is (1-methyl-3-phenyl-5-[3-(trifluoromethyl) phenyl]-4(1H)-pyridinone). Fluridone is available in both liquid and slow-release granular formulations.

Mode of Action and Degradation

Fluridone's mode of action is to reduce a plant's ability to protect itself from sun damage. The herbicide prevents the plant from making a protective pigment and as a result, sunlight causes the plant's chlorophyll to break down. Treated plants will turn white or pink at the growing tips a week after exposure and will begin to die one to two months after treatment (Madsen et al. 2002). Therefore, fluridone is only effective if plants are actively growing at the time of treatment. Effective use of fluridone requires low, sustained concentrations and a relatively long contact time (e.g., 45-90 days). Due to this requirement, fluridone is usually applied to an entire waterbody or basin. Some success has been demonstrated when additional follow-up 'bump' treatments are used to maintain the low concentrations over a long enough period of time to produce control. Fluridone has also been applied to riverine systems using a drip system to maintain adequate CET.

Following treatment, the amount of fluridone in the water is reduced through dilution and water movement, uptake by plants, adsorption to the sediments, and via breakdown caused by light and microbes. Fluridone is primarily degraded through photolysis (Saunders and Mosier 1983), while depth, water clarity and light penetration can influence degradation rates (Mossler et al. 1989; West et al. 1983). There are two major degradation products from fluridone: n-methyl formamide (NMF) and 3-trifluoromethyl benzoic acid.

The half-life of fluridone can be as short as several hours, or hundreds of days, depending on conditions (West et al. 1979; West et al. 1983; Langeland and Warner 1986; Fox et al. 1991, 1996; Jacob et al. 2016). Preliminary work on a seepage lake in Waushara County, WI detected fluridone in the water nearly 400 days following an initial application that was then augmented to maintain concentrations via a 'bump' treatment at 60 and 100 days later (Onterra 2017a). Light exposure is influential in controlling degradation rate, with a half-life ranging from 15 to 36 hours when exposed to the full spectrum of natural sunlight (Mossler et al. 1989). As light wavelength increases, the half-life increases too, indicating that season and timing may affect fluridone persistence. Fluridone half-life has been shown to be only slightly dependent on fluridone concentration, oxygen concentration, and pH (Saunders and Mosier 1983). One study found that the half-life of fluridone in water was slightly lower when the herbicide was applied to the surface of the water as opposed to a sub-surface application, suggesting that degradation may also be affected by mode of application (West and Parka 1981).

The persistence of herbicide in the sediment has been reported to be much longer than in the overlying water column, with studies showing persistence ranges from 3 months to a year in sediments (Muir et al. 1980; Muir and Grift 1982; West et al. 1983). Persistence in soil is influenced by soil chemistry (Shea and Weber 1983; Mossler et al. 1993). Fluridone concentrations measured in sediments reach a maximum in one to four weeks after treatment and decline in four months to a year depending on environmental conditions. Fluridone adsorbs to clay and soils with high organic matter, especially in pellet form, and can reduce the concentration of fluridone in the water. Adsorption to the sediments is reversible; fluridone gradually dissipates back into the water where it is subject to chemical breakdown.
Some studies have shown variable release time of the herbicide among different granular fluridone products (Mossler et al. 1993; Koschnick et al. 2003; Bultemeier and Haller 2015). In addition, pelletized formulations may be more effective in sandy hydrosoils, while aqueous suspension formulations may be more appropriate for areas with high amounts of clay or organic matter (Mossler et al. 1993)

Toxicology

Fluridone does not appear to have short-term or long-term effects on fish at approved application rates, but fish exposed to water treated with fluridone do absorb fluridone into their tissues. However, fluridone has demonstrated a very low potential for bioconcentration in fish, zooplankton, and aquatic plants (McCowen et al. 1979; West et al. 1979; Muir et al. 1980; Paul et al. 1994). Fluridone concentrations in fish decrease as the herbicide disappears from the water. Studies on the effects of fluridone on aquatic invertebrates (e.g., midge and water flea) have shown increased mortality at label application rates (Hamelink et al. 1986; Yi et al. 2011). Studies on birds indicate that fluridone would not pose an acute or chronic risk to birds. In addition, no treatment related effects were noted in mice, rats, and dogs exposed to dietary doses. No studies have been published on amphibians or reptiles. There are no restrictions on swimming, eating fish from treated waterbodies, human drinking water or pet/livestock drinking water. Depending on the type of waterbody treated and the type of plant being watered, irrigation restrictions may apply for up to 30 days. There is some evidence that the fluridone degradation product NMF causes birth defects, though NMF has only been detected in the lab and not following actual fluridone treatments in the field, including those at maximum label rate (Osborne et al. 1989; West et al. 1990).

Species Susceptibility

Because fluridone treatments are often applied at a lakewide scale and many plant species are susceptible to fluridone, careful consideration should be given to potential non-target impacts and changes in water quality in response to treatment. Sustained native plant species declines and reductions in water clarity have been observed following fluridone treatments in field applications (O'Dell et al. 1995; Valley et al. 2006; Wagner et al. 2007; Parsons et al. 2009). However, reductions in water clarity are not always observed and can be avoided (Crowell et al. 2006). Additionally, the selective activity of fluridone is primarily rate-dependent based on analysis of pigments in nine aquatic plant species (Sprecher et al. 1998b).

Fluridone is most often used for control of invasive species such as Eurasian and hybrid watermilfoil (*Myriophyllum spicatum* x *sibiricum*), Brazilian waterweed (*Egeria densa*), and hydrilla (*Hydrilla verticillata*; Schmitz et al. 1987; MacDonald et al. 1993; Netherland et al. 1993; Netherland and Getsinger 1995a, 1995b; Cockreham and Netherland 2000; Hofstra and Clayton 2001; Madsen et al. 2002; Netherland 2015). However, fluridone tolerance has been observed in some hydrilla and hybrid watermilfoil populations (Michel et al. 2004; Arias et al. 2005; Puri et al. 2006; Slade et al. 2007; Berger et al. 2012, 2015; Thum et al. 2012; Benoit and Les 2013; Netherland and Jones 2015). Fluridone has also been shown to affect flowering rush (*Butomus umbellatus*), fanwort (*Cabomba caroliniana*), buttercups (*Ranunculus* spp.), long-leaf pondweed (*Potamogeton nodosus*), Illinois pondweed (*P. illinoensis*), leafy pondweed (*P. foliosus*), flat-stem pondweed (*P. zosteriformis*), sago pondweed (*Stuckenia pectinata*), oxygen-weed (*Lagarosiphon major*), northern watermilfoil (*Myriophyllum sibiricum*), variable-leaf watermilfoil (*M. heterophyllum*), curly-leaf pondweed (*Potamogeton crispus*), coontail (*Ceratophyllum demersum*), common waterweed (*Elodea canadensis*), southern naiad (*Najas guadalupensis*), slender naiad (*N. flexilis*), white waterlily (*Nymphaea odorata*), water marigold (*Bidens beckii*), duckweed (*Lemna* spp.), and watermeal (*Wolffia columbiana*) (Wells et al. 1986; Kay 1991; Farone and McNabb 1993; Netherland et al. 1997; Koschnick et al. 2003; Crowell et al. 2006; Wagner et al. 2007; Parsons et al. 2009; Cheshier et al. 2011; Madsen et al. 2016). Muskgrasses (*Chara* spp.), water celery (*Vallisneria americana*), cattails (*Typha* spp.), and willows (*Salix* spp.) have been shown to be somewhat tolerant of fluridone (Farone and McNabb 1993; Poovey et al. 2004; Crowell et al. 2006).

Large-scale fluridone treatments that targeted Eurasian and hybrid watermilfoils have been conducted in several Wisconsin lakes. Recently, five of these waterbodies treated with low-dose fluridone (2-4 ppb) have been tracked over time to understand herbicide dissipation and degradation patterns, as well as the efficacy, selectivity, and longevity of these treatments. These field trials resulted in a pre- vs. post-treatment decrease in the number of vegetated littoral zone sampling sites, with a 9-26% decrease observed following treatment (an average decrease in vegetated littoral zone sites of 17.4% across waterbodies). In four of the five waterbodies, substantial decreases in plant biomass (≥10% reductions in average total rake fullness) was documented at sites where plants occurred in both the year of and year after treatment. Good milfoil control was achieved, and long-term monitoring is ongoing to understand the longevity of target species control over time. However, non-target native plant populations were also observed to be negatively impacted in conjunction with these treatments, and long-term monitoring is ongoing to understand their recovery over time. Exposure times in the five waterbodies monitored were found to range from 320 to 539 days before falling below detectable limits. Data from these recent projects is currently being compiled and a compressive analysis and report is anticipated in the near future.

Endothall

Registration and Formulations

Endothall was registered with the U.S. EPA for aquatic use in 1960 and reregistered in 2005 (Menninger 2012). Endothall is the common name of the active ingredient endothal acid (7-oxabicyclo[2,2,1] heptane-2,3-dicarboxylic acid). Granular and liquid formulations are currently registered by EPA and DATCP. Endothall products are used to control a wide range of terrestrial and aquatic plants. Two types of endothall are available: dipotassium salt and dimethylalkylamine salt ("mono-N,N-dimethylalkylamine salt" or "monoamine salt"). The dimethylalkylamine salt form is toxic to fish and other aquatic organisms and is faster-acting than the dipotassium salt form.

Mode of Action and Degradation

Endothall is considered a contact herbicide that inhibits respiration, prevents the production of proteins and lipids, and disrupts the cellular membrane in plants (MacDonald et al. 1993; MacDonald et al. 2001; EPA RED Endothall 2005; Bajsa et al. 2012). Although typical rates of endothall application inhibit plant respiration, higher concentrations have been shown to increase respiration (MacDonald et al. 2001). The mode of action of endothall is unlike any other commercial herbicide. For effective control, endothall should be applied when plants are actively growing, and plants begin to weaken and die within a few days after application.

Uptake of endothall is increased at higher water temperatures and higher amounts of light (Haller and Sutton 1973). Netherland et al. (2000) found that while biomass reduction of curly-leaf pondweed (*Potamogeton crispus*) was greater at higher water temperature, reductions of turion production were much greater when curly-leaf pondweed was treated a lower water temperature (18 °C vs 25 °C).

Degradation of endothall is primarily microbial (Sikka and Saxena 1973) and half-life of the dipotassium salt formulations is between 4 to 10 days (Reinert and Rodgers 1987; Reynolds 1992), although dissipation due to water movement may significantly shorten the effective half-life in some treatment scenarios. Half of the active ingredient from granular endothall formulations has been shown to be released within 1-5 hours under conditions that included water movement (Reinert et al. 1985; Bultemeier and Haller 2015). Endothall is highly water soluble and does not readily adsorb to sediments or lipids (Sprecher et al. 2002; Reinert and Rodgers 1984). Degradation from sunlight or hydrolysis is very low (Sprecher et al. 2002). The degradation rate of endothall has been shown to increase with increasing water temperature (UPI, *unpublished data*). The degradation rate is also highly variable across aquatic systems and is much slower under anaerobic conditions (Simsiman and Chesters 1975). Relative to other herbicides, endothall is unique in that is comprised of carbon, hydrogen, and oxygen with the addition of potassium and nitrogen in the dipotassium and dimethylalkylamine formulations, respectively. This allows for complete breakdown of the herbicide without additional intermediate breakdown products (Sprecher et al. 2002).

Toxicology

All endothall products have a drinking water standard of 0.1 ppm and cannot be applied within 600 feet of a potable water intake. Use restrictions for dimethylalkylamine salt formulations have additional irrigation and aquatic life restrictions.

Dipotassium salt formulations

At recommended rates, the dipotassium salt formulations appear to have few short-term behavioral or reproductive effects on bluegill (*Lepomis macrochirus*) or largemouth bass (*Micropterus salmoides;* Serns 1977; Bettolli and Clark 1992; Maceina et al. 2008). Bioaccumulation of dipotassium salt formulations by fish from water treated with the herbicide is unlikely, with studies showing less than 1% of endothall being taken up by bluegill (Sikka et al. 1975; Serns 1977). In addition, studies have shown the dipotassium salt formulation induces no significant adverse effects on aquatic invertebrates when used at label application rates (Serns 1975; Williams et al. 1984). A freshwater mussel species was found to be more sensitive to dipotassium salt endothall than other invertebrate species tested, but significant acute toxicity was still only found at concentrations well above the maximum label rate. However, as with other plant control approaches, some aquatic plant-dwelling populations of aquatic organisms may be adversely affected by application of endothall formulations due to habitat loss.

During EPA reregistration of endothall in 2005, it was required that product labels state that lower rates of endothall should be used when treating large areas, "such as coves where reduced water movement will not result in rapid dilution of the herbicide from the target treatment area or when treating entire lakes or ponds."

Dimethylalkylamine salt formulations

In contrast to the respective low to slight toxicity of the dipotassium salt formulations to fish and aquatic invertebrates, laboratory studies have shown the dimethylalkylamine formulations are toxic to fish and macroinvertebrates at concentrations above 0.3 ppm. In particular, the liquid formulation will readily kill fish present in a treatment site. Product labels for the dimethylalkylamine salt formulations recommend no treatment where fish are an important resource.

The dimethylalkylamine formulations are more active on aquatic plants than the dipotassium formulations, but also are 2-3 orders of magnitude more toxic to non-target aquatic organisms (EPA RED Endothall 2005; Keckemet 1969). The 2005 reregistration decision document limits aquatic use of the dimethylalkylamine formulations to algae, Indian swampweed (*Hygrophila polysperma*), water celery (*Vallisneria americana*), hydrilla (*Hydrilla verticillata*), fanwort (*Cabomba caroliniana*), bur reed (*Sparganium* sp.), common waterweed (*Elodea canadensis*), and Brazilian waterweed (*Egeria densa*). Coontail (*Ceratophyllum demersum*), watermilfoils (*Myriophyllum* spp.), naiads (*Najas* spp.), pondweeds (*Potamogeton* spp.), water stargrass

(*Heteranthera dubia*), and horned pondweed (*Zannichellia palustris*) were to be removed from product labels (EPA RED Endothall 2005).

Species Susceptibility

According to the herbicide label, the maximum target concentration of endothall is 5000 ppb (5.0 ppm) acid equivalent (ae). Endothall is used to control a wide range of submersed species, including non-native species such as curly-leaf pondweed and Eurasian watermilfoil (*Myriophyllum spicatum*). The effects of the different formulations of endothall on various species of aquatic plants are discussed below.

Dipotassium salt formulations

At least one mesocosm or lab study has shown that endothall (at or below the maximum label rate) will control the invasive species hydrilla (Netherland et al. 1991; Wells and Clayton 1993; Hofstra and Clayton 2001; Pennington et al. 2001; Skogerboe and Getsinger 2001; Shearer and Nelson 2002; Netherland and Haller 2006; Poovey and Getsinger 2010), oxygen-weed (*Lagarosiphon major*; Wells and Clayton 1993; Hofstra and Clayton 2001), Eurasian watermilfoil (Netherland et al. 1991; Skogerboe and Getsinger 2002; Mudge and Theel 2011), water lettuce (*Pistia stratiotes*; Conant et al. 1998), curly-leaf pondweed (Yeo 1970), and giant salvinia (*Salvinia molesta*; Nelson et al. 2001). Wersal and Madsen (2010a) found that parrot feather (*Myriophyllum aquaticum*) control with endothall was less than 40% even with two days of exposure time at the maximum label rate. Endothall was shown to control the shoots of flowering rush (*Butomus umbellatus*), but control of the roots was variable (Poovey et al. 2012; Poovey et al. 2013). One study found that endothall did not significantly affect photosynthesis in fanwort with 6 days of exposure at 2.12 ppm ae (2120 ppb ae; Bultemeier et al. 2009). Large-scale, low-dose endothall treatments were found to reduce curly-leaf pondweed frequency, biomass, and turion production substantially in Minnesota lakes, particularly in the first 2-3 years of treatments (Johnson et al. 2012).

Native species that were significantly impacted (at or below the maximum endothall label rate in at least one mesocosm or lab study) include coontail (Yeo 1970; Hofstra and Clayton 2001; Hofstra et al. 2001; Skogerboe and Getsinger 2002; Wells and Clayton 1993; Mudge 2013), southern naiad (*Najas guadalupensis*; Yeo 1970; Skogerboe and Getsinger 2001), white waterlily (*Nymphaea odorata*; Skogerboe and Getsinger 2001), leafy pondweed (*Potamogeton foliosus*; Yeo 1970), Illinois pondweed (*Potamogeton illinoensis*; Skogerboe and Getsinger 2001; Shearer and Nelson 2002; Skogerboe and Getsinger 2002; Mudge 2013), long-leaf pondweed (*Potamogeton nodosus*; Yeo 1970; Skogerboe and Getsinger 2001; Shearer and Nelson 2002; Mudge 2013), small pondweed (*P. pusillus*; Yeo 1970), broadleaf arrowhead (*Sagittaria latifolia*; Skogerboe and Getsinger 2001), sago pondweed (*Stuckenia pectinata*; Yeo 1970; Sprecher et al. 1998a; Skogerboe and Getsinger 2002; Slade et al. 2008), water celery (*Vallisneria americana*; Skogerboe and Getsinger 2001; Skogerboe and Getsinger 2002; Shearer and Nelson 2002; Mudge 2013), and horned pondweed (Yeo 1970; Gyselinck and Courter 2015).

Species which were not significantly impacted or which recovered quickly include watershield (*Brasenia schreberi*; Skogerboe and Getsinger 2001), muskgrasses (*Chara* spp.; Yeo 1970; Wells and Clayton 1993; Hofstra and Clayton 2001), common waterweed (Yeo 1970; Wells and Clayton

1993; Skogerboe and Getsinger 2002), water stargrass (Skogerboe and Getsinger 2001), water net (*Hydrodictyon reticulatum*; Wells and Clayton 1993), the freshwater macroalgae *Nitella clavata* (Yeo 1970), yellow pond-lily (*Nuphar advena*; Skogerboe and Getsinger 2002), swamp smartweed (*Polygonum hydropiperoides*; Skogerboe and Getsinger 2002), pickerelweed (*Pontederia cordata*; Skogerboe and Getsinger 2001), softstem bulrush (*Schoenoplectus tabernaemontani*; Skogerboe and Getsinger 2001), and broadleaf cattail (*Typha latifolia*; Skogerboe and Getsinger 2002).

Field trials mirror the species susceptibility above and in addition show that endothall also can impact several high-value pondweed species (*Potamogeton* spp.), including large-leaf pondweed (*P. amplifolius*; Parsons et al. 2004), fern pondweed (*P. robbinsii*; Onterra 2015; Onterra 2018), white-stem pondweed (*P. praelongus*; Onterra 2018), small pondweed (Big Chetac Chain Lake Association 2016; Onterra 2018), clasping-leaf pondweed (*P. richardsonii*; Onterra 2018), and flat-stem pondweed (*P. zosteriformis*; Onterra 2017b).

Dimethylalkylamine salt formulations

The dimethylalkylamine formulations are more active on aquatic plants than the dipotassium formulations (EPA RED Endothall 2005; Keckemet 1969). At least one mesocosm study has shown that dimethylalkylamine formulation of endothall (at or below the maximum label rate) will control the invasive species fanwort (Hunt et al. 2015) and the native species common waterweed (Mudge et al. 2015), while others have shown that the dipotassium formulation does not control these species well.

Imazamox

Registration and Formulations

Imazamox is the common name of the active ingredient ammonium salt of imazamox (2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-(methoxymethl)-3-pyridinecarboxylic acid. It was registered with U.S. EPA in 2008 and is currently under registration review with an estimated registration decision between 2019 and 2020 (EPA Imazamox Plan 2014). In aquatic environments, a liquid formulation is typically applied to submerged vegetation by broadcast spray or underwater hose application and to emergent or floating leaf vegetation by broadcast spray or foliar application. There is also a granular formulation.

Mode of Action and Degradation

Imazamox is a systemic herbicide that moves throughout the plant tissue and prevents plants from producing a necessary enzyme, acetolactate synthase (ALS), which is not found in animals. Susceptible plants will stop growing soon after treatment, but plant death and decomposition will occur over several weeks (Mudge and Netherland 2014). If used as a post-emergence herbicide, imazamox should be applied to plants that are actively growing. Resistance to ALS-inhibiting herbicides has appeared in weeds at a higher rate than other herbicide types in terrestrial environments (Tranel and Wright 2002).
Dissipation studies in lakes indicate a half-life ranging from 4 to 49 days with an average of 17 days. Herbicide breakdown does not occur readily in deep, poorly-oxygenated water where there

is no light. In this part of a lake, imazamox will tend to bind to sediments rather than breaking down, with a half-life of approximately 2 years. Once in soil, leaching to groundwater is believed to be very limited. The breakdown products of imazamox are nicotinic acid and di- and tricarboxylic acids. It has been suggested that photolytic break down of imazamox is faster than other herbicides, reducing exposure times. However, short-term imazamox exposures have also been associated with extended regrowth times relative to other herbicides (Netherland 2011).

Toxicology

Treated water may be used immediately following application for fishing, swimming, cooking, bathing, and watering livestock. If water is to be used as potable water or for irrigation, the tolerance is 0.05 ppm (50 ppb), and a 24-hour irrigation restriction may apply depending on the waterbody. None of the breakdown products are herbicidal nor suggest concerns for aquatic organisms or human health.

Most concerns about adverse effects on human health involve applicator exposure. Concentrated imazamox can cause eye and skin irritation and is harmful if inhaled. Applicators should minimize exposure by wearing long-sleeved shirts and pants, rubber gloves, and shoes and socks.

Honeybees are affected at application rates so drift during application should be minimized. Laboratory tests using rainbow trout (*Oncorhynchus mykiss*), bluegill (*Lepomis macrochirus*), and water fleas (*Daphnia magna*) indicate that imazamox is not toxic to these species at label application rates.

Imazamox is rated "practically non-toxic" to fish and aquatic invertebrates and does not bioaccumulate in fish. Additional studies on birds indicate toxicity only at dosages that exceed approved application rates.

In chronic tests, imazamox was not shown to cause tumors, birth defects or reproductive toxicity in test animals. Most studies show no evidence of mutagenicity. Imazamox is not metabolized and was excreted by mammals tested. Based on its low acute toxicity to mammals, and its rapid disappearance from the water column due to light and microbial degradation and binding to soil, imazamox is not considered to pose a risk to recreational water users.

Species Susceptibility

In Wisconsin, imazamox is used for treating non-native emergent vegetation such as non-native phragmites (*Phragmites australis* subsp. *australis*) and flowering rush (*Butomus umbellatus*). Imazamox may also be used to treat the invasive curly-leaf pondweed (*Potamogeton crispus*). Desirable native species that may be affected could include other pondweed species (long-leaf pondweed (*P. nodosus*), flat-stem pondweed (*P. zosteriformis*), leafy pondweed (*P. foliosus*), Illinois pondweed (*P. illinoensis*), small pondweed (*P. pusillus*), variable-leaf pondweed (*P. gramineus*), water-thread pondweed (*P. diversifolius*), perfoliate pondweed (*P. perfoliatus*), large-leaf pondweed (*P. amplifolius*), watershield (*Brasenia schreberi*), and some bladderworts (*Utricularia* spp.). Higher rates of imazamox will control Eurasian watermilfoil (*Myriophyllum* *spicatum*) but would also have greater non-target impacts on native plants. Imazamox can also be used during a drawdown to prevent plant regrowth and on emergent vegetation.

At low concentrations, imazamox can cause growth regulation rather than mortality in some plant species. This has been shown for non-native phragmites and hydrilla (*Hydrilla verticillata*; Netherland 2011; Cheshier et al. 2012; Theel et al. 2012). In the case of hydrilla, some have suggested that this effect could be used to maintain habitat complexity while providing some target species control (Theel et al. 2012). Imazamox can reduce biomass of non-native phragmites though some studies found regrowth to occur, suggesting a combination of imazapyr and glyphosate to be more effective (Cheshier et al. 2012; Knezevic et al. 2013).

Some level of control of imazamox has also been reported for water hyacinth (*Eichhornia crassipes*), parrot feather (*Myriophyllum aquaticum*), Japanese stiltgrass (*Microstegium vimineum*), water lettuce (*Pistia stratiotes*), and southern cattail (*Typha domingensis*; Emerine et al. 2010; de Campos et al. 2012; Rodgers and Black 2012; Hall et al. 2014; Mudge and Netherland 2014). Imazamox was observed to have greater efficacy in controlling floating plants than emergents in a study of six aquatic plant species, including water hyacinth, water lettuce, parrot feather, and giant salvinia (*Salvinia molesta*; Emerine et al. 2010). Non-target effects have been observed for softstem bulrush (*Schoenoplectus tabernaemontani*), pickerelweed (*Pontederia cordata*), and the native pondweeds long-leaf pondweed, Illinois pondweed, and coontail (*Ceratophyllum demersum*; Koschnick et al. 2007; Mudge 2013). Giant salvinia, white waterlily (*Nymphaea odorata*), bog smartweed (*Polygonum setaceum*), giant bulrush (*Schoenoplectus californicus*), water celery (*Vallisneria americana*; though the root biomass of wide-leaf *Vallisneria* may be reduced), and several algal species have been found by multiple studies to be unaffected by imazamox (Netherland et al. 2009; Emerine et al. 2010; Rodgers and Black 2012; Mudge 2013; Mudge and Netherland 2014). Other species are likely to be susceptible, for which the effects of imazamox have not yet been evaluated.

Florpyrauxifen-benzyl

Registration and Formulations

Florpyrauxifen-benzyl is a relatively new herbicide, which was first registered with the U.S. EPA in September 2017. The active ingredient is 4-amino-3-chloro-6-(4-chloro-2-fluoro-3-methoxyphenyl)-5-fluoro-pyridine-2-benzyl ester, also identified as florpyrauxifen-benzyl. Florpyrauxifen-benzyl is used for submerged, floating, and emergent aquatic plant control (e.g., ProcellaCORTM) in slow-moving and quiescent waters, as well as for broad spectrum weed control in rice (*Oryza sativa*) culture systems and other crops (e.g., RinskorTM).

Mode of Action and Degradation

Florpyrauxifen-benzyl is a member of a new class of synthetic auxins, the arylpicolinates, that differ in binding affinity compared to other currently registered synthetic auxins such as 2,4-D and triclopyr (Bell et al. 2015). Florpyrauxifen-benzyl is a systemic herbicide (Heilman et al. 2017).

Laboratory studies and preliminary field dissipation studies indicate that florpyrauxifen-benzyl in water is subject to rapid photolysis (Heilman et al. 2017). In addition, the herbicide can also convert partially via hydrolysis to an acid form at high pH (>9) and higher water temperatures (>25°C), and microbial activity in the water and sediment can also enhance degradation (Heilman et al. 2017). The acid form is noted to have reduced herbicidal activity (Netherland and Richardson 2016; Richardson et al. 2016). Under growth chamber conditions, water samples at 1 DAT found that 44-59% of the applied herbicide had converted to acid form, while sampling at 7 and 14 DAT indicated that all the herbicide had converted to acid form (Netherland and Richardson 2016). The herbicide is short-lived, with half-lives ranging from 4 to 6 days in aerobic aquatic environments, and 2 days in anaerobic aquatic environments (WSDE 2017). Degradation in surface water is accelerated when exposed to sunlight, with a reported photolytic half-life in laboratory testing of 0.07 days (WSDE 2017).

There is some anecdotal evidence that initial water temperature and/or pH may impact the efficacy of florpyrauxifen-benzyl (Beets and Netherland 2018). Florpyrauxifen-benzyl has a high soil adsorption coefficient (KOC) and low volatility, which allows for rapid plant uptake resulting in short exposure time requirements (Heilman et al. 2017). Florpyrauxifen-benzyl degrades quickly (2-15 days) in soil and sediment (Netherland et al. 2016). Few studies have yet been completed for groundwater, but based on known environmental properties, florpyrauxifen-benzyl is not expected to be associated with potential environmental impacts in groundwater (WSDE 2017).

Toxicology

No adverse human health effects were observed in toxicological studies submitted for EPA herbicide registration, regardless of the route of exposure (Heilman et al. 2017). There are no drinking water or recreational use restrictions, including swimming and fishing. There are no restrictions on irrigating turf, and a short waiting period (dependent on application rate) for other non-agricultural irrigation purposes.
Florpyrauxifen-benzyl showed a good environmental profile for use in water, and is "practically non-toxic" to birds, bees, reptiles, amphibians, and mammals (Heilman et al. 2017). No ecotoxicological effects were observed on freshwater mussel or juvenile chinook salmon (Heilman et al. 2017). Florpyrauxifen-benzyl will temporarily bioaccumulate in freshwater organisms but is rapidly depurated and/or metabolized within 1 to 3 days after exposure to high (>150 ppb) concentrations (WSDE 2017).

An LC50 value indicates the concentration of a chemical required to kill 50% of a test population of organisms. LC50 values are commonly used to describe the toxicity of a substance. Label recommendations for milfoils do not exceed 9.65 ppb and the maximum label rate for an acre-foot of water is 48.25 ppb. Acute toxicity results using rainbow trout (*Oncorhynchus mykiss*), fathead minnow (*Pimephales promelas*), and sheepshead minnows (*Cyprinodon variegatus variegatus*) indicated LC50 values of greater than 49 ppb, 41 ppb, and 40 ppb, respectively when exposed to the technical grade active ingredient (WSDE 2017). An LC50 value of greater than 1,900 ppb was reported for common carp (*Cyprinus carpio*) exposed to the ProcellaCOR end-use formulation (WSDE 2017).

Acute toxicity results for the technical grade active ingredient using water flea (*Daphnia magna*) and midge (*Chironomus* sp.) indicated LC50 values of greater than 62 ppb and 60 ppb, respectively (WSDE 2017). Comparable acute ecotoxicity testing performed on *D. magna* using the ProcellaCOR end-use formulation indicated an LC50 value of greater than 8 ppm (80,000 ppb; WSDE 2017).

The ecotoxicological no observed effect concentration (NOEC) for various organisms as reported by Netherland et al. (2016) are: fish (>515 ppb ai), water flea (*Daphnia* spp.; >21440 ppb ai), freshwater mussels (>1023 ppb ai), saltwater mysid (>362 ppb ai), saltwater oyster (>289 ppb ai), and green algae (>480 ppb ai). Additional details on currently available ecotoxicological information is compiled by WSDE (2017).

Species Susceptibility

Florpyrauxifen-benzyl is a labeled for control of invasive watermilfoils (e.g., Eurasian watermilfoil (*Myriophyllum spicatum*), hybrid watermilfoil (*M. spicatum* x *sibiricum*), parrot feather (*M. aquaticum*)), hydrilla (*Hydrilla verticillata*), and other non-native floating plants such as floating hearts (*Nymphoides* spp.), water hyacinth (*Eichhornia crassipes*), and water chestnut (*Trapa natans*; Netherland and Richardson 2016; Richardson et al. 2016). Natives species listed on the product label as susceptible to florpyrauxifen-benzyl include coontail (*Ceratophyllum demersum*; Heilman et al. 2017), watershield (*Brasenia schreberi*), and American lotus (*Nelumbo lutea*). In laboratory settings, pickerelweed (*Pontederia cordata*) vegetation has also been shown to be affected (Beets and Netherland 2018).

Based on available data, florpyrauxifen-benzyl appears to show few impacts to native aquatic plants such as aquatic grasses, bulrush (*Schoenoplectus* spp.), cattail (*Typha* spp.), pondweeds (*Potamogeton* spp.), naiads (*Najas* spp.), and water celery (*Vallisneria americana*; WSDE 2017). Laboratory and mesocosm studies also found water marigold (*Bidens beckii*), white waterlily (*Nymphaea odorata*), common waterweed (*Elodea canadensis*), water stargrass (*Heteranthera dubia*), long-leaf pondweed (*Potamogeton nodosus*), and Illinois pondweed (*P. illinoensis*) to be relatively less sensitive to florpyrauxifen-benzyl than labeled species (Netherland et al. 2016; Netherland and Richardson 2016). Non-native fanwort (*Cabomba caroliniana*) was also found to be tolerant in laboratory study (Richardson et al. 2016).

Since florpyrauxifen-benzyl is a relatively new approved herbicide, detailed information on field applications is very limited. Trials in small waterbodies have shown control of parrot feather (*Myriophyllum aquaticum*), variable-leaf watermilfoil (*M. heterophyllum*), and yellow floating heart (*Nymphoides peltata*; Heilman et al. 2017).

S.3.3.3. Emergent and Wetland Herbicides

Glyphosate

Registration and Formulations

Glyphosate is a commonly used herbicide that is utilized in both aquatic and terrestrial sites. It was first registered for use in 1974. EPA is currently re-evaluating glyphosate and the registration decision was expected in 2014 (EPA Glyphosate Plan 2009). The use of glyphosate-based herbicides in aquatic environments that are not approved for aquatic use is very unsafe and is a violation of federal and state pesticide laws. Different formulations of glyphosate are available, including isopropylamine salt of glyphosate and potassium glyphosate.

Glyphosate is effective only on plants that grow above the water and needs to be applied to plants that are actively growing. It will not be effective on plants that are submerged or have most of their foliage underwater, nor will it control regrowth from seed.

Mode of Action and Degradation

Glyphosate is a systemic herbicide that moves throughout the plant tissue and works by inhibiting an important enzyme needed for multiple plant processes, including growth. Following treatment, plants will gradually wilt, appear yellow, and will die in approximately 2 to 7 days. It may take up to 30 days for these effects to become apparent for woody species.

Application should be avoided when heavy rain is predicted within 6 hours. To avoid drift, application is not recommended when winds exceed 5 mph. In addition, excessive speed or pressure during application may allow spray to drift and must be avoided. Effectiveness of glyphosate treatments may be reduced if applied when plants are growing poorly, such as due to drought stress, disease, or insect damage. A surfactant approved for aquatic sites must be mixed with glyphosate before application.

In water, the concentration of glyphosate is reduced through dispersal by water movement, binding to the sediments, and break-down by microorganisms. The half-life of glyphosate is between 3 and 133 days, depending on water conditions. Glyphosate disperses rapidly in water so dilution occurs quickly, thus moving water will decrease concentration, but not half-life. The primary breakdown product of glyphosate is aminomethylphosphonic acid (AMPA), which is also degraded by microbes in water and soil.

Toxicology

Most aquatic forms of glyphosate have no restrictions on swimming or eating fish from treated waterbodies. However, potable water intakes within ½ mile of application must be turned off for 48 hours after treatment. Different formulations and products containing glyphosate may vary in post-treatment water use restrictions.

Most glyphosate-related health concerns for humans involve applicator exposure, exposure through drift, and the surfactant exposure. Some adverse effects from direct contact with the herbicide include temporary symptoms of dermatitis, eye ailments, headaches, dizziness, and nausea. Protective clothing (goggles, a face shield, chemical resistant gloves, aprons, and footwear) should be worn by applicators to reduce exposure. Recently it has been demonstrated that terrestrial formulations of glyphosate can have toxic effects to human embryonic cells and linked to endocrine disruption (Benachour et al. 2007; Gasnier et al. 2009).

Laboratory testing indicates that glyphosate is toxic to carp (*Cyprinus* spp.), bluegills (*Lepomis macrochirus*), rainbow trout (*Oncorhynchus mykiss*), and water fleas (*Daphnia* spp.) only at dosages well above the label application rates. Similarly, it is rated "practically non-toxic" to other aquatic species tested. Studies by other researchers examining the effects of glyphosate on important food chain organisms such as midge larvae, mayfly nymphs, and scuds have demonstrated a wide margin of safety between application rates.

EPA data suggest that toxicological effects of the AMPA compound are similar to that of glyphosate itself. Glyphosate also contains a nitrosamine (n-nitroso-glyphosate) as a contaminant at levels of 0.1 ppm or less. Tests to determine the potential health risks of nitrosamines are not required by the EPA unless the level exceeds 1.0 ppm.

Species Susceptibility

Glyphosate is only effective on actively growing plants that grow above the water's surface. It can be used to control reed canary grass (*Phalaris arundinacea*), cattails (*Typha* spp.; Linz et al. 1992; Messersmith et al. 1992), purple loosestrife (*Lythrum salicaria*), phragmites (*Phragmites australis* subsp. *australis*; Back and Holomuzki 2008; True et al. 2010; Back et al. 2012; Cheshier et al. 2012), water hyacinth (*Eichhornia crassipes*; Lopez 1993; Jadhav et al. 2008), water lettuce (*Pistia stratiotes*; Mudge and Netherland 2014), water chestnut (*Trapa natans*; Rector et al. 2015), Japanese stiltgrass (*Microstegium vimineum*; Hall et al. 2014), giant reed (*Arundo donax*; Spencer 2014), and perennial pepperweed (*Lepidium latifolium*; Boyer and Burdick 2010). Glyphosate will also reduce abundance of white waterlily (*Nymphaea odorata*) and pond-lilies (*Nuphar* spp.; Riemer and Welker 1974). Purple loosestrife biocontrol beetle (*Galerucella calmariensis*) oviposition and survival have been shown not to be affected by integrated management with glyphosate. Studies have found pickerelweed (*Pontederia cordata*) and floating marsh pennywort (*Hydrocotyle ranunculoides*) to be somewhat tolerant to glyphosate (Newman and Dawson 1999; Gettys and Sutton 2004).

Imazapyr

Registration and Formulations

Imazapyr was registered with the U.S. EPA for aquatic use in 2003 and is currently under registration review. It was estimated to have a registration review decision in 2017 (EPA Imazapyr Plan 2014). The active ingredient is isopropylamine salt of imazapyr (2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-3-pyridinecarboxylic acid). Imazapyr is used for control of emergent and floating-leaf vegetation. It is not recommended for control of submersed vegetation.

Mode of Action and Degradation

Imazapyr is a systemic herbicide that moves throughout the plant tissue and prevents plants from producing a necessary enzyme, acetolactate synthase (ALS), which is not found in animals. Susceptible plants will stop growing soon after treatment and become reddish at the tips of the plant. Plant death and decomposition will occur gradually over several weeks to months. Imazapyr should be applied to plants that are actively growing. If applied to mature plants, a higher concentration of herbicide and a longer contact time will be required.

Imazapyr is broken down in the water by light and has a half-life ranging from three to five days. Three degradation products are created as imazapyr breaks down: pyridine hydroxy-dicarboxylic acid, pyridine dicarboxylic acid (quinolinic acid), and nicotinic acid. These degradates persist in water for approximately the same amount of time as imazapyr (half-lives of three to eight days). In soils imazapyr is broken down by microbes, rather than light, and persists with a half-life of one to five months (Boyer and Burdick 2010). Imazapyr doesn't bind to sediments, so leaching through soil into groundwater is likely.

Toxicology

There are no restrictions on recreational use of treated water, including swimming and eating fish from treated waterbodies. If application occurs within a ½ mile of a drinking water intake, then the intake must be shut off for 48 hours following treatment. There is a 120-day irrigation restriction for treated water, but irrigation can begin sooner if the concentration falls below 0.001 ppm (1 ppb). Imazapyr degradates are no more toxic than imazapyr itself and are excreted faster than imazapyr when ingested.

Concentrated imazapyr has low acute toxicity on the skin or if ingested but is harmful if inhaled and may cause irreversible damage if it gets in the eyes. Applicators should wear chemical-resistant gloves while handling, and persons not involved in application should avoid the treatment area during treatment. Chronic toxicity tests for imazapyr indicate that it is not carcinogenic, mutagenic, or neurotoxic. It also does not cause reproductive or developmental toxicity and is not a suspected endocrine disrupter.

Imazapyr is "practically non-toxic" to fish, invertebrates, birds and mammals. Studies have also shown imazapyr to be "practically non-toxic" to "slightly toxic" to tadpoles and juvenile frogs (Trumbo and Waligora 2009; Yahnke et al. 2013). Toxicity tests have not been published on reptiles. Imazapyr does not bioaccumulate in animal tissues.

Species Susceptibility

The imazapyr herbicide label is listed to control the invasive plants phragmites (*Phragmites australis* subsp. *australis*), purple loosestrife (*Lythrum salicaria*), reed canary grass (*Phalaris arundinacea*), non-native cattails (*Typha* spp.) and Japanese knotweed (*Fallopia japonica*) in

Wisconsin. Native species that are also controlled include cattails (*Typha* spp.), waterlilies (*Nymphaea* sp.), pickerelweed (*Pontederia cordata*), duckweeds (*Lemna* spp.), and arrowhead (*Sagittaria* spp.).

Studies have shown imazapyr to effectively control giant reed (*Arundo donax*), water hyacinth (*Eichhornia crassipes*), manyflower marsh-pennywort (*Hydrocotyle umbellata*); yellow iris (*Iris pseudacorus*), water lettuce (*Pistia stratiotes*), perennial pepperweed (*Lepidium latifolium*), Japanese stiltgrass (*Microstegium vimineum*), parrot feather (*Myriophyllum aquaticum*), and cattails (Boyer and Burdick 2010; True et al. 2010; Back et al. 2012; Cheshier et al. 2012; Whitcraft and Grewell 2012; Hall et al. 2014; Spencer 2014; Cruz et al. 2015; DiTomaso and Kyser 2016). Giant salvinia (*Salvinia molesta*) was found to be imazapyr-tolerant (Nelson et al. 2001).

S.3.3.4. Herbicides Used for Submersed and Emergent Plants

Triclopyr

Registration and Formulations

Triclopyr was initially registered with the U.S. EPA in 1979, reregistered in 1997, and is currently under review with an estimated registration review decision in 2019 (EPA Triclopyr Plan 2014). There are two forms of triclopyr used commercially as herbicides: the triethylamine salt (TEA) and the butoxyethyl ester (BEE). BEE formulations are considered highly toxic to aquatic organisms, with observed lethal effects on fish (Kreutzweiser et al. 1994) as well as avoidance behavior and growth impairment in amphibians (Wojtaszek et al. 2005). The active ingredient triethylamine salt (3,5,6-trichloro-2-pyridinyloxyacetic acid) is the formulation registered for use in aquatic systems. It is sold both in liquid and granular forms for control of submerged, emergent, and floating-leaf vegetation. There is also a liquid premixed formulation that contains triclopyr and 2,4-D, which when combined together are reported to have synergistic impacts. Only triclopyr products labeled for use in aquatic environments may be used to control aquatic plants.

Mode of Action and Degradation

Triclopyr is a systemic plant growth regulator that is believed to selectively act on broadleaf (dicot) and woody plants. Following treatment, triclopyr is taken up through the roots, stems and leaf tissues, plant growth becomes abnormal and twisted, and plants die within one to two weeks after application (Getsinger et al. 2000). Triclopyr is somewhat persistent and can move through soil, although only mobile enough to permeate top soil layers and likely not mobile enough to potentially contaminate groundwater (Lee et al. 1986; Morris et al. 1987; Stephenson et al. 1990).

Triclopyr is broken down rapidly by light (photolysis) and microbes, while hydrolysis is not a significant route of degradation. Triclopyr photodegrades and is further metabolized to carbon dioxide, water, and various organic acids by aquatic organisms (McCall and Gavit 1986). It has been hypothesized that the major mechanism for the removal of triclopyr from the aquatic environment is microbial degradation, though the role of photolysis likely remains important in near-surface and shallow waters (Petty et al. 2001). Degradation of triclopyr by microbial action is slowed in the absence of light (Petty et al. 2003). Triclopyr is very slowly degraded under anaerobic conditions, with a reported half-life (the time it takes for half of the active ingredient to degrade) of about 3.5 years (Laskowski and Bidlack 1984). Another study of triclopyr under aerobic aquatic conditions yielded a half-life of 4.7 months (Woodburn and Cranor 1987). The initial breakdown products of triclopyr are TCP (3,5,6-trichloro-2-pyridinol) and TMP (3,5,6-trichloro-2-methoxypridine).

Several studies reported triclopyr half-lives between 0.5-7.5 days (Woodburn et al. 1993; Getsinger et al. 2000; Petty et al. 2001; Petty et al. 2003). Two large-scale, low-dose treatments were reported to have longer triclopyr half-lives from 3.7-12.1 days (Netherland and Jones 2015). Triclopyr half-lives have been shown to range from 3.4 days in plants, 2.8-5.8 days in sediment, up to 11 days in fish tissue, and 11.5 days in crayfish (Woodburn et al. 1993; Getsinger et al. 2000; Petty et al. 2003). TMP and TCP may have longer half-lives than triclopyr, with higher levels in bottom-feeding fish and the inedible parts of fish (Getsinger et al. 2000).

Toxicology

Based upon the triclopyr herbicide label, there are no restrictions on swimming, eating fish from treated waterbodies, or pet/livestock drinking water use. Before treated water can be used for irrigation, the concentration must be below 0.001 ppm (1 ppb), or at least 120 days must pass. Treated water should not be used for drinking water until concentrations of triclopyr are less than 0.4 ppm (400 ppb). There is a least one case of direct human ingestion of triclopyr TEA which resulted in metabolic acidosis and coma with cardiovascular impairment (Kyong et al. 2010).

There are substantial differences in toxicity of BEE and TEA, with the BEE shown to be more toxic in aquatic settings. BEE formulations are considered highly toxic to aquatic organisms, with observed lethal effects on fish (Kreutzweiser et al. 1994) as well as avoidance behavior and growth impairment in amphibians (Wojtaszek et al. 2005). Triclopyr TEA is "practically non-toxic" to freshwater fish and invertebrates (Mayes et al. 1984; Gersich et al. 1984). It ranges from "practically non-toxic" to "slightly toxic" to birds (EPA Triclopyr RED 1998). TCP and TMP appear to be slightly more toxic to aquatic organisms than triclopyr; however, the peak concentration of these degradates is low following treatment and depurates from organisms readily, so that they are not believed to pose a concern to aquatic organisms.

Species susceptibility

Triclopyr has been used to control Eurasian watermilfoil (*Myriophyllum spicatum*) and hybrid watermilfoil (*M. spicatum* x *sibiricum*) at both small- and large-scales (Netherland and Getsinger 1992; Getsinger et al. 1997; Poovey et al. 2004; Poovey et al. 2007; Nelson and Shearer 2008; Heilman et al. 2009; Glomski and Netherland 2010; Netherland and Glomski 2014; Netherland and Jones 2015). Getsinger et al. (2000) found that peak triclopyr accumulation was higher in Eurasian watermilfoil than flat-stem pondweed (*Potamogeton zosteriformis*), indicating triclopyr's affinity for Eurasian watermilfoil as a target species.

According to product labels, triclopyr is capable of controlling or affecting many emergent woody plant species, purple loosestrife (*Lythrum salicaria*), phragmites (*Phragmites australis* subsp. *australis*), American lotus (*Nelumbo lutea*), milfoils (*Myriophyllum* spp.), and many others. Triclopyr application has resulted in reduced frequency of occurrence, reduced biomass, or growth regulation for the following species: common waterweed (*Elodea canadensis*), water stargrass (*Heteranthera dubia*), white waterlily (*Nymphaea odorata*), purple loosestrife, Eurasian watermilfoil, parrot feather (*Myriophyllum aquaticum*), variable-leaf watermilfoil (*M. heterophyllum*), watercress (*Nasturtium officinale*), phragmites, flat-stem pondweed (*Potamogeton zosteriformis*), clasping-leaf pondweed (*P. richardsonii*), stiff pondweed (*P. strictifolius*), variable-leaf pondweed (*P. gramineus*), white water crowfoot (*Ranunculus aquatilis*), sago pondweed (*Stuckenia pectinata*), softstem bulrush (*Schoenoplectus tabernaemontani*), hardstem bulrush (*S. acutus*), water chestnut (*Trapa natans*), duckweeds (*Lemna* spp.), and submerged flowering rush (*Butomus umbellatus*; Cowgill et al. 1989; Gabor et al. 1995; Sprecher and Stewart 1995; Getsinger et al. 2003; Poovey et al. 2004; Hofstra et al. 2006; Poovey and Getsinger 2007; Champion et al. 2008; Derr 2008; Glomski and Nelson 2008; Glomski et al. 2009; True et al. 2010; Cheshier et al. 2012; Netherland and Jones 2015; Madsen et al. 2015; Madsen et al. 2016). Wild rice (*Zizania palustris*) biomass and height has been shown to decrease significantly following triclopyr application at 2.5 mg/L. Declines were not significant at lower concentrations (0.75 mg/L), though seedlings were more sensitive than young or mature plants (Madsen et al. 2008). American bulrush (*Schoenoplectus americanus*), spatterdock (*Nuphar variegata*), fern pondweed (*Potamogeton robbinsii*), large-leaf pondweed (*P. amplifolius*), leafy pondweed (*P. foliosus*), white-stem pondweed (*P. praelongus*), long-leaf pondweed (*P. nodosus*), Illinois pondweed (*P. illinoensis*), and water celery (*Vallisneria americana*) can be somewhat tolerant of triclopyr applications depending on waterbody characteristics and application rates (Sprecher and Stewart 1995; Glomski et al. 2009; Wersal et al. 2010b; Netherland and Glomski 2014).

Netherland and Jones (2015) evaluated the impact of large-scale, low-dose (~0.1-0.3 ppm) granular triclopyr) applications for control of non-native watermilfoil on several bays of Lake Minnetonka, Minnesota. Near complete loss of milfoil in the treated bays was observed the year of treatment, with increased milfoil frequency reported the following season. However, despite the observed increase in frequency, milfoil biomass remained a minor component of bay-wide biomass (<2%). The number of points with native plants, mean native species per point, and native species richness in the bays were not reduced following treatment. However, reductions in frequency were seen amongst individual species, including northern watermilfoil (*Myriophyllum sibiricum*), water stargrass, common waterweed, and flat-stem pondweed.

Penoxsulam

Registration and Formulations

Penoxsulam (2-(2,2-difluoroethoxy)--6-(trifluoromethyl-N-(5,8-dimethoxy[1,2,4] triazolo[1,5-c]pyrimidin-2-yl))benzenesulfonamide), also referred to as DE-638, XDE-638, XR-638 is a post-emergence, acetolactate synthase (ALS) inhibiting herbicide. It was first registered for use by the U.S. EPA in 2009. It is liquid in formulation and used for large-scale control of submerged, emergent, and floating-leaf vegetation. Information presented here can be found in the EPA pesticide fact sheet (EPA Penoxsulam 2004).

Mode of Action and Degradation

Penoxsulam is a slow-acting herbicide that is absorbed by above- and below-ground plant tissue and translocated throughout the plant. Penoxsulam interferes with plant growth by inhibiting the AHAS/ALS enzyme which in turn inhibits the production of important amino acids (Tranel and Wright 2002). Plant injury or death usually occurs between 2 and 4 weeks following application.

Penoxsulam is highly mobile but not persistent in either aquatic or terrestrial settings. However, the degradation process is complex. Two degradation pathways have been identified that result in at least 13 degradation products that persist for far longer than the original chemical. Both microbial- and photo-degradation are likely important means by which the herbicide is removed from the environment (Monika et al. 2017). It is relatively stable in water alone without sunlight, which means it may persist in light-limited areas.

The half-life for penoxsulam is between 12 and 38 days. Penoxsulam must remain in contact with plants for around 60 days. Thus, supplemental applications following initial treatment may be required to maintain adequate concentration exposure time (CET). Due to the long CET requirement, penoxsulam is likely best suited to large-scale or whole-lake applications.

Toxicology

Penoxsulam is unlikely to be toxic to animals but may be "slightly toxic" to birds that consume it. Human health studies have not revealed evidence of acute or chronic toxicity, though some indication of endocrine disruption deserves further study. However, screening-level assessments of risk have not been conducted on the major degradates which may have unknown non-target effects. Penoxsulam itself is unlikely to bioaccumulate in fish.

Species Susceptibility

Penoxsulam is used to control monocot and dicot plant species in aquatic and terrestrial environments. The herbicide is often applied at low concentrations of 0.002-0.02 ppm (2-20 ppb), but as a result long exposure times are usually required for effective target species control (Cheshier et al. 2011; Mudge et al. 2012b). For aquatic plant management applications, penoxsulam is most commonly utilized for control of hydrilla (*Hydrilla verticillata*). It has also been used for control of giant salvinia (*Salvinia molesta*), water hyacinth (*Eichhornia crassipes*), and water lettuce (*Pistia stratiotes*; Richardson and Gardner 2007; Mudge and Netherland 2014). However, the herbicide is only semi-selective; it has been implicated in injury to non-target emergent native species, including arrowheads (*Sagittaria* spp.) and spikerushes (*Eleocharis* spp.) and free-floating species like duckweed (Mudge and Netherland 2014; Cheshier et al. 2011). Penoxsulam can also be used to control milfoils such as Eurasian watermilfoil (*Myriophyllum spicatum*) and variable-leaf watermilfoil (*M. heterophyllum*; Glomski and Netherland 2008). Seedling emergence as well as vegetative vigor is impaired by penoxsulam in both dicots and monocots, so buffer zone and dissipation reduction strategies may be necessary to avoid non-target impacts (EPA Penoxsulam 2004).

When used to treat salvinia, the herbicide was found to have effects lasting through 10 weeks following treatment (Mudge et al. 2012b). The herbicide is effective at low doses, but while low-concentration applications of slow-acting herbicides like penoxsulam often result in temporary growth regulation and stunting, plants are likely to recover following treatment. Thus, complementary management strategies should be employed to discourage early regrowth (Mudge et al. 2012b). In particular, joint biological and herbicidal control with penoxsulam has shown good control of water hyacinth (Moran 2012). Alternately, a low concentration may be maintained over time by repeated low-dose applications. Studies show that maintaining a low concentration for at least 8-12 weeks provided excellent control of salvinia, and that a low dose followed by a high-dose application was even more efficacious (Mudge et al. 2012b).

S.3.4. Physical Removal Techniques

There are several management options which involve physical removal of aquatic plants, either by manual or mechanical means. Some of these include manual and mechanical cutting and hand-pulling or Diver-Assisted Suction Harvesting (DASH).

S.3.4.1. Harvesting: Manual, Mechanical, and DASH

Manual and Mechanical Cutting

Manual and mechanical cutting involve slicing off a portion of the target plants and removing the cut portion from the waterbody. In addition to actively removing parts of the target plants, destruction of vegetative material may help prevent further plant growth by decreasing photosynthetic uptake, and preventing the formation of rhizomes, tubers, and other growth types (Dall Armellina et al. 1996a, 1996b; Fox et al. 2002). These approaches can be quick to allow recreational use of a waterbody but because the plant is still established and will continue to grow from where it was cut, it often serves to provide short-term relief (Bickel and Closs 2009; Crowell et al. 1994).

The amount of time for macrophytes to return to pre-cutting levels can vary between waterbodies and with the dominant plant species present (Kaenel et al. 1998). Some studies have suggested that annual or biannual cutting of Eurasian watermilfoil (*Myriophyllum spicatum*) may be needed, while others have shown biomass can remain low the year after cutting (Kimbel and Carpenter 1981; Painter 1988; Barton et al. 2013). Hydrilla (*Hydrilla verticillata*) has been shown to recover beyond pre-harvest levels within weeks in some cases (Serafy et al. 1994). In deeper waters, greater cutting depth may lead to increased persistence of vegetative control (Unmuth et al. 1998; Barton et al. 2013). Higher frequency of cutting, rather than the amount of plant that is cut, can result in larger reductions to propagules such as turions (Fox et al. 2002).

The timing of cutting operations, as for other management approaches, is important. For species dependent on vegetative propagules, control methods should be taken before the propagules are formed. However, for species with rhizomes, cutting too early in the season merely postpones growth while later-season cutting can better reduce plant abundance (Dall Armellina et al. 1996a, 1996b). Eurasian watermilfoil regrowth may be slower if cutting is conducted later in the summer (June or later). Cutting in the fall, rather than spring or summer, may result in the lowest amount of Eurasian watermilfoil regrowth the year after management (Kimbel and Carpenter 1981). However, managing early in the growing season may reduce non-target impacts to native plant populations when early-growing non-native plants are the dominant targets (Nichols and Shaw 1986). Depending on regrowth rate and management goals, multiple harvests per growing season may be necessary (Rawls 1975).

Vegetative fragments which are not collected after cutting can produce new localized populations, potentially leading to higher plant densities (Dall Armellina et al. 1996a). Eurasian watermilfoil and common waterweed (*Elodea canadensis*) biomass can be reduced by cutting (Abernethy et al. 1996), though Eurasian watermilfoil can maintain its growth rate following cutting by developing a more-densely branched form (Rawls 1975; Mony et al. 2011). Cutting and physical removal tend to be less expensive but require more effort than benthic barriers, so these approaches may be best used for small infestations or where non-native and native species inhabit the same stand (Bailey and Calhoun 2008).

Hand Pulling and Diver-Assisted Suction Harvesting

Hand-pulling and DASH involve removing rooted plants from the bottom sediment of the water body. The entire plant is removed and disposed of elsewhere. Hand-pulling can be done at shallower depths whereas DASH, in which SCUBA divers do the pulling, may be better suited for deeper aquatic plant beds. As a permit condition, DASH and hand-pulling may not result in lifting or removal of bottom sediment (i.e., dredging). Efforts should be made to preserve water clarity because turbid conditions reduce visibility for divers, slowing the removal process and making species identification difficult. When operated with the intent to distinguish between species and minimize disturbance to desirable vegetation, DASH can be selective and provide multi-year control (Boylen et al. 1996). One study found reduced cover of Eurasian watermilfoil both in the year of harvest and the following year, along with increased native plant diversity and reduced overall plant cover the year following DASH implementation (Eichler et al. 1993). However, hand harvesting or DASH may require a large time or economic investment for Eurasian watermilfoil and other aquatic vegetation control on a large-scale (Madsen et al. 1989; Kelting and Laxson 2010). Lake type, water clarity, sediment composition, underwater obstacles and presences of dense native plants, may slow DASH efforts or even prohibit the ability to utilized DASH. Costs of DASH per acre have been reported to typically range from approximately $5,060-8,100 (Cooke et al. 1993; Mattson et al. 2004). Additionally, physical removal of turions from sediments, when applicable, has been shown to greatly reduce plant abundance for multiple subsequent growing seasons (Caffrey and Monahan 2006), though this has not been implemented in Wisconsin due to the significant effort it requires.

Ecological Impacts of Physical Removal Techniques

Plants accrue nutrients into their tissues, and thus plant removal may also remove nutrients from waterbodies (Boyd 1970), though this nutrient removal may not be significant among lake types. Cutting and harvesting of aquatic plants can lead to declines in fish as well as beneficial zooplankton, macroinvertebrate, and native plant and mussel populations (Garner et al. 1996;

Aldridge 2000; Torn et al. 2010; Barton et al. 2013). Many studies suggest leaving some vegetated areas undisturbed to reduce negative effects of cutting on fish and other aquatic organisms (Swales 1982; Garner et al. 1996; Unmuth et al. 1998; Aldridge 2000; Greer et al. 2012). Recovery of these populations to cutting in the long-term is understudied and poorly understood (Barton et al. 2013). Effects on water quality can be minimal but nutrient cycling may be affected in wetland systems (Dall Armellina et al. 1996a; Martin et al. 2003). Cutting can also increase algal production, and turbidity temporarily if sediments are disturbed (Wile 1978; Bailey and Calhoun 2008).

Some changes to macroinvertebrate community composition can occur as a result of cutting (Monahan and Caffrey 1996; Bickel and Closs 2009). Studies have also shown 12-85% reductions in macroinvertebrates following cutting operations in flowing systems (Dawson et al. 1991; Kaenel et al. 1998). Macroinvertebrate communities may not rebound to pre-management levels for 4-6 months and species dependent on aquatic plants as habitat (such as simuliids and chironomids) are likely to be most affected. Reserving cutting operations for summer, rather than spring, may reduce impacts to macroinvertebrate communities (Kaenel et al. 1998).

Mechanical harvesting can also incidentally remove fish and turtles inhabiting the vegetation and lead to shifts in aquatic plant community composition (Engel 1990; Booms 1999). Studies have shown mechanical harvesting can remove between 2%-32% of the fish community by fish number, with juvenile game fish and smaller species being the primary species removed (Haller et al. 1980; Mikol 1985). Haller et al. (1980) estimated a 32% reduction in the fish community at a value of $6000/hectare. However, fish numbers rebounded to similar levels as an unmanaged area within 43 days after harvesting in the Potomac River in Maryland (Serafy et al. 1994). In addition to direct impacts to fish populations, reductions in fish growth rates may correspond with declines in zooplankton populations in response to cutting (Garner et al. 1996). Because divers are physically uprooting plants from the lake bed, hand removal may disturb benthic organisms. Additionally, DASH may also result in some accidental capture of fish and invertebrates, small amounts of sediment removal, or increased turbidity. It is possible that equipment modifications could help minimize some of these unintended effects.

G

APPENDIX G

Comment Response Document for the Official First Draft

Comments to Lost Lake Draft Comprehensive Management Plan (11/20/18) – Comments Received 1/28/2019

Response by Eddie Heath
Response by Josephine Barlament
Response by Tim Hoyman

WDNR Official Comments: Carol Warden – Team Leader
(UW Trout Lake Station Center for Limnology Aquatic Invasive Species Specialist)

- What is the asterisk by Internal Nutrient Loading on pg 12? Typo was removed.

- Page 30, NR115: What do you think about changing the terminology from "stricter shoreland ordinances" to "more protective shoreland ordinances"? I've been in discussions with colleagues from Vilas County Lakes and River Association, Trout Lake, Vilas County, and others about how these words around zoning and regulations matter. Words like "more strict" or "restrictive" take away from what those regulations are actually put in place to do, which is to protect. Justification for word-smithing understood. Change was made in the majority of locations.

- Pages 30-39. This may be a good place to mention the Healthy Lakes grants program through UWEX Lakes and DNR. Text added referring to this program.

- Page 46, Herbicide table. Do we need to add ProcellaCOR to this? Table 3.4-4 was updated to include a few newer herbicide modes of action.

- Approxmately page 71-74: When referencing a "majority," the finding must be greater than 50%. There seems to be confusion with the meaning of "majority" and "modal" – a modal response is the most frequent response and may not be a majority. By referencing a modal response as the majority (when it is not the majority), they are misrepresenting the data. Please review and correct. We were unable to find a location on page 71-74 where "majority" was used incorrectly instead of "plurality." An incorrect usage was modified on page 7.

- Page 74: nice breakdown of CLP strategy. No action taken.

- Page 92: recommendation for herbicide treatment is eligible but this will still be evaluated annually when the permit application comes in. Also, a statement should be added to include DNR in discussions when the trigger for considering an herbicide treatment is met. A few disclaimer sentences were added above Figure 5.0-1.

- Page 93: typo "as occurred in 2018 and 2018" Change has been made.

- Page 97: Update VCLRA president to Tom Ewing. tomewingjr@aol.com I'm checking to see if the president@vclra.us is still a viable email address. Fisheries biologist should be updated back to Steve Gilbert as well. Change has been made.

Comments from Great Lakes Indian Fish & Wildlife Commission (GLIFWC)

- No treatments should be allowed in Lost Lake when downstream rice beds are most vulnerable. In addition, post-treatment concentration monitoring at/within the rice bed should be mandatory in order to document the duration and levels detected from Lost Lake's treatment. The monitoring and implementation plans incorporate these sentiments.

Comments from Lac du Flambeau Band of Lake Superior Chippewa Indians (LDF Tribe)

- Public Participation/Stakeholder Survey: According to the report- the Survey was only available to lake property owners and NOT lake users. Lake users without lake property were not contacted nor considered. Lake users on the downstream waterbody were also not considered. Our lake management plans are created with our clients and are intended for those groups to implement; therefore, the lake group membership and riparian property owners are the focal group for the stakeholder surveys. This is the case whether we are assisting a lake district, a lake association, or a municipality. The survey is a riparian survey used to gather information from that group regarding their use of the lake, how they believe it has changed over time, and how they can be involved in the lake group. Most of the questions within these surveys are not applicable to transient users of the lake and those who do not own property on the lake. It is a goal with any social survey to define the geographical boundary or sampling population so a statistical determination can be made confirming that the results of that survey represent the thoughts and position of that geographical area or population

  For this project, the riparian stakeholder survey was sent to all LLPRD district members, which are property owners on Lost Lake. It is important that the data are understood in the context of the population sampled. The survey did not solicit opinions from transient boaters nor from property owners on hydrologically connected waterbodies. Qualifying text was added throughout this document indicating this was a riparian stakeholder survey.

- The outlet creek and downstream lake are impacted by any herbicide treatment lake management. The Town of Saint Germain Lakes Committee, which includes representation of downstream waterbodies (i.e. Big St. Germain Lake), has been included on lake management planning and AIS management discussions. The chair of the Town of Saint Germain Lakes Committee was on the Lost Lake Planning Committee. Aquatic plant surveys and riparian stakeholder surveys on Big St. Germain Lake are schedule to occur in 2019.

  For large-scale herbicide treatments (WDNR definition is >10 acres or 10% of littoral area), such as those that have been completed on Lost Lake, the WDNR has a mechanism for involving interested stakeholders under NR107.04 (3,4,5). This includes the applicant placing a public notice in the local paper as part of the permitting process. If the WDNR receives 5 requests relating to that posting, a public meeting is scheduled to provide citizens with information about the forthcoming management activity.

  To solicit perspective on this management plan from other stakeholder groups, a draft of the plan was WDNR, GLIFWC, LDF Tribe, Vilas County, and Town of St. Germain Lakes Committee provided for official comment. The comments are addressed if applicable and all comments, such as those provided on this plan, are published as an appendix to the plan.

- The Plan reports that water clarity is much better than expected and the reason is unclear. The report also asserts that something else- other than planktonic algae- are important. The unexplained better than expected water clarity could be attributed to the presence of native vegetation. Therefore- there is a concern that herbicide application and subsequent vegetation decline could negatively affect water clarity. Our team, lead by Paul Garrison, investigated the water quality data in regards to this comment. During that investigation, it was uncovered that there was quite a bit of inconsistency in what parameters were sampled each year. Because of the range of trophic variability Lost Lake experiences, it is most appropriate to create a working average of only years where all parameters were sampled. Years with high biological TSI but no corresponding Secchi transparency, and vice-versa, skew the weighted average if not corrected for this influence. The trophic state sub-section and corresponding figure 3.1-8 have been updated accordingly.

- Previous herbicide treatments resulted in higher concentrations at the downstream monitoring location than in the treatment area. 2017 Herbicide Treatment monitoring efforts and results were not discussed in the report and important to future planning efforts. This is important to downstream native plants of importance including wild rice. Figure 3.4-16 was updated to include both 2017 and 2018 data. The 2018 herbicide concentrations were higher in downstream locations compared to 2017 and were attributed to lower water flows in 2018. As discussed in the *2018 AIS Monitoring & Control Strategy Assessment Report*, alterations to future dosing strategies will be made during years with low flows and potential to manipulate the dam (addressed in Implementation Plan Section). Following this plan, the 2019 strategy incorporated a lower dose of endothall compared with 2017 and 2018.

- Very little information of the manual removal efforts were included. Also no quantifiable data regarding manual removal efforts were included (hours spent, volume removed, technique utilized). More detailed information on manual removal efforts are needed. Specific information regarding the 2013-2015 EWM hand-harvesting program is included within each years' *AIS Monitoring & Control Strategy Assessment Report*, which are housed on the district's website. Hand-harvesting as an AIS management tool must be scale appropriate, particularly targeting low acreage and density occurrences. Targeting 30 acres of dense CLP with hand-harvesting is not a scale-appropriate population suppression tool. The WDNR has recently provided comment on denied grant(s) for using hand-harvesting methods in non-scale-appropriate situations.

Implementation Plan

The lake management implementation excluded lake user input and only included lake property owners serving on a planning committee. The authors acknowledge that the commenter would have liked to see a more expansive effort to understand perspectives of lake users, not just lake property owners (i.e. district members).

- Management Action: Conduct CLP population management using herbicide spot treatments - The Lac du Flambeau Tribal Natural Resource Department maintains opposition to herbicide treatment on an affected wild rice waterbody and fishery within ceded territory. This perspective is understood and was added to the implementation plan. A viable alternative is possible and has not been thoroughly explored or implemented. Alternatives analysis was conducted as a part of this project, including attention to population management vs nuisance minimization and the scale-appropriate tools available.

- Implementation plan does not correspond to public outreach. The Implementation Plan is the district's plan for how they pursue future management and monitoring of Lost Lake.

- Even though the survey effort biased to only property owners and ignored lake users, the survey results show manual control was favored above herbicide control. The Implementation Plan ignores the survey results and instead inserts herbicide treatment over manual control. The district planning committee discussed the applicability of manual removal and determined it was not scale appropriate. Actually, more time was spent discussing mechanical harvesting as a possible nuisance control tool and may require revisiting this strategy in the future. The WDNR has indicated favorability to exploring mechanical harvesting on Lost Lake. The district may consider mechanical harvesting as an option if CLP population management does not meet objectives.

- We would like to see an environmental assessment prior to activities proposed. We suspect this comment is directed at the Wisconsin DNR.

Steve Gilbert Comments, WDNR Fisheries Biologist

- Table 3.6-4 The lake association has stocked large fingerling walleye in 2000, 02, 03, 07, 09, 11, 13, 15, 17. They should be able to provide you with the numbers.
  Contacted Gary Heeler who sent historical stocking data of Lost Lake Community Club and the Lost Lake District. Integrated these data into the report.
- Table 3.6-5 The trolling regulation on all lakes in Vilas County is One line per person with no more than three trolled lines per boat.
  Updated the table regulation text. The 2011 Fisheries Information Sheet was also provided by Steve Gilbert and provided as Appendix E. Fish species present in Lost Lake was updated to match what was found during the 2011 fishery survey.