A

APPENDIX A

Public Participation Materials

Planning Meeting I Presentation

Planning Meeting II Presentation

Presentation Outline

- Eurasian watermilfoil biology and control
- GLA historic control actions
- Herbicide spot treatment function and research
- Whole-lake treatment function and research
- WDNR EWM Long-Term Trends Research Project
- Preliminary discussion of 2018 EWM control strategy

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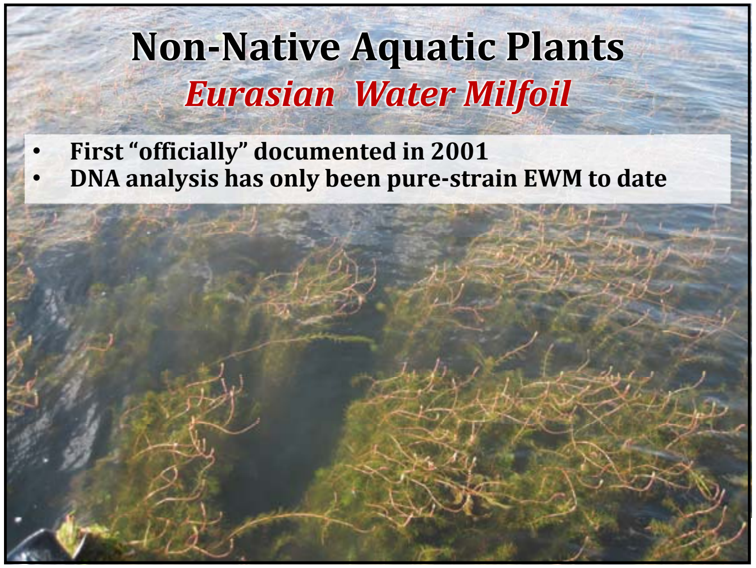
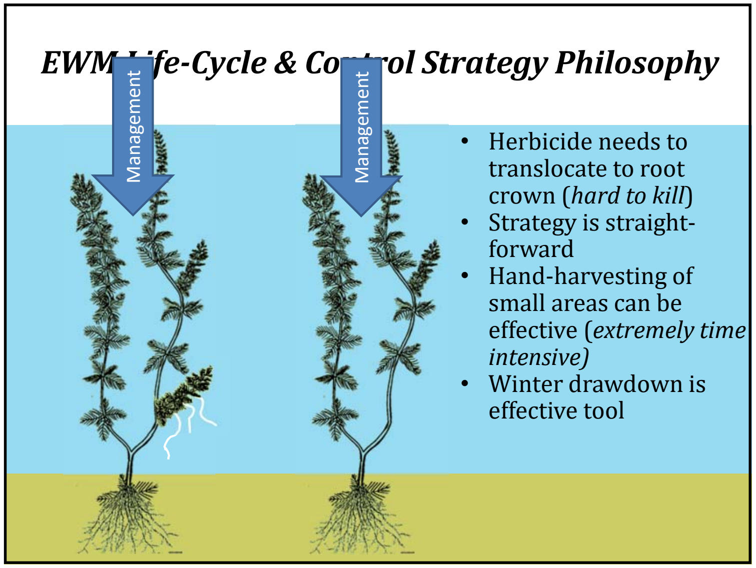
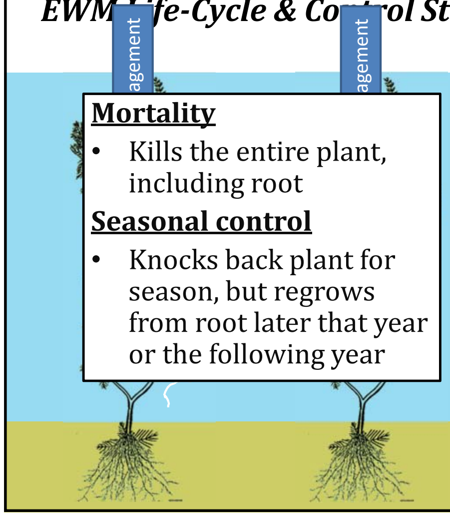




EWM Life-Cycle & Control Strategy Philosophy



Mortality

- Kills the entire plant, including root

Seasonal control

- Knocks back plant for season, but regrows from root later that year or the following year

- Herbicide needs to translocate to root crown (*hard to kill*)
- Strategy is straight-forward
- Hand-harvesting of small areas can be effective (*extremely time intensive)*
- Winter drawdown is effective tool

Herbicide Use History

	Acres	Average Size	Conclusions within Annual Report
2007	7.9	0.6	Failed treatment, maybe due to steep sides. Add buffer for next year.
2008	8.1	0.6	Failed treatment, steep sides and narrow bands discussed. Expand buffer and increase dose for next year.
2009	9.8	0.9	Mixed results, retreat most sites next year. Increase dose to max label rates.
2010	15.3	1.0	Mixed results. Switch to different herbicide next year so can increase dose.
2011	6.6	0.8	Seasonal control documented. Increase dose for next year.
2012	3.4	0.9	Seasonal control documented. Increase dose to max label rates for next year.
2013	5.8	0.6	Failed treatment. Only larger sites saw reductions. Colonies too small to be controlled with herbicides.

Onterra recommended no herbicide treatment in 2014 because treatments weren't working. Consider hand-harvesting.

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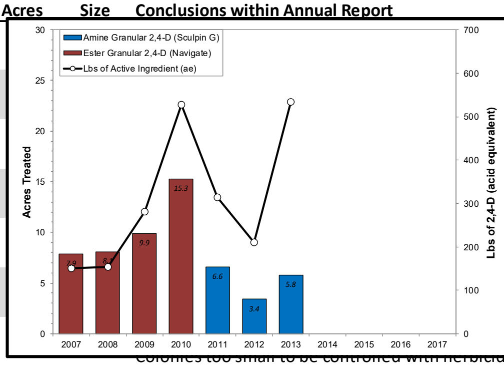
Herbicide Use History

	Acres	Average Size	Conclusions within Annual Report
2007			
2008			iscussed.
2009			
2010			rease dose.
2011			
2012			
2013			s. Colonies too small to be controlled with herbicides.



Onterra recommended no herbicide treatment in 2014 because treatments weren't working. Consider hand-harvesting.

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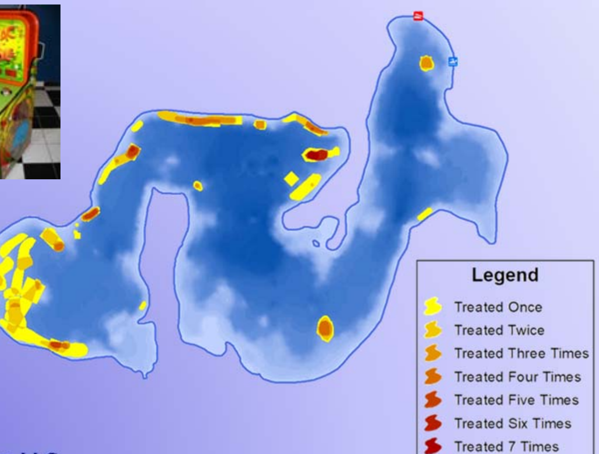
2007-2013 Treatment Footprint



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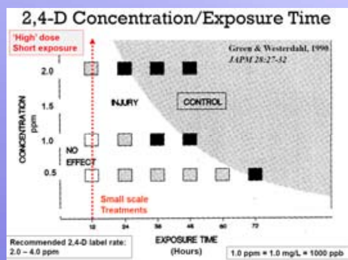
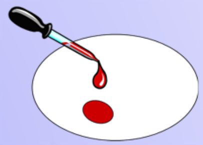
Herbicide Spot Treatment

- **Ecological Definition:** Herbicide applied at a scale where dissipation will not result in significant lake wide concentrations; impacts are anticipated to be localized to in/around application area.





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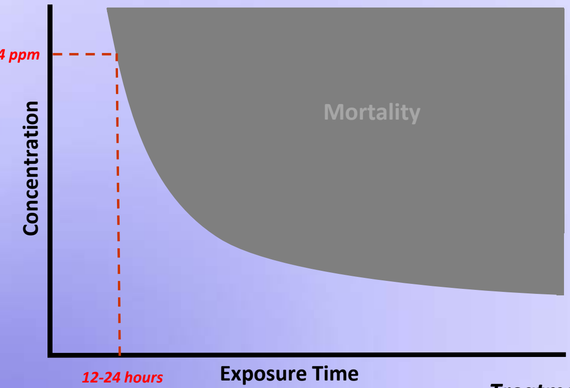
Herbicide Use Patterns



Treatment Type

High Concentration ▶ Short Exposure Time

Spot

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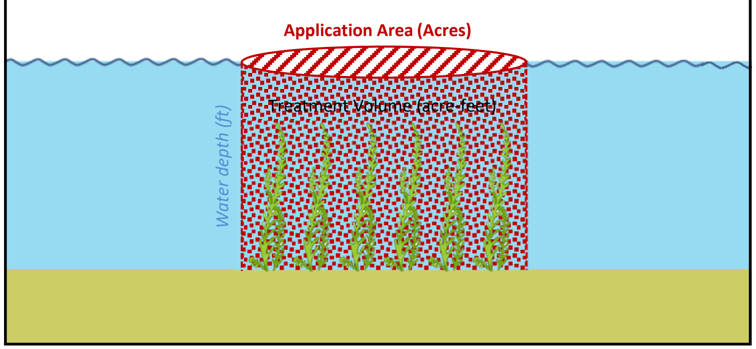
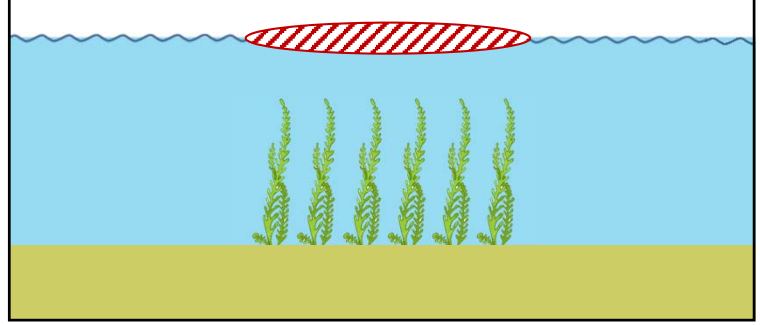
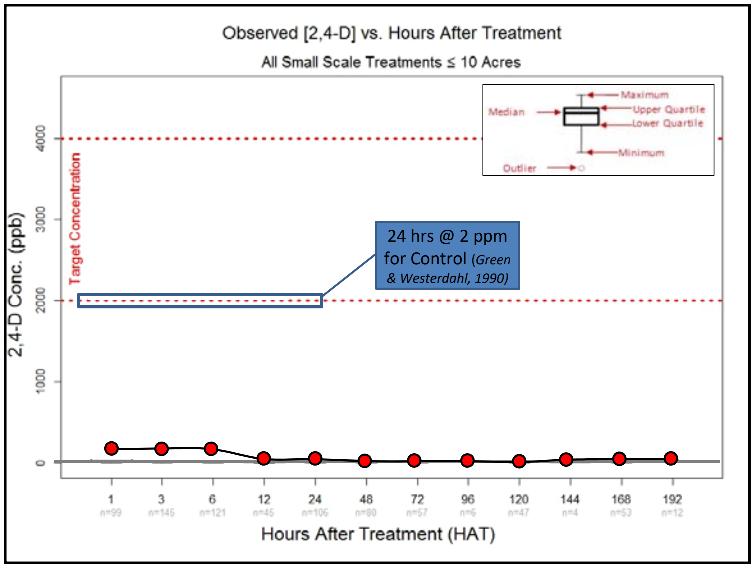
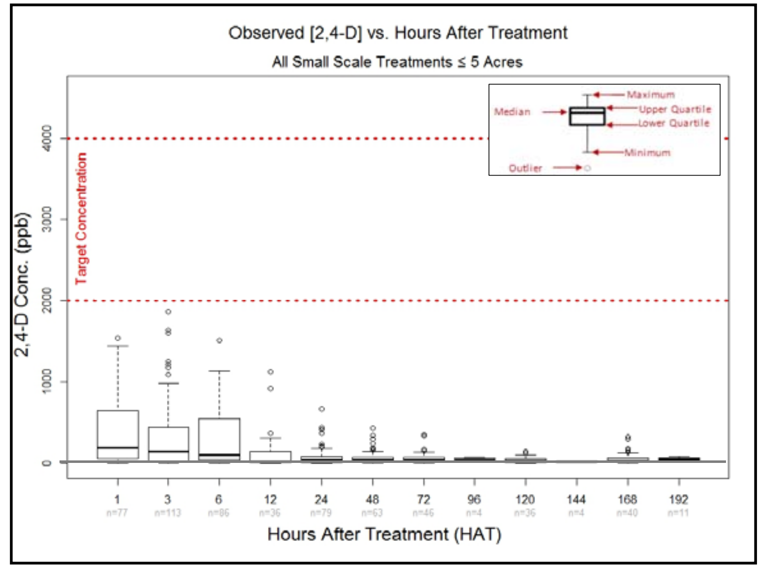
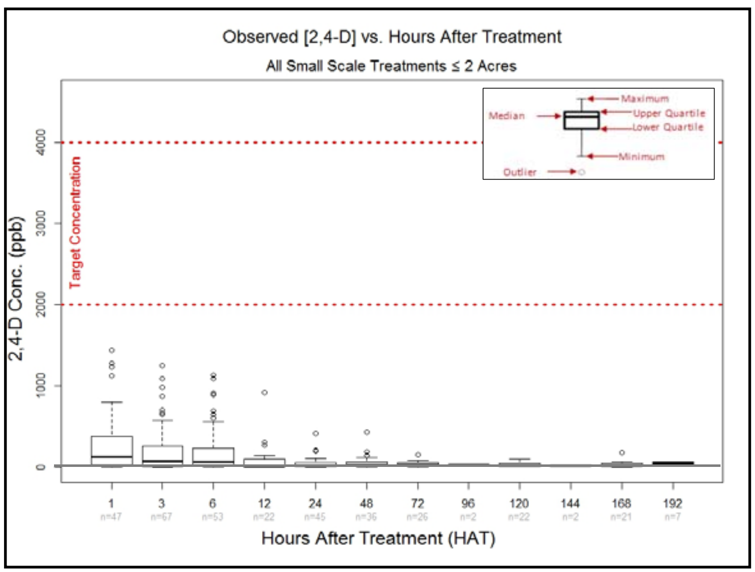
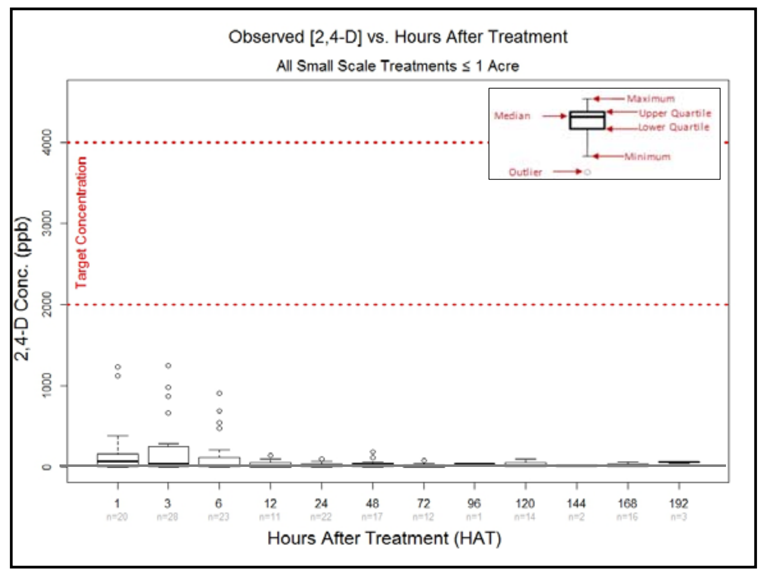


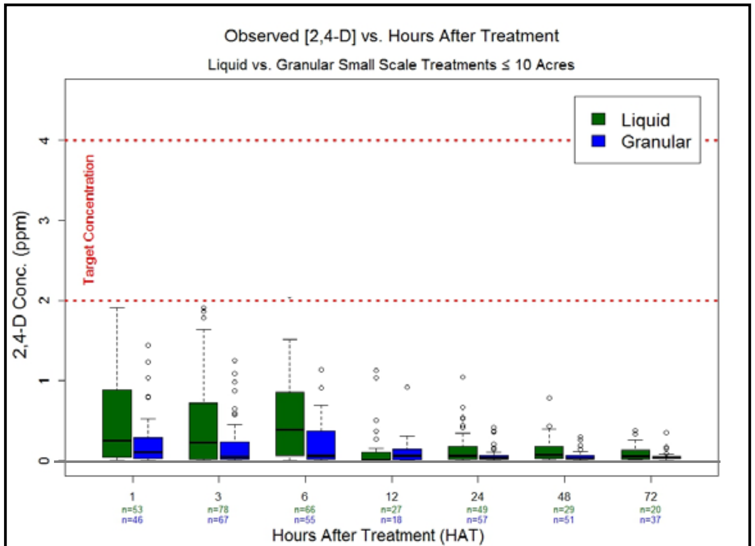



Observed [2,4-D] vs. Hours After Treatment
All Small Scale Treatments ≤ 10 Acres
2,4-D Conc. (ppb)
Target Concentration
24 hrs @ 2 ppm for Control (Green & Westerdahl, 1990)
Median
Maximum
Upper Quartile
Lower Quartile
Minimum
Outlier
0
1000
2000
3000
4000
1
3
6
12
24
48
72
96
120
144
168
192
Hours After Treatment (HAT)

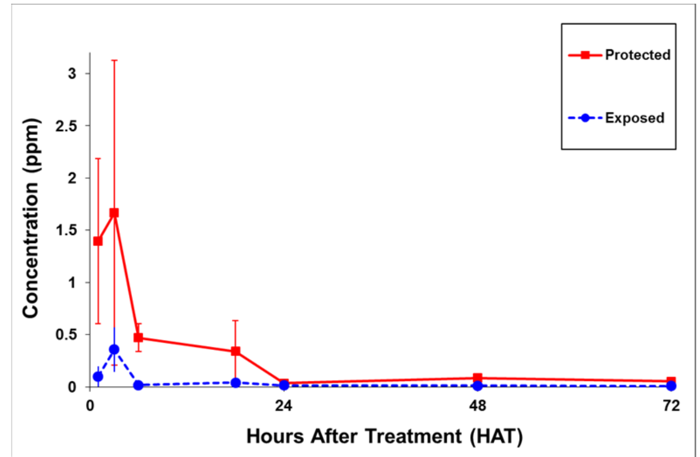

Observed [2,4-D] vs. Hours After Treatment
All Small Scale Treatments ≤ 5 Acres
2,4-D Conc. (ppb)
Target Concentration
Median
Maximum
Upper Quartile
Lower Quartile
Minimum
Outlier
0
1000
2000
3000
4000
1
3
6
12
24
48
72
96
120
144
168
192
Hours After Treatment (HAT)


Observed [2,4-D] vs. Hours After Treatment
All Small Scale Treatments ≤ 2 Acres
2,4-D Conc. (ppb)
Target Concentration
Median
Maximum
Upper Quartile
Lower Quartile
Minimum
Outlier
0
1000
2000
3000
4000
1
3
6
12
24
48
72
96
120
144
168
192
Hours After Treatment (HAT)


Observed [2,4-D] vs. Hours After Treatment
All Small Scale Treatments ≤ 1 Acre
2,4-D Conc. (ppb)
Target Concentration
Median
Maximum
Upper Quartile
Lower Quartile
Minimum
Outlier
0
1000
2000
3000
4000
1
3
6
12
24
48
72
96
120
144
168
192
Hours After Treatment (HAT)



Location



Spot Treatment Specifications

- Treatments size (>5 acres), shape (broad vs narrow), and location (protected vs exposed) are important design components
- Winds within 6hrs of treatment greatly impact outcomes
- Some groups consider herbicides w/ short CETs
  - 2,4-D + endothall
  - Diquat
  - Diquat + endothall

Larger non-target impacts, unsure if effective at control

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2015 Treatment on Loon Lake

- ~24 acres of 305 acre lake (7.8%)
- Tracer Dye (Rhodamine WT) Survey
- Pre (spring) & post (late-summer) point-intercept sub-sampling

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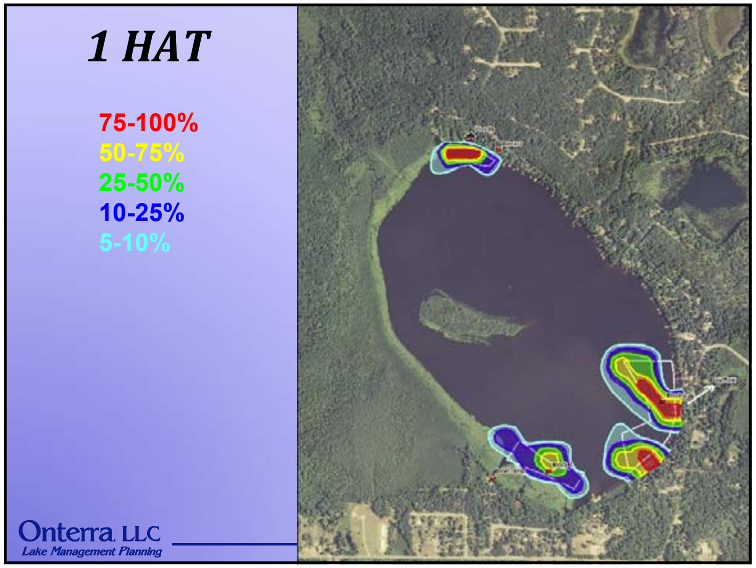
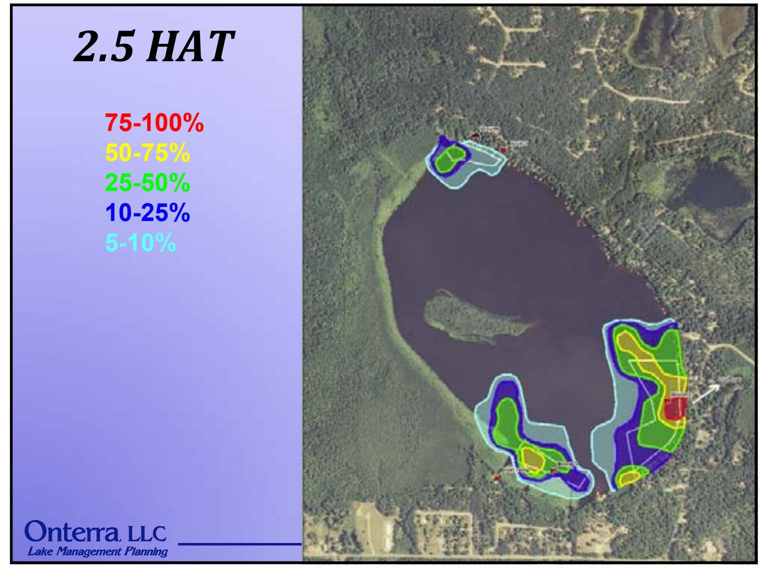
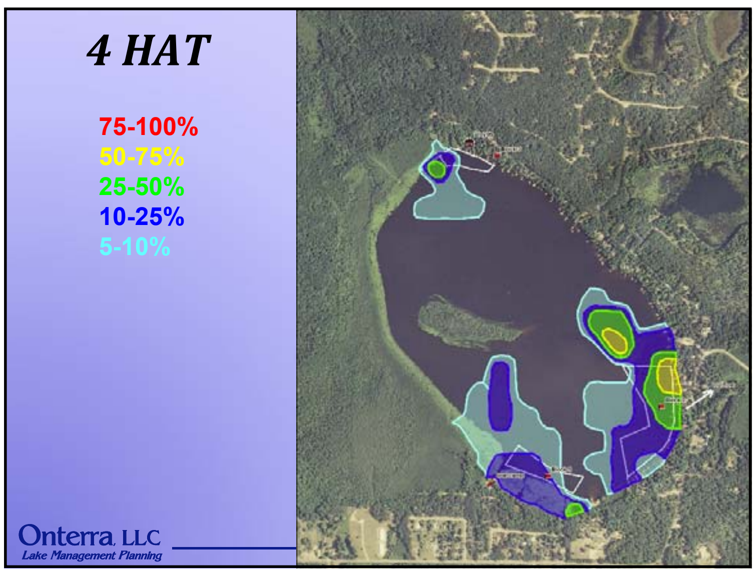
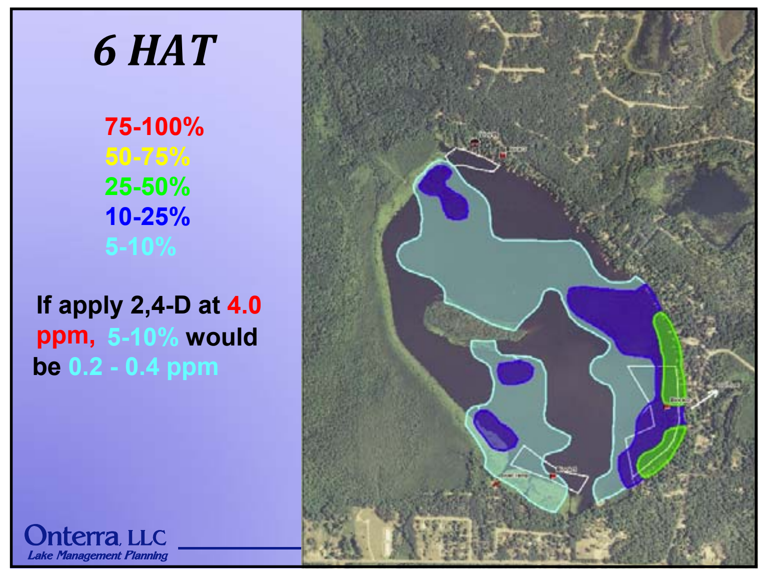

1 HAT
75-100%
50-75%
25-50%
10-25%
5-10%
Onterra LLC
Lake Management Planning


2.5 HAT
75-100%
50-75%
25-50%
10-25%
5-10%
Onterra LLC
Lake Management Planning


4 HAT
75-100%
50-75%
25-50%
10-25%
5-10%
Onterra LLC
Lake Management Planning


6 HAT
75-100%
50-75%
25-50%
10-25%
5-10%
If apply 2,4-D at 4.0 ppm, 5-10% would be 0.2 - 0.4 ppm
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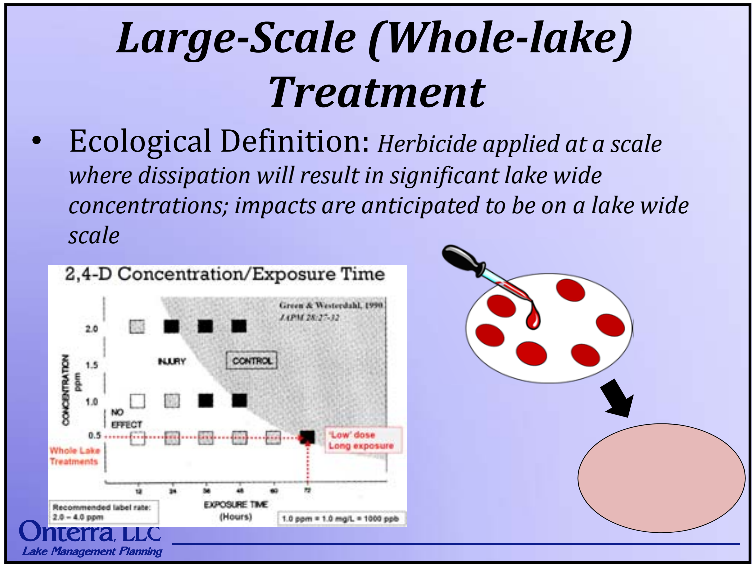
Lake Management Planning


Large-Scale (Whole-lake) Treatment
• Ecological Definition: Herbicide applied at a scale where dissipation will result in significant lake wide concentrations; impacts are anticipated to be on a lake wide scale
2,4-D Concentration/Exposure Time
Green & Westerdahl, 1990
JAPM 28:27-32
INJURY
CONTROL
NO EFFECT
CONCENTRATION ppm
Whole Lake Treatments
'Low' dose Long exposure
EXPOSURE TIME (Hours)
Recommended label rate: 2.0 – 4.0 ppm
1.0 ppm = 1.0 mg/L = 1000 ppb
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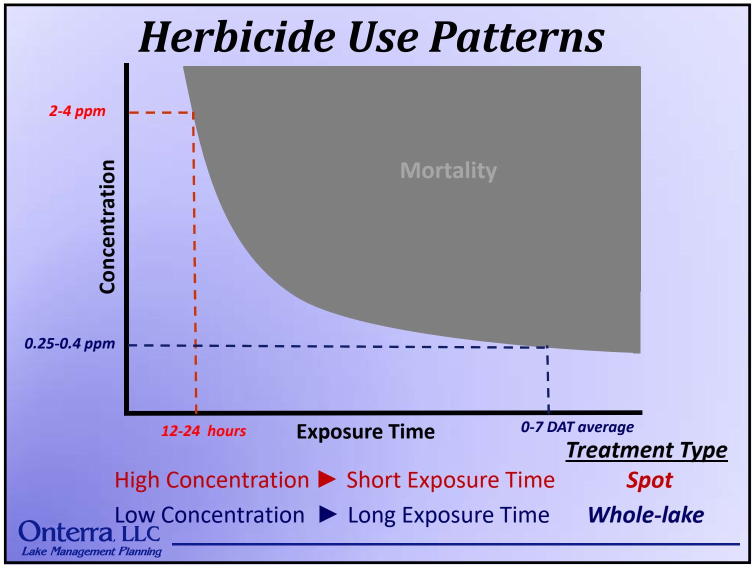
Lake Management Planning


Herbicide Use Patterns
2-4 ppm
Mortality
Concentration
0.25-0.4 ppm
12-24 hours
Exposure Time
0-7 DAT average
Treatment Type
High Concentration ▶ Short Exposure Time
Spot
Low Concentration ▶ Long Exposure Time
Whole-lake
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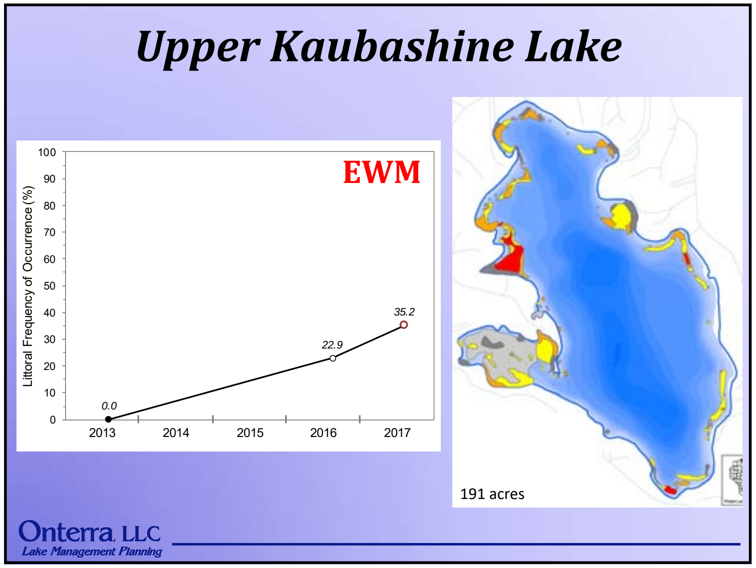
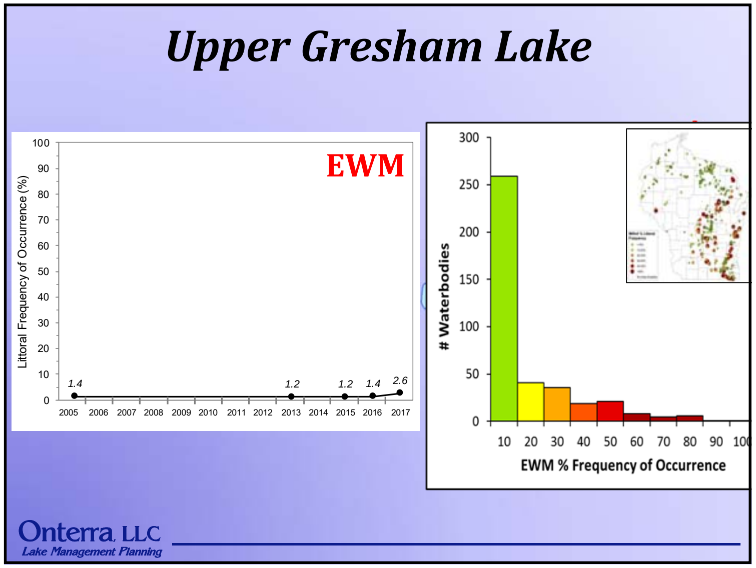
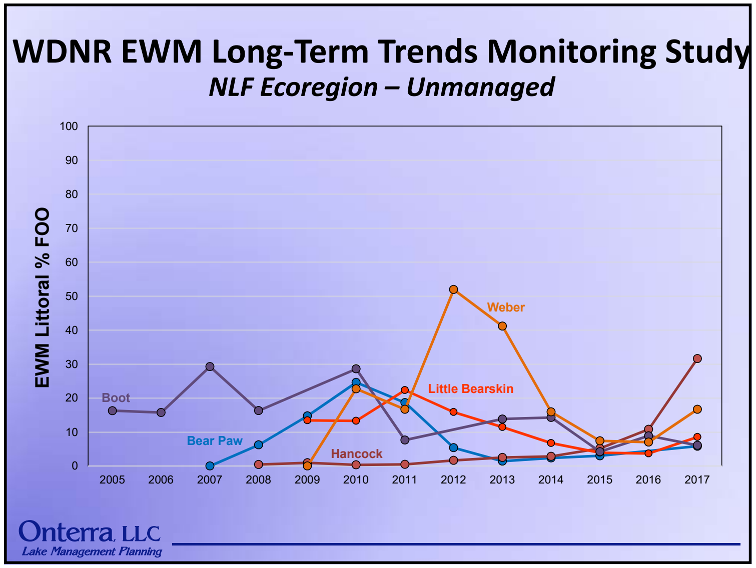
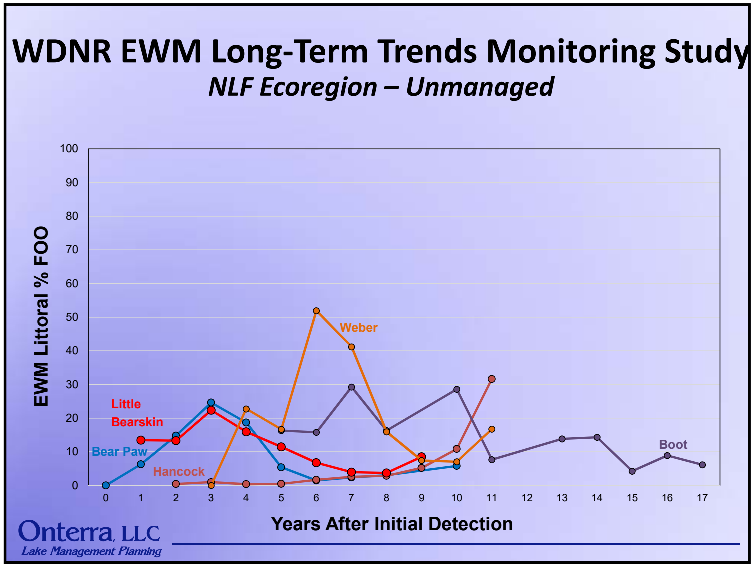
Lake Management Planning


Upper Kaubashine Lake
EWM
Littoral Frequency of Occurrence (%)
0.0
22.9
35.2
2013
2014
2015
2016
2017
191 acres
Onterra, LLC
Lake Management Planning


Upper Gresham Lake
EWM
Littoral Frequency of Occurrence (%)
1.4
1.2
1.2
1.4
2.6
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Waterbodies
EWM % Frequency of Occurrence
Onterra, LLC
Lake Management Planning


WDNR EWM Long-Term Trends Monitoring Study
NLF Ecoregion – Unmanaged
EWM Littoral % FOO
Weber
Little Bearskin
Boot
Bear Paw
Hancock
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Onterra, LLC
Lake Management Planning


WDNR EWM Long-Term Trends Monitoring Study
NLF Ecoregion – Unmanaged
EWM Littoral % FOO
Weber
Little Bearskin
Bear Paw
Hancock
Boot
Years After Initial Detection
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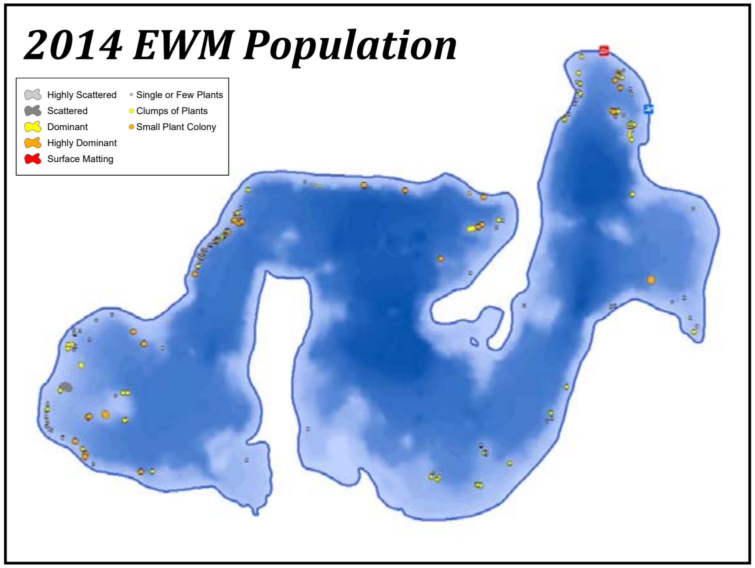
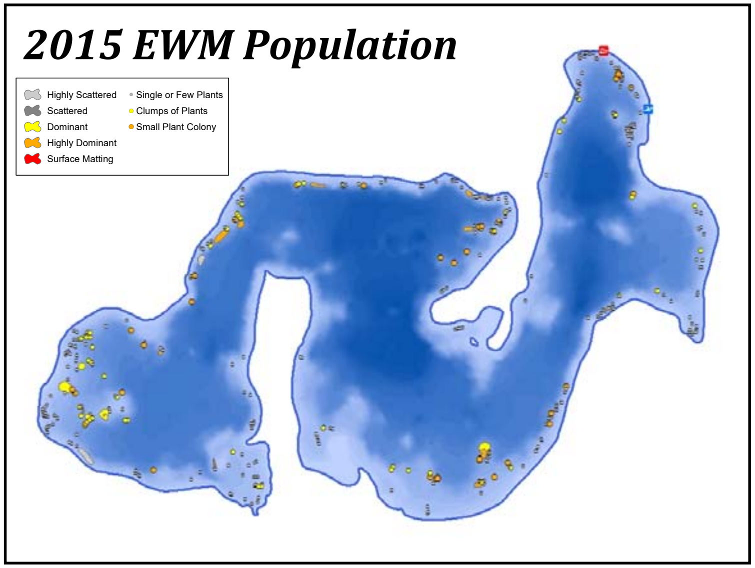
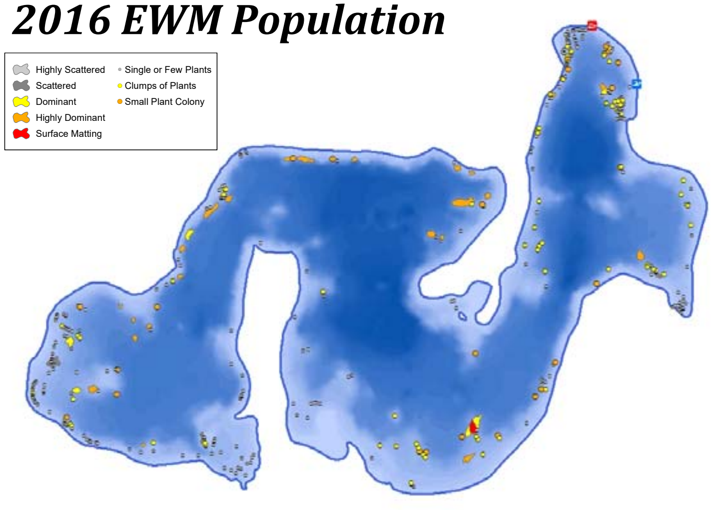
Lake Management Planning

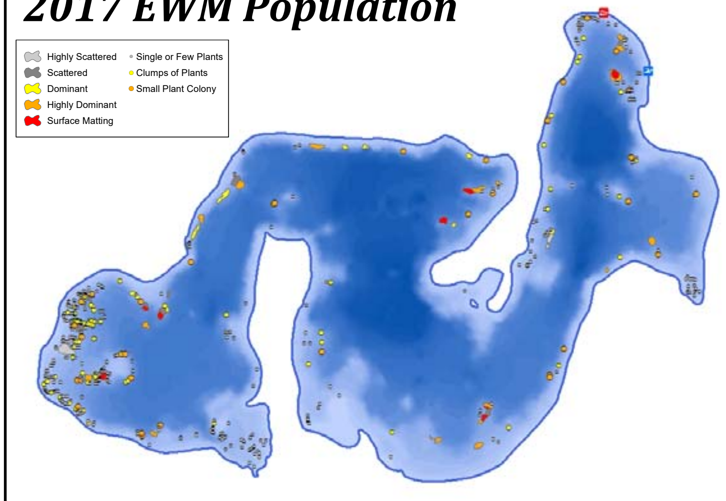

2014 EWM Population
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting
Single or Few Plants
Clumps of Plants
Small Plant Colony


2015 EWM Population
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting
Single or Few Plants
Clumps of Plants
Small Plant Colony

2016 EWM Population



2017 EWM Population



APM Alternatives Analysis

- No Active Management (only monitor)
- Management
  - ~~Biocontrol (weevils)~~ — Passively used
  - Hand removal (DASH)
  - Herbicide treatment
  - ~~Winter drawdown~~
  - Mechanical harvesting

  (Hand removal, herbicide treatment, winter drawdown, mechanical harvesting): Most commonly employed in WI
  - ~~Benthic mats~~ — Limited application
  - ~~Grass Carp introduction~~
  - ~~Rotovation~~
  - ~~UV-C Exposure~~
  - ~~Substrate Alteration~~

  (Grass Carp introduction, rotovation, UV-C exposure, substrate alteration): Not Permitted in Wisconsin because do not restore ecosystem to pre-AIS condition

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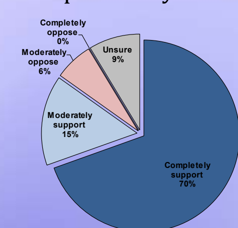
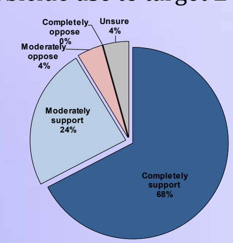
Stakeholder Survey

How do you feel about the past use of herbicides to treat EWM in previous years?



Support	85%
Not Support	6%
Unsure	9%

What is your level of support or opposition for future aquatic herbicide use to target EWM?



Support	92%
Not Support	4%
Unsure/Neutral	4%

UGL response rate = 62%

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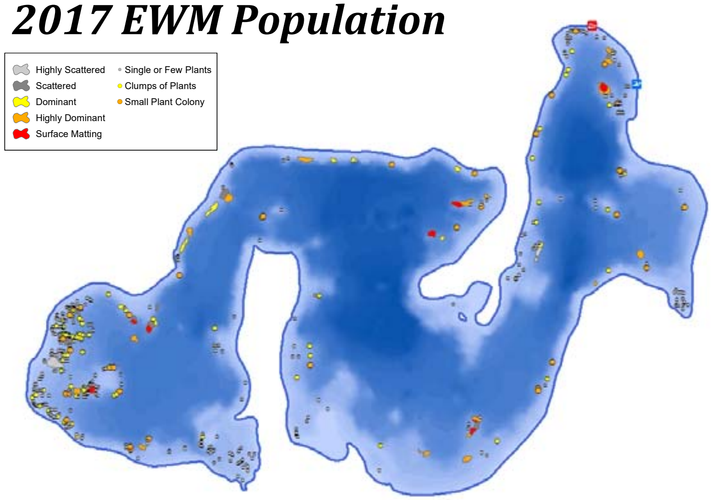
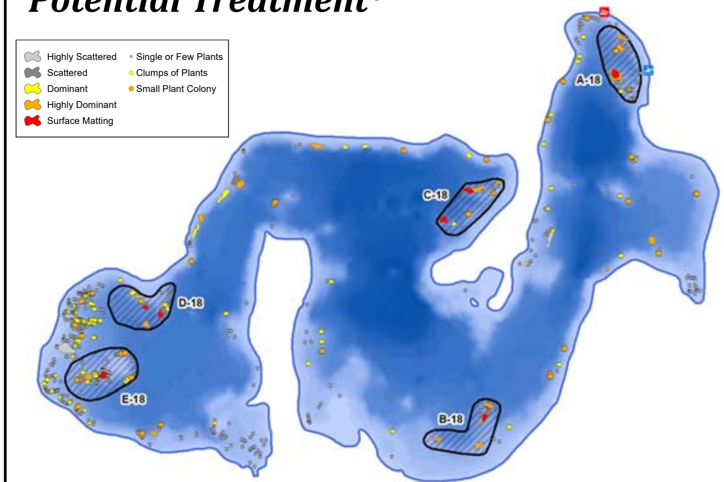
2017 EWM Population



*Potential Treatment**



* For discussion purposes, not a recommendation

*Potential Treatment**

Upper Gresham Lake

Site	Acres	Ave Depth	Total Volume (acre-feet)	2,4-D PPM ae*	2,4-D (gallons)*
A-18	5.4	9.5	51.1	4.00	146.0
B-18	5.4	8.9	48.5	4.00	139.0
C-18	5.0	11.4	56.3	4.00	161.0
D-18	5.4	11.1	59.8	4.00	171.0
E-18	6.7	7.7	52.0	4.00	149.0
Total	**27.9**		**267.8**		**766.0**

Method	*Whole-Lake Volume*	*Epilimnetic Volume*	*Lake-wide 2,4-D ppm ae*
1968 WDNR Bathy Map (Trapezoidal)	4,811.24	4,292.04	0.250
2017 Acoustic (Trapezoidal)	4,656.17	4,284.31	0.250
2017 Acoustic (Histogram)	4,661.52	4,320.93	0.248

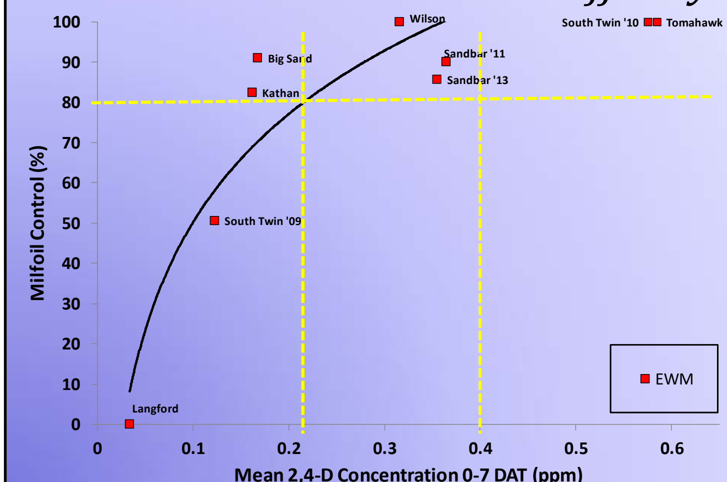
Dosing Depth (ft)	18	*Target:*

Mobilization	$1,000.00	per trip
Application fees	$150.00	per acre
2,4-D	$23.00	per gallon

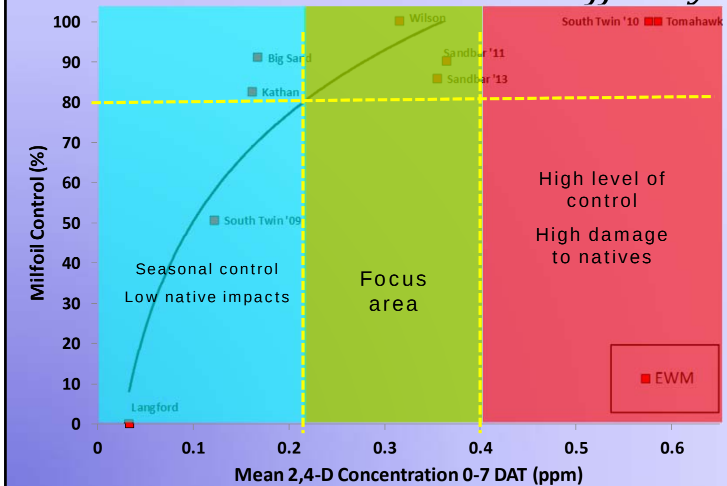
		Cost
Treat Acres	27.9	$4,185.73
Gallons of 2,4-D	766.0	$17,618.00
Mobilization		$1,000.00
		$22,803.73

* For discussion purposes, not a recommendation

***Results** – Concentration vs Efficacy*

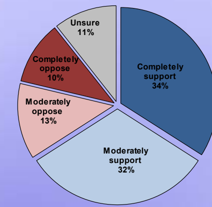


Results – Concentration vs Efficacy



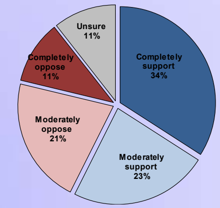
Stakeholder Survey

How do you feel about the past use of prof. hand-harvesting to target EWM in previous years?



Support	66%
Not Support	23%
Unsure	11%

What is your level of support or opposition for future prof. hand harvesting use to target EWM?



Support	56%
Not Support	32%
Unsure/Neutral	11%

UGL response rate = 62%

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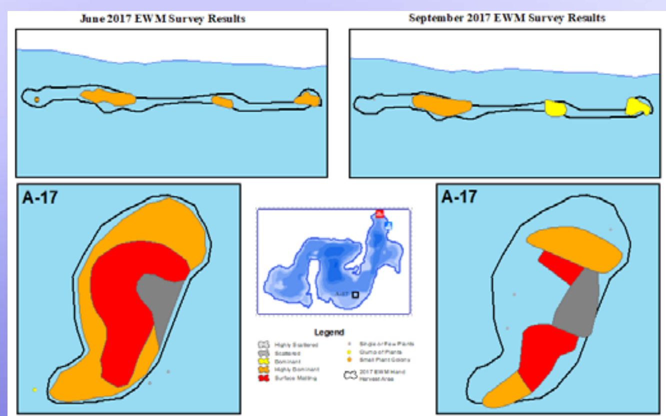
2017 Hand-Harvesting Assessment



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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

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Lake Management Planning

Management Plan Document

Upper Gresham Lake
Comprehensive Management Plan - Draft 1

TABLE OF CONTENTS

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Lake Management Planning

Presentation Objective

- Planning Meeting I (Dec 2017) focused on aquatic plants and EWM control
  - Interim strategy presented at 2018 GLA Annual Meeting
- Planning Meeting II
  - Revisit EWM Control Strategy (3.1)
  - Water Quality & Paleoecology (3.2)
  - Watershed (3.3)
  - Shoreland Condition & Habitat (3.4)
  - Fisheries Data Integration (3.6)
  - Develop Implementation Plan (5.0)

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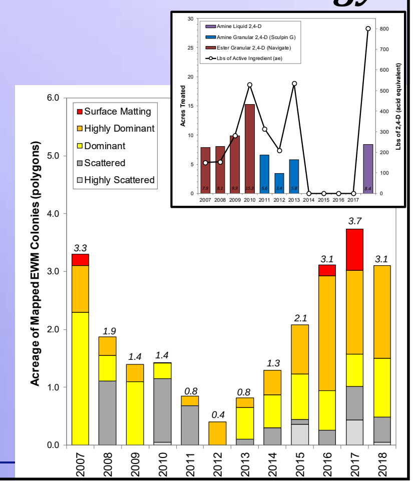
GLA Historic EWM Control Strategy

- Spot treatment program 2007-2013
- Hand-harvesting program 2014-2015
- One site targeted for hand-harvesting (DASH) in 2017
- Two sites targeted for herbicide treatment in 2018



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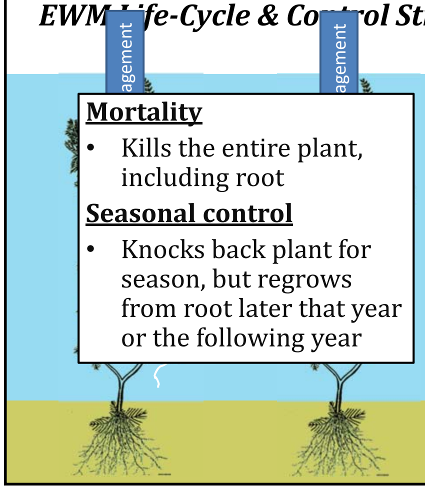
Lake Management Planning

EWM Life-Cycle & Control Strategy Philosophy



Mortality

- Kills the entire plant, including root

Seasonal control

- Knocks back plant for season, but regrows from root later that year or the following year

- Herbicide needs to translocate to root crown (*hard to kill*)
- Strategy is straight-forward
- Hand-harvesting of small areas can be effective (*extremely time intensive)*
- Mechanical harvesting can reduce nuisance conditions, but not kill EWM

Spot Treatment Specifications

- Treatments size (>5 acres), shape (broad vs narrow), and location (protected vs exposed) are thought to be important design components
- Winds within 6hrs of treatment can impact outcomes
- Some groups consider herbicides w/ short CETs
  - 2,4-D + endothall
  - Diquat
  - Diquat + endothall
  - ProcellaCOR

Larger non-target impacts, unsure if effective at control

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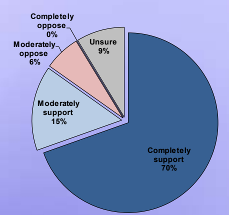
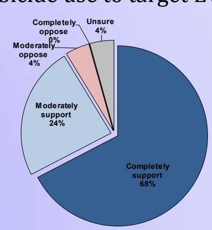
Stakeholder Survey

How do you feel about the past use of herbicides to treat EWM in previous years?



Support	85%
Not Support	6%
Unsure	9%

What is your level of support or opposition for future aquatic herbicide use to target EWM?



Support	92%
Not Support	4%
Unsure/Neutral	4%

UGL response rate = 62%

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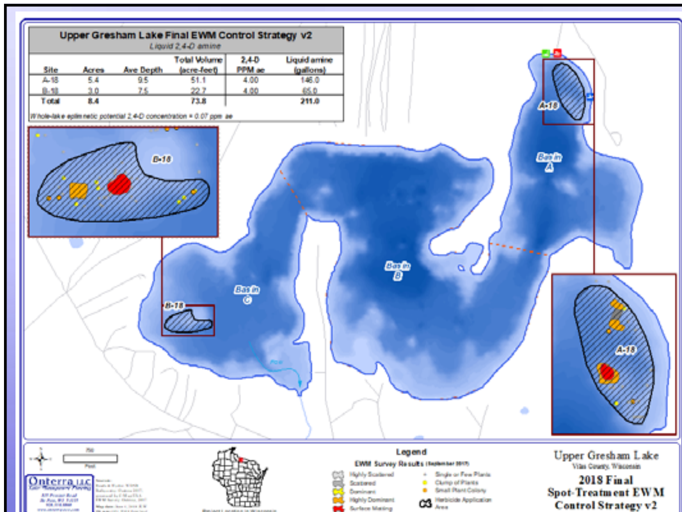

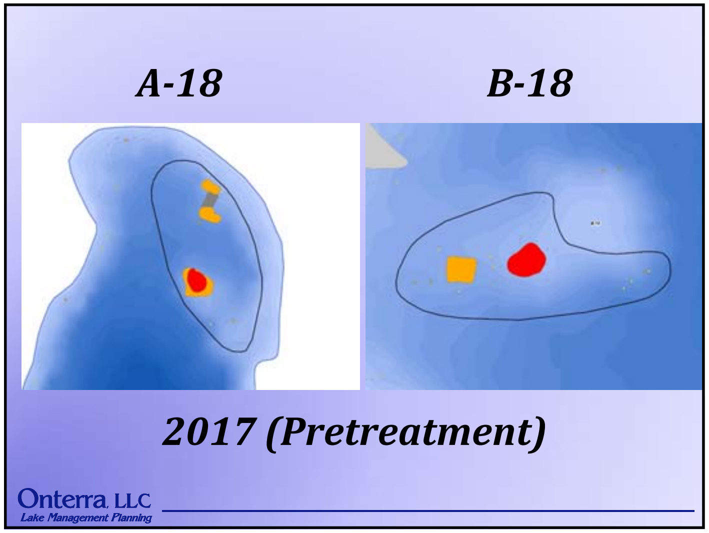
A-18
B-18
2017 (Pretreatment)
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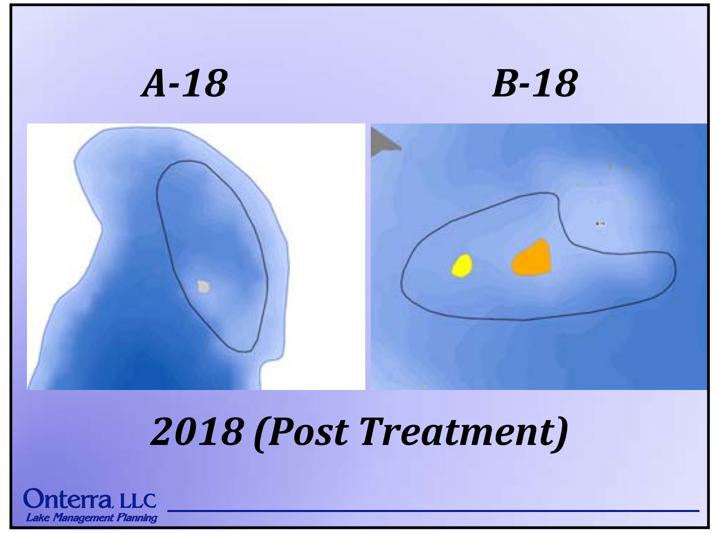
A-18
B-18
2018 (Post Treatment)
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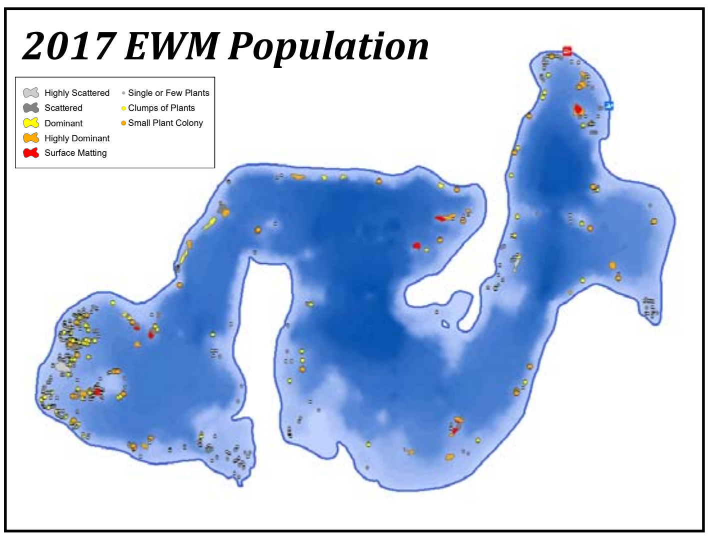
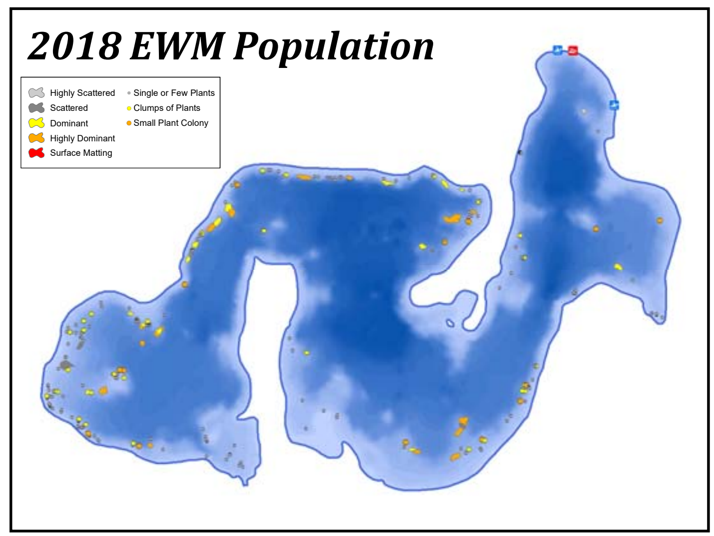
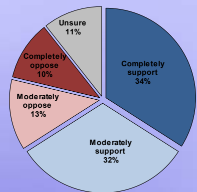

2017 EWM Population
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting
Single or Few Plants
Clumps of Plants
Small Plant Colony


2018 EWM Population
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting
Single or Few Plants
Clumps of Plants
Small Plant Colony

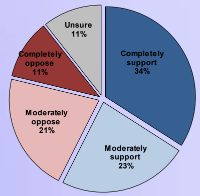
Stakeholder Survey

How do you feel about the past use of prof. hand-harvesting to target EWM in previous years?



Support	66%
Not Support	23%
Unsure	11%

What is your level of support or opposition for future prof. hand harvesting use to target EWM?



Support	56%
Not Support	32%
Unsure/Neutral	11%

UGL response rate = 62%

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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

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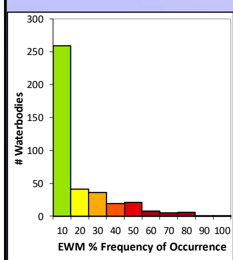
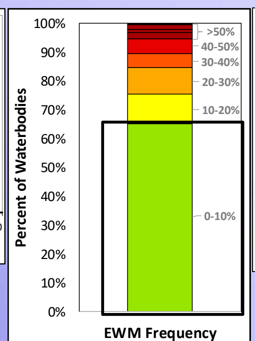
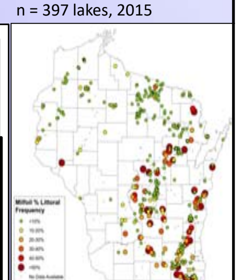
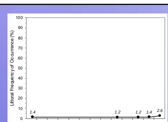
State-wide EWM Population Trends

n = 397 lakes, 2015









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The science behind the "so-called" superweed. Nault 2016

AIS Management Options

1. **No Coordinated Active Management (Let Nature Take its Course)**
   - Focus on education of manual removal by property owners
2. **Reduce AIS Population on a lake-wide level (Population Management)**
   - Would likely rely on herbicide treatment strategies (risk assessment)
   - Will not "eradicate" AIS
   - Set triggers (thresholds) of implementation and tolerance
3. **Minimize navigation and recreation impediment (Nuisance Control)**
   - May be accomplished through professional hand-harvesting of areas or lanes
   - Hand-harvesting may not be able to reach this goal and herbicides or a mechanical harvester may be required to reach goals

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Looking Past EWM Management

- Important that in parallel with EWM management, GLA is conducting other lake stewardship activities to keep the Gresham Lakes healthy

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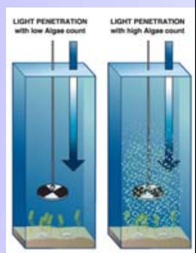
Introduction to Lake Water Quality

Phosphorus
Naturally occurring & essential for all life
Regulates phytoplankton biomass in **most** WI lakes
Most often 'limiting plant nutrient' (shortest supply) **20:1**
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



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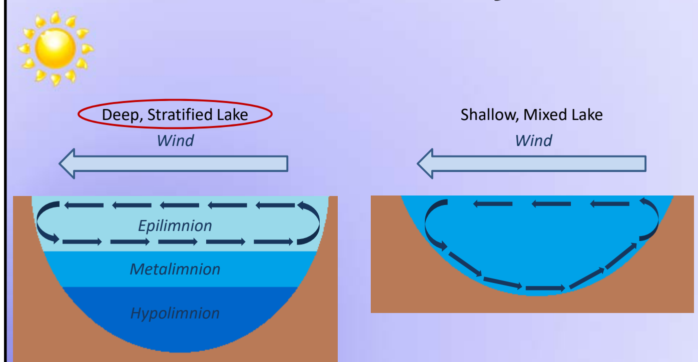
Wisconsin Lakes Classification



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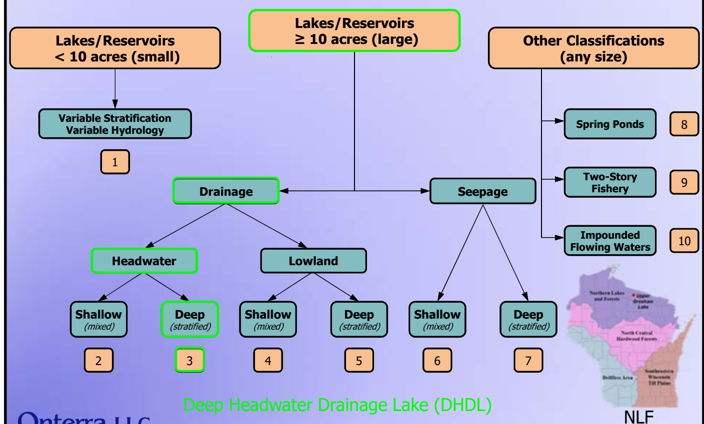
Wisconsin Lakes Natural Community Types



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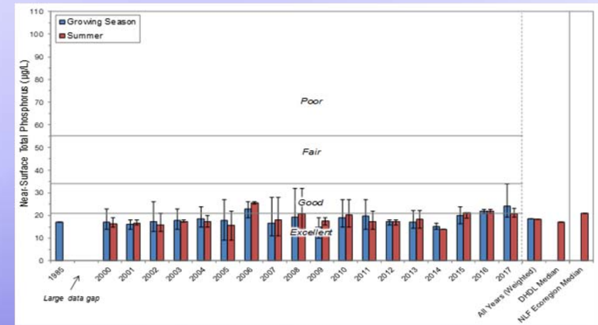
Total Phosphorus



Average summer = 18.5 µg/L

- *Excellent* for DHDL
- Similar to DHDL median
- Lower than ecoregion median

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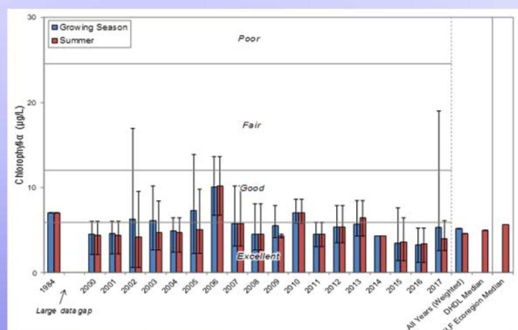
Chlorophyll-a



Average summer = 5 µg/L

- *Excellent* for DHDL
- Similar to DHDL median
- Lower than ecoregion median

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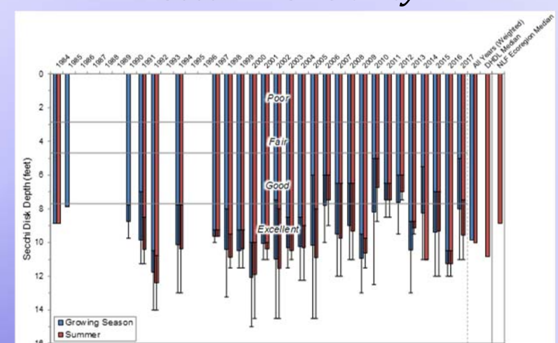
Secchi Disk Clarity



Average summer = 10 feet

- *Excellent* for DHDL
- Similar to DHDL median
- Slightly better than ecoregion median

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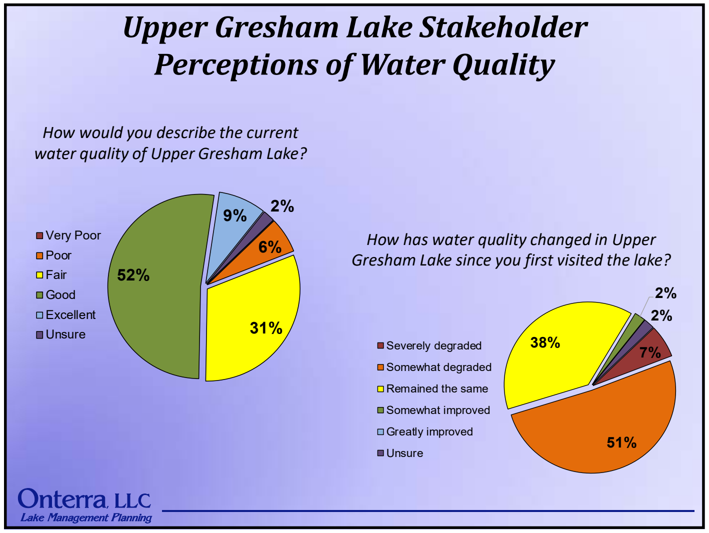

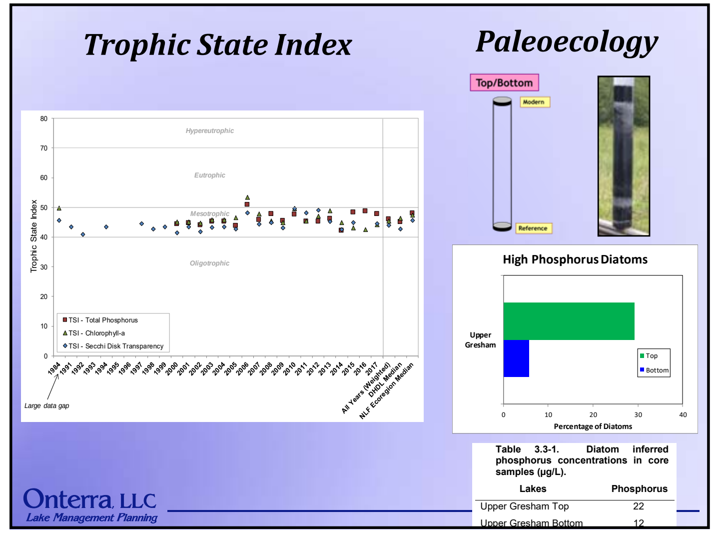

Management Goal:
Maintain Current Water Quality Conditions

Previous Management Actions

1. **Monitor water quality through WDNR Citizens Lake Monitoring Network.**
   Continuation of current effort
   Requires mechanism to ensure volunteerism
2. **Reduce phosphorus and sediment loads from shoreland watershed to Gresham Lakes.**
   Focus on education

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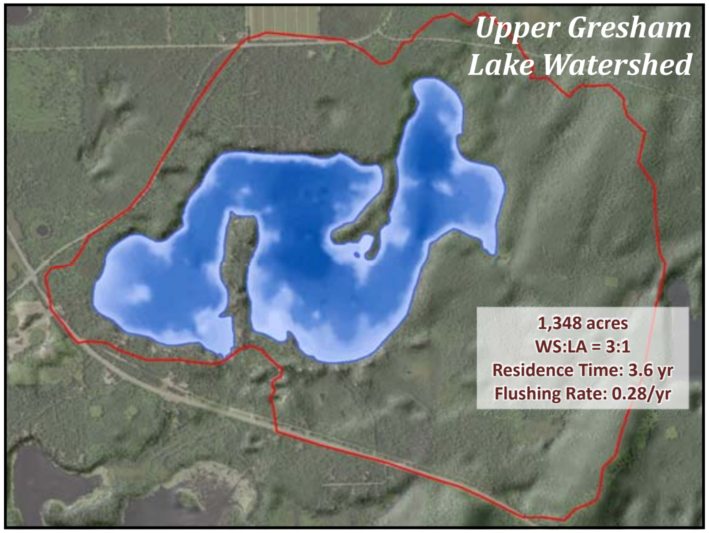
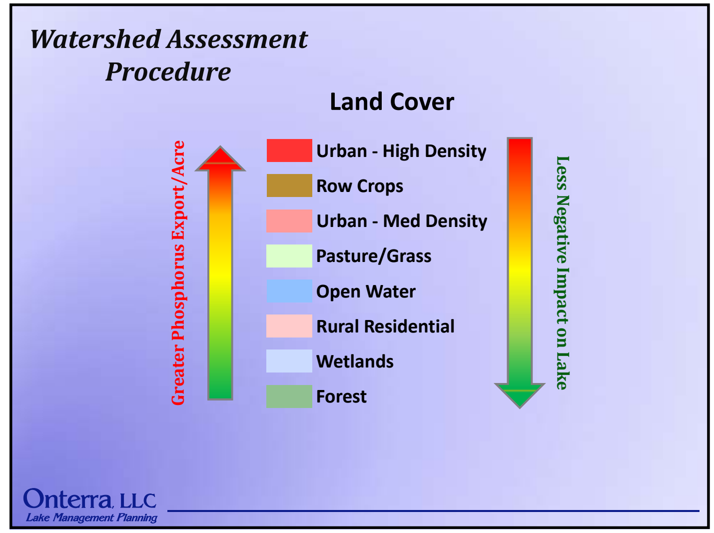

Upper Gresham
Lake Watershed
1,348 acres
WS:LA = 3:1
Residence Time: 3.6 yr
Flushing Rate: 0.28/yr


Watershed Assessment
Procedure
Land Cover
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
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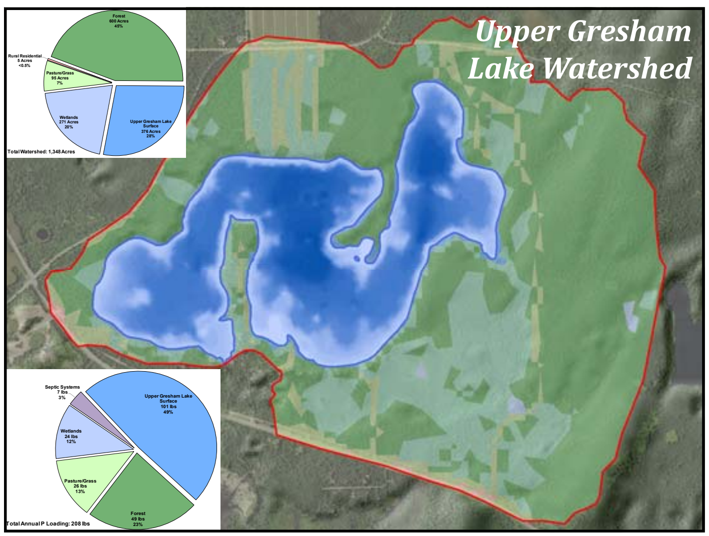
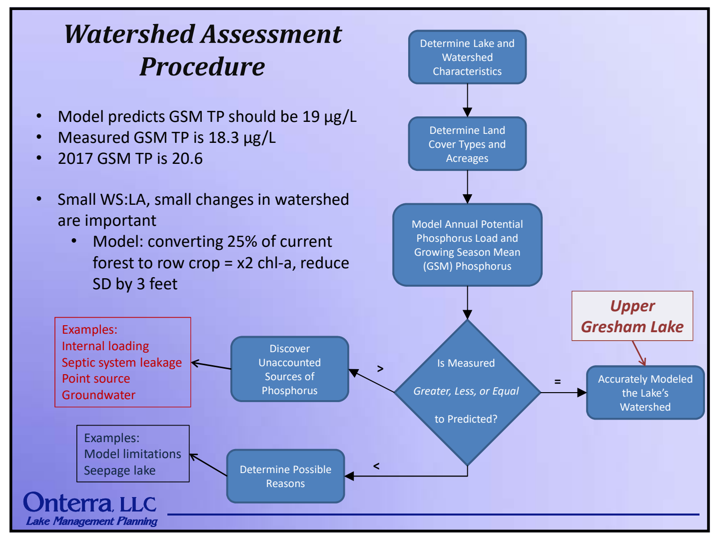
Lake Management Planning


Upper Gresham
Lake Watershed
Forest
600 Acres
45%
Rural Residential
5 Acres
<0.5%
Pasture/Grass
95 Acres
7%
Wetlands
271 Acres
20%
Upper Gresham Lake
Surface
376 Acres
28%
Total Watershed: 1,348 Acres
Septic Systems
7 lbs
3%
Upper Gresham Lake
Surface
101 lbs
49%
Wetlands
24 lbs
12%
Pasture/Grass
26 lbs
13%
Forest
49 lbs
23%
Total Annual P Loading: 208 lbs


Watershed Assessment
Procedure
• Model predicts GSM TP should be 19 µg/L
• Measured GSM TP is 18.3 µg/L
• 2017 GSM TP is 20.6
• Small WS:LA, small changes in watershed are important
• Model: converting 25% of current forest to row crop = x2 chl-a, reduce SD by 3 feet
Determine Lake and Watershed Characteristics
Determine Land Cover Types and Acreages
Model Annual Potential Phosphorus Load and Growing Season Mean (GSM) Phosphorus
Is Measured Greater, Less, or Equal to Predicted?
>
=
<
Upper Gresham Lake
Accurately Modeled the Lake's Watershed
Discover Unaccounted Sources of Phosphorus
Examples:
Internal loading
Septic system leakage
Point source
Groundwater
Determine Possible Reasons
Examples:
Model limitations
Seepage lake
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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

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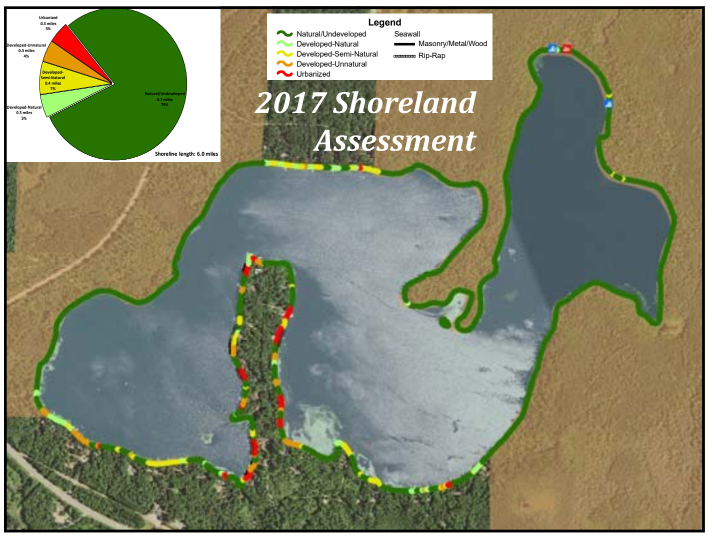
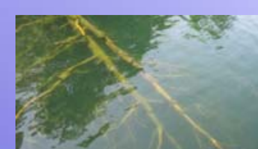


Coarse Woody Habitat

- 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 Upper Gresham Lake



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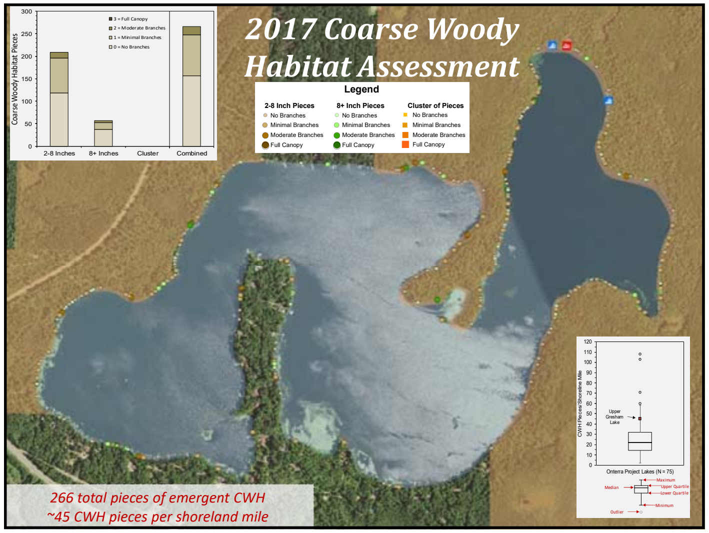

Management Goal:
Maintain and Improve Lake Resourc

Possible Management Actions

1. **Educate Stakeholders on the Importance of Shoreland Condition, Shoreland Restoration, and Coarse Woody Habitat**
2. **Initiate activities (Healthy Lakes Grant Program)**
2. **Protect natural shoreland zones**

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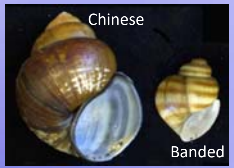
Aquatic Invasive Species

Type	Common name	Scientific name	Location within the report
Plants	Eurasian watermilfoil	*Myriophyllum spicatum*	Section 3.4 – Aquatic Plants
Invertebrates	Chinese mystery snail	*Cipangopaludina chinensis*	Section 3.5 - Aquatic Invasive Species
	Rusty crayfish	*Orconectes rusticus*	Section 3.5 - Aquatic Invasive Species



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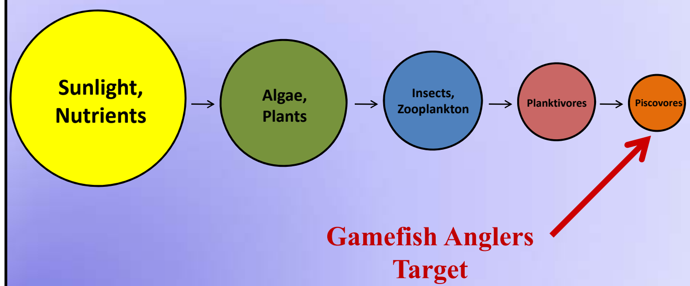
Fisheries

Energy Flow



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Stakeholder Survey Responses

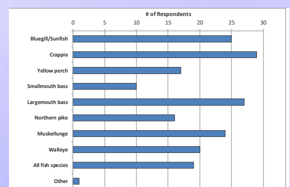

Figure 3.6-2. Stakeholder survey response Question #11. What species of fish do you like to catch on Upper Gresham Lake?

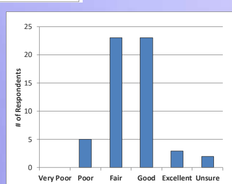

Figure 3.6-3. Stakeholder survey response Question #12. How would you describe the current quality of fishing on Upper Gresham Lake?

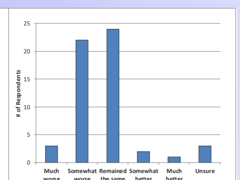

Figure 3.6-4. Stakeholder survey response Question #13. How has the quality of fishing changed on Upper Gresham Lake since you started fishing the lake?

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Open Water Spear Harvest

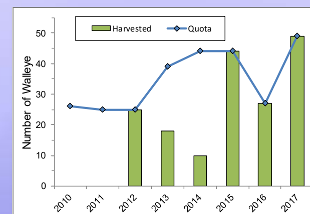

Figure 3.6-6. **Upper Gresham Lake walleye spear harvest data.** (GLIFWC 2010-2017).

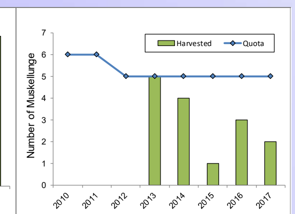

Figure 3.6-7. **Upper Gresham Lake muskellunge spear harvest data.** (GLIFWC 2010-2017).

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Fish Stocking

Table 3.6-2. Stocking data available for muskellunge in Upper Gresham Lake (1975-2017).

Year	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1975	Unspecified	Fingerling	400	9
1977	Unspecified	Fingerling	700	7
1979	Unspecified	Fingerling	350	11
1981	Unspecified	Fingerling	400	12
1985	Unspecified	Fingerling	700	11
1987	Unspecified	Fingerling	2,100	12
1989	Unspecified	Fingerling	338	5
1991	Unspecified	Fingerling	100	11
1992	Unspecified	Fingerling	100	11
1993	Unspecified	Fingerling	300	11
1995	Unspecified	Fingerling	300	11.3
1997	Unspecified	Large Fingerling	150	9.9
1999	Unspecified	Large Fingerling	152	10.5
2001	Unspecified	Large Fingerling	366	10.2
2003	Unspecified	Large Fingerling	366	9.9
2005	Unspecified	Large Fingerling	382	10.6
2007	Upper Wisconsin River	Large Fingerling	244	13
2009	Upper Wisconsin River	Large Fingerling	365	10.5
2011	Upper Wisconsin River	Large Fingerling	363	9.2
2013	Upper Wisconsin River	Large Fingerling	366	11.35
2015	Upper Wisconsin River	Large Fingerling	372	11.8
2016	Upper Wisconsin River	Large Fingerling	363	10.3
2017	Upper Wisconsin River	Large Fingerling	227	10.9

Table 3.6-3. Stocking data available for walleye in Upper Gresham Lake (1972-2016).

Year	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1972	Unspecified	Fingerling	9,000	3
1974	Unspecified	Fingerling	15,000	3
1975	Unspecified	Fingerling	15,000	3
1976	Unspecified	Fingerling	15,000	3
1977	Unspecified	Fingerling	17,000	3
1980	Unspecified	Fingerling	10,000	2.5
1984	Unspecified	Fingerling	19,080	2
1986	Unspecified	Fingerling	19,000	3
1988	Unspecified	Fingerling	19,000	5
1990	Unspecified	Fingerling	18,900	3
1991	Unspecified	Fingerling	9,072	3
1992	Unspecified	Fingerling	9,312	2
1994	Unspecified	Fingerling	17,919	2.3
1996	Unspecified	Fingerling	18,054	1.8
1998	Unspecified	Small Fingerling	36,000	1.5
2000	Unspecified	Small Fingerling	18,203	3.1
2002	Mississippi Headwaters	Small Fingerling	18,300	1.7
2004	Mississippi Headwaters	Small Fingerling	18,290	1.3
2006	Mississippi Headwaters	Small Fingerling	13,062	1.8
2008	Mississippi Headwaters	Small Fingerling	12,790	1.7
2010	Mississippi Headwaters	Small Fingerling	12,796	1.75
2012	Mississippi Headwaters	Small Fingerling	12,810	1.7
2014	Mississippi Headwaters	Large Fingerling	5,432	7.4
2016	Mississippi Headwaters	Large Fingerling	5,302	7.8

28 inch minimum – to reduce overall population so muskies will grow larger

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4.0 Conclusions

Water Quality & Watershed

- Overall good for deep headwater drainage
- Watershed is in great shape and supports the great water quality
    - Model indicates no unaccounted sources of phosphorus
    - Unknown implication of cranberry bog
- Shoreland areas are in relatively good conditions, but this aspect could always be improved upon

Aquatic Plants

- EWM has been managed over time
- Native plant community relatively stable
- Developing next phase of EWM management required

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Additional topics

Possible Management Actions/Goals

1. **General education goals**
2. **Communication Capacity**
3. **Loon watch**

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Remaining Steps

- Step 1
    - Onterra sends Draft Outline of Implementation Plan to Committee
    - Onterra sends draft Results Section (3.1-3.6) of Plan to Committee
- Step 2
    - Committee's review Implementation Plan Outline (most critical)
    - Committee's review of report sections
- Step 3
    - Meeting with WDNR (potentially teleconference, but likely GLA in person)
- Step 4
    - Official First Draft of Complete Plan released for public comment
        - Gresham lakes stakeholders, WDNR, County, GLIFWC, LDF Tribe, etc.
- Step 5
    - Onterra integrates comments to First Draft in second draft
- Step 6
    - Second draft is adopted as Final, or small additional changes made to result in Final
- Step 7
    - Committee provides Final plan to BOD for official approval

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B

APPENDIX B

Stakeholder Survey Response Charts & Comments

Pooled Results from all three Gresham Lakes

Upper Gresham Lake Results

Gresham Lakes - Anonymous Stakeholder Survey

	Total	Upper Gresham Lake	Middle Gresham Lake	Lower Gresham Lake
Surveys Distributed:	118	78	15	25
Surveys Returned:	66	48	5	12
Response Rate:	56%	62%	33%	48%

Gresham Lakes Property

1. Which of the Gresham Lakes do you reside on?

Answer Options	Response Percent	Response Count
Upper Gresham Lake	73.9%	48
Middle Gresham ake	7.7%	5
Lower Gresham Lake	18.5%	12
	answered question	**65**
	skipped question	**1**

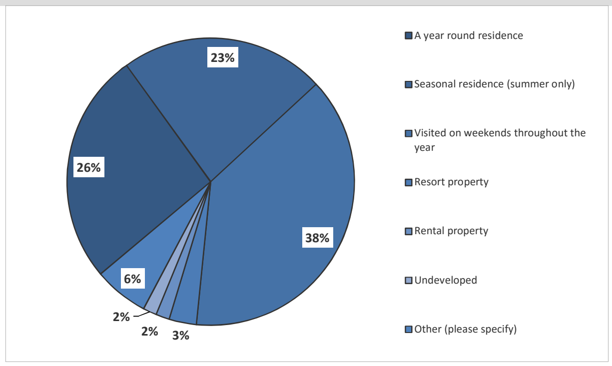
2. Do you rent or own your property on your lake?

Answer Options	Response Percent	Response Count
Own	100.0%	65
Rent	0.0%	0
	answered question	**65**
	skipped question	**1**

3. How is your property on your lake utilized?

Answer Options	Response Percent	Response Count
A year round residence	26.2%	17
Seasonal residence (summer only)	23.1%	15
Visited on weekends throughout the year	38.5%	25
Resort property	3.1%	2
Rental property	1.5%	1
Undeveloped	1.5%	1
Other (please specify)	6.2%	4
	answered question	**65**
	skipped question	**1**

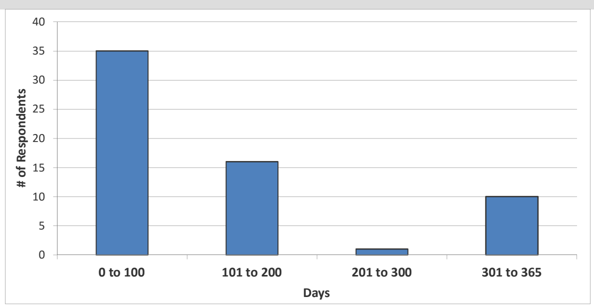
Number	Other (please specify)
1	Mostly summer. It is a year round home so we go as often as we can during the school year.
2	Week-long stays 10-12 weeks throughout the year
3	2nd residence
4	Occasional weekends after "ice off"



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

Answer Options	Response Count
	62
answered question	**62**
skipped question	**4**

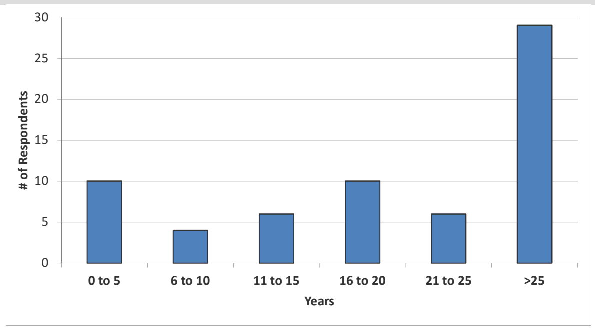
Category (# of days)	**Responses**	
0 to 100	**35**	**56.5%**
101 to 200	**16**	**25.8%**
201 to 300	**1**	**1.6%**
301 to 365	**10**	**16.1%**



5. How long have you owned or rented your property on your lake?

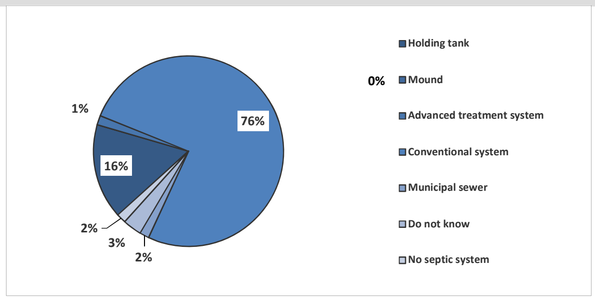
Answer Options	Response Count
	65
answered question	65
skipped question	1

Category (# of years)	Responses	% Response
0 to 5	10	15.4%
6 to 10	4	6.2%
11 to 15	6	9.2%
16 to 20	10	15.4%
21 to 25	6	9.2%
>25	29	44.6%



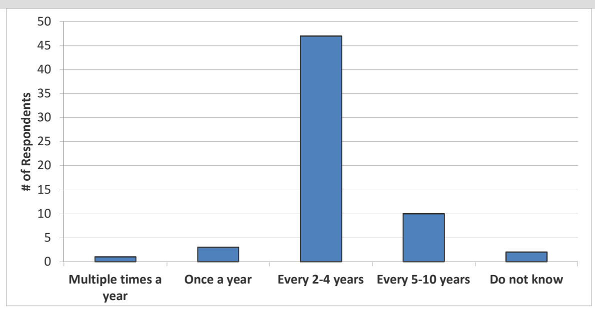
6. What type of septic system does your property utilize?

Answer Options	Response Percent	Response Count
Holding tank	16.1%	10
Mound	0.0%	0
Advanced treatment system	1.6%	1
Conventional system	75.8%	47
Municipal sewer	1.6%	1
Do not know	3.2%	2
No septic system	1.6%	1
answered question		62
skipped question		4



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

Answer Options	Response Percent	Response Count
Multiple times a year	1.6%	1
Once a year	4.8%	3
Every 2-4 years	74.6%	47
Every 5-10 years	15.9%	10
Do not know	3.2%	2
answered question		63
skipped question		3

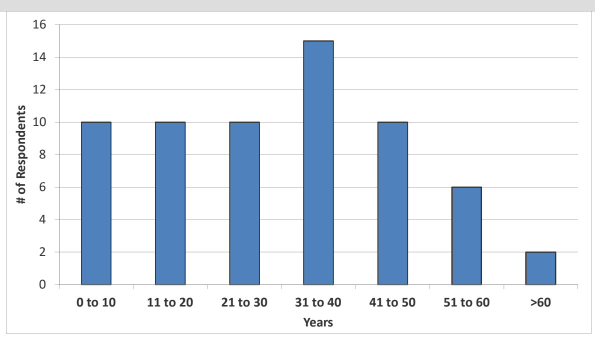


Recreational Activity on the Gresham Lakes

8. How many years ago did you first visit your lake?

Answer Options	Response Count
	63
answered question	63
skipped question	3

Category (# of days)	Responses	% Response
0 to 10	10	15.9%
11 to 20	10	15.9%
21 to 30	10	15.9%
31 to 40	15	23.8%
41 to 50	10	15.9%
51 to 60	6	9.5%
>60	2	3.2%



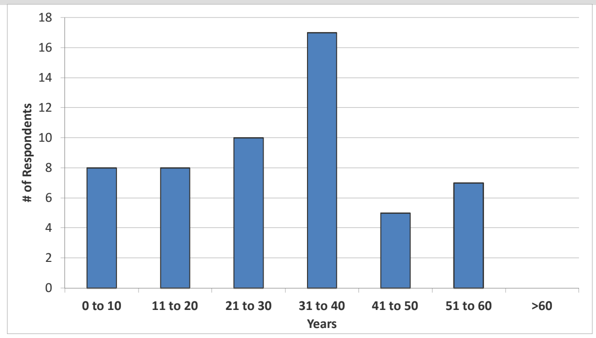
9. Have you personally fished on your lake in the past three years?

Answer Options	Response Percent	Response Count
Yes	84.6%	55
No	15.4%	10
	answered question	**65**
	skipped question	**1**

10. For how many years have you fished your lake?

Answer Options	Response Count
	55
answered question	**55**
skipped question	**11**

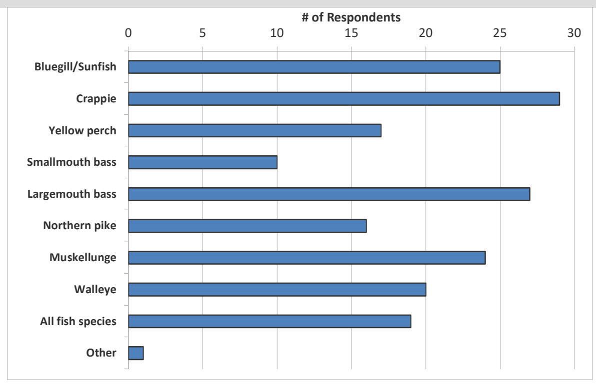
Category (# of years)	Responses	% Response
0 to 10	**8**	**14.5%**
11 to 20	**8**	**14.5%**
21 to 30	**10**	**18.2%**
31 to 40	**17**	**30.9%**
41 to 50	**5**	**9.1%**
51 to 60	**7**	**12.7%**
>60	**0**	**0.0%**



11. What species of fish do you like to catch on your lake?

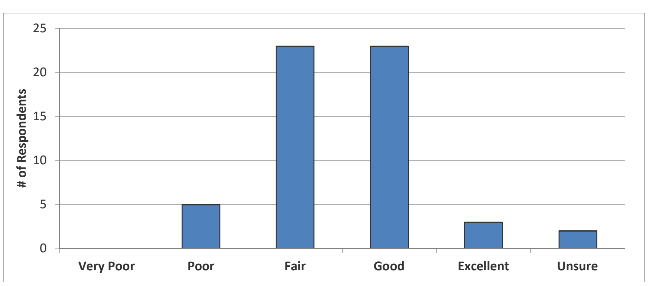
Answer Options	Response Percent	Response Count
Bluegill/Sunfish	43.9%	25
Crappie	50.9%	29
Yellow perch	29.8%	17
Smallmouth bass	17.5%	10
Largemouth bass	47.4%	27
Northern pike	28.1%	16
Muskellunge	42.1%	24
Walleye	35.1%	20
All fish species	33.3%	19
Other (please specify)	1.8%	1
	answered question	**57**
	skipped question	**9**

Number	Other (please specify)
2	We do not fish



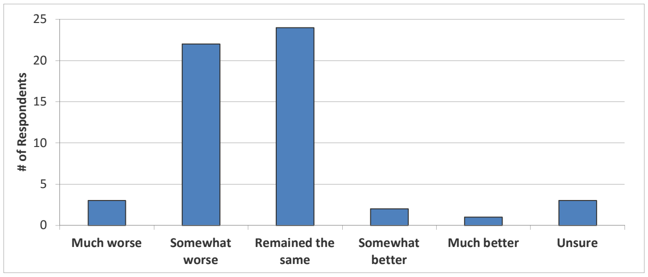
12. How would you describe the current quality of fishing on your lake?

Answer Options	Very Poor	Poor	Fair	Good	Excellent	Unsure	Response Count
	0	5	23	23	3	2	56
						answered question	**56**
						skipped question	**10**



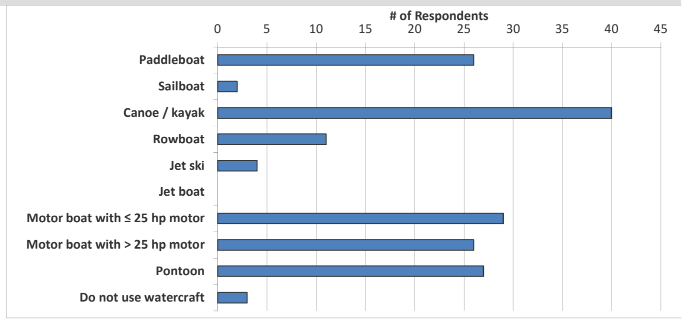
13. How has the quality of fishing changed on your lake since you have started fishing the lake?

Answer Options	Much worse	Somewhat worse	Remained the same	Somewhat better	Much better	Unsure	Response Count
	3	22	24	2	1	3	55
						answered question	55
						skipped question	11



14. What types of watercraft do you currently use on your lake?

Answer Options	Response Percent	Response Count
Paddleboat	40.0%	26
Sailboat	3.1%	2
Canoe / kayak	61.5%	40
Rowboat	16.9%	11
Jet ski (personal water craft)	6.2%	4
Jet boat	0.0%	0
Motor boat with 25 hp or less motor	44.6%	29
Motor boat with greater than 25 hp motor	40.0%	26
Pontoon	41.5%	27
Do not use watercraft on any waters	4.6%	3
	answered question	65
	skipped question	1



15. Do you use your watercraft on waters other than your lake?

Answer Options	Response Percent	Response Count
Yes	27.9%	17
No	72.1%	44
	answered question	61
	skipped question	5

16. What is your typical cleaning routine after using your watercraft on waters other than your lake?

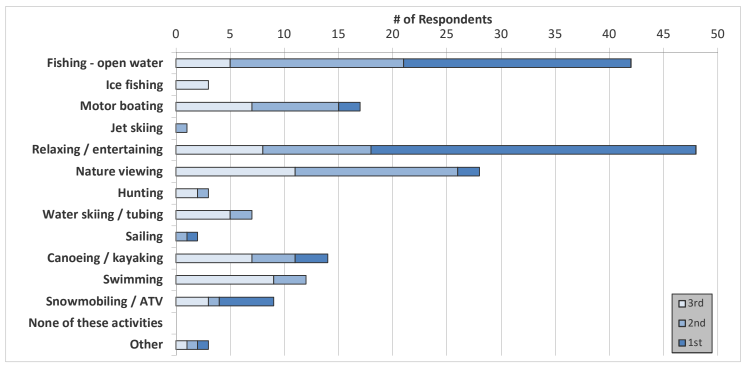
Answer Options	Response Percent	Response Count
Remove aquatic hitch-hikers (ex. - plant material, clams, mussels)	86.7%	13
Drain bilge	73.3%	11
Rinse boat	40.0%	6
Power wash boat	6.7%	1
Apply bleach	0.0%	0
Do not clean boat	6.7%	1
Other (please specify)		4
	answered question	15
	skipped question	51

Number	Other (please specify)
1	Hand wash
2	just go down creek to Middle Gresham
3	Non-toxic
4	Dry 5+ days

17. For the list below, rank up to three activities that are important reasons for owning or renting your property on your lake, with 1 being the most important.

Answer Options	1st	2nd	3rd	Rating Average	Response Count
Fishing - open water	21	16	5	1.62	42
Ice fishing	0	0	3	3	3
Motor boating	2	8	7	2.29	17
Jet skiing	0	1	0	2	1
Relaxing / entertaining	30	10	8	1.54	48
Nature viewing	2	15	11	2.32	28
Hunting	0	1	2	2.67	3
Water skiing / tubing	0	2	5	2.71	7
Sailing	1	1	0	1.5	2
Canoeing / kayaking	3	4	7	2.29	14
Swimming	0	3	9	2.75	12
Snowmobiling / ATV	5	1	3	1.78	9
None of these activities are important to me	0	0	0	0	0
Other (please specify below)	1	1	1	2	3
				answered question	65
				skipped question	1

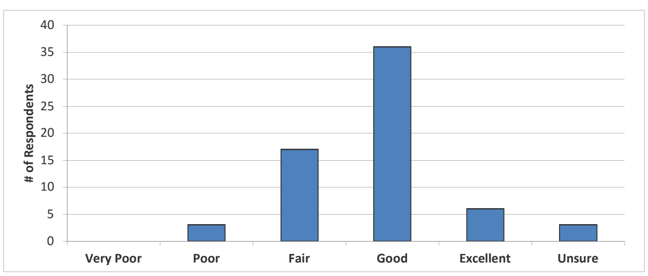
Number	"Other" responses
1	Respondent selected 7 choices, only first three recorded. The choices selected were a-c, e, f, j-l.
2	enjoy the area. shoping, zoo, restaurants, etc.
3	Family visits
4	Do not use any / no activities



Gresham Lakes Current and Historic Condition, Health and Management

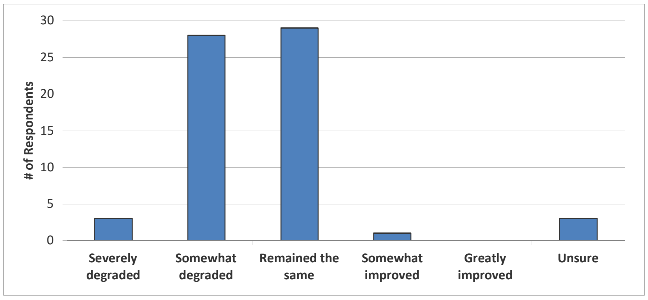
18. How would you describe the current water quality of your lake?

Answer Options	Very Poor	Poor	Fair	Good	Excellent	Unsure	Response Count
	0	3	17	36	6	3	65
						answered question	65
						skipped question	1



19. How has the water quality changed in your lake since you first visited the lake?

Answer Options	Severely degraded	Somewhat degraded	Remained the same	Somewhat improved	Greatly improved	Unsure	Response Count
	3	28	29	1	0	3	64
						answered question	**64**
						skipped question	**2**



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

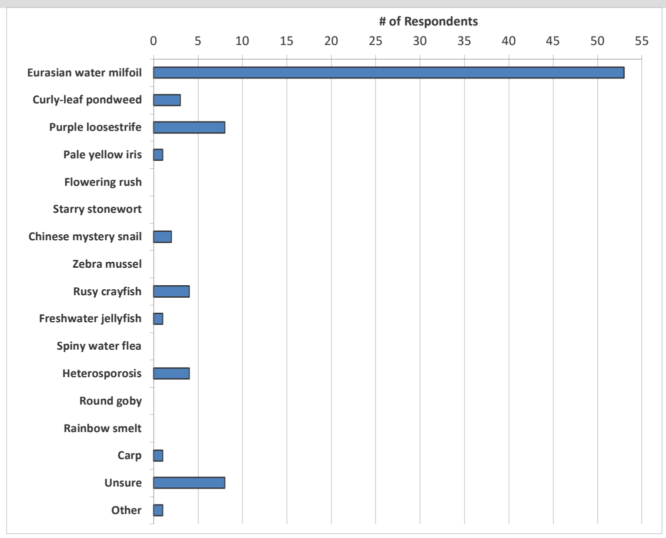
Answer Options	Response Percent	Response Count
Yes	98.5%	64
No	1.5%	1
	answered question	**65**
	skipped question	**1**

21. Do you believe aquatic invasive species are present within your lake?

Answer Options	Response Percent	Response Count
Yes	78.1%	50
I think so but am not certain	17.2%	11
No	4.7%	3
	answered question	**64**
	skipped question	**2**

22. Which aquatic invasive species do you believe are in your lake?

Answer Options	Response Percent	Response Count
Eurasian water milfoil	86.9%	53
Curly-leaf pondweed	4.9%	3
Purple loosestrife	13.1%	8
Pale yellow iris	1.6%	1
Flowering rush	0.0%	0
Starry stonewort	0.0%	0
Chinese mystery snail	3.3%	2
Zebra mussel	0.0%	0
Rusy crayfish	6.6%	4
Freshwater jellyfish	1.6%	1
Spiny water flea	0.0%	0
Heterosporosis (Yellow perch parasite)	6.6%	4
Round goby	0.0%	0
Rainbow smelt	0.0%	0
Carp	1.6%	1
Unsure but presume AIS to be present	13.1%	8
Other (please specify)	1.6%	1
	answered question	**61**
	skipped question	**5**

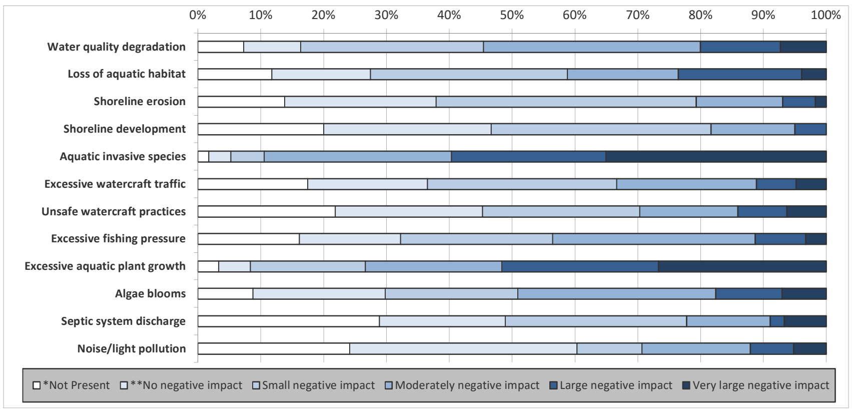


Number	"Other" responses
1	Suckers

23. To what level do you believe each of the following factors may currently be negatively impacting your lake?
*** Not Present means that you believe the issue does not exist on your lake.**
**** No Impact means that the issue may exist on your 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
Water quality degradation	4	5	16	19	7	4	8	1.44	63
Loss of aquatic habitat	6	8	16	9	10	2	12	1.14	63
Shoreline erosion	8	14	24	8	3	1	6	0.83	64
Shoreline development	12	16	21	8	3	0	4	0.72	64
Aquatic invasive species	1	2	3	17	14	20	6	2.52	63
Excessive watercraft traffic	11	12	19	14	4	3	1	1.11	64
Unsafe watercraft practices	14	15	16	10	5	4	1	1.03	65
Excessive fishing pressure	10	10	15	20	5	2	3	1.20	65
Excessive aquatic plant growth	2	3	11	13	15	16	5	2.25	65
Algae blooms	5	12	12	18	6	4	8	1.26	65
Septic system discharge	13	9	13	6	1	3	20	0.62	65
Noise/light pollution	14	21	6	10	4	3	4	0.81	62
Other (please specify)									4
								answered question	**65**
								skipped question	**1**

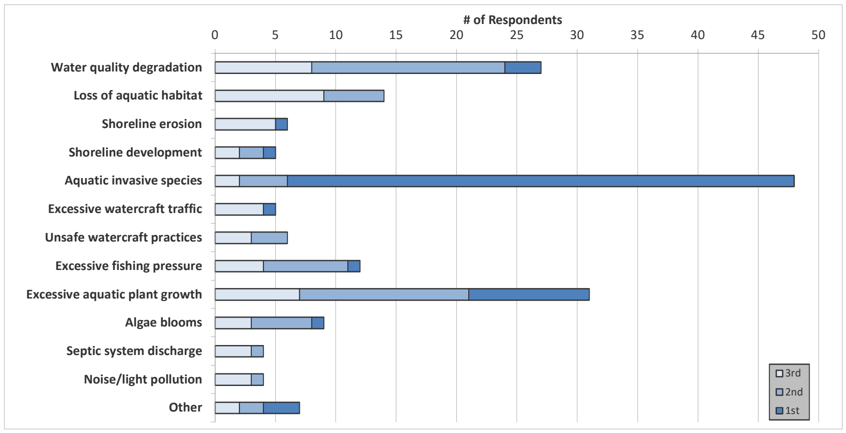
Number	Other (please specify)
1	Dumb answers. All various levels of negative
2	Beaver dams - large negative impact (4)
3	Moderately impact - beaver
4	Very large neg impact - use from campsite



24. From the list below, please rank your top three concerns regarding your lake, with 1 being your greatest concern.

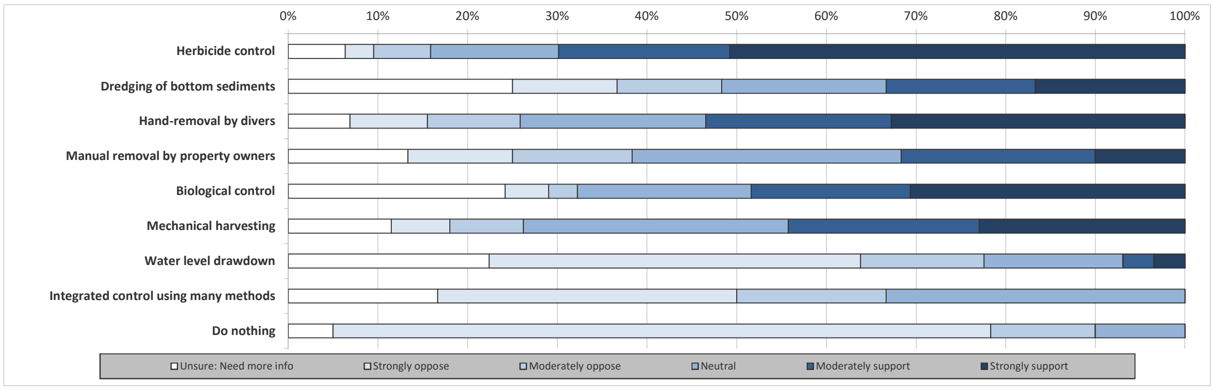
Answer Options	1st	2nd	3rd	Response Count
Water quality degradation	3	16	8	27
Loss of aquatic habitat	0	5	9	14
Shoreline erosion	1	0	5	6
Shoreline development	1	2	2	5
Aquatic invasive species	42	4	2	48
Excessive watercraft traffic	1	0	4	5
Unsafe watercraft practices	0	3	3	6
Excessive fishing pressure	1	7	4	12
Excessive aquatic plant growth (excluding algae)	10	14	7	31
Algae blooms	1	5	3	9
Septic system discharge	0	1	3	4
Noise/light pollution	0	1	3	4
Other (please specify)	3	2	2	7
			answered question	63
			skipped question	3

Number	"Other" responses
1	cranberry bog water useage.
2	boats from upper lake
3	Campground expansion
4	None
5	clear water for loons to feed easier
6	Boat speeds near shoreline
7	Also "b" and "I"
8	not specified
9	Campsite use



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

Answer Options	Strongly oppose	Moderately oppose	Neutral	Moderately support	Strongly support	Unsure: Need more info	Rating Average	Response Count
Herbicide (chemical) control	2	4	9	12	32	4	3.89	63
Dredging of bottom sediments	7	7	11	10	10	15	2.4	60
Hand-removal by divers	5	6	12	12	19	4	3.38	58
Manual removal by property owners	7	8	18	13	6	8	2.65	60
Biological control (milfoil weevil, loosestrife beetle, etc)	3	2	12	11	19	15	2.94	62
Mechanical harvesting	4	5	18	13	14	7	3.11	61
Water level drawdown	24	8	9	2	2	13	1.47	58
Integrated control using many methods	2	1	2	0	0	1	1.67	6
Do nothing (do not manage plants)	44	7	6	0	0	3	1.27	60
							answered question	63
							skipped question	3



26. Did you know that aquatic herbicides and hand harvesting were being applied before the present year in Upper Gresham Lake to help control EWM?

Answer Options	Response Percet	Response Count
Yes, I knew about both	80.7%	50
I only knew about the aquatic herbicides	4.8%	3
I only knew about the hand harvesting	3.2%	2
I did not know about either	11.3%	7
	answered question	62
	skipped question	4

27. How do you feel about the past use of herbicides to treat EWM in previous years?

Answer Options	Completely support	Moderately support	Unsure	Moderately oppose	Completely oppose	Rating Average	Response Count
	37	11	10	5	0	1.73	63
						answered question	63
						skipped question	3

28. What is your level of support or opposition for future aquatic herbicide use to target EWM in Upper Gresham Lake?

Answer Options	Completely support	Moderately support	Unsure	Moderately oppose	Completely oppose	Rating Average	Response Count
	35	18	4	3	1	1.64	61
						answered question	61
						skipped question	5

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

Answer Options	Response Percet	Response Count
Potential cost of treatment is too high	14.3%	1
Potential impacts to native aquatic plant species	42.9%	3
Potential impacts to native (non-plant) species such as fish, insects, etc.	85.7%	6
Potential impacts to human health	57.1%	4
Not effective	28.6%	2
Future impacts are unknown	42.9%	3
Another reason (please specify)	14.3%	1
	answered question	**7**
	skipped question	**59**

Number	"Other" responses
1	There seems to be more EWM than before treatments

30. How do you feel about the past use of professional hand harvesting to target EWM in previous years?

Answer Options	Completely support	Moderately support	Unsure	Moderately oppose	Completely oppose	Rating Average	Response Count
	23	16	11	7	7	2.36	64
						answered question	**64**
						skipped question	**2**

31. What is your level of support or opposition for future professional hand harvesting use to target EWM in Upper Gresham Lake?

Answer Options	Completely support	Moderately support	Unsure	Moderately oppose	Completely oppose	Rating Average	Response Count
	22	13	11	11	7	2.5	64
						answered question	**64**
						skipped question	**2**

32. What is the reason(s) you oppose the future use of hand harvesting/removal to target EWM in Upper Gresham Lake?

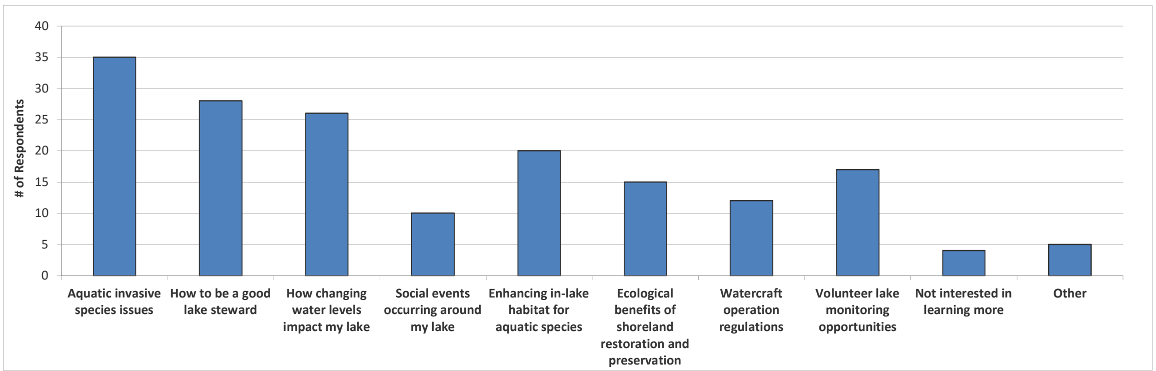
Answer Options	Response Percet	Response Count
Cost of hand harvesting / removal is too high	58.3%	14
Potential to spread Eurasian water milfoil	62.5%	15
Not effective	79.2%	19
Another reason (please specify)	16.7%	4
	answered question	**24**
	skipped question	**42**

Number	"Other" responses
1	Waste of money
2	Unsure of impirical evidence to support the effectiveness of this approach; fear it may be counter productive.
3	Wasted $7500 in 2017 when we knew it was ineffective in past years.
4	While I support hand harvesting, ineffective on its own.

33. 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
Aquatic invasive species impacts, means of transport, identification, control options, etc.	61.4%	35
How to be a good lake steward	49.1%	28
How changing water levels impact my lake	45.6%	26
Social events occurring around my lake	17.5%	10
Enhancing in-lake habitat (not shoreland or adjacent wetlands) for aquatic species	35.1%	20
Ecological benefits of shoreland restoration and preservation	26.3%	15
Watercraft operation regulations – lake specific, local and statewide	21.1%	12
Volunteer lake monitoring opportunities (CBCW,CLMN, Loon Watch, GLA programs, etc.)	29.8%	17
Not interested in learning more on any of these subjects	7.0%	4
Other (please specify)	8.8%	5
	answered question	**57**
	skipped question	**9**

Number	Other (please specify)
1	Impact of cranberry bogs on lake
2	What is the anticipated impact of cranberry bogs?
3	We feel well informed
4	Fish species population estimation
5	Impact (or lack thereof) from the cranberry bogs located along Co Rd H, as well as its future expansion.



Gresham Lakes Association (GLA)

34. Before receiving this mailing, had you ever heard of the GLA?

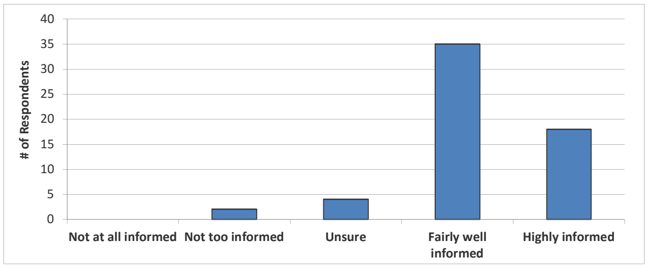
Answer Options	Response Percent	Response Count
Yes	98.5%	65
No	1.5%	1
	answered question	**66**
	skipped question	**0**

35. What is your membership status with the GLA?

Answer Options	Response Percent	Response Count
Current member	81.3%	52
Former member	9.4%	6
Never been a member	9.4%	6
	answered question	**64**
	skipped question	**2**

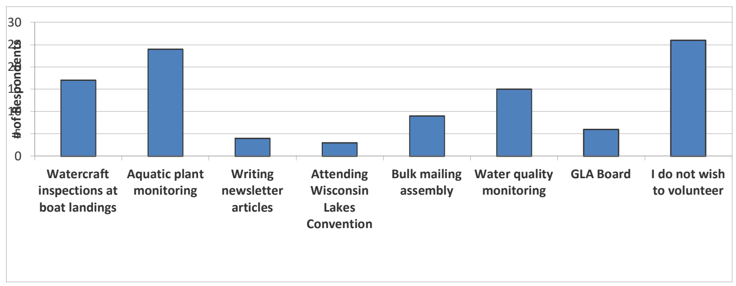
36. How informed has (or had) the GLA kept you regarding issues with your lake and its management?

Answer Options	Not at all informed	Not too informed	Unsure	Fairly well informed	Highly informed	Response Count
	0	2	4	35	18	59
					answered question	**59**
					skipped question	**7**



37. 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 GLA requires additional assistance.

Answer Options	Response Percent	Response Count
Watercraft inspections at boat landings	29.3%	17
Aquatic plant monitoring	41.4%	24
Writing newsletter articles	6.9%	4
Attending Wisconsin Lakes Convention	5.2%	3
Bulk mailing assembly	15.5%	9
Water quality monitoring	25.9%	15
GLA Board	10.3%	6
I do not wish to volunteer	44.8%	26
answered question		**58**
skipped question		**8**



38. Please feel free to provide written comments concerning your lake, its current and/or historic condition and its management.

Answer Options	Response Count
	31
answered question	**31**
skipped question	**35**

Number	Response Text
1	Don't know much about the lakes. i do know that lower is so very weedy-can not swim at our place because of the weeds. Wish we could do something.
2	A huge thank you to you and the Board for the work all of you put in to monitor and inform the owners of the lake. we sincerely appreciate your efforts.
3	Some of the questions and/or answers could have been better, different, or more clear. Also survey could have been done online with survveymoney.com would save postage & mailing cost as well as time to manually read and count.
4	1) Aquatic plant growth out of control 2) AIS is of great concern 3) Accolades to GLA Board - thanks for your efforts
5	Not here enough to volunteer. Would be interested when I retire.
6	Concerned that DNR doesn't think milfoil will continue to be a problem. Definitely more growth last summer with no treatment
7	There are several very bright light sources illuminating shoreline areas that burn all night. We find these to be objectionable, unnecessary and excessive. The excessive illumination interferes with viewing of the night sky.
8	Up until the past 2-3 years, my sense was that there was a substantial awareness, understanding, qualification, & committment to address AIs on the chain, and particularly Upper Gresham where I have my property. In recent years that seems to have changed and at the same time the water quality and evidence of AIS seems to have taken a turn for the worse. Also,the water level sees to be unusually low the past 2 summers, with no understanding as to why. Beaver dams between Middle and Lower Gresham seem to be managed (or not) on an ad-hoc basis, with no accountability or control nor the consequences of over management(ie, blowing them up all the time) can be severe. At the same time, water extraction for the cranberry bog on Upper Gresham appears to be uncontrolled, unregulated, and the ? unaccountable. That's my perception, the facts may be different, this is another completely unnaturaldrain on the lakes ecosystem& therefore needs to be carefully monitored. Very many thanks to the board and all volunteers organization for their stewardship of the chain and having the courage and foresight to solicit input from all stakeholders.
9	Weeds on Middle Gresham need to be addressed
10	The only effective control of Eurasian milfoil is chemical trreatment. Inability to treat during the six lake 3 year study was disasterous for GLA.
11	I thought this questionaire was to address invasive aquatic plants. How did watercraft useage become an issue. I have contributed regularly to the GLA for aquatic plant control. If watercraft useage becomes a GLA initiative I will stop all support to GLA. Watercraft has been allowed on the lake and should not be restricted in any way.
12	We are only up North 4-5 days every other week (so volunteering is difficult). We will gladly pay our share.
13	I appreciate what the GLA is doing. It's important. Thank you.
14	All efforts and attention appear to be focused on Upper Gresham, and sometimes Middle Gresham, but none on Lower Gresham. It's a bit of a Catch-22 in that no one on Lower Gresham wants to take the lead, so the Association focuses on Upper an Middle. That's ok if invasive species are controlled in Upper and Middle, they won't make their way to Lower. But Lower should at least be monitored to make sure invasives don't get a foothold.

Number	Response Text
15	I worry about the new cranberry bogs going in close to the present bogs on the north side of Upper Gresham. Are they going to use our lake water to flood the new bogs? Also in the DNR master plan is putting approx 50 more campsites on the state campground on Upper Gresham. We already have 37 campsites and that is fine, but any more will be too many for our lake size. Also hate being an experimental lake and not being able to treat EWM. We had it under control, but haven't been able to treat the last 2 years and its running rampant again. Who pays? The State should pay for treatment as they are the ones that won't let us keep it under control.
16	Survey Recorder Comment - respondent includes personal info in summary comments, including contact information. Asks someone to let her know if not current on GLA dues.
17	Survey Recorder Comment - largely incomplete response, as respondent indicates most answers on this anonymous survey are similar to those on the 2008 survey. Respondent comments - "all answers are the same as 2008 survey. Current required program is a wast of State $, Stakeholder $ and volunteer time. Virtually nothing has changed in the lake except EWM has come back. State protocols need to change to be more efficient and realistic.
18	Survey Recorder Comment - please see original envelope for annual contribution from respondent
19	The EWM problem has grown exponentially over the past 2 years and is now significantly impacting lake enjoyment, specifically boating, fishing and swimming. It is imperative that measures be taken in early 2018 to abate EWM significantly and effectively, or our lake will be lost. Thank you.
20	Never used the lake. Purchase vacant lot intending to build, but never did. Selling the lot this month
21	I believe that John Winkelman and other longtime members of the GLA board have done a phenomenal job overseeing and working so hard to ensure that Upper Gresham Lake remains the beautiful lake that it is. I was shocked to see how much new milfoil had grown since the DNR stopped the treatment. Weeds need to be addressed soon. Wish I could volunteer more. I am a senior non-WI resident. Don't get up there as much as I wish I could. My sincere thanks to the Board!
22	The GLA is doing a great job. I would like to see all property owners (on the chain) have a financial responsibility for the 3 lakes.
23	I have been living on Upper Gresham for over 17 years. I am an avid musky fisherman (catch and release) but have seen the musky population destroyed since the DNR lowered the harvesting length to 28 inches. This sucks. Wee need to fight to raise it. Also, I see more and larger weed patches throughout the lake. These are the patches we want to get rid of. But I have witnessed / chased several ski boats / skiers going through them and breaking them apart. This is exactly how milfoil spreads throughout the lake. Unacceptable!! When we have words with them (home owners living on the lake with ski boats) they don't seem to care. These owners should be singled out and educated! Survey Recorder Comment - respondent has a few other comments, and a couple of names that I elected not to transpose. They are available on the hardcopy response, which is indexed as M-23.
24	Since we are on Lower Gresham, I must admit I do not know to what degree Upper and Middle affect our lake. I'd be interested to learn though. We enjoy our small, quiet lake and are hopeful to status clean and healthy for wildlife, native plants and humans alike. Thank you for the commitment to our lakes and considering different opinions.
25	The GLA keeps the lake owners informed. The annual meeting helps with concerns of members. The board does a good job with the management of the lake. Thank you.
26	Its current and historic condition are fine, except the channel pass now is not usable by motorboat due to heavy overgrowth. It used to be serviced, so what has transpired? We the value of our property as including accessibility to all 3 Gresham Lakes. Can we correct this? We can all contribute funds to cover. The new Cranberry field and taking water from Upper Gresham os also troubling as well as ???? erosion. The upcoming new campsites make us very unhappy peace may be altered with crime occurring, and subtracting from our quantity of fish. For a small lake, there are too many campsites now. This hurts the value of our property. Who is responsible for restocking the lake? Campsite people spread milfoil and are generally careless in obeying DNR rules and regs, perhaps because of unawareness. We've seen this firsthand. We pay taxes and want to be seen as more valuable than strangers. The income with certainty benefits Boulder Junction and the DNR, but not us. Please advise. Tom and Shirley Scheik
27	Survey Recorder Comment - see survey response for add'l written comments on individual questions. Respondents summary comments: Earlier I mentioned my concern that our lakes were not able to use chemicals for up to 10 years due to a ban by the DNR. That restriction definitely worsened the presence of AIS in the chain. Since our lake is downstream, we have been impacted negatively to some degree. I'm concerned that we don't know to what degree, because Lower Gresham has received very little attention through the years. I'm also uncertain if testing for AIS has been conducted in the channels between lakes.
28	Upper Gresham is a beautiful lake with a high percentage of state-owned undeveloped shoreline - which was a primary reason we decided to purchase property here. We should resist / oppose any and all efforts to further develop state-owned land. For example, 1) do not sell state-owned land for private use/development and 2) do not further expand the state-owned campground.
29	The increase in trash found in the lake and on our shoreline has increased over the last years. We believe it to be related to lack of management / oversight of the campsite and landing
31	Future ownership of Pope's Lodge is an unknown. This is a significant waterfront property and the only water access on the lake. Potential concerns are excessive development and negative water quality impact.

Upper Gresham Lake - Anonymous Stakeholder Survey

Surveys Distributed:	78
Surveys Returned:	48
Response Rate:	62%

Gresham Lakes Property

1. Which of the Gresham Lakes do you reside on?

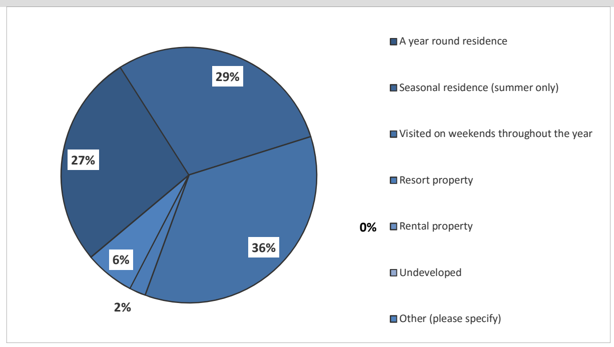
Answer Options	Response Percent	Response Count
Upper Gresham Lake	100.0%	48
Middle Gresham ake	0.0%	0
Lower Gresham Lake	0.0%	0
	answered question	**48**
	skipped question	**0**

2. Do you rent or own your property on your lake?

Answer Options	Response Percent	Response Count
Own	100.0%	48
Rent	0.0%	0
	answered question	**48**
	skipped question	**0**

3. How is your property on your lake utilized?

Answer Options	Response Percent	Response Count
A year round residence	27.1%	13
Seasonal residence (summer only)	29.2%	14
Visited on weekends throughout the year	35.4%	17
Resort property	2.1%	1
Rental property	0.0%	0
Undeveloped	0.0%	0
Other (please specify)	6.3%	3
	answered question	**48**
	skipped question	**0**

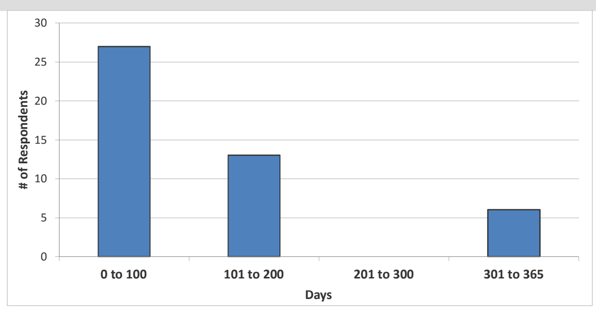


Number	Other (please specify)
1	Week-long stays 10-12 weeks throughout the year
2	2nd residence
3	Occasional weekends after "ice off"

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

Answer Options	Response Count
	46
answered question	**46**
skipped question	**2**

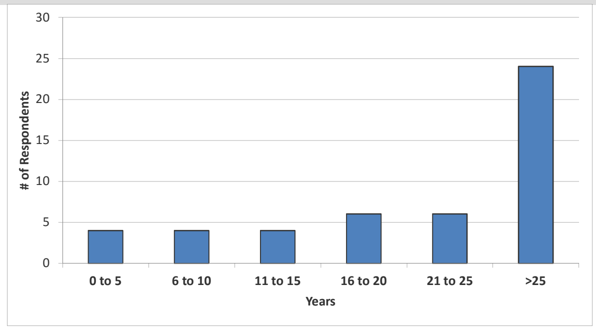
Category (# of days)	Responses	
0 to 100	**27**	**58.7%**
101 to 200	**13**	**28.3%**
201 to 300	**0**	**0.0%**
301 to 365	**6**	**13.0%**



5. How long have you owned or rented your property on your lake?

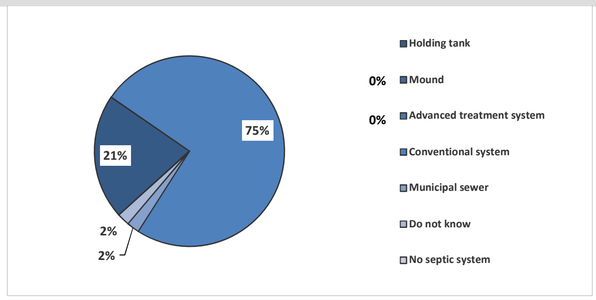
Answer Options	Response Count
	48
answered question	48
skipped question	0

Category (# of years)	Responses	% Response
0 to 5	4	8.3%
6 to 10	4	8.3%
11 to 15	4	8.3%
16 to 20	6	12.5%
21 to 25	6	12.5%
>25	24	50.0%



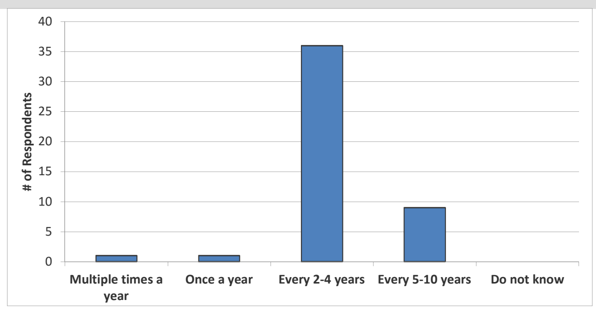
6. What type of septic system does your property utilize?

Answer Options	Response Percent	Response Count
Holding tank	21.3%	10
Mound	0.0%	0
Advanced treatment system	0.0%	0
Conventional system	74.5%	35
Municipal sewer	2.1%	1
Do not know	2.1%	1
No septic system	0.0%	0
answered question		47
skipped question		1



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

Answer Options	Response Percent	Response Count
Multiple times a year	2.1%	1
Once a year	2.1%	1
Every 2-4 years	76.6%	36
Every 5-10 years	19.2%	9
Do not know	0.0%	0
answered question		47
skipped question		1

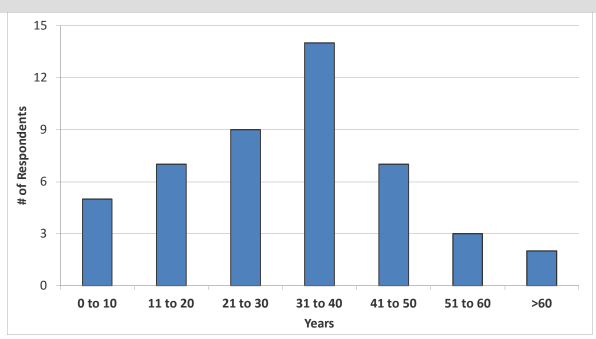


Recreational Activity on the Gresham Lakes

8. How many years ago did you first visit your lake?

Answer Options	Response Count
	47
answered question	47
skipped question	1

Category (# of days)	Responses	% Response
0 to 10	5	10.6%
11 to 20	7	14.9%
21 to 30	9	19.1%
31 to 40	14	29.8%
41 to 50	7	14.9%
51 to 60	3	6.4%
>60	2	4.3%



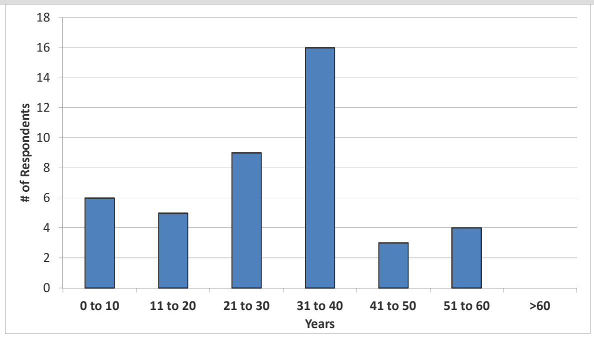
9. Have you personally fished on your lake in the past three years?

Answer Options	Response Percent	Response Count
Yes	89.6%	43
No	10.4%	5
	answered question	48
	skipped question	0

10. For how many years have you fished your lake?

Answer Options	Response Count
	43
answered question	43
skipped question	5

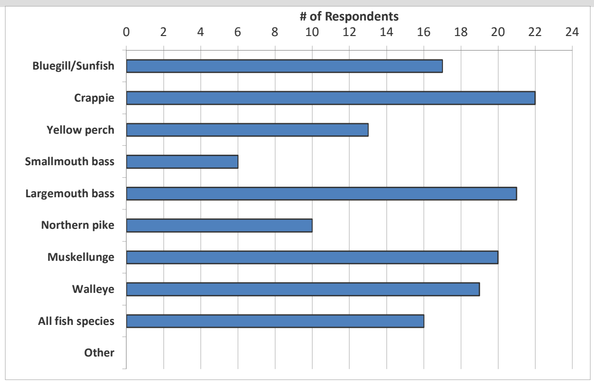
Category (# of years)	Responses	% Response
0 to 10	6	14.0%
11 to 20	5	11.6%
21 to 30	9	20.9%
31 to 40	16	37.2%
41 to 50	3	7.0%
51 to 60	4	9.3%
>60	0	0.0%



11. What species of fish do you like to catch on your lake?

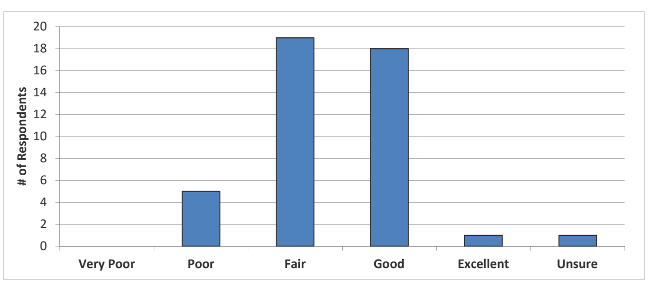
Answer Options	Response Percent	Response Count
Bluegill/Sunfish	38.6%	17
Crappie	50.0%	22
Yellow perch	29.6%	13
Smallmouth bass	13.6%	6
Largemouth bass	47.7%	21
Northern pike	22.7%	10
Muskellunge	45.5%	20
Walleye	43.2%	19
All fish species	36.4%	16
Other (please specify)	0.0%	0
	answered question	44
	skipped question	4

Number	Other (please specify)
2	We do not fish



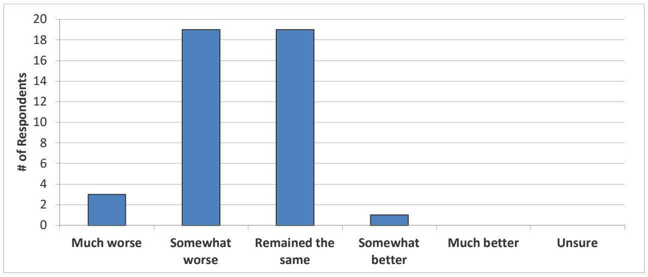
12. How would you describe the current quality of fishing on your lake?

Answer Options	Very Poor	Poor	Fair	Good	Excellent	Unsure	Response Count
	0	5	19	18	1	1	44
						answered question	44
						skipped question	4



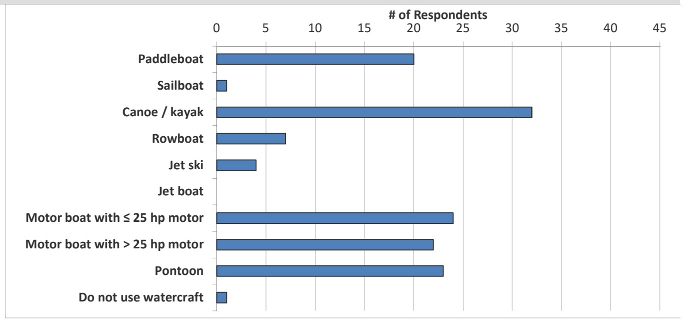
13. How has the quality of fishing changed on your lake since you have started fishing the lake?

Answer Options	Much worse	Somewhat worse	Remained the same	Somewhat better	Much better	Unsure	Response Count
	3	19	19	1	0	0	42
						answered question	42
						skipped question	6



14. What types of watercraft do you currently use on your lake?

Answer Options	Response Percent	Response Count
Paddleboat	41.7%	20
Sailboat	2.1%	1
Canoe / kayak	66.7%	32
Rowboat	14.6%	7
Jet ski (personal water craft)	8.3%	4
Jet boat	0.0%	0
Motor boat with 25 hp or less motor	50.0%	24
Motor boat with greater than 25 hp motor	45.8%	22
Pontoon	47.9%	23
Do not use watercraft on any waters	2.1%	1
	answered question	48
	skipped question	0



15. Do you use your watercraft on waters other than your lake?

Answer Options	Response Percent	Response Count
Yes	28.3%	13
No	71.7%	33
	answered question	48
	skipped question	0

16. What is your typical cleaning routine after using your watercraft on waters other than your lake?

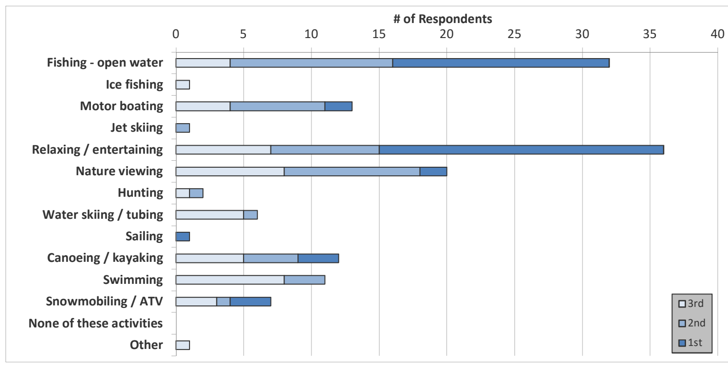
Answer Options	Response Percent	Response Count
Remove aquatic hitch-hikers (ex. - plant material, clams, mussels)	91.7%	11
Drain bilge	66.7%	8
Rinse boat	50.0%	6
Power wash boat	8.3%	1
Apply bleach	0.0%	0
Do not clean boat	8.3%	1
Other (please specify)		2
	answered question	12
	skipped question	36

Number	Other (please specify)
1	just go down creek to Middle Gresham
2	Non-toxic

17. For the list below, rank up to three activities that are important reasons for owning or renting your property on your lake, with 1 being the most important.

Answer Options	1st	2nd	3rd	Rating Average	Response Count
Fishing - open water	16	12	4	1.63	32
Ice fishing	0	0	1	3	1
Motor boating	2	7	4	2.15	13
Jet skiing	0	1	0	2	1
Relaxing / entertaining	21	8	7	1.61	36
Nature viewing	2	10	8	2.3	20
Hunting	0	1	1	2.5	2
Water skiing / tubing	0	1	5	2.83	6
Sailing	1	0	0	1	1
Canoeing / kayaking	3	4	5	2.17	12
Swimming	0	3	8	2.73	11
Snowmobiling / ATV	3	1	3	2	7
None of these activities are important to me	0	0	0	0	0
Other (please specify below)	0	0	1	3	1
				answered question	**48**
				skipped question	**0**

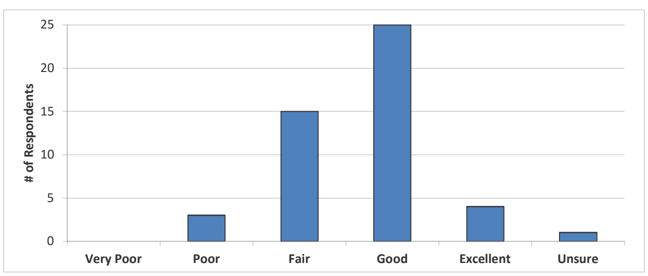
Number	"Other" responses
1	Respondent selected 7 choices, only first three recorded. The choices selected were a-c, e, f, j-l.
2	Family visits



Gresham Lakes Current and Historic Condition, Health and Management

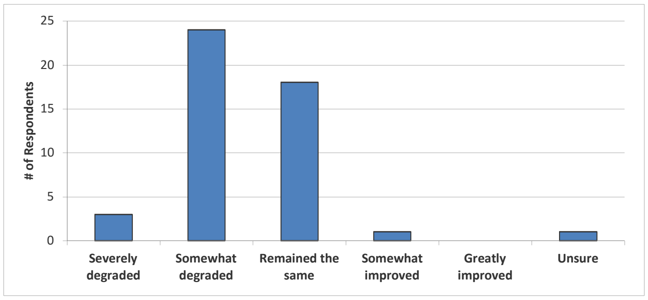
18. How would you describe the current water quality of your lake?

Answer Options	Very Poor	Poor	Fair	Good	Excellent	Unsure	Response Count
	0	3	15	25	4	1	48
						answered question	**48**
						skipped question	**0**



19. How has the water quality changed in your lake since you first visited the lake?

Answer Options	Severely degraded	Somewhat degraded	Remained the same	Somewhat improved	Greatly improved	Unsure	Response Count
	3	24	18	1	0	1	47
						answered question	**47**
						skipped question	**1**



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

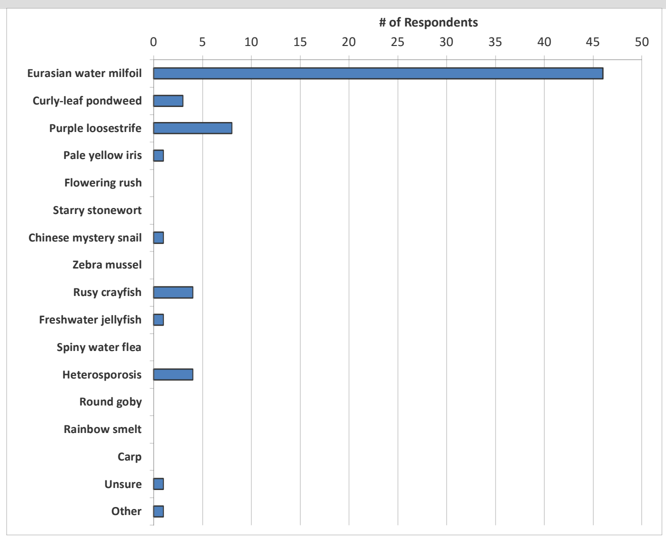
Answer Options	Response Percent	Response Count
Yes	97.9%	47
No	2.1%	1
	answered question	**48**
	skipped question	**0**

21. Do you believe aquatic invasive species are present within your lake?

Answer Options	Response Percent	Response Count
Yes	97.9%	46
I think so but am not certain	2.1%	1
No	0.0%	0
	answered question	**47**
	skipped question	**1**

22. Which aquatic invasive species do you believe are in your lake?

Answer Options	Response Percent	Response Count
Eurasian water milfoil	97.9%	46
Curly-leaf pondweed	6.4%	3
Purple loosestrife	17.0%	8
Pale yellow iris	2.1%	1
Flowering rush	0.0%	0
Starry stonewort	0.0%	0
Chinese mystery snail	2.1%	1
Zebra mussel	0.0%	0
Rusy crayfish	8.5%	4
Freshwater jellyfish	2.1%	1
Spiny water flea	0.0%	0
Heterosporosis (Yellow perch parasite)	8.5%	4
Round goby	0.0%	0
Rainbow smelt	0.0%	0
Carp	0.0%	0
Unsure but presume AIS to be present	2.1%	1
Other (please specify)	2.1%	1
	answered question	**47**
	skipped question	**1**

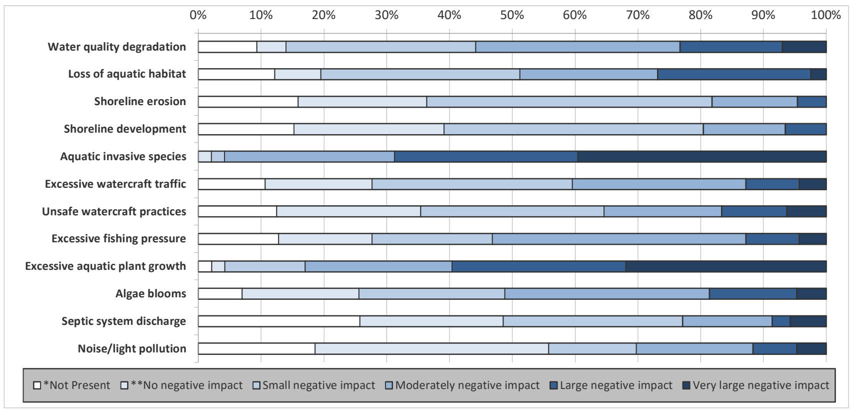


Number	"Other" responses
1	Suckers

23. To what level do you believe each of the following factors may currently be negatively impacting your lake?
*** Not Present means that you believe the issue does not exist on your lake.**
**** No Impact means that the issue may exist on your 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
Water quality degradation	4	2	13	14	7	3	4	1.57	47
Loss of aquatic habitat	5	3	13	9	10	1	5	1.41	46
Shoreline erosion	7	9	20	6	2	0	3	0.81	47
Shoreline development	7	11	19	6	3	0	1	0.85	47
Aquatic invasive species	0	1	1	13	14	19	0	3.02	48
Excessive watercraft traffic	5	8	15	13	4	2	0	1.30	47
Unsafe watercraft practices	6	11	14	9	5	3	0	1.23	48
Excessive fishing pressure	6	7	9	19	4	2	1	1.40	48
Excessive aquatic plant growth	1	1	6	11	13	15	1	2.65	48
Algae blooms	3	8	10	14	6	2	5	1.33	48
Septic system discharge	9	8	10	5	1	2	13	0.65	48
Noise/light pollution	8	16	6	8	3	2	2	0.87	45
Other (please specify)									2
								answered question	65
								skipped question	1

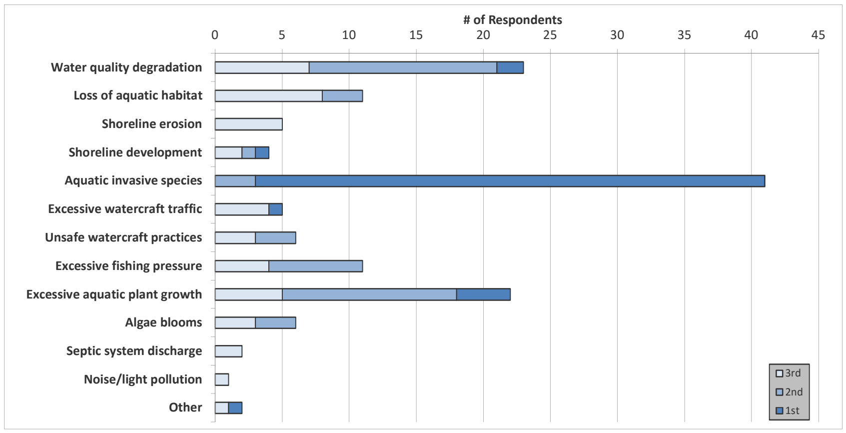
Number	Other (please specify)
1	Beaver dams - large negative impact (4)
2	Very large neg impact - use from campsite



24. From the list below, please rank your top three concerns regarding your lake, with 1 being your greatest concern.

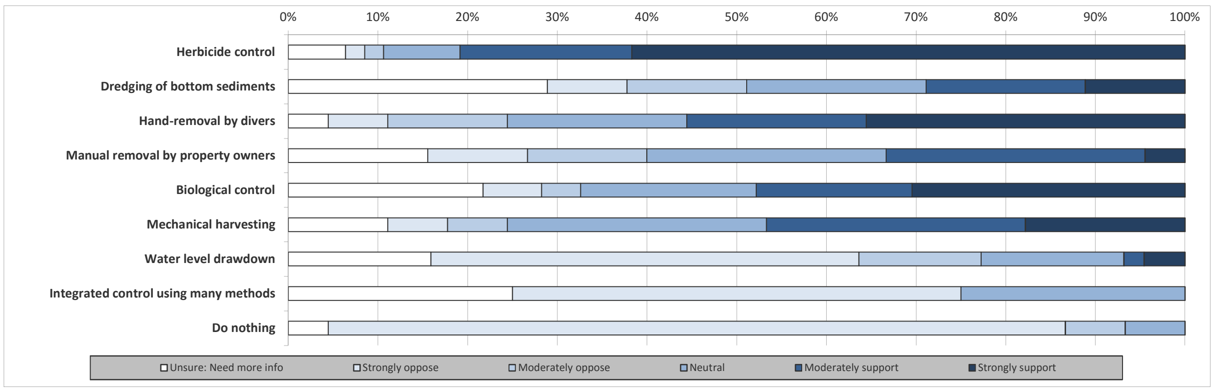
Answer Options	1st	2nd	3rd	Response Count
Water quality degradation	2	14	7	23
Loss of aquatic habitat	0	3	8	11
Shoreline erosion	0	0	5	5
Shoreline development	1	1	2	4
Aquatic invasive species	38	3	0	41
Excessive watercraft traffic	1	0	4	5
Unsafe watercraft practices	0	3	3	6
Excessive fishing pressure	0	7	4	11
Excessive aquatic plant growth (excluding algae)	4	13	5	22
Algae blooms	0	3	3	6
Septic system discharge	0	0	2	2
Noise/light pollution	0	0	1	1
Other (please specify)	1	0	1	2
			answered question	47
			skipped question	1

Number	"Other" responses
1	cranberry bog water useage.
2	Campground expansion
3	Campsite use



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

Answer Options	Strongly oppose	Moderately oppose	Neutral	Moderately support	Strongly support	Unsure: Need more info	Rating Average	Response Count
Herbicide (chemical) control	1	1	4	9	29	3	4.17	47
Dredging of bottom sediments	4	6	9	8	5	13	2.22	45
Hand-removal by divers	3	6	9	9	16	2	3.51	45
Manual removal by property owners	5	6	12	13	2	7	2.56	45
Biological control (milfoil weevil, loosestrife beetle, etc)	3	2	9	8	14	10	2.96	46
Mechanical harvesting	3	3	13	13	8	5	3.11	45
Water level drawdown	21	6	7	1	2	7	1.55	44
Integrated control using many methods	2	0	1	0	0	1	1.25	4
Do nothing (do not manage plants)	37	3	3	0	0	2	1.16	45
							answered question	**47**
							skipped question	**1**



26. Did you know that aquatic herbicides and hand harvesting were being applied before the present year in Upper Gresham Lake to help control EWM?

Answer Options	Response Percet	Response Count
Yes, I knew about both	87.0%	40
I only knew about the aquatic herbicides	6.5%	3
I only knew about the hand harvesting	0.0%	0
I did not know about either	6.5%	3
	answered question	**46**
	skipped question	**2**

27. How do you feel about the past use of herbicides to treat EWM in previous years?

Answer Options	Completely support	Moderately support	Unsure	Moderately oppose	Completely oppose	Rating Average	Response Count
	32	7	4	3	0	1.52	46
						answered question	**46**
						skipped question	**2**

28. What is your level of support or opposition for future aquatic herbicide use to target EWM in Upper Gresham Lake?

Answer Options	Completely support	Moderately support	Unsure	Moderately oppose	Completely oppose	Rating Average	Response Count
	31	11	2	2	0	1.46	46
						answered question	**46**
						skipped question	**2**

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

Answer Options	Response Percet	Response Count
Potential cost of treatment is too high	20.0%	1
Potential impacts to native aquatic plant species	40.0%	2
Potential impacts to native (non-plant) species such as fish, insects, etc.	80.0%	4
Potential impacts to human health	40.0%	2
Not effective	40.0%	2
Future impacts are unknown	60.0%	3
Another reason (please specify)	20.0%	1
	answered question	5
	skipped question	43

Number	"Other" responses
1	There seems to be more EWM than before treatments

30. How do you feel about the past use of professional hand harvesting to target EWM in previous years?

Answer Options	Completely support	Moderately support	Unsure	Moderately oppose	Completely oppose	Rating Average	Response Count
	16	15	5	6	5	2.34	47
						answered question	47
						skipped question	1

31. What is your level of support or opposition for future professional hand harvesting use to target EWM in Upper Gresham Lake?

Answer Options	Completely support	Moderately support	Unsure	Moderately oppose	Completely oppose	Rating Average	Response Count
	16	11	5	10	5	2.51	47
						answered question	47
						skipped question	1

32. What is the reason(s) you oppose the future use of hand harvesting/removal to target EWM in Upper Gresham Lake?

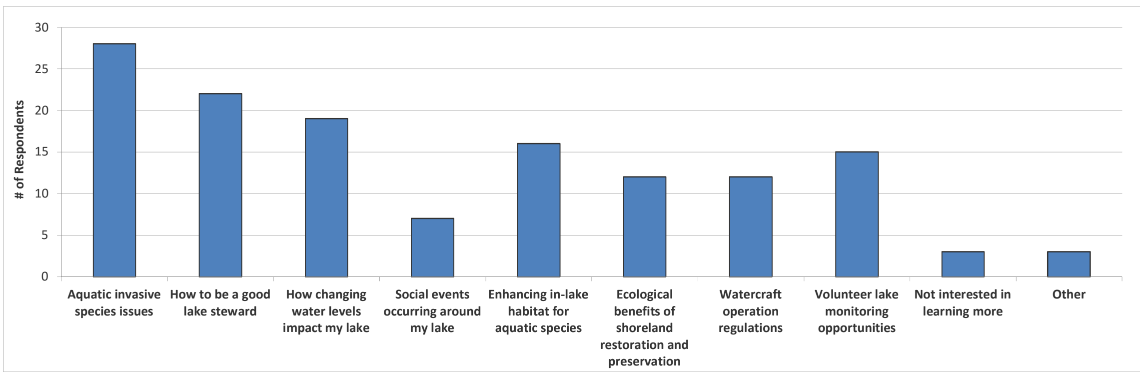
Answer Options	Response Percet	Response Count
Cost of hand harvesting / removal is too high	63.2%	12
Potential to spread Eurasian water milfoil	68.4%	13
Not effective	79.0%	15
Another reason (please specify)	10.5%	2
	answered question	19
	skipped question	29

Number	"Other" responses
1	Waste of money
2	Unsure of impirical evidence to support the effectiveness of this approach; fear it may be counter productive.

33. 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
Aquatic invasive species impacts, means of transport, identification, control options, etc.	65.1%	28
How to be a good lake steward	51.2%	22
How changing water levels impact my lake	44.2%	19
Social events occurring around my lake	16.3%	7
Enhancing in-lake habitat (not shoreland or adjacent wetlands) for aquatic species	37.2%	16
Ecological benefits of shoreland restoration and preservation	27.9%	12
Watercraft operation regulations – lake specific, local and statewide	27.9%	12
Volunteer lake monitoring opportunities (CBCW,CLMN, Loon Watch, GLA programs, etc.)	34.9%	15
Not interested in learning more on any of these subjects	7.0%	3
Other (please specify)	7.0%	3
	answered question	**43**
	skipped question	**5**

Number	Other (please specify)
1	Impact of cranberry bogs on lake
2	We feel well informed
3	Impact (or lack thereof) from the cranberry bogs located along Co Rd H, as well as its future expansion.



Gresham Lakes Association (GLA)

34. Before receiving this mailing, had you ever heard of the GLA?

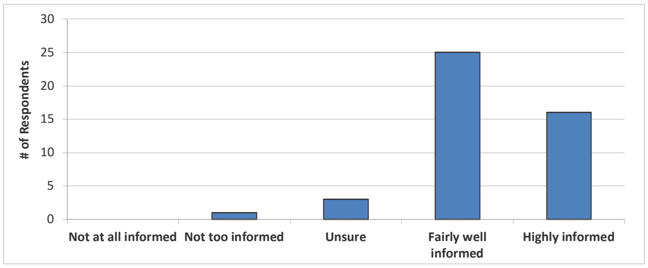
Answer Options	Response Percent	Response Count
Yes	97.9%	47
No	2.1%	1
	answered question	**48**
	skipped question	**0**

35. What is your membership status with the GLA?

Answer Options	Response Percent	Response Count
Current member	87.2%	41
Former member	8.5%	4
Never been a member	4.3%	2
	answered question	**47**
	skipped question	**1**

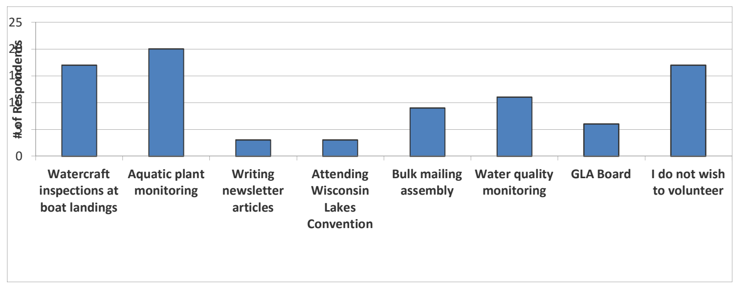
36. How informed has (or had) the GLA kept you regarding issues with your lake and its management?

Answer Options	Not at all informed	Not too informed	Unsure	Fairly well informed	Highly informed	Response Count
	0	1	3	25	16	45
					answered question	**45**
					skipped question	**3**



37. 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 GLA requires additional assistance.

Answer Options	Response Percent	Response Count
Watercraft inspections at boat landings	38.6%	17
Aquatic plant monitoring	45.5%	20
Writing newsletter articles	6.8%	3
Attending Wisconsin Lakes Convention	6.8%	3
Bulk mailing assembly	20.5%	9
Water quality monitoring	25.0%	11
GLA Board	13.6%	6
I do not wish to volunteer	38.6%	17
answered question		**44**
skipped question		**4**



38. Please feel free to provide written comments concerning your lake, its current and/or historic condition and its management.

Answer Options	Response Count
	19
answered question	**19**
skipped question	**29**

Number	Response Text
1	A huge thank you to you and the Board for the work all of you put in to monitor and inform the owners of the lake. we sincerely appreciate your efforts.
2	1) Aquatic plant growth out of control 2) AIS is of great concern 3) Accolades to GLA Board - thanks for your efforts
3	Concerned that DNR doesn't think milfoil will continue to be a problem. Definitely more growth last summer with no treatment.
4	There are several very bright light sources illuminating shoreline areas that burn all night. We find these to be objectionable, unnecessary and excessive. The excessive illumination interferes with viewing of the night sky.
5	Up until the past 2-3 years, my sense was that there was a substantial awareness, understanding, qualification, & committment to address AIs on the chain, and particularly Upper Gresham where I have my property. In recent years that seems to have changed and at the same time the water quality and evidence of AIS seems to have taken a turn for the worse. Also,the water level sees to be unusually low the past 2 summers, with no understanding as to why. Beaver dams between Middle and Lower Gresham seem to be managed (or not) on an ad-hoc basis, with no accountability or control nor the consequences of over management(ie, blowing them up all the time) can be severe. At the same time, water extraction for the cranberry bog on Upper Gresham appears to be uncontrolled, unregulated, and the ? unaccountable. That's my perception, the facts may be different, this is another completely unnaturaldrain on the lakes ecosystem& therefore needs to be carefully monitored. Very many thanks to the board and all volunteers organization for their stewardship of the chain and having the courage and foresight to solicit input from all stakeholders.
6	The only effective control of Eurasian milfoil is chemical trreatment. Inability to treat during the six lake 3 year study was disasterous for GLA.
7	I thought this questionaire was to address invasive aquatic plants. How did watercraft useage become an issue. I have contributed regularly to the GLA for aquatic plant control. If watercraft useage becomes a GLA initiative I will stop all support to GLA. Watercraft has been allowed on the lake and should not be restricted in any way.
8	We are only up North 4-5 days every other week (so volunteering is difficult). We will gladly pay our share.
9	I appreciate what the GLA is doing. It's important. Thank you.
10	I worry about the new cranberry bogs going in close to the present bogs on the north side of Upper Gresham. Are they going to use our lake water to flood the new bogs? Also in the DNR master plan is putting approx 50 more campsites on the state campground on Upper Gresham. We already have 37 campsites and that is fine, but any more will be too many for our lake size. Also hate being an experimental lake and not being able to treat EWM. We had it under control, but haven't been able to treat the last 2 years and its running rampant again. Who pays? The State should pay for treatment as they are the ones that won't let us keep it under control.
11	Survey Recorder Comment - respondent includes personal info in summary comments, including contact information. Asks someone to let her know if not current on GLA dues.

Number	Response Text
12	Survey Recorder Comment - please see original envelope for annual contribution from respondent
13	The EWM problem has grown exponentially over the past 2 years and is now significantly impacting lake enjoyment, specifically boating, fishing and swimming. It is imperative that measures be taken in early 2018 to abate EWM significantly and effectively, or our lake will be lost. Thank you.
14	I believe that John Winkelman and other longtime members of the GLA board have done a phenomenal job overseeing and working so hard to ensure that Upper Gresham Lake remains the beautiful lake that it is. I was shocked to see how much new milfoil had grown since the DNR stopped the treatment. Weeds need to be addressed soon. Wish I could volunteer more. I am a senior non-WI resident. Don't get up there as much as I wish I could. My sincere thanks to the Board!
15	I have been living on Upper Gresham for over 17 years. I am an avid musky fisherman (catch and release) but have seen the musky population destroyed since the DNR lowered the harvesting length to 28 inches. This sucks. Wee need to fight to raise it. Also, I see more and larger weed patches throughout the lake. These are the patches we want to get rid of. But I have witnessed / chased several ski boats / skiers going through them and breaking them apart. This is exactly how milfoil spreads throughout the lake. Unacceptable!! When we have words with them (home owners living on the lake with ski boats) they don't seem to care. These owners should be singled out and educated! Survey Recorder Comment - respondent has a few other comments, and a couple of names that I elected not to transpose. They are available on the hardcopy response, which is indexed as M-23.
16	The GLA keeps the lake owners informed. The annual meeting helps with concerns of members. The board does a good job with the management of the lake. Thank you.
17	Its current and historic condition are fine, except the channel pass now is not usable by motorboat due to heavy overgrowth. It used to be serviced, so what has transpired? We the value of our property as including accessibility to all 3 Gresham Lakes. Can we correct this? We can all contribute funds to cover. The new Cranberry field and taking water from Upper Gresham os also troubling as well as ???? erosion. The upcoming new campsites make us very unhappy peace may be altered with crime occurring, and subtracting from our quantity of fish. For a small lake, there are too many campsites now. This hurts the value of our property. Who is responsible for restocking the lake? Campsite people spread milfoil and are generally careless in obeying DNR rules and regs, perhaps because of unawareness. We've seen this firsthand. We pay taxes and want to be seen as more valuable than strangers. The income with certainty benefits Boulder Junction and the DNR, but not us. Please advise. Tom and Shirley Scheik
18	Upper Gresham is a beautiful lake with a high percentage of state-owned undeveloped shoreline - which was a primary reason we decided to purchase property here. We should resist / oppose any and all efforts to further develop state-owned land. For example, 1) do not sell state-owned land for private use/development and 2) do not further expand the state-owned campground.
19	The increase in trash found in the lake and on our shoreline has increased over the last years. We believe it to be related to lack of management / oversight of the campsite and landing

C

APPENDIX C

Water Quality Data

Year	Secchi (feet)				Chlorophyll-*a* (µg/L)				Total Phosphorus (µg/L)			
	Growing Season		Summer		Growing Season		Summer		Growing Season		Summer	
	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean
1984	1	8.9	1	8.9	1	7.0	1	7.0	0		0.0	
1985	1	7.9	0						1	17.0	0.0	
1986	0		0									
1987	0		0									
1988	0		0									
1989	0		0									
1990	2	8.8	0									
1991	6	9.8	5	10.4								
1992	3	11.8	2	12.4								
1993	0		0									
1994	4	10.1	2	10.4								
1995	0		0									
1996	0		0									
1997	2	9.6	2	9.6								
1998	7	10.4	4	10.9								
1999	5	10.5	4	10.4								
2000	9	12.1	5	11.9	4	4.5	3	4.4	5	17.2	3.0	16.3
2001	7	10.1	4	10.4	4	4.6	3	4.4	5	16.2	3.0	16.7
2002	9	11.0	7	11.5	6	6.3	5	4.2	9	17.4	6.0	15.8
2003	5	10.3	3	10.5	4	6.1	3	4.7	5	17.8	3.0	17.3
2004	7	10.3	4	10.3	5	4.9	4	4.7	7	18.6	4.0	17.3
2005	5	10.2	3	10.9	4	7.3	3	5.0	5	17.8	3.0	15.7
2006	5	7.8	2		3	10.0	2		4	23.0	2.0	25.5
2007	8	9.5	6	9.8	3	5.8	3	5.8	4	16.5	3.0	18.0
2008	4	9.0	3	9.3	3	4.5	3	4.5	4	19.3	3.0	20.7
2009	4	10.9	2	10.6	3	5.5	2	4.3	4	15.0	2.0	17.5
2010	4	8.2	3	6.8	3	7.0	3	7.0	4	19.0	3.0	20.3
2011	3	7.5	3	7.5	3	4.5	3	4.5	4	19.8	3.0	17.3
2012	4	7.6	3	7.0	3	5.3	3	5.3	3	17.3	3.0	17.3
2013	4	10.4	2	9.1	3	5.7	2	6.4	4	17.1	2.0	18.4
2014	2	8.3	1	11.0	1	4.3	1	4.3	2	15.2	1.0	13.9
2015	4	9.4	3	9.3	13	3.5	12	3.6	4	20.1	3.0	21.3
2016	2	11.3	2	11.3	9	3.2	8	3.4	2	21.8	2.0	21.8
2017	6	8.0	3	9.6	15	5.3	11	4.0	6	24.2	3.0	20.6
All Years (Weighted)		9.9		9.8		5.1		4.3		18.5		18.3
DHDL Median				10.8				5.0				17.0
NLF Ecoregion Median				8.9				5.6				21.0

D

APPENDIX D

Point-Intercept Aquatic Macrophyte Survey Data

	Scientific Name	Common Name	LFOO (%)				
			2005	2013	2015	2016	2017
Dicots	*Myriophyllum spicatum*	Eurasian watermilfoil	1.4	1.2	1.2	1.4	2.6
	Ceratophyllum demersum	Coontail	18.4	26.5	17.1	13.7	19.2
	Bidens beckii	Water marigold	12.0	3.1	9.9	7.9	3.3
	Myriophyllum sibiricum	Northern watermilfoil	6.2	5.2	2.9	1.9	4.9
	Nymphaea odorata	White water lily	1.2	1.9	0.3	0.5	2.3
	Myriophyllum tenellum	Dwarf watermilfoil	1.2	1.0	1.2	0.5	1.9
	Brasenia schreberi	Watershield	0.5	2.5	0.6	0.7	1.4
	Nuphar variegata	Spatterdock	0.5	1.9	1.7	0.0	1.4
	Utricularia vulgaris	Common bladderwort	0.7	0.0	0.0	0.0	0.2
	Utricularia minor	Small bladderwort	0.0	0.0	0.0	0.0	0.2
	Utricularia geminiscapa	Twin-stemmed bladderwort	0.0	0.0	0.0	0.0	0.2
	Ranunculus aquatilis	White water crowfoot	0.0	0.0	0.0	0.0	0.2
	Ranunculus flammula	Creeping spearwort	0.2	0.0	0.0	0.0	0.0
Non-dicots	*Potamogeton crispus*	Curly-leaf pondweed	0.0	0.0	0.0	0.0	0.0
	Potamogeton robbinsii	Fern-leaf pondweed	26.7	26.3	33.9	27.0	29.7
	Chara spp. & Nitella spp.	Muskgrasses & Stoneworts	19.6	16.2	17.7	17.4	21.5
	Vallisneria americana	Wild celery	21.9	16.2	16.5	19.1	18.2
	Elodea canadensis	Common waterweed	16.1	24.6	9.9	12.6	16.8
	Potamogeton pusillus & P. berchtoldii	Small & Slender pondweed	4.4	12.1	7.2	15.1	18.0
	Potamogeton pusillus	Small pondweed	4.4	12.1	6.4	15.1	18.0
	Chara spp.	Muskgrasses	7.8	15.4	8.7	8.4	13.8
	Najas flexilis	Slender naiad	9.7	9.4	11.9	10.5	9.8
	Nitella spp.	Stoneworts	12.0	0.8	10.1	9.8	7.9
	Potamogeton zosteriformis	Flat-stem pondweed	7.6	13.3	7.0	1.9	6.5
	Potamogeton amplifolius	Large-leaf pondweed	5.3	4.6	5.8	7.0	5.1
	Potamogeton friesii	Fries' pondweed	1.2	10.2	2.3	0.0	7.2
	Potamogeton gramineus	Variable-leaf pondweed	2.8	7.3	3.8	2.8	5.4
	Filamentous algae	Filamentous algae	0.0	0.0	5.5	10.5	4.7
	Potamogeton richardsonii	Clasping-leaf pondweed	5.8	5.2	1.7	2.8	2.3
	Potamogeton praelongus	White-stem pondweed	4.1	2.9	2.6	1.2	2.1
	Heteranthera dubia	Water stargrass	1.8	1.7	3.2	0.0	4.0
	Eleocharis acicularis	Needle spikerush	2.5	1.5	2.3	1.6	2.1
	Potamogeton strictifolius	Stiff pondweed	3.0	3.5	0.0	0.0	0.0
	Juncus pelocarpus	Brown-fruited rush	1.2	0.8	0.6	0.9	0.7
	Potamogeton berchtoldii	Slender pondweed	0.0	2.7	0.9	0.0	0.0
	Isoetes spp.	Quillwort spp.	0.7	0.8	0.3	1.2	0.5
	Schoenoplectus acutus	Hardstem bulrush	0.0	1.3	0.6	0.2	0.5
	Potamogeton foliosus	Leafy pondweed	0.0	0.0	1.4	0.0	0.9
	Potamogeton natans	Floating-leaf pondweed	0.5	0.6	0.0	0.0	0.7
	Potamogeton epihydrus	Ribbon-leaf pondweed	0.0	0.4	0.9	1.2	0.0
	Potamogeton vaseyi	Vasey's pondweed	0.0	0.6	0.0	0.2	0.5
	Pontederia cordata	Pickerelweed	0.0	1.2	0.0	0.0	0.2
	Lobelia dortmanna	Water lobelia	0.5	0.4	0.0	0.0	0.5
	Stuckenia pectinata	Sago pondweed	0.5	0.0	0.3	0.0	0.2
	Sagittaria cristata	Crested arrowhead	0.0	0.8	0.0	0.0	0.0
	Freshwater sponge	Freshwater sponge	0.0	0.0	0.0	0.0	0.5
	Eriocaulon aquaticum	Pipewort	0.2	0.2	0.0	0.0	0.2
	Sparganium emersum var. acaule	Short-stemmed bur-reed	0.0	0.6	0.0	0.0	0.0
	Sparganium angustifolium	Narrow-leaf bur-reed	0.2	0.0	0.0	0.0	0.2
	Schoenoplectus subterminalis	Water bulrush	0.0	0.2	0.0	0.0	0.2
	Fissidens spp. & Fontinalis spp.	Aquatic Moss	0.0	0.0	0.3	0.0	0.2
	Sparganium natans	Little bur-reed	0.0	0.0	0.0	0.0	0.2
	Sparganium sp.	Bur-reed sp.	0.0	0.0	0.0	0.0	0.2
	Lemna minor	Lesser duckweed	0.0	0.0	0.0	0.0	0.2
	Eleocharis palustris	Creeping spikerush	0.0	0.0	0.0	0.0	0.2
	Persicaria amphibia	Water smartweed	0.0	0.2	0.0	0.0	0.0
	Equisetum fluviatile	Water horsetail	0.0	0.2	0.0	0.0	0.0

E

APPENDIX E

Extracted Relevant Supplemental Chapters from Strategic Analysis of Aquatic Plant Management in Wisconsin (June 2019)

3.3 Herbicide Treatment

3.4 Physical Removal

3.5 Biological Control

In 2016-2019, the WDNR conducted a Strategy Analysis of Aquatic Plant Management in Wisconsin, which will serve as a reference document to mold future 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 indicate that the combination of two chemicals (e.g., 2,4-D and endothall) applied together produces synergistic efficacy results that are greater than if each product was applied alone (Skogerboe et al. 2012). Conversely, there are studies which indicate 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.

Carfentrazone-ethyl

Registration and Formulations

Carfentrazone-ethyl is a contact herbicide that was registered with the EPA in 1998. The active ingredient is ethyl 2-chloro-3-[2 -chloro-4-fluoro-5-[4 -(difluoromethyl)-4,5-diydro-3-methyl-5-oxo-1H-1,2,4-trizol-1-yl)phenyl]propanoate. A liquid formulation of carfentrazone-ethyl is commercially sold for aquatic use.

Mode of Action and Degradation

Carfentrazone-ethyl controls plants through the process of membrane disruption which is initiated by the inhibition of the enzyme protoporphyrinogen oxidase, which interferes with the chlorophyll biosynthetic pathway. The herbicide is absorbed through the foliage of plants, with injury symptoms viable within a few hours after application, and necrosis and death observed in subsequent weeks.

Carfentrazone-ethyl breaks down rapidly in the environment, while its degradates are persistent in aquatic and terrestrial environments. The herbicide primarily degrades via chemical hydrolysis to carfentrazone-chloropropionic acid, which is then further degraded to carfentrazone -cinnamic, -propionic, -benzoic and 3-(hydroxymethyl)-carfentrazone-benzoic acids. Studies have shown that degradation of carfentrazone-ethyl applied to water (pH = 7-9) has a half-life range of 3.4-131 hours, with longer half-lives (>830 hours) documented in waters with lower pH (pH = 5). Extremes in environmental conditions such as temperature and pH may affect the activity of the herbicide, with herbicide symptoms being accelerated under warm conditions.

While low levels of chemical residue may occur in surface and groundwater, risk concerns to non-target organisms are not expected. If applied into water, carfentrazone-ethyl is expected to adsorb to suspended solids and sediment.

Toxicology

There is no restriction on the use of treated water for recreation (e.g., fishing and swimming). Carfentrazone-ethyl should not be applied directly to water within ¼ mile of an active potable water intake. If applied around or within potable water intakes, intakes must be turned off prior to application and remain turned off for a minimum of 24 hours following application; the intake may be turned on prior to 24 hours only if the carfentrazone-ethyl and major degradate level is determined by laboratory analysis to be below 200 ppb. Do not use water treated with carfentrazone-ethyl for irrigation in commercial nurseries or greenhouses. In scenarios where the herbicide is applied to 20% or more of the surface area, treated water should not be used for irrigation of crops until 14 days after treatment, or until the carfentrazone-ethyl and major degradate level is determined by analysis to be below 5 ppb.

In scenarios where the herbicide is applied as a spot treatment to less than 20% of the waterbody surface area, treated water may be used for irrigation by commercial turf farms and on residential turf and ornamentals without restriction. If more than 20% of the waterbody surface area is treated, water should not be used for irrigation of turf or ornamentals until 14 days after treatment, or until the carfentrazone-ethyl and major degradate level is determined by analysis to be below 5 ppb.

Carfentrazone-ethyl is listed as very toxic to certain species of algae and listed as moderately toxic to fish and aquatic animals. Treatment of dense plants beds may result in dissolved oxygen declines from plant decomposition which may lead to fish suffocation or death. To minimize impacts, applications of this herbicide should treat up to a maximum of half of the waterbody at a time and wait a minimum of 14 days before retreatment or treatment of the remaining half of the waterbody. Carfentrazone-ethyl is considered to be practically non-toxic to birds on an acute and sub-acute basis.

Carfentrazone-ethyl is harmful if swallowed and can be absorbed through the skin or inhaled. Those who mix or apply the herbicide need to protect their skin and eyes from contact with the herbicide to minimize irritation and avoid breathing the spray mist. Carfentrazone-ethyl is not carcinogenic, neurotoxic, or mutagenic and is not a developmental or reproductive toxicant.

Species Susceptibility

Carfentrazone-ethyl is used for the control of floating and emergent aquatic plants such as duckweeds (*Lemna* spp.), watermeals (*Wolffia* spp.), water lettuce (*Pistia stratiotes*), water hyacinth (*Eichhornia crassipes*), and salvinia (*Salvinia* spp.). Carfentrazone-ethyl can also be used to control submersed plants such as Eurasian watermilfoil (*Myriophyllum spicatum*).

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).

<u>Species Susceptibility</u>

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.

<u>Species Susceptibility</u>

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. Manual and Mechanical Cutting

<u>Manual and Mechanical Cutting</u>

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). A synthesis of numerous historical mechanical harvesting studies is compiled by Breck et al. 1979.

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).

Ecological Impacts of Manual and Mechanical Cutting

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 all 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).

S.3.4.2. 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 Hand-Pulling and DASH

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. Because DASH is a relatively new management approach, less information is available about potential impacts than for some more established techniques like large-scale mechanical harvesting.

S.3.4.3. Benthic Barriers

Benthic barriers can be used to kill existing plants or prevent their growth from the outset. They are sometimes referred to as benthic mats, or screens, and involve placing some sort of covering over a plant bed, which provides a physical obstruction to plant growth and reduces light availability. They may be best used for dense, confined infestations or along shore or for providing boat lanes (Engel 1983; Payne et al. 1993; Bailey and Calhoun 2008). Reductions in abundance of live aquatic plants beneath the barrier may be seen within weeks (Payne et al. 1993; Carter et al. 1994). The target plant species, light availability, and sediment accumulation have been shown to influence the efficacy of benthic barriers for aquatic plant control. Effects on the target plants may be more rapid in finer sediments because anoxic conditions are reached more quickly due to higher sediment organic content and oxidization by bacteria (Carter et al. 1994). Benthic barriers may be more expensive but less time intensive than some of the physical removal approaches described above (Carter et al. 1994; Bailey and Calhoun 2008). Engel (1983) suggests that benthic barriers may be useful in situations where plants are growing too deep for other physical removal approaches or effective herbicide application. They may also improve plant control when used in combination with herbicide treatments to hold most of the herbicide to a given treatment area (Helsel et al. 1996).

There is some necessary upkeep associated with the use of benthic barriers. Some barriers can be difficult to re-use because of algae and plants that can grow on top of the barrier. Periodically removing sediment that accumulates on the barrier can help offset this (Engel 1983; Carter et al. 1994; Laitala et al. 2012). Some materials are made to be removed after the growing season, which may make cleaning and re-use easier (Engel 1983). Additionally, gases often accumulate beneath benthic barriers as a result of plant decay, which can cause them to rise off the bottom of the waterbody, requiring further maintenance (Engel 1983; Ussery et al. 1997; Bailey and Calhoun 2008). Eurasian watermilfoil (*Myriophyllum spicatum*) and other plant species have been shown to recolonize the managed area quickly following barrier removal (Eichler et al. 1995; Boylen et al. 1996), so this approach may require hand-pulling or other integrated approaches once the barrier is removed (Carter et al. 1994; Eichler et al. 1995; Bailey and Calhoun 2008). Some studies have observed low abundance of plants maintained for 1-2 months after barriers were removed (Engel 1983). Others found that combining 2,4-D treatments with benthic barriers could reduce Eurasian watermilfoil to a degree that helped native plants recolonize the target site (Helsel et al. 1996).

The material used to create benthic barriers can vary and include biodegradable jute matting, fiberglass screens, and woven polypropylene fibers (Mayer 1978; Perkins et al. 1980; Lewis et al. 1983; Hoffman et al. 2013). Some plants such as Eurasian watermilfoil and common waterweed (Elodea canadensis; Eichler et al. 1995) are able to growth through the mesh in woven barriers but this material can be effective in reducing growth on certain target plant species (Payne et al. 1993; Caffrey et al. 2010; Hoffman et al. 2013). Hofstra and Clayton (2012) suggested that less dense materials barriers may provide selective control of some species while allowing more tolerant species, such as some charophytes (*Chara* spp. and *Nitella* spp.), to grow through. More dense materials may prevent growth of a wider range of aquatic plants (Hofstra and Clayton 2012). Most materials must be well anchored to the bottom of the waterbody, which can be accomplished early in the growing season or by placing the barriers on ice before thawing of the waterbody (Engel 1983). Gas accumulation can occur in using both fibrous mesh and screen-type barriers (Engel 1983).

Eurasian watermilfoil and common waterweed have been found to be somewhat resistant to control by benthic barriers (Perkins et al. 1980; Engel 1983) while affected species include hydrilla (*Hydrilla verticillata*), curly-leaf pondweed (*Potamogeton crispus*), and coontails (*Ceratophyllum* spp.; Engel 1983; Payne et al. 1993; Carter et al. 1994). One study found that an 8-week barrier placement removed Eurasian watermilfoil while allowing native plant regrowth after the barrier was retrieved; while shorter durations were less effective in reducing Eurasian watermilfoil abundance and longer durations negatively impacted native plant regrowth (Laitala et al. 2012).

<u>Ecological Impacts of Benthic Barriers</u>

Macroinvertebrates will be negatively affected by benthic barriers while they are in place (Engel 1983) but have been shown to rebound to pre-management conditions shortly after removal of the barrier (Payne et al. 1993; Ussery et al. 1997). Benthic barriers may also affect spawning of some warm water fish species through direct disruption of spawning habitat (NYSFOLA 2009). Additionally, increased ammonium and decreased dissolved oxygen contents are often observed beneath benthic barriers (Carter et al. 1994; Ussery et al. 1997). These water chemistry considerations may partially explain decreases in macroinvertebrate populations (Engel 1983; Payne et al. 1993) and ammonium content is likely to increase with sediment organic content (Eakin 1992). Toxic methane gas has also been found to accumulate beneath benthic barriers (Gunnison and Barko 1992).

There may be some positive ecological aspects of benthic barriers. Barriers may reduce turbidity and nutrient release from sediments (Engel 1983). They may also provide channels that improve ease of fish foraging when other aquatic plant cover is present near the managed area. Fish may feed on the benthic organisms colonizing any sediment accumulating on top of the barrier (Payne et al. 1993). Payne et al. (1993) also suggest that, despite negative impacts in the managed area, the overall impact of benthic barriers is negligible since they typically are only utilized in small areas of the littoral zone. However, further research is needed on the effects of benthic barriers on fish and wildlife populations and their ability to rebound following barrier removal (Eichler et al. 1995).

S.3.4.4. Dredging

Dredging is a method that involves the removal of top layers of sediment and associated rooted plants, sediment-dwelling organisms, and sediment-bound nutrients. This approach is "non-selective" (USACE 2012), meaning that it offers limited control over what material is removed. In addition to being employed as an APM technique, dredging is often used to manage water flow, provide navigation channels, and reduce the chance of flooding (USACE 2012). Due to the expense of this method, APM via dredging is often an auxiliary effect of dredging performed for other purposes (Gettys et al. 2014). However, reduced sediment nutrient load and decreased light penetration due to greater depth post-dredging may result in multi-season reductions in plant biomass and density (Gettys et al. 2014).

Several studies discuss the utility of dredging for APM. Dredging may be effective in controlling species that propagate by rhizomes, by removing the rhizomes from the sediment before they have a chance to grow (Dall Armellina et al. 1996b). Additionally, invasive phragmites has been controlled in areas where dredging increases water depth to ≥ 5-6 feet; though movement of the equipment used in dredging activities has been implicated in expanding the range of invasive phragmites (Gettys et al. 2014). In streams, dredging resulted in a significant reduction in plant biomass (≥ 90%). However, recovery of plant populations reflected the timing of management actions relative to flowering: removal prior to flowering allowed for plant population recovery within the same growing season, while removal after flowering meant populations did not rebound until the next spring (Kaenel and Uehlinger 1999). Sediment testing for chemical residue levels high enough to be considered hazardous waste (from historically used sodium arsenite, copper, chromium, and other inorganic compounds) should be conducted before dredging, to avoid stirring of toxic material into the water column. The department routinely requires sediment analysis before dredging begins and destination approval of spoils to prevent impacts from sediment leachate outside of the disposal area. Planning and testing can be an extensive component to a dredging project.

Ecological effects of Dredging

Repeated dredging may result in plant communities consisting of populations of fast-growing species that are capable of rebounding quickly (Sand-Jensen et al. 2000). In experimental studies, faster growing invasive plant species with a higher tolerance for disturbance were able to better recover from simulated dredging than slower growing native plant species, suggesting that post-dredging plant communities may be comprised of undesirable invasives (Stiers et al. 2011).

Macroinvertebrate biomass has been shown to decrease up to 65% following dredging, particularly among species which use plants as habitat. Species that live deeper in sediments, or those that are highly mobile, were less affected. As macroinvertebrates are valuable components of aquatic ecosystems, it is recommended that plant removal activities consider impacts on macroinvertebrates (Kaenel and Uehlinger 1999). Dredging can also result in declines to native mussel populations (Aldridge 2000).

Impacts to fish and water quality parameters have also been observed. Dredging to remove aquatic plants significantly increased both dissolved oxygen levels and the number of fish species found inhabiting farm ponds (Mitsuo et al. 2014). This increase in fish abundance may have been due to extremely high pre-dredging density of aquatic plants, which can negatively influence fish foraging success. In another study, aquatic plant removal decreased the amplitude of daily oxygen fluctuations in streams. However, post-dredging changes in metabolism were short-lived, suggesting that algae may have taken over primary productivity (Kaenel et al. 2000). Finally, several studies have also documented or suggested a reduction in sediment phosphorous levels after dredging, which may in turn reduce nutrient availability for aquatic plant growth (Van der Does et al. 1992; Kleeberg and Kohl 1999; Meijer et al. 1999; Søndergaard et al. 2001; Zuccarini et al. 2011). However, consideration must be given to factors affecting whether goals are obtainable via dredging (e.g., internal or external phosphorus inputs, water retention time, sediment characteristics, etc.).

S.3.4.5. Drawdown

Water-level drawdown is another approach for aquatic plant control as well as aquatic plant restoration. Exposure of aquatic plant vegetation, seeds, and other reproductive structures may reduce plant abundance by freezing, drying, or consolidation of sediments. This management technique is not effective for control of all aquatic plant species. Due to potential ecological impacts, it is necessary to consider other factors such as: waterfowl habitat, fisheries enhancement, release of nutrients and solids downstream, and refill and sediment consolidation potential. Often drawdowns for aquatic plant control and/or restoration can be coordinated to time with dam repair or repair of shoreline structures. A review by Cooke (1980), suggests drawdown can provide at least short-term aquatic plant control (1-2 years) when the target species is vulnerable to drawdown and where sediment can be dewatered under rigorous heat or cold for 1-2 months. Costs can be relatively low when a structure for manipulating water level is in place (otherwise high capacity pumps must be used). Conversely, costs can be high to reimburse an owner for lost power generation if the water control structure produces hydro-electric power. The aesthetic and recreational value of a waterbody may be reduced during a drawdown, as large areas of sediment are exposed prior to revegetation. Bathymetry is also important to consider, as small decreases in water level may lead to drop-offs if a basin does not have a gradual slope (Cooke 1980). The downcutting of the stream to form a new channel can also release high amounts of solids and organic matter that can impair water quality downstream. For example, in July 2005, the Waupaca Millpond, Waupaca Co. had to conduct an emergency drawdown that resulted in the river downcutting a new channel. High suspended solid concentrations and BOD resulted in decreased water clarity, sedimentation and depressed dissolved oxygen levels. A similar case occurred in 2015 with the Amherst Mill Pond, Portage Co. during a drawdown at a rate of six inches per day (Scott Provost [WDNR], *personal communication*).

Because extreme heat or cold provide optimal conditions for aquatic plant control, drawdowns are typically conducted in the summer or winter. Because of Wisconsin's cold winters, winter drawdown is likely to have several advantages when used for aquatic plant management, including avoiding many conflicts with recreational use, potential for cyanobacterial blooms, and terrestrial and emergent plant growth in sediments exposed by reduced water levels (ter Heerdt and Drost 1994; Bakker and Hilt 2016).

A synthesis of the abiotic and biotic responses to annual and novel winter water level drawdowns in littoral zones of lakes and reservoirs is summarized by Carmignani and Roy 2017. Climatic conditions also determine the capacity of a waterbody to support drawdown (Coops et al. 2003). Resources managers pursuing drawdown must carefully calculate the waterbody's water budget and the potential for increased cyanobacterial blooms in the future may reduce the number of suitable waterbodies (Callieri et al. 2014). Additionally, mild winters and groundwater seepage in some waterbodies may prevent dewatering, leading to reduced aquatic plant control (Cooke 1980). Complete freezing of sediment is more likely to control aquatic plants. Sediment exposure during warmer temperatures (>5° C) can also result in the additional benefit of oxidizing and compacting organic sediments (Scott Provost and Ted Johnson [DNR], *personal communication*). When drawdowns are conducted to improve migratory bird habitat, summer drawdowns prove to be more beneficial for species of shorebirds, as mudflats and shallow water are exposed to promote the production of and accessibility to invertebrates during late summer months that coincide with southward migration (Herwig and Gelvin-Innvaer 2015). Drawdowns conducted during mid-late summer can result in conditions that are favorable for cattails (*Typha* spp.) germination and expansion. However, cattails can be controlled if certain stressors are implemented in conjunction with a drawdown, such as cutting, burning or herbicide treatment during the peak of the growing season. The ideal situation is to cut cattail during a drawdown and flood over cut leaves when water is raised. However, this option is not always feasible due to soil conditions and equipment limitations.

Ecological Impacts of Water-level Drawdown

Artificial manipulation of water level is a major disturbance which can affect many ecological aspects of a waterbody. Because drawdown provides species-selective aquatic plant control, it can alter aquatic plant community composition and relative abundance and distribution of species (Boschilia et al. 2012; Keddy 2000). Sometimes this is the intent of the drawdown, which creates plant community characteristics that are desired for wildlife or fish habitat. Consecutive annual drawdowns may prevent the re-establishment of native aquatic plants or lead to reduced control of aquatic plant abundance as drawdown-tolerant species begin to dominate the community (Nichols 1975). Sediment exposure can also lead to colonization of emergent vegetation in the drawdown zone. In one study, four years of consecutive marsh drawdown led to dominance of invasive phragmites (*Phragmites australis subsp. australis*; ter Heerdt and Drost 1994). However, when drawdowns are conducted properly, it can provide a favorable response to native emergent plants for providing food and cover for migrating waterfowl in the fall. Population increases in emergent plant species such as bulrush (*Schoenoplectus* spp.), bur-reeds (*Sparganium* spp.), and wild rice (*Zizania palustris*) is often a goal of drawdowns, which provides a great food source for fish and wildlife, and provides important spawning and nesting habitat. Full or partial drawdowns that are conducted after wild rice production in the fall tend to favor early successional emergent germination such as wild rice and bulrush the following spring. Spring drawdowns are also possible for producing wild rice but must be done during a tight window following ice-out and slowly raised prior to the wild rice floating leaf stage.

Drawdown can also have various effects on ecosystem fauna. Drawdowns can influence the mortality, movement and behavior of native freshwater mussels (Newton et al. 2014). Although mussels can move with lowering water levels, they can be stranded and die if they are unable to move fast enough or get trapped behind logs or other obstacles (WDNR et al. 2006). Some mussels will burrow down into the mud or sand to find water but can desiccate if the water levels continue to lower (Watters et al. 2001). Maintaining a slow drawdown rate can allow mussels to respond and stranded individuals can be relocated to deeper water during the drawdown period to reduce mussel death (WDNR et al. 2006). Macroinvertebrate communities may experience reduced species diversity and abundance from changes to their environment due to drawdown and loss of habitat provided by aquatic plants (Wilcox and Meeker 1992; McEwen and Butler 2008). These effects may be reduced by considering benthic invertebrate phenology in determining optimal timing for drawdown release. Adequate moisture is required to support the emergence of many macroinvertebrate species and complete drawdown may also result in hardening of sediments which can trap some species (Coops et al. 2003). Reduced macroinvertebrate availability can have negative effects on waterfowl and game fish species which rely on macroinvertebrate food sources (Wilcox and Meeker 1992). Depending on the time of year, drawdown may also lead to decreased reproductive success of some waterfowl through nest loss, including common loon (*Gavia immer*) and red-necked grebe (*Podiceps grisegena*; Reiser 1998). However, drawdown may lead to increased production of annual plants and seed production, thereby increasing food availability for brooding and migrating waterfowl. Semi-aquatic mammals such as muskrats and beavers may also be adversely affected by water level drawdown (Smith and Peterson 1988, 1991). DNR Wildlife Management staff follow guidance to ensure drawdowns are timed with the seasons or temperature to minimize negative impacts to wildlife. Negative impacts to reptiles are possible during the spring if water is raised following a drawdown, as nests may be flooded. In the fall, negative impacts to reptiles and amphibians are possible if water is lowered when species are attempting to settle into sediments for hibernation. The impact may be reduced dissolved oxygen if they are below the water or freezing if the water is dropped below the point of hibernation (Herwig and Smith 2016a, 2016b). Surveying and relocation of stranded organisms may help to mitigate some of these impacts. In Wisconsin there are general provisions for conducting drawdowns for APM that are designed to mitigate or even eliminate potential negative impacts.

Water chemistry can also be affected by water level fluctuation. Beard (1973) describes a substantial algal bloom occurring the summer following a winter drawdown which provided successful aquatic plant control. Other studies reported reduced dissolved oxygen, severe cyanobacterial blooms with summer drawdown, or increased nutrient concentrations and reduced water clarity during summer drawdown for urban water supply (Cooke 1980; Geraldes and Boavida 2005; Bakker and Hilt 2016). Water clarity and trophic state may be improved when drawdown level is similar to a waterbody's natural water level regime (Christensen and Maki 2015).

Species Susceptibility to Water-level Drawdown

Not all plant species are susceptible to management by water level drawdown and some dry- or cold-tolerant species may benefit from it (Cooke 1980). Generally, plants and charophytes which reproduce primarily by seed benefit from drawdowns while those that reproduce vegetatively tend to be more negatively affected. Marsh vegetation can be dependent on water level fluctuation (Keddy and Reznicek 1986). Cooke (1980) provides a summary table of drawdown responses for 63 aquatic plant species. Watershield (Brasenia schreberi), fern pondweed (*Potamogeton robbinsii*), pond-lilies (*Nuphar* spp.) and watermilfoils (*Myriophyllum* spp.) tend to be controlled by drawdown. Increases in abundance associated with drawdown have often been seen for duckweed (*Lemna minor*), rice cutgrass (*Leersia oryzoides*) and slender naiad (*Najas flexilis*; Cooke 1980). One study showed drawdown reduced Eurasian watermilfoil (*Myriophyllum spicatum*) at shallow depths while another cautioned that Eurasian watermilfoil vegetative fragments may be able to grow even after complete desiccation (Siver et al. 1986; Evans et al. 2011). Similarly, a tank-simulated drawdown experiment suggested short-term summer drawdown may be effective in controlling monoecious hydrilla (*Hydrilla verticillata*; Poovey and Kay 1998). However, other studies have shown hydrilla fragments to be resistant to drying following drawdown (Doyle and Smart 2001; Silveira et al. 2009). A study on Brazilian waterweed (*Egeria densa*) showed that stems were no longer viable after 22 days of exposure due to drawdown (Dugdale et al. 2012).

Two examples of recent drawdowns in Wisconsin that were evaluated for their efficacy in controlling invasive aquatic plants occurred in Lac Sault Dore and Musser Lake, both in Price County, which were conducted in 2010 and 2013, respectively. Dam maintenance was the initial reason for these drawdowns, with the anticipated control of nuisance causing aquatic invasive species as a secondary benefit. Aquatic plant surveys showed that the drawdown in Lac Sault Dore resulted in a 99% relative reduction in the littoral cover of Eurasian watermilfoil when comparing pre- vs. post-drawdown frequencies. Native plant cover expanded following the drawdown and Eurasian watermilfoil cover has continued to remain low (82% relative reduction compared to pre-drawdown) as of 2017 (Onterra 2013). Lake-wide cover of curly-leaf pondweed in Musser Lake decreased following drawdown (63% relative reduction compared to pre-drawdown), and turion viability was also reduced. Reductions in native plant populations were observed, though population recovery could be seen in the second year following the drawdown (Onterra 2016). These examples of water-level drawdowns in Wisconsin show that they can be valuable approaches for aquatic invasive species control in some waterbodies. Water level reduction must be conducted such that a sufficient proportion of the area occupied by the target species is exposed. Numerous other single season winter drawdowns monitored in central Wisconsin by department staff show similar results (Scott Provost [DNR], *personal communication*). Careful timing and proper duration is needed to maximize control of target species and growth of favorable species.

S.3.5.Biological Control

Biological control refers to any method involving the use of one organism to control another. This method can be applied to both invasive and native plant populations, since all organisms experience growth limitation through various mechanisms (e.g., competition, parasitism, disease, predation) in their native communities. As such, when control of aquatic plants is desired it is possible that a growth limiting organism, such as a predator, exists and is suitable for this purpose.

Care must be taken to ensure that the chosen biological control method will effectively limit the target population and will not cause unintended negative effects on the ecosystem. The world is full of examples of biological control attempts gone wrong: for example, Asian lady beetles (*Harmonia axyridis*) have been introduced to control agricultural aphid pests. While the beetles have been successful in controlling aphid populations in some areas, they can also outcompete native lady beetles and be a nuisance to humans by amassing on buildings (Koch 2003). Additionally, a method of control that works in some Wisconsin lakes may not work in other parts of the state where differing water chemistry and/or biological communities may affect the success of the organism. The department recognizes the variation in control efficacy and well as potential unintentional effects of some organisms and is very cautious in allowing their use for control of aquatic plants.

Purple loosestrife beetles

The use of herbivorous insects to reduce populations of aquatic plants is another method of biocontrol. Several beetle species native to Eurasia (*Galerucella calmariensis*, *G. pusilla*, *Hylobius transversovittatus*, and *Nanophyes marmoratus*) have been well-studied and intentionally released in North America for their ability to suppress populations of the invasive wetland plant, purple loosestrife (*Lythrum salicaria*). These beetles only feed on loosestrife plants and therefore are not a threat to other wetland plant species (Kok et al. 1992; Blossey et al. 1994a, 1994b; Blossey and Schroeder 1995). The department implements a purple loosestrife biocontrol program, in which citizens rear and release beetles on purple loosestrife stands to reduce the plants' ability to overtake wetlands, lakeshores, and other riparian areas.

Beetle biocontrol can provide successful long-term control of purple loosestrife. The beetles feed on purple loosestrife foliage which in turn can reduce seed production (Katovich et al. 2001). This approach typically does not eradicate purple loosestrife but stresses loosestrife populations such that other plants are able to compete and coexist with them (Katovich et al. 1999). Depending on the composition of the plant community invaded by purple loosestrife and the presence of other non-native invasive species, further restoration efforts may be needed following biocontrol efforts to support the regrowth of beneficial native plants (McAvoy et al. 2016).

Several factors have been identified that may influence the efficacy of beetle biocontrol of purple loosestrife. Purple loosestrife beetles have for the most part been shown to be capable of successfully surviving and establishing in a variety of locations (Hight et al. 1995; McAvoy et al. 2002; Landis et al. 2003). The different species have different preferred temperatures for feeding and reproduction (McAvoy and Kok 1999; McAvoy and Kok 2004). In addition, one study suggests that the number of beetles introduced does not necessarily correlate with greater beetle colonization (Yeates et al. 2012). Disturbance, such as flooding and predation by other animals on the beetles, can also reduce desired effects on loosestrife populations (Nechols et al. 1996; Dech and Nosko 2002; Denoth and Myers 2005). Finally, one study suggests that the use of triclopyr amine for purple loosestrife control may be compatible with beetle biocontrol, although there may be negative effects on beetle egg-batch size or indirect effects if the beetle's food source is too greatly depleted (Lindgren et al. 1998). Some mosquito larvicides may harm purple loosestrife beetles (Lowe and Hershberger 2004).

Milfoil weevils

Similar to the use of beetles for biological control of purple loosestrife, the use of milfoil weevils (*Euhrychiopsis lecontei*) has been investigated in North America to control populations of non-native Eurasian and hybrid watermilfoils (*Myriophyllum spicatum* x *sibiricum*). This weevil species is native to North America and is often naturally present in waterbodies that contain native watermilfoils, such as northern watermilfoil (*M. sibiricum*). The weevils have the potential to damage Eurasian watermilfoil (*M. spicatum*) by feeding on stems and leaves and/or burrowing into stems. Weevils may reduce milfoil plant biomass, inhibit growth, and compromise buoyancy (Creed and Sheldon 1993; Creed and Sheldon 1995; Havel et al. 2017a). Damage caused to the milfoil tissue may then indirectly increase susceptibility to pathogens (Sheldon and Creed 1995).

In experiments, weevils have been shown to negatively impact Eurasian watermilfoil populations to varying degrees. Experiments by Creed and Sheldon (1994) found that plant weight was negatively affected when weevils were at densities of 1 and 2 larvae/tank, and Eurasian watermilfoil in untreated control tanks added more root biomass than those in tanks with weevils, suggesting that weevil larvae may interfere with the plant's ability to move nutrients. Similarly, experiments by Newman et al. (1996) found that weevils at densities of 6, 12, and 24 adults/tank caused significant decreases in Eurasian watermilfoil stem and root biomass, and that higher weevil densities generally produced more damage.

In natural communities, effects of weevils have been mixed, likely because waterbody characteristics may play a role in determining weevil effects on Eurasian watermilfoil populations in natural lakes. In a 56 ha (138 acre) pond in Vermont, weevil density was negatively associated with Eurasian watermilfoil biomass and distribution; Eurasian watermilfoil beds were reduced from 2.5 (6.2 acres) to 1 ha (2.5 acres) in one year, and biomass decreased by 4 to 30 times (Creed and Sheldon 1995). A survey of Wisconsin waterbodies conducted by Jester et al. (2000) revealed that most lakes containing Eurasian watermilfoil also contained weevils. Weevil abundance varied from functionally non-detectable to 2.5 weevils/stem and was positively associated with the presence of large, shallow Eurasian watermilfoil beds (compared to deep, completely submerged beds). There was no relationship between natural weevil abundance and Eurasian watermilfoil density between lakes. However, when the authors augmented natural weevil populations in plots in an attempt to achieve target densities of 1, 2, or 4/stem, they found that augmentation was associated with significant decreases in Eurasian watermilfoil biomass, stem density and length, and tips/stem (Jester et al. 2000). However, another more recent study conducted in several northern Wisconsin lakes found no effect of weevil stocking on Eurasian watermilfoil or native plant biomass (Havel et al. 2017a).

There are several factors to consider when determining whether weevils are an appropriate method of biocontrol. First, previous research has suggested that densities of at least 1.5 weevils per stem are required for control (Newman and Biesboer 2000). Adequate densities may not be achievable due to factors including natural population fluctuations, the amount of available milfoil biomass within a waterbody, the presence of insectivorous predators, such as bluegills (*Lepomis macrochirus*), and the availability of nearshore overwintering habitat (Thorstenson et al. 2013; Havel et al. 2017a). In addition, weevils fed and reproduce on native milfoil species and biocontrol efforts could potentially impact these species, although experiments conducted by Sheldon and Creed (2003) found that native milfoil weevil density was lower and weevils caused less damage than when they were found on Eurasian watermilfoil. Adult weevils spend their winters on land, so available habitat for adults must be present for a waterbody to sustain weevil populations (Reeves and Lorch 2011; Newman et al. 2001). Additionally, one study found that lakes with no Eurasian watermilfoil (despite the presence of other milfoil species) and lakes that had a recent history of herbicide treatment had lower weevil densities than similar, untreated lakes or lakes with Eurasian watermilfoil (Havel et al. 2017b).

Grass carp – not allowed in Wisconsin

The use of grass carp (*Ctenopharyngodon idella*) to control aquatic plants is not allowed in Wisconsin; they are a prohibited invasive species under ch. NR 40, Wis. Admin. Code, which makes it illegal to possess, transport, transfer, or introduce grass carp in Wisconsin.

Sterile (also known as triploid) grass carp have been used to control populations of aquatic plants with varying success (Pípalová 2002; Hanlon et al. 2000). Whether this method is effective depends on several factors. For instance, each individual fish must be tested to ensure sterility before stocking, which can be a time- and resource-consuming process. Since the sterile fish do not reproduce, it can be difficult to achieve the desired density in a given waterbody. In addition, grass carp, like many fish species, have dietary preferences for different plant species which must be considered (Pine and Anderson 1991). Further information summarizing the effects of stocking triploid grass carp can be found in Pípalová (2006), Dibble and Kovalenko (2009), and Bain (1993).

F

APPENDIX F

Summary Sheet: <u>Effects of 2,4-D Herbicide Treatments used to Control Eurasian Watermilfoil on Fish and Zooplankton in Northern Wisconsin Lakes</u>

Effects of 2, 4-D Herbicide Treatments Used to Control Eurasian Watermilfoil on Fish and Zooplankton in Northern Wisconsin Lakes

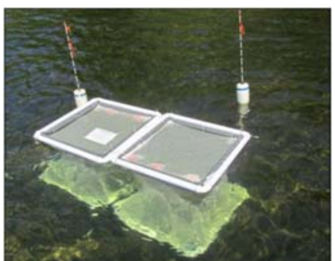
Larval Black Crappie

Eurasian Watermilfoil (EWM; *Myriophyllum spicatum*) is one of the most prolific aquatic invasive plants in North America. Since the 1950s, the herbicide 2, 4-dichlorophenoxyacetic acid (2, 4-D) has been used to control EWM. Little was known regarding the effect of 2, 4-D treatments on young fish and zooplankton outside of a few laboratory studies. Increasing demand for whole-lake 2, 4-D treatments to control EWM in Midwest lakes warranted additional examination of fish and zooplankton responses to these treatments. Our sampling occurred over 3 years (2015-2017) on 6 lakes in northern Wisconsin. No treatment occurred on any lake in 2015 (pre-treatment) or 2017 (post-treatment). In 2016, whole lake treatments using 2, 4-D were conducted on 3 lakes between May 24th and June 7th; the remaining 3 lakes served as reference systems.

Zooplankton and Larval Fish

Zooplankton are the first prey item for all larval fish. Zooplankton were sampled from May through August. Larval fish were collected each year from May through July using ichthyoplankton nets and quatrefoil light traps. Otoliths (a bone from the inner ear) develop rings similar to trees, and were removed from larval black crappie to determine hatch dates and daily growth rates. Larval crappie diets were examined to determine any changes in feeding success.

Ichthyoplankton tow nets (left) and light traps (right) were set overnight to catch larval fish.



Net pens used to hold juvenile fish during 2,4-D treatments.

Juvenile and Adult Fish

Juvenile and adult fish were sampled from May to August of each year using seines and electrofishing. Net pen trials with juvenile yellow perch or bluegill (< 5 inches) were conducted before, during, and after herbicide applications to assess mortality.

Aquatic Plants and 2, 4-D Concentrations

Aquatic plants were sampled once in late summer of each year to monitor changes in abundance of both native plants and EWM. Water samples were collected to determine concentration of 2, 4-D up to 62 days post-treatment.

Larval fish otolith magnified to show daily rings.

Results

Peak concentrations of 2, 4-D were lower than expected (0.152 to 0.257 ppm), but no EWM was detected after herbicide treatments in 2016. In 2017, EWM was sampled in Kathan Lake (4% vegetative coverage) and Manson Lake (9.4% vegetative coverage), but was not detected in Silver Lake. Zooplankton densities were similar within lakes in 2015 and 2016, but different trends were observed for some zooplankton in treatment lakes in 2017. Peak abundance of larval yellow perch was visually (but not statistically) lower in the year after herbicide was applied (2017) and this was not observed in reference lakes. No significant effect was observed on peak abundance of larval largemouth bass, minnows, black crappie or bluegill. Larval black crappie showed no detectable response in growth or feeding success. There was no difference between treatments in juvenile yellow perch abundance from August seines. 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. The lack of statistically significant responses to 2, 4-D herbicide treatments observed in our evaluation does not mean that herbicide application has no effects. However, potential effects may not be detectable in a lake setting given the inherent variation in many of the metrics we measured. Observed declines in larval yellow perch abundance and changes in zooplankton trends for treatment lakes in the year after herbicide treatments occurred, may be a result of changes in aquatic plant communities and not a direct effect of treatment. These observations warrant further investigation.

For additional information contact: Nick Rydell, Nick.Rydell@uwsp.edu

G

APPENDIX G

Comment Response Document for the Official First Draft

Comments to Upper Gresham Lake Draft Aquatic Plant Management Plan (9/19/19) – Comments Received 11/26/2019

Response by Eddie Heath (Onterra, LLC)
Response by Paul Garrison (Onterra, LLC)

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

Contributing comments by:

Kevin Gauthier (Regional Lake Biologist)
Scott Van Egeren (Regional Lake Biologist)
Ty Krajewski (Water Resource Management Specialist)
Jordan Petchenik (Resource Sociologist)
Susan Knight (UW Trout Lake Station Center for Limnology Research Scientist)
Michelle Nault (State-Wide Lakes & Reservoir Ecologist)

We have reviewed the Upper Gresham Lake Plan. We offer these comments from our review.

1. General comment: This is a comprehensive, highly readable evaluation of the Gresham Lakes, including coverage of many topics pertinent to other lakes.

2. Very nice discussion of phosphorus in intro.

3. Typos:
    a. p.21. Change *ration* to *ratio*. Edit made
    b. p.22 (last line) Change *organ* to *organic.* Edit made
    c. P. Fig. 3.1-14 Change *How as* to *How has.* Edit made
    d. P.41. change *aUpper Gresham Lake shorelands* to *along Upper Gresham Lake shorelands.* Edit made

4. p.20. Did you mean that summer P and Secchi are both decreasing since 2000? Maybe P is going up? Correct – change made. Also inserted figure 3.1-8 that shows trend analysis.

5. p.23 It looks like there is ***not*** enough oxygen (<5mg/l) to support the fishery for half the water column in winter (??). What is the minimum for fish? Is it assumed fish can swim up in the water column (until they hit ice)? I guess most of the lake may not achieve depths below which there is no oxygen. Additional discussion was added

6. Fig. 3.2-1. If each open circle is one of a pair from a lake, picturing them all the same (as open circles) seems insignificant? The purpose of the non-labeled open circles is to give a sense that the Gresham lakes are not that unusual limnologically from other lakes.

7. Great discussion of historic and modern diatom analysis. It seems like the nutrient data (increased N,P in modern times) is in contrast with findings from the LDCI that the

diatom community is mostly unchanged. Does this mean the LDCI is of limited use in cases such as Upper Gresham (UG) where the change is small? It seems like the change in N,P in UG warrants a warning to the lake group to try to mediate against increased nutrient inputs, even though the diatom community has not seen major changes (??). The LDCI incorporates nutrients but also other ecological factors. This means that it classifies the lake for nutrients as well as community diversity and overall community integrity. This means that nutrients can increase some and the lake can still maintain a good ecological integrity. This is what has happened in Upper Gresham Lake. In other words, P and N are currently higher than they were historically but the lake has maintained its good ecological integrity. This is a common result of shore land development in northern lakes. If nutrient levels continue to increase eventually the ecological integrity of the lake will decline.

8. Sediment core indicates that nutrient levels now are higher than pre-development and that this is likely from shoreland development. Shoreland and watershed development. This includes impact from some of the early practices, which included clear-cut logging and little consideration to erosion abatement during building.

9. p.37. Watershed analysis. I appreciate that the nearby cranberry operation is not in the UG watershed, and that water removed from UG for the cranberry operation in fall is not returned to UG. However, the analysis that an increase in row crops could have a large impact on the N & P inputs in UG raises the question of what would happen if a new cranberry operation were developed in the UG watershed. Is it reasonable to assume a cranberry operation within the UG watershed would have the same effect as a row crop in your hypothetical scenario? An additional paragraph was added. Some estimates indicate 3.4-5.3 kg/ha/yr phosphorus exports from cranberry bog compared to 1.0 kg/ha/yr from row crop agriculture. That being said, cranberry production operations often can alter runoff timing and location using pumps, which would change their potential impact to a lake.

10. p.45. While the area of disturbed shoreland is low in UG, it looks like it is high if you only consider the non-State Forest lands. Perhaps it would be useful to show a pie chart of the level of disturbance within the privately-owned lands? That would emphasize that riparian residents are responsible for considerable disturbance along the lake edge. Suggestion included.

11. p.59. Isn't it odd that the hardest sediments are deeper? Could that be evidence that aquatic plant growth along the shore has changed in modern times and is creating near-shore mucky sediments in recent history? But, since 66% of the lake has plants, recent aquatic plant expansion maybe is not responsible for this pattern of sediments. Interesting speculation. No changes made.

12. Page 60: Aquatic plant rake fullness from PI surveys is trending down – don't really know why I guess, but if and when this occurs, extra caution should be taken if and

when any aquatic plant management might be proposed/permitted. The WDNR's perspective is acknowledged.

13. General Comment: I could have missed this, but there seems to be a lack of mention and/or recognition of the all of the data collected by the Isermann project – seems like this would be important to recognize all that was collected and available for use, even if this plan didn't use it, or much of it – this might be in one of the appendices? Discussion of these data are generically mention on page 76-77, with Appendix F containing the one-page summary. We encourage the WDNR to include this project's final deliverables under this project's grant page, allowing a stable URL to be included in future reporting.

14. pp. 63-65, 69. Why not a graph of EWM like you have for the natives? The LFOO figure for EWM is on page 72 (Fig 3.5-12) in the separate EWM sub-section.

15. Page 71, 1st paragraph: Just some more thoughts on fluctuating aquatic plant abundance is indicative of normal, healthy aquatic systems. As lake ecologists, we continually observe ebb and flow of populations of all sorts of species. Variability in ewm is comparable to walleye, or snails, or small mammals or any number of naturally occurring populations. The EWM levels observed in unmanaged lakes has not negatively impacted lake ecology. What has been found is EWM levels within lakes can impact some recreation at some points in some years, but there is a lot of annual variation and not all years have levels that impact recreation. Emphasize that variability across lake types and through time is normal ecology. The WDNR's perspective is acknowledged.

16. p.75. Was it not possible to evaluate EWM treatment areas in 2019? This document was written before the September 2019 Late-Season EWM Mapping Survey occurred. These data are now available and integrated into the report.

17. P.76. Was there any evaluation of native plants through these spot treatments? Granted, the acreage is small, but if the chemical is moving off-site, could it be affecting non-target plants? Native plant monitoring did not occur. Discussion of impacts is mentioned on page 76.

18. EWM has been in the system for quite a while, at least since 2001 (pg 71), likely longer. Like many/most other lakes, it has not demonstrated any lake-wide long-term ecological impacts. It can get abundant and reach the surface in spots and may be a recreational issue at some places during some years, but this also seems variable. Because of this, EWM management should be focused on monitoring and then managing if and when EWM is impacting recreation with the least impactful management to alleviate the recreational issue (perhaps mechanical harvesting?) The WDNR's perspective is acknowledged.

19. P.93. The statement "Future spot treatments…" gives the impression that some of these chemicals, such as Florpyrauxifen-benzyl (ProcellaCor) are known to be more effective under short exposure situations. This has not yet been substantiated under

field conditions as far as we know, at least for ProcellaCor. The text indicates "thought to be more effective under short exposure situations than with traditional weak-acid auxin herbicides." An additional qualifying statement was added.

20. Page 93: It is stated in the 'Herbicide spot treatment' section that if they were going to use 'new-to-the-region herbicide strategies' that WDNR could request the quantitative pre/post sub-PI monitoring assessment vs. just comparing the late-season EWM bed mapping surveys. No real comment/change requested here, but just reiterating that the Department may ask for this more rigorous quantitative assessment if they decide to go down that 'new herbicide' route (esp. ProcellaCOR where we currently have very limited data and are hoping to learn more). The WDNR's perspective is understood.

21. Page 95: In the 'Mechanical Harvesting' section it states that harvesting would "*cut no more than half the water*". I'm not totally clear on what this means. Cut no more than 50% of the surface area of the lake? Only cut 50% of the plant biovolume within the water column (i.e., in 8 ft of water, only cut plants 4 ft tall?). I would ask for some clarity on this. Cut more than half the water "depth." The last word (depth)was not present within first draft). This is a standard WDNR condition of mechanical harvesting permits.

22. Page 93, the plan says DNR prefers hand harvesting: DNR will still evaluate data and make annual recommendations/decisions based on this – perhaps we recommend using the least secondarily impactful method that is feasible to alleviate an aquatic plant issue. This statement was added to the document.

23. Page 96: DNR will always work with the lake association to determine the appropriate strategy for EWM management that reduces recreational nuisance and minimizes the loss of ecosystem value. DNR is fine with setting a setting a target criteria in order to start a discussion about a change in management strategy, However, ultimately DNR and the lake group must weigh the level of nuisance and the potential ecological costs of the management when making a decision to move to a more aggressive and ecologically damaging management strategy. DNR will not automatically permit any given aquatic plant management activity based on passing a frequency of occurrence criteria alone. The WDNR's perspective is understood.

24. Upper Gresham is generally high quality so protecting high quality areas and/or areas that could become high quality, and making any improvements in habitat and storm water mgmt. should be the biggest, most important implementation action items in the plan. The WDNR's perspective is understood.

    While the biota measured (I guess mainly through the PI surveys and diatom assemblages in the sediment core) and water quality indicate a "healthy" lake system, it is concerning that the water quality has changed quite a bit since pre-development given that the watershed is about as good it can get – i.e., forested….stormwater management and shoreland stewardship should be of the utmost priority (studying AIS and secondarily managing AIS should be done in context with stormwater management and shoreland stewardship – these should not be thought of as separate and independent of each other activities). The plan seems to be a little soft here. Lakes like the Gresham Lakes should be focused on protecting anything that is high quality before it degrades, and improving areas that could use help – these are the long-term strategies to keep and improve the HEALTH of the lakes (i.e., the fish, the loons, dragonflies, the aquatic plants, minimize AIS establishment and expansion and ultimately annual abundance, property values….) Additional text added to the Summary/Conclusions section.

Additions to implementation plan may include: Appreciate these examples for future discussion and consideration by the GLA.

a. For protection – recommend providing the Northwoods Land Trust info as an option for landowners looking to protect what they have and love forever.
    i. Could also highlight "high" quality areas and how important stewardship of these areas is, so that current landowners in these areas are either recognized for their already good practices in place and/or are encouraged to take steps to keep and protect them. These could include large % of buffer area intact and/or the 3 layers of shoreland (grasses/shrubs/canopy), species diversity from point intercept (PI) surveys (check out the APM APP attached below that Ali created), lots of wood, others….?
b. For improving – just encourage everyone to keep promoting and finding folks to actually take on improvement projects. A lot of the maps from the shoreland surveys provide clues on where to start looking…Vilas County Land and Water is looking for folks to work with and will plan and potentially sponsor projects. I also would encourage lake leaders from each lake to take a close look at their properties and sponsor projects where appropriate as demonstration projects.
    i. Could also encourage a pledge of sorts by property owners to keep their shoreland areas healthy also – i.e., no mow, weed whack, leaf blowing, picking up sticks, other? And in these areas, keep a record of plants and animals found over time.
c. In the future you could use the State shoreland protocol to help identify high quality and improvement areas.