A

APPENDIX A

Public Participation Materials

Management Planning Meeting

Tomahawk Lake Association

APM Planning Project
Planning Meeting I

March 8, 2022

AEPP-629-21
AEPP-640-21
AEPP-641-21

Eddie Heath
Onterra LLC
Lake Management Planning

TOMAHAWK LAKE Association, Inc.
Hazelhurst • Lake Tomahawk • Minocqua • Woodruff

Presentation Outline

- Why Create a Management Plan
- Aquatic Plants
- Aquatic Invasive Plants
- Best Management Practices (BMPs) & Integrated Pest Management (IPM) Strategies
- Implementation Plan

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Onterra, LLC

- Founded in 2005
- Staff
  - Four full-time ecologists
  - One part-time paleoecologist
  - Two full-time field technicians
  - 4/5 summer interns
- Services
  - Science and planning
- Philosophy
  - Promote realistic planning
  - Assist, not direct

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Why Create a Lake Management Plan?

- Preserve/restore ecological function
- To create a better understanding of lake's positive and negative attributes.
- To discover ways to minimize the negative attributes and maximize the positive attributes.
- Snapshot of lake's current status or health.
- Foster realistic expectations and dispel any misconceptions.

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Management Plan and Grants

- WDNR recommends *Comprehensive Lake Management Plans* generally get updated every 10 years (implementation grants)
  - longer if a plan has been actively implemented and updated during its lifespan
- WDNR recommends lakes conducting active management update aspects of the plan every 5 years (AIS control grants)
  - longer if a plan has been actively implemented and updated during its lifespan and whole-lake PI survey is within 5 years

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Management Planning History

- Comprehensive Management Plan – 2016
- Official Mechanical Harvesting Addendum – November 2021

Grant Number	Project Name	Amount
AIRR-0003-05	EWM Rapid Response	$4,000.00
LPL-1109-07	Mgmt Plan (Phase I)	$7,800.00
LPL-1110-07	Mgmt Plan (Phase II)	$10,000.00
LPL-1152-07	Mgmt Plan (Phase III)	$10,000.00
SPL-137-07	Mgmt Plan (additonal waterbodies)	$3,000.00
AIRR-026-07	EWM Rapid Response: APM Plans	$10,000.00
AIRR-045-08	EWM Rapid Response; Strategy #1	$9,622.50
AIRR-046-08	EWM Rapid Response; Strategy #2	$10,000.00
ACEI-051-08	HCS Demo Project (2008)	$45,033.50
ACEI-063-09	AIS Control Project (2009-2011)	$149,701.00
ACEI-093-11	AIS Control Project (2011-2012)	$173,333.00
ACEI-130-13	AIS Control Project (2013-2014)	$173,333.00
LPL-1553-14	Comp Lake Mgmt Plan (Phase I)	$24,332.00
LPL-1554-14	Comp Lake Mgmt Plan (Phase 2)	$16,692.00
ACEI-166-15	AIS Control Project (2015)	$79,505.25
ACEI-185-16	AIS Control Project (2016)	$82,733.70
ACEI-198-17	AIS Control Project (2017)	$25,000.00
ACEI-215-18	AIS Control Project (2018)	$23,277.30
AEPP-548-18	AIS Monitoring, Mapping, Planning (2018)	$24,400.00
LPL-1688-19	Shoreland Restoration & Mapping	$8,723.40
AEPP-577-19	AIS Monitoring, Mapping, Planning (2019)	$20,119.64
AEPP-629-21	APM Plan Update (EWM Mapping Phase)	$9,483.85
AEPP-640-21	APM Plan Update (PI Survey Phase)	$9,406.80
AEPP-641-21	APM Plan Update (Mgmt Planning Phase)	$8,649.70
		$938,146.64

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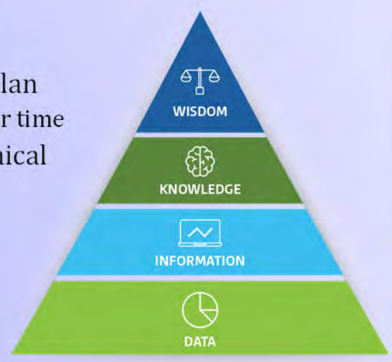
Management Planning Project Overview

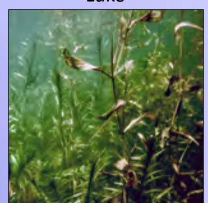
- Collect & analyze data
  - Technical & sociological
- Construct long-term & useable plan
  - Living plan subject to revision over time
- Onterra's role is to provide technical direction
  - Not really recommendations



Native Aquatic Plants

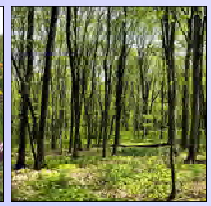
- Foundation of the lake ecosystem
- Provide oxygen, food, and shelter
- Play a role in water quality
- Stabilize bottom and shoreline sediments

Lake



Grasslands

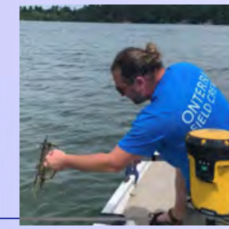
Forest



Point-Intercept Surveys

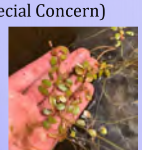
- Systematic approach to collecting aquatic plant information from a waterbody
- Using established protocol, WDNR dictates grid spacing
  - Snapshot of current plant community
  - Trend analysis (2007, 2014, 2021)
  - Allows comparisons between lakes (state, ecoregion)

Lake	Distance Between Sampling Points (meters)	Number of Sampling Locations
Tomahawk Lake	58	4149
Little Tomahawk Lake	35	536
Tomahawk Thoroughfare	58	134
Mud Lake	35	89
Paddle Pond	25	27
Inkwell Lake	35	43



2021 Species List

- ~62 total species within/around Tomahawk Lake system during PI
  - Minimal aquatic plants found within Paddle Pond and Inkwell Lake
  - Natural Heritage Inventory:
    - Vasey's pondweed (Special Concern)

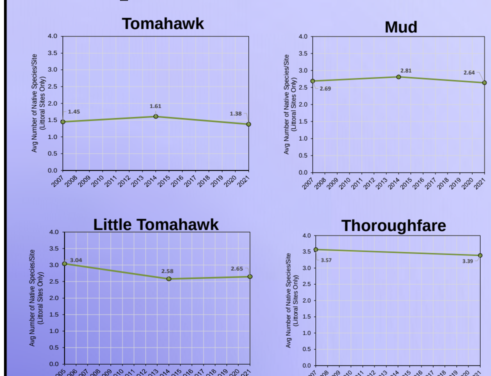


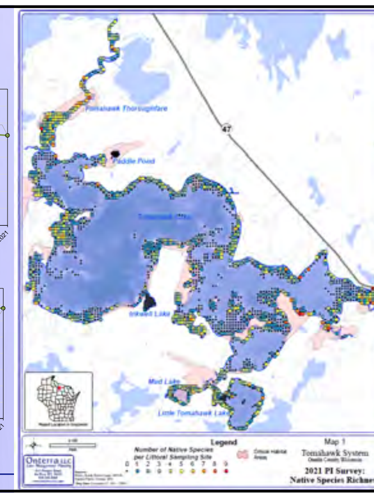
- Non-native Plants:
  - Eurasian watermilfoil
  - Curly-leaf pondweed

Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	Growth Form	Tomahawk 2021	Little Tomahawk 2021	Thoroughfare 2021	Mud 2021
Eleocharis palustris	Creeping spikerush	Native	6	E			X	
Pontederia cordata	Pickerelweed	Native	9	E	X	X	X	
Brasenia schreberi	Watershield	Native	7	FL	X	X	X	X
Nuphar variegata	Spatterdock	Native	6	FL	X		X	X
Nymphaea odorata	White water lily	Native	6	FL	X	X	X	X
Sparganium angustifolium	Narrow-leaf bur-reed	Native	9	FL		X		
Sparganium fluctuans	Floating-leaf bur-reed	Native	10	FL	X			
Bidens beckii	Water marigold	Native	8	S	X	X	X	X
Ceratophyllum demersum	Coontail	Native	3	S	X	X	X	X
Ceratophyllum echinatum	Spiny hornwort	Native	10	S			X	
Chara spp.	Muskgrasses	Native	7	S	X	X	X	X
Elatine minima	Waterwort	Native	9	S	X			
Elodea canadensis	Common waterweed	Native	3	S	X	X	X	X
Elodea nuttallii	Slender waterweed	Native	7	S	X		X	
Heteranthera dubia	Water stargrass	Native	6	S	X	X	X	
Isoetes spp.	Quillwort spp.	Native	8	S	X			
Lobelia dortmanna	Water lobelia	Native	10	S	X			
Myriophyllum alterniflorum	Alternate-flowered watermilfoil	Native	10	S	X			
Myriophyllum sibiricum	Northern watermilfoil	Native	7	S	X	X	X	X
Myriophyllum spicatum	Eurasian watermilfoil	Non-Native - Invasive	N/A	S	X	X	X	
Myriophyllum tenellum	Dwarf watermilfoil	Native	10	S	X	X		
Najas flexilis	Slender naiad	Native	6	S	X	X	X	
Najas guadalupensis	Southern naiad	Native	7	S	X	X	X	X
Nitella spp.	Stoneworts	Native	7	S	X		X	
Potamogeton alpinus	Alpine pondweed	Native	9	S			X	
Potamogeton amplifolius	Large-leaf pondweed	Native	7	S	X	X	X	X
Potamogeton berchtoldii	Slender pondweed	Native	7	S	X			
Potamogeton crispus	Curly-leaf pondweed	Non-Native - Invasive	N/A	S			X	
Potamogeton epihydrus	Ribbon-leaf pondweed	Native	8	S			X	
Potamogeton foliosus	Leafy pondweed	Native	6	S	X	X	X	
Potamogeton friesii	Fries' pondweed	Native	8	S	X	X		X
Potamogeton gramineus	Variable-leaf pondweed	Native	7	S	X	X	X	
Potamogeton hybrid 1	Pondweed Hybrid 1	Native	N/A	S	X			
Potamogeton illinoensis	Illinois pondweed	Native	6	S	X	X	X	
Potamogeton natans	Floating-leaf pondweed	Native	5	S	X		X	
Potamogeton praelongus	White-stem pondweed	Native	8	S	X	X	X	
Potamogeton pusillus	Small pondweed	Native	7	S	X	X	X	
Potamogeton richardsonii	Clasping-leaf pondweed	Native	5	S	X	X	X	
Potamogeton robbinsii	Fern-leaf pondweed	Native	8	S	X	X	X	X
Potamogeton spirillus	Spiral-fruited pondweed	Native	8	S	X			
Potamogeton strictifolius	Stiff pondweed	Native	8	S	X			X
Potamogeton vaseyi	Vasey's pondweed	Native - Special Concern	10	S			X	
Potamogeton zosteriformis	Flat-stem pondweed	Native	6	S	X	X	X	X
Ranunculus aquatilis	White water crowfoot	Native	8	S	X	X	X	
Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	Native	N/A	S	X	X		
Stuckenia pectinata	Sago pondweed	Native	3	S	X	X	X	
Utricularia intermedia	Flat-leaf bladderwort	Native	9	S				X
Utricularia minor	Small bladderwort	Native	10	S			X	X
Utricularia purpurea	Large purple bladderwort	Native	9	S	X	X		X
Utricularia vulgaris	Common bladderwort	Native	7	S	X		X	X
Vallisneria americana	Wild celery	Native	6	S	X	X	X	
Eleocharis acicularis	Needle spikerush	Native	5	S/E	X	X	X	
Juncus pelocarpus	Brown-fruited rush	Native	8	S/E	X			
Sagittaria cristata	Crested arrowhead	Native	9	S/E	X			
Schoenoplectus subterminalis	Water bulrush	Native	9	S/E	X			
Lemna minor	Lesser duckweed	Native	5	FF	X			
Lemna trisulca	Forked duckweed	Native	6	FF	X	X	X	
Spirodela polyrhiza	Greater duckweed	Native	5	FF	X		X	

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; FF = Free Floating; S= Submergent; E = Emergent
X = Located on rake during point-intercept survey

Species Richness

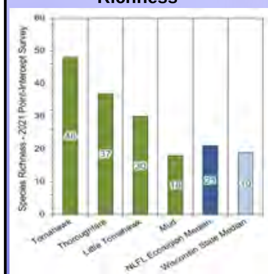


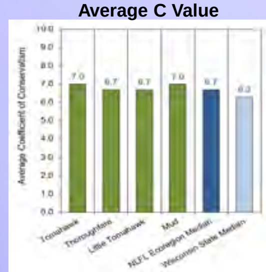


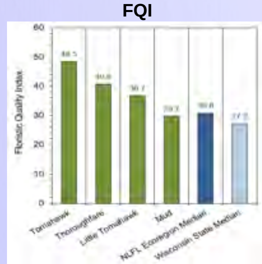
Floristic Quality

Evaluates the closeness of a lake's flora to undisturbed conditions.

*FQI = Average Coefficient of Conservatism * √ Number of Native Species*







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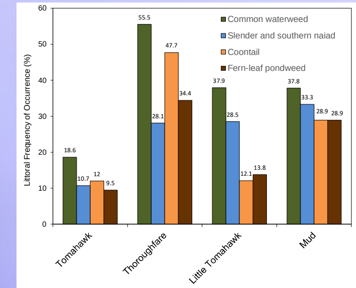
Dominant Species

Common waterweed
- No true-roots

Slender & southern naiad
- Slender is annual (left)
- Southern is perennial (right)



Coontail
- No true-roots

Fern Pondweed
- Low-growing
- Year round

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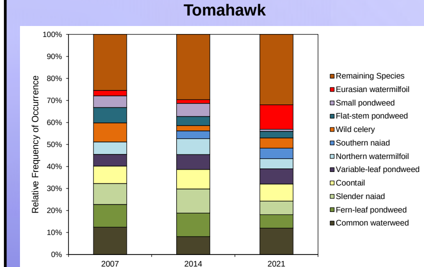
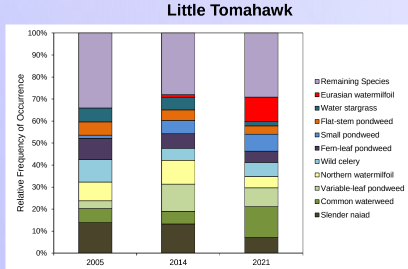
Relative Frequency





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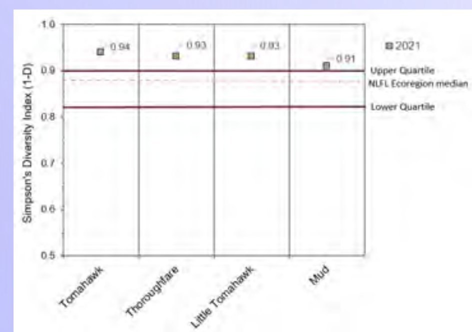
Species Diversity

- Simpson's Diversity Index
  - Likelihood of next plant encountered is different from previous one
  - Species Richness
  - Evenness of distribution



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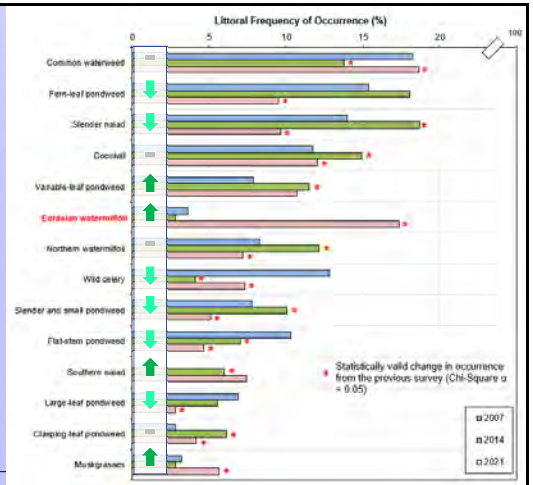
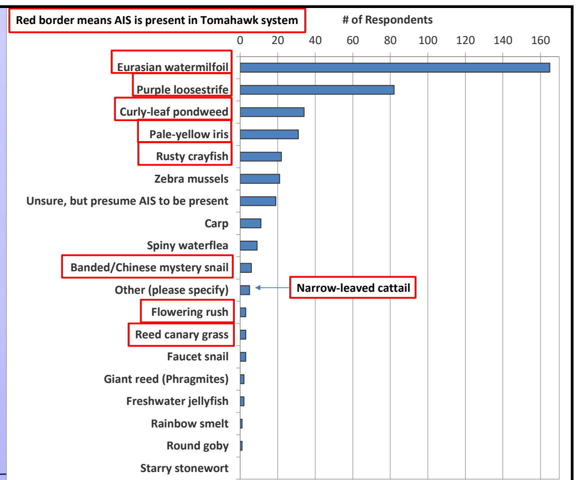
Tomahawk Lake Littoral Frequency



Riparian Perceptions

41.3% Response Rate

Which aquatic invasive species do you believe are present in or immediately around the Tomahawk Lakes?



AIS Prevention & Containment

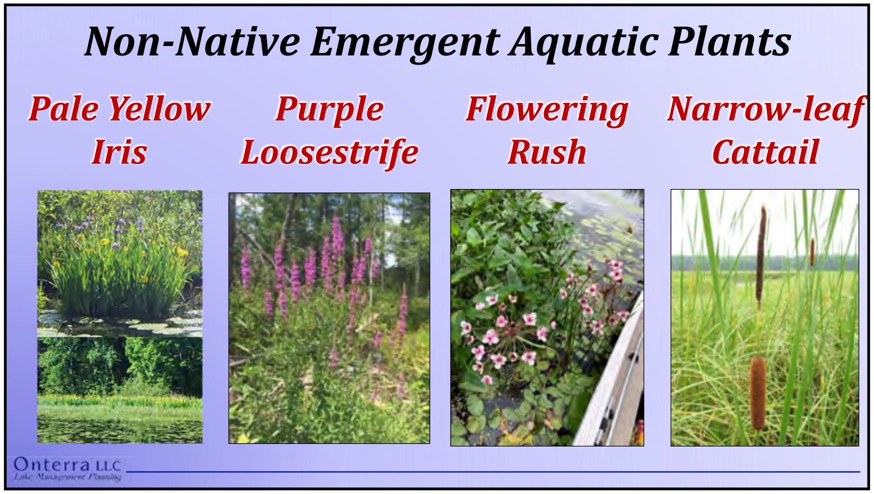
Clean Boats Clean Waters

Indian Mounds Campground	2015	2016	2017	2018	2019	2020
Boats Inspected	132	347	453	785	816	759
Hours Spent	36	229	350	182	268	181
Boats Inspected/Hrs Spent	0.27	0.66	0.77	0.23	0.33	0.24

Coffen Ln off Hwy 47	2015	2016	2017	2018	2019	2020
Boats Inspected	1,783	1,971	1,734	1,900	1,883	2,021
Hours Spent	304	322	319	332	340	356
Boats Inspected/Hrs Spent	0.17	0.16	0.18	0.17	0.18	0.18

Supplemental?

- UW-CFL identified as top 300 AIS Prevention
  - Decontamination stations
  - Remove video surveillance


Non-Native Emergent Aquatic Plants
Pale Yellow Iris
Purple Loosestrife
Flowering Rush
Narrow-leaf Cattail
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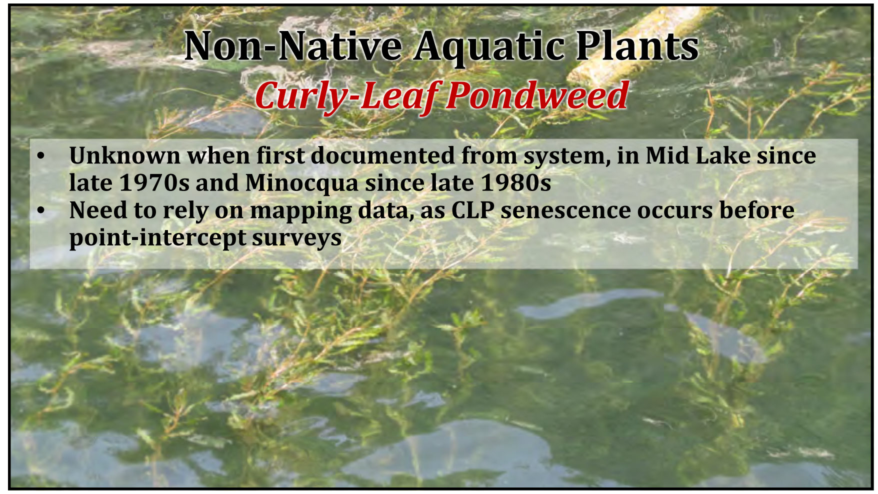
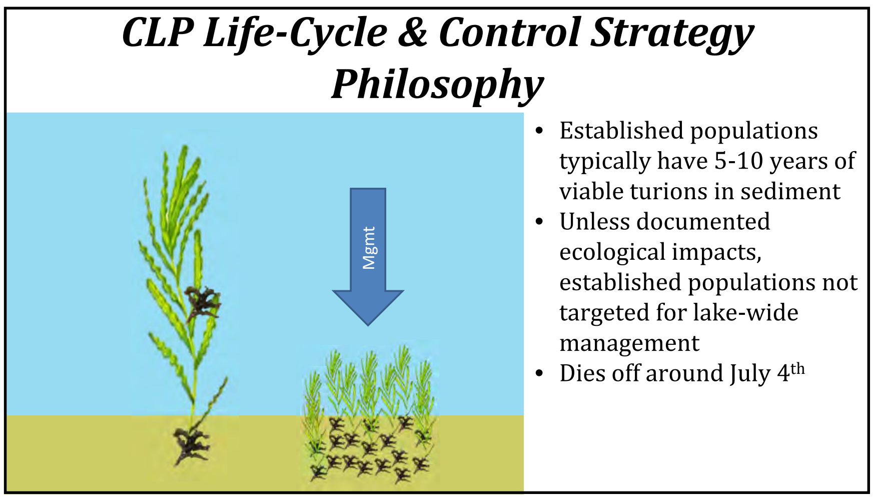
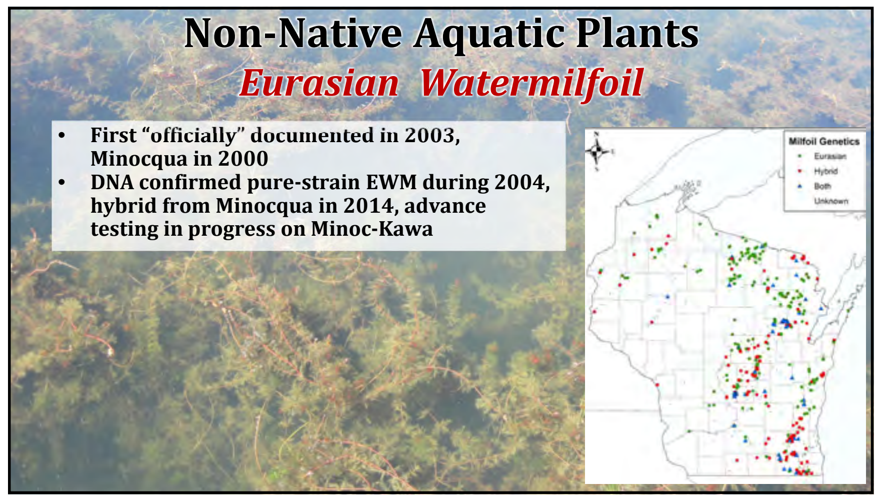
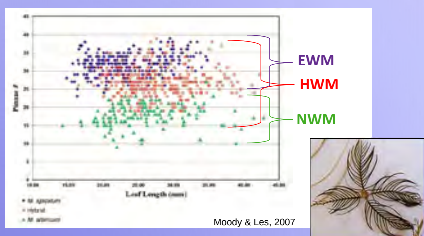
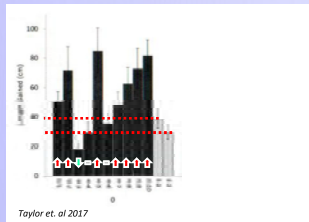

Non-Native Aquatic Plants
Curly-Leaf Pondweed
• Unknown when first documented from system, in Mid Lake since late 1970s and Minocqua since late 1980s
• Need to rely on mapping data, as CLP senescence occurs before point-intercept surveys


CLP Life-Cycle & Control Strategy Philosophy
Mgmt
• Established populations typically have 5-10 years of viable turions in sediment
• Unless documented ecological impacts, established populations not targeted for lake-wide management
• Dies off around July 4th


Non-Native Aquatic Plants
Eurasian Watermilfoil
• First "officially" documented in 2003, Minocqua in 2000
• DNA confirmed pure-strain EWM during 2004, hybrid from Minocqua in 2014, advance testing in progress on Minoc-Kawa
Milfoil Genetics
Eurasian
Hybrid
Both
Unknown

Science on Invasive Watermilfoil Hybridity





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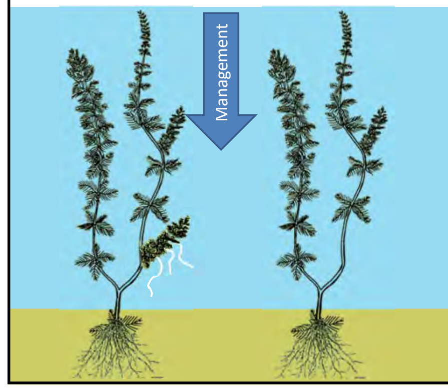
EWM Life-Cycle & Control Strategy Philosophy



- Strategy is straight-forward compared to CLP management
- Herbicide needs to translocate to root crown (*hard to kill with herbicides*)
- Hand-harvesting is analogous to single treatment (*extremely time intensive)*
- Winter drawdown can be effective if completely de-water and desiccate/freeze roots.

Types of Aquatic Plant Surveys

Quantitative

- Point-Intercept Survey
  - Numeric & systematic
  - Applied at various scales

Qualitative

- EWM Mapping Surveys
  - Fine-scale location accuracy
  - Subjective designations

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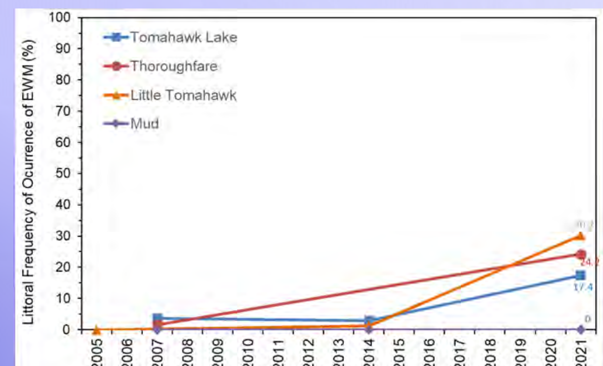
EWM LFOO



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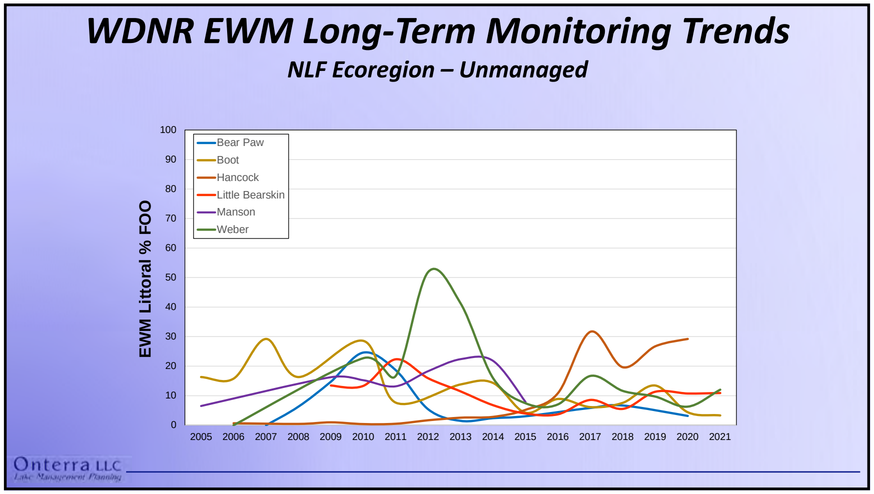
WDNR EWM Long-Term Monitoring Trends
NLF Ecoregion – Unmanaged
EWM Littoral % FOO
100
90
80
70
60
50
40
30
20
10
0
Bear Paw
Boot
Hancock
Little Bearskin
Manson
Weber
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
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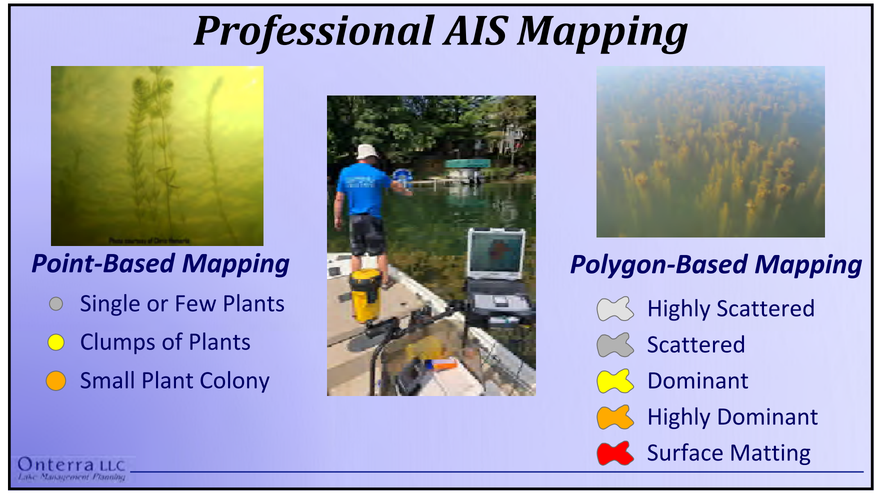
Professional AIS Mapping
Point-Based Mapping
Single or Few Plants
Clumps of Plants
Small Plant Colony
Polygon-Based Mapping
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting
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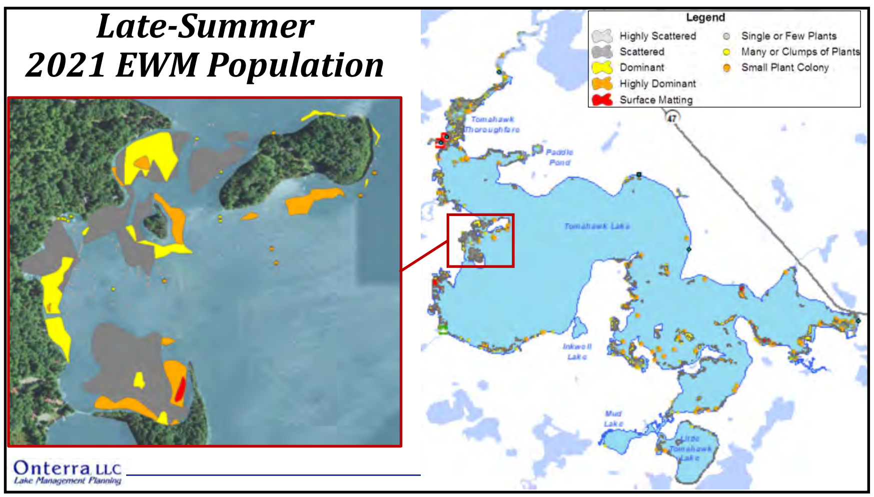
Late-Summer
2021 EWM Population
Legend
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting
Single or Few Plants
Many or Clumps of Plants
Small Plant Colony
Tomahawk Thoroughfare
Paddle Pond
Tomahawk Lake
Inkwell Lake
Mud Lake
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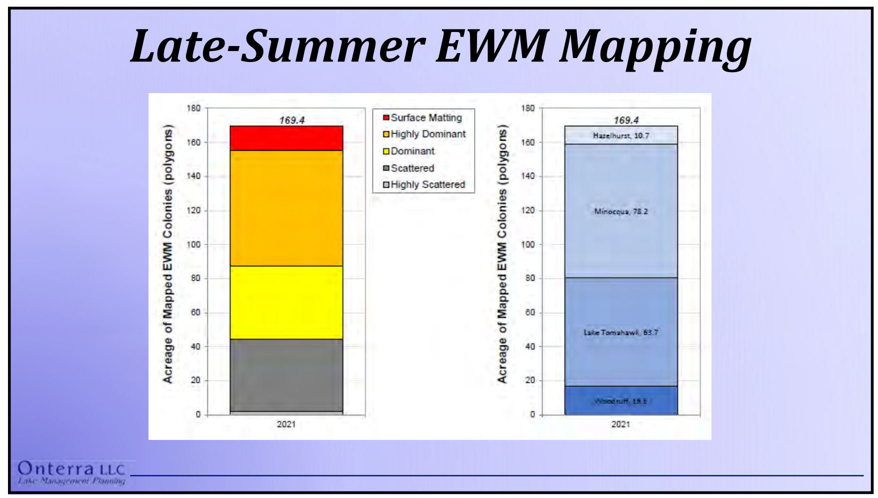
Late-Summer EWM Mapping
Acreage of Mapped EWM Colonies (polygons)
180
160
140
120
100
80
60
40
20
0
169.4
2021
Surface Matting
Highly Dominant
Dominant
Scattered
Highly Scattered
Hazelhurst, 10.7
Minocqua, 78.2
Lake Tomahawk, 63.7
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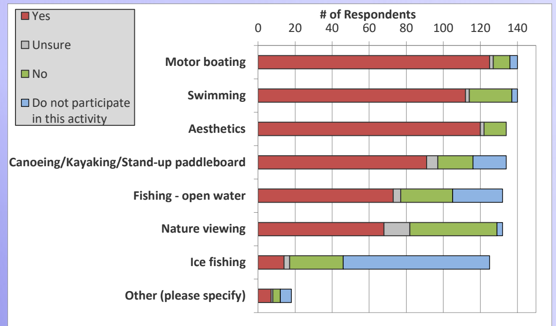
Riparian Perceptions

41.3% Response Rate

Has the EWM population ever had a negative impact on your enjoyment of Tomahawk Lake?



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Best Management Practices (BMPs)

- **A "placeholder" term to represent the management option that is currently supported by that latest science and policy**
- **Definition evolves over time**
  - Pre 2010 - small spot treatments with granular products
  - Early 2010s - larger spot treatments with liquid products
  - Mid 2010s – whole-lake treatments, spot treatments with herbicide combos, hand-harvesting/DASH
  - Current– whole-lake/basin approaches, nuisance maintenance vs population management, mechanical harvesting, increasing human tolerance, new herbicides

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Integrated Pest Management Strategies (IPM)

- **Using a combination of methods that are more effective when applied collectively as part of defined strategy than when conducted separately**

- Prevention
- Biological control
- Biomanipulation
- Nutrient management
- Habitat manipulation
- Substantial modification of cultural practices
- Pesticide application
- Water level manipulation
- Mechanical removal
- Feasibility planning
- Population monitoring

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AIS Management Perspectives

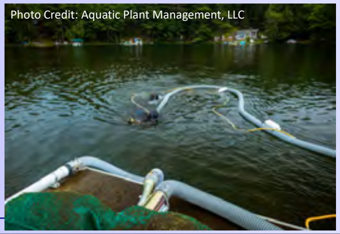
1. **No Coordinated Active Management (Let Nature Take its Course)**
   - Focus on education of manual removal by property owners
2. **Reduce AIS Population on a lake-wide level (Population Management)**
   - Would likely rely on herbicide treatment (risk assessment)
   - Will not "eradicate" AIS
  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

Active Management

- **Hand-Harvest/DASH/HCS**
- **Mechanical Harvesting**
- **Herbicide Treatment**

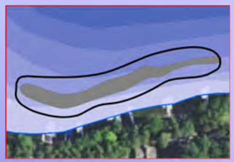
Hand-Harvesting

- **Removal of entire root material required for EWM/HWM**
- **Scale limitations, not for large or dense areas**
- **Diver-Assisted Suction Harvest (DASH, HCS) can increase efficacy**
- **Limitations**
  - –Density of EWM & native plants
  - –Clarity of water
  - –Sediment type
  - –Obstructions



Goal: Reduce Population & Inhibit Expansion

Before



Scale: 0.93 acres

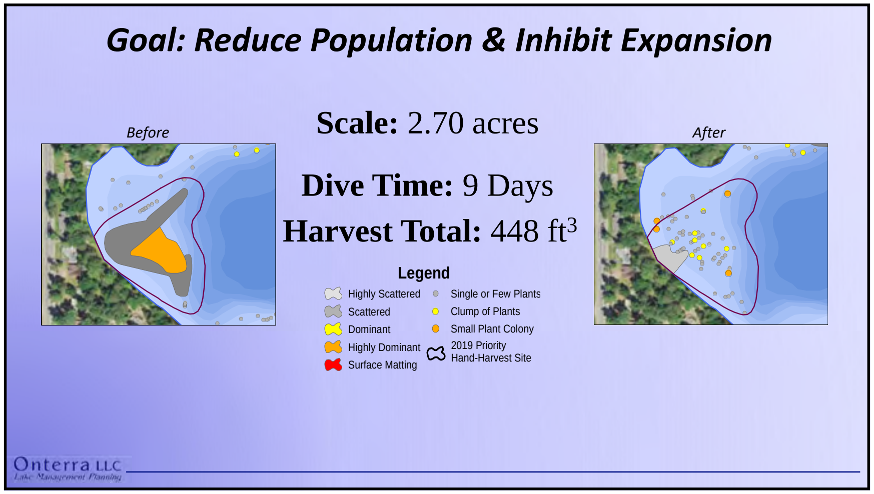
Dive Time: 20.91 Hours

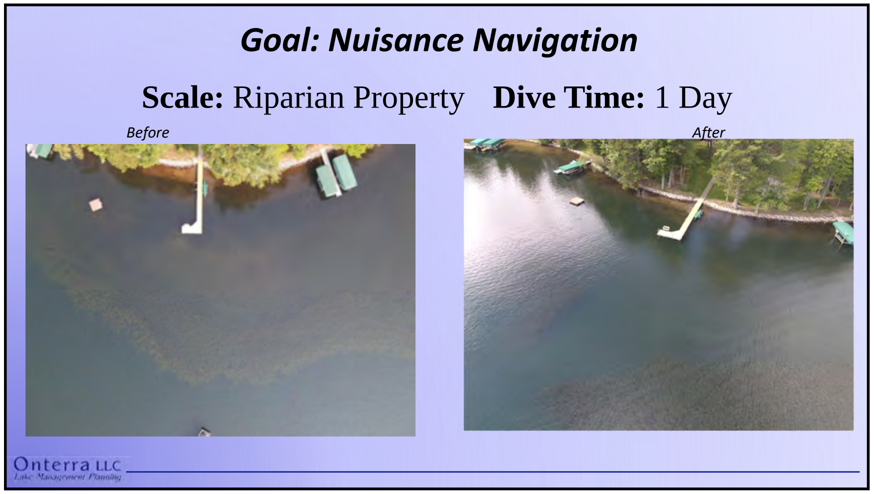
Harvest Total: 46 ft^3

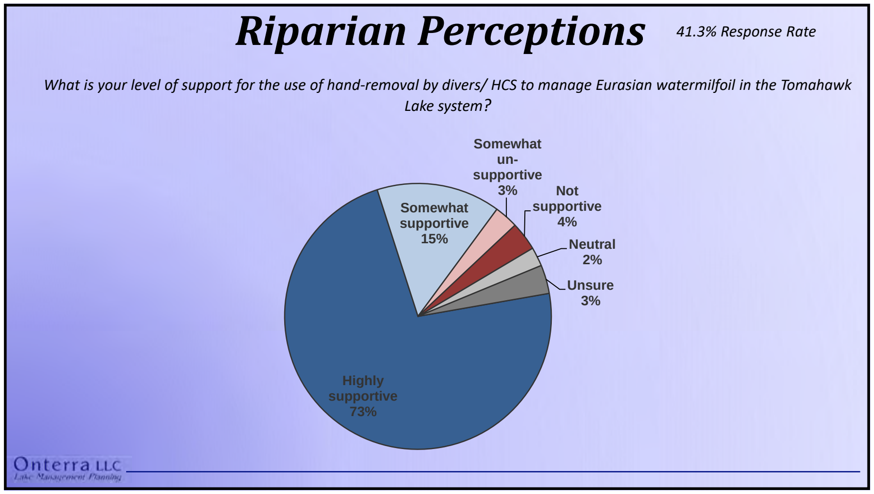
After

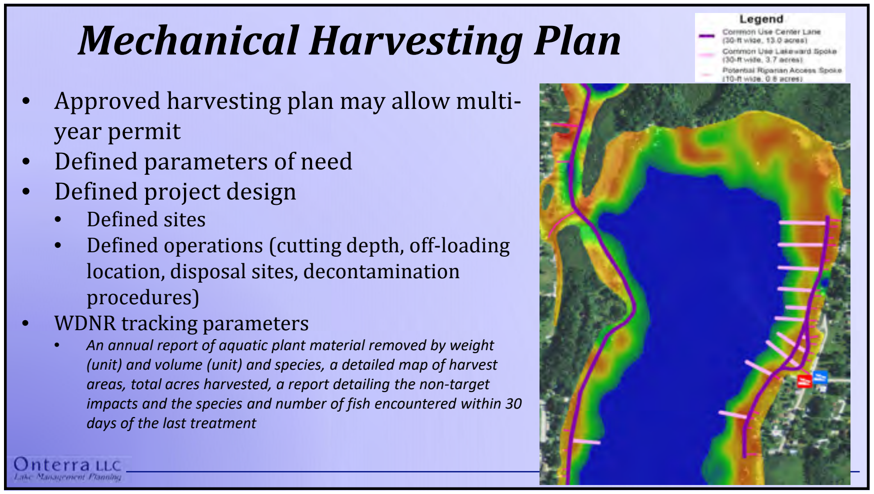
Legend

Highly Scattered | Single or Few Plants
Scattered | Clump of Plants
Dominant | Small Plant Colony
Highly Dominant | 2019 Priority Hand-Harvest Site
Surface Matting


Goal: Reduce Population & Inhibit Expansion
Before
Scale: 2.70 acres
Dive Time: 9 Days
Harvest Total: 448 ft3
After
Legend
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting
Single or Few Plants
Clump of Plants
Small Plant Colony
2019 Priority Hand-Harvest Site
Onterra LLC


Goal: Nuisance Navigation
Scale: Riparian Property Dive Time: 1 Day
Before
After
Onterra LLC


Riparian Perceptions
41.3% Response Rate
What is your level of support for the use of hand-removal by divers/ HCS to manage Eurasian watermilfoil in the Tomahawk Lake system?
Somewhat un-supportive 3%
Not supportive 4%
Neutral 2%
Unsure 3%
Somewhat supportive 15%
Highly supportive 73%
Onterra LLC


Mechanical Harvesting Plan
Legend
Approved harvesting plan may allow multi-year permit
Defined parameters of need
Defined project design
Defined sites
Defined operations (cutting depth, off-loading location, disposal sites, decontamination procedures)
WDNR tracking parameters
An annual report of aquatic plant material removed by weight (unit) and volume (unit) and species, a detailed map of harvest areas, total acres harvested, a report detailing the non-target impacts and the species and number of fish encountered within 30 days of the last treatment
Onterra LLC

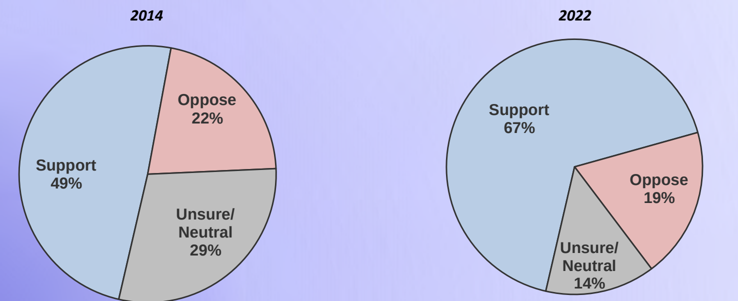
Current Strategy

- Goal: alleviate nuisance conditions cased by EWM
- WDNR Grant secured for 2022-2023 trial program
- Target around 125 acres
- Slightly larger equipment secured for 2022-2023
- Professional monitoring for changes in aquatic plant community
- Volunteer monitoring of longevity of nuisance relief

Riparian Perceptions

41.3% Response Rate

What is your level of support for the use of the following Eurasian watermilfoil management techniques (mechanical harvesting [i.e. weed cutter]) in the Tomahawk Lake system?

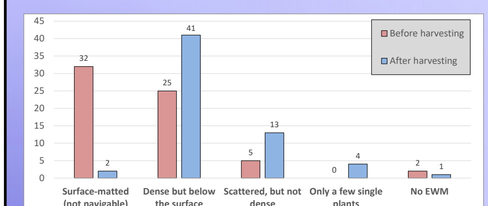


Riparian Perceptions

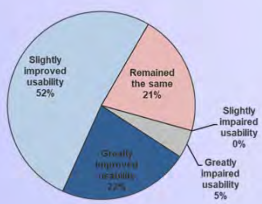
41.3% Response Rate

*Question 32 (2022): What was the density of the Eurasian watermilfoil **prior** to the harvesting in front of your property?*

*Question 33 (2022): What was the density of the Eurasian watermilfoil **after** being harvesting in front of your property?*

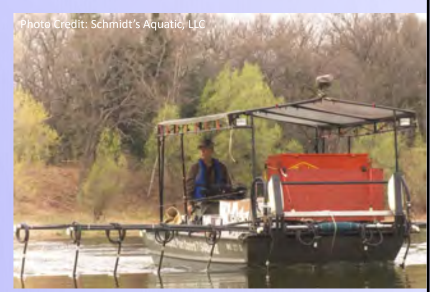


To what extent would you say the outcome of harvesting in front of your property altered the usability of the lake?

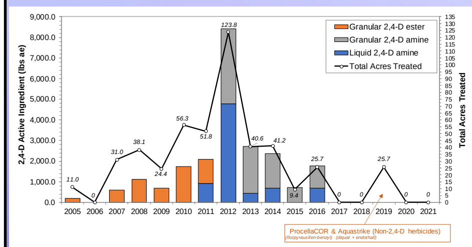


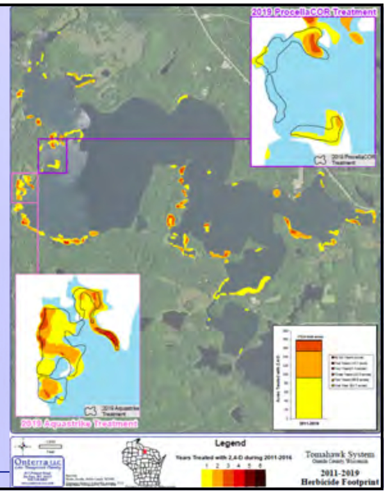
Herbicide Treatment

- **Introduces greater need for risk assessment discussion**
  - Known impacts of herbicides
  - Unknown impacts of herbicides
  - Public sentiment
- **How they work**
  - Concentration & Exposure Time (CET)
  - Herbicide dissipation
  - Spot vs whole-lake (whole-basin)
  - Herbicide formulation



Herbicide Use History





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Lake Management Planning

Herbicide Treatment on Lake Metonga

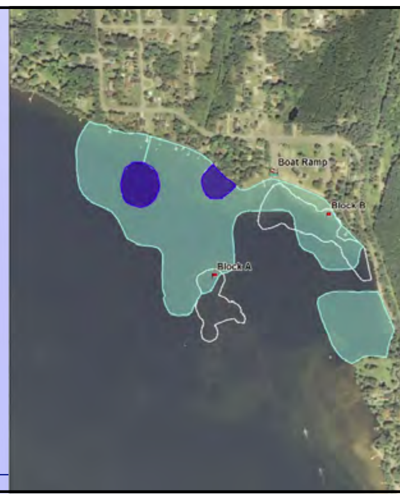
- Tracer Dye (Rhodamine WT)
- A-15 (south) ~ 3 acres
- B-15 (north) ~ 5 acres

Onterra LLC
Lake Management Planning

5 HAT

75-100%
50-75%
25-50%
10-25%
5-10%

2,4-D CET needed for EWM control based upon published studies:
sustained 4.0 ppm for 12 hours
sustained 2.0 ppm for 24 hours



US Army Corps of Engineers. Engineer Research and Development Center

Onterra LLC
Lake Management Planning

Herbicide Treatment on Loon Lake

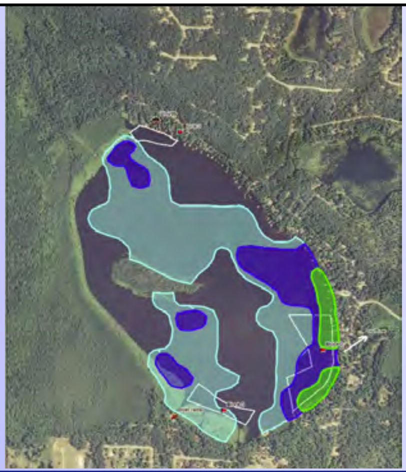
- Tracer Dye (Rhodamine WT)
- ~24 acres of 305 acre lake (7.8%)

Onterra LLC
Lake Management Planning

6 HAT

75-100%
50-75%
25-50%
10-25%
5-10%

2,4-D CET needed for EWM control based upon published studies:
sustained 4.0 ppm for 12 hours
sustained 2.0 ppm for 24 hours
0.1-0.3 ppm for 6 weeks+ (whole-lake)



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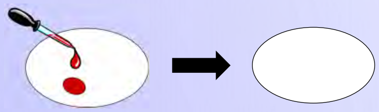
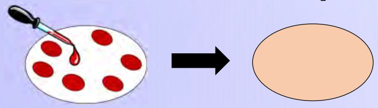
Lake Management Planning

Ecological Definitions of Herbicide Treatment

Spot Treatment: 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.



Whole-Lake (basin-wide) Treatment: Herbicide applied at a scale where dissipation will result in significant lake wide concentrations; impacts are anticipated to be on a lake wide scale.



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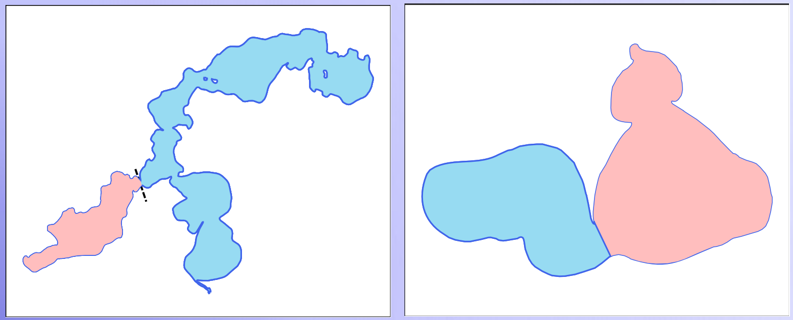
Area of Potential Impact (AOPI)

- Mixing area, reaches equilibrium - basin or bay of a lake



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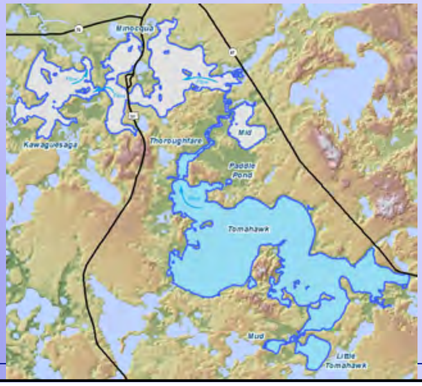
Area of Potential Impact (AOPI)

- Mixing area, reaches equilibrium - basin or bay of a lake



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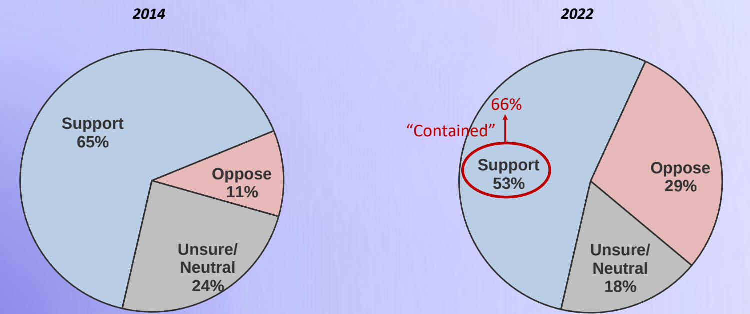
Herbicide Spot Treatment BMPs

- **Factors that lead to longer exposure time**
  - Larger size
  - Broader shape (hold concentrations in core of treatment area)
  - Protected location (limit dissipation direction)
  - Stagnant waters (flow increases dissipation)
- **New Management Directions**
  - Short CET herbicides (ProcellaCOR™, herbicide combos)
  - Herbicide resistance

Riparian Perceptions

41.3% Response Rate

What is your level of support for the use of the following Eurasian watermilfoil management techniques (herbicide use - uncontained application to target areas) in the Tomahawk Lake system?



Planning Meeting II

Primary Objective: Create implementation plan framework

Steps to Achieve Objective:

1. Discuss challenges facing lake and lake group (APM-focused)
2. Convert challenges to management goals
3. Create management actions to meet management goals
4. Determine timeframes and facilitators to carry out actions

Assignment for TLA - Planning Meeting II

1. Create list of challenges facing lake and lake group (keep to yourself)
2. Continue to review riparian/TLA stakeholder survey results
3. Send potential report section edits and questions to Onterra

Tomahawk Lake Association

APM Planning Project
Planning Meeting II

April 12, 2022

AEPP-629-21
AEPP-640-21
AEPP-641-21

Eddie Heath
Onterra LLC
Lake Management Planning

TOMAHAWK LAKE Association, Inc.
Hazelhurst • Lake Tomahawk • Minocqua • Woodruff

2016 CLMP Implementation Plan

Management Goals *(self-defined as broad statements of direction)*

1. Maintain a diverse, native aquatic plant community.
2. Preserve the quality of Tomahawk Lake System waters
3. Balance recreational use with preservation of the natural lake environment
4. Engage the lake community in lake and watershed stewardship practices
5. Partner with area organizations, government agencies, and local businesses to support the goals of the lake management plan

Onterra LLC *Lake Management Planning*

2016 CLMP Implementation Plan

Goal 1: Maintain a diverse, native aquatic plant community.

1. Avoid a trend of long-term increase in dense growth of EWM
   - Monitoring
2. Manage EWM using most appropriate, effective method
   - Herbicide
     - High density, >0.1 acre, factors that impact herbicide CET
   - HCS/DASH
     - New areas, small areas, shallow water, flowing water, mixed invasive/native
   - Volunteer hand removal & avoidance
3. Manage/monitor purple loosestrife, pale-yellow iris, narrow-leaved cattail
4. Prevent new AIS
   - CBCW (3 landings using paid & volunteer)
   - Education & monitoring (annual monitoring, disposal, identify pathways, "special forces", nutrient management, community education)

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Implementation Plan Development

Goal
- Reflects big picture
- Ambitious, but attainable

Action
- Step to meet goal
- Measurable outcome
- Timeframe
- Facilitator

- Management goals are statements, were as management actions are detailed.
- Typical Onterra APM Plans will have a 2-4 goals, with multiple actions under each goal.

Onterra LLC *Lake Management Planning*

AIS Management Perspectives

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 (risk assessment)
   - Will not "eradicate" AIS
   - Set triggers (thresholds) of implementation and tolerance
3. **Minimize navigation and recreation impediment (Nuisance Control)**
   - Navigation lanes, targeted areas
   - May be accomplished through herbicide treatment, hand-harvesting, or mechanical harvesting

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Lake Management Planning

APM Actions Alternatives Analysis

	How meets goal	Scale of Impact	Cost ($)	Risk Potential	Support
Herbicide Treatment					
Mechanical Harvest					
Hand-Harvest (DASH/HCS)					
Let Nature Take Its Course					

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Implementation Plan Development

- Native Plants
  - Submergent
  - Floating-leaf/Emergent
- Non-Native Plants
  - EWM
  - CLP
  - Purple Loosestrife
  - Pale-yellow Iris
  - Flowering rush

- Monitoring
  - Strategy
  - Frequency

- Management
  - Implementation Triggers
  - Monitoring Framework
  - Success Criteria
  - Funding Avenues

- Education & Outreach
  - Updated Planning Efforts
  - Education
  - Lake Stewardship

- Prevention & Containment
  - Awareness
  - Inspections
  - Supplemental Programs
    - Cleaning
    - Surveillance

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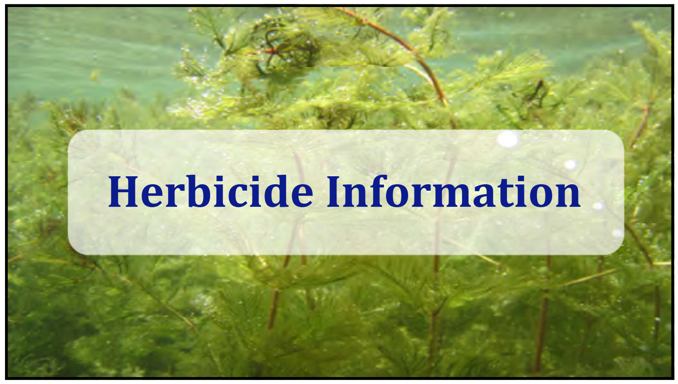

Herbicides Used in APM in WI

General Mode of Action		Compound	Specific Mode of Action	Most Common Target Species in Wisconsin
Contact		Copper	plant cell toxicant	Algae, including macro-algae (i.e. muskgrasses & stoneworts)
		Endothall	Inhibits respiration & protein synthesis	Submersed species, largely for curly-leaf pondweed; invasive watermilfoil control when mixed with auxin herbicides
		Diquat	Inhibits photosynthesis & destroys cell membranes	Nusiance species including duckweeds, targeted AIS control when exposure times are low
		Flumioxazin	Inhibits photosynthesis & destroys cell membranes	Nusiance species, targeted AIS control when exposure times are low
Systemic	Auxin Mimics	2,4-D	auxin mimic, plant growth regulator	Submersed species, largely for invasive watermilfoil
		Triclopyr	auxin mimic, plant growth regulator	Submersed species, largely for invasive watermilfoil
		Florpyrauxifen-benzyl	arylpicolinate auxin mimic, growth regulator, different binding afinity than 2,4-D or triclopyr	Submersed species, largely for invasive watermilfoil
	In Water Use Only	Fluridone	Inhibits plant specific enzyme, new growth bleached	Submersed species, largely for invasive watermilfoil
	Enzyme Specific (ALS)	Penoxsulam	Inhibits plant-specific enzyme (ALS), new growth stunted	Emergent species with potential for submergent and floating-leaf species
		Imazamox	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating-leaf species
	Enzyme Specific (foliar use only)	Glyphosate	Inhibits plant-specific enzyme (ALS)	Emergent species, including purple loosestrife
		Imazapyr	Inhibits plant-specific enzyme (EPSP)	Hardy emergent species, including common reed

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WDNR Administrative Code (NR 107):

Aquatic Plant Management Conditions

(1) The department may stop or limit the application of chemicals to a body of water if at any time it determines that chemical treatment will be ineffective, or will result in unreasonable restrictions on current water uses, or will produce unnecessary adverse side effects on non-target organisms.

(4) Treatment of areas containing high value species of aquatic plants shall be done in a manner which will not result in adverse long–term or permanent changes to a plant community in a specific aquatic ecosystem.

Underscores the importance of proper planning and monitoring

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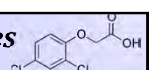
Lake Management Planning

2.4-D Impacts on Early Fish Life Stages



US EPA registration of aquatic herbicides requires organismal toxicity studies to be conducted using CETs consistent with spot-treatment use patterns (high concentrations, short exposure times).

- DeQuattro and Karasov 2016 demonstrated statistically valid reduction in fathead minnow larval survivability when 2,4-D is exposed to full duration of embryo (eggs) and larval (hatched). Also demonstrated sub-lethal endocrine disruption impacts (tubercles).
- Dehnert et. al 2018 indicates the first 14 days post hatch (dph) is the most critical period for fathead minnow.
- Rydell and Isermann did not find significant fish or zooplankton impacts insitu paired study
- Dehnert et. al 2021 investigated multiple gamefish species, exposing to 30 dph to conform with EPA's definition of "chronic"

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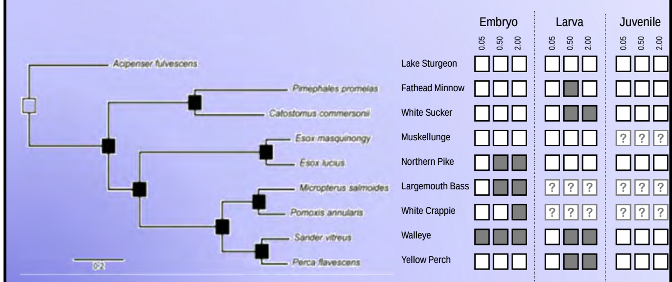
Dehnert et al. 2021



Embryo: affected (deformities present)
Larval & Juvenile: survivability

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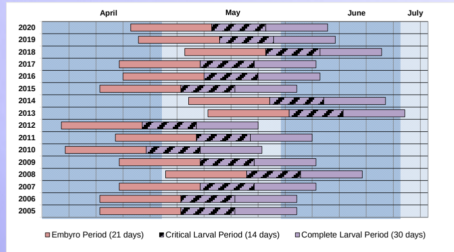
Application of UW Studies - Walleye

- Example from a Bayfield County Lake
- Peak tribal walleye spear harvest = fertilization date
- 21 day embryo period (5 days in lab due to Temp)
- 14 day critical larval period
- 30 day full larval period

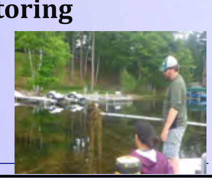


Florpyrauxifen-benzyl (ProcellaCOR™)

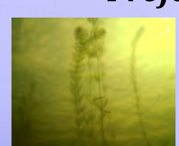
- New class of synthetic auxin hormone mimics
  - Much different binding affinity than other auxins
  - Use at PPB rate vs PPM
- Short contact exposure time (CET) requirement
- Short environmental fate of ae
  - Half life 1-6 days (photolysis, higher rates in clear water)
  - High Koc (soil/organic binding affinity)
- Currently formulated for spot treatments, but manufacturer working towards whole-lake use patterns
- Detailed information on field applications is limited

Treatment Monitoring

- **Qualitative Target Plant Monitoring**
  - Comparative pre/post EWM mapping surveys
- **Quantitative Aquatic Plant Monitoring**
  - Comparative pre/post sub-sample point-intercept surveys
- **Herbicide Concentration Monitoring**
  - Volunteer-based in situ water testing

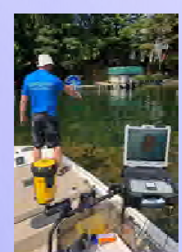


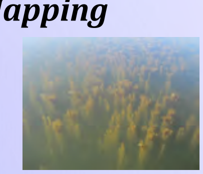
Professional EWM Mapping



Point-Based Mapping

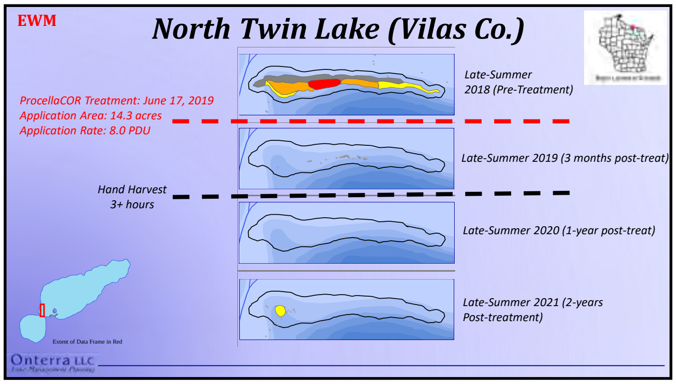
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony



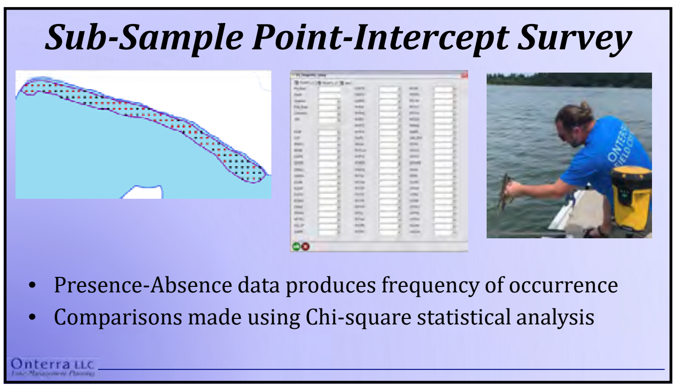


Polygon-Based Mapping

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting


EWM
North Twin Lake (Vilas Co.)
ProcellaCOR Treatment: June 17, 2019
Application Area: 14.3 acres
Application Rate: 8.0 PDU
Late-Summer 2018 (Pre-Treatment)
Late-Summer 2019 (3 months post-treat)
Hand Harvest 3+ hours
Late-Summer 2020 (1-year post-treat)
Late-Summer 2021 (2-years Post-treatment)
Extent of Data Frame in Red
Onterra LLC


Quantitative Sub-Sample Monitoring


Sub-Sample Point-Intercept Survey
• Presence-Absence data produces frequency of occurrence
• Comparisons made using Chi-square statistical analysis
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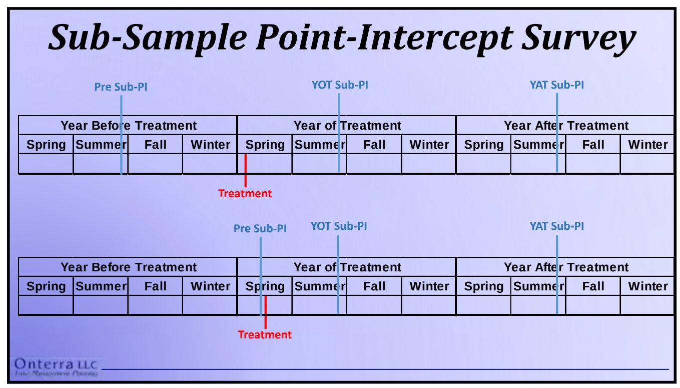
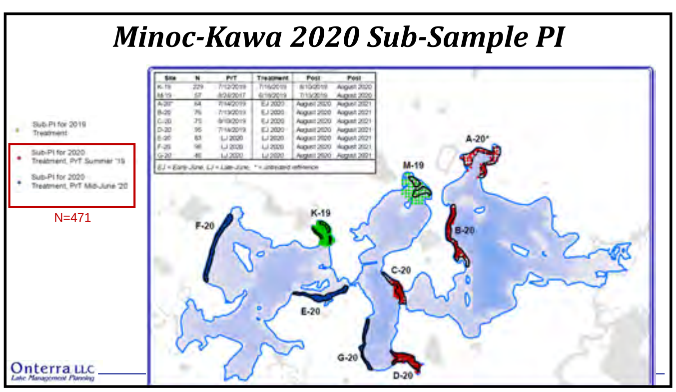
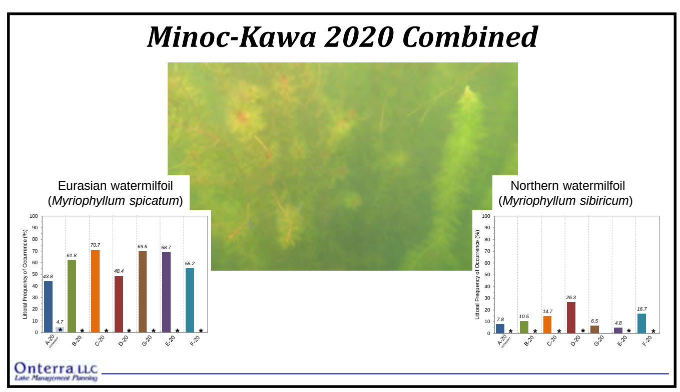

Sub-Sample Point-Intercept Survey
Pre Sub-PI
YOT Sub-PI
YAT Sub-PI
Year Before Treatment
Year of Treatment
Year After Treatment
Spring Summer Fall Winter Spring Summer Fall Winter Spring Summer Fall Winter
Treatment
Pre Sub-PI
YOT Sub-PI
YAT Sub-PI
Year Before Treatment
Year of Treatment
Year After Treatment
Spring Summer Fall Winter Spring Summer Fall Winter Spring Summer Fall Winter
Treatment
Onterra LLC


Minoc-Kawa 2020 Sub-Sample PI
N=471
A-20*
M-19
K-19
F-20
B-20
C-20
E-20
G-20
D-20
Onterra LLC


Minoc-Kawa 2020 Combined
Eurasian watermilfoil (Myriophyllum spicatum)
Northern watermilfoil (Myriophyllum sibiricum)
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Onterra Projects

2019-2021

- 34 Treatments, 14 Lakes
- Application Rate 3.0-8.0 PDU/acre-ft
- Almost all highly effective
  - Less effective: Kettle Moraine, Boulder
- Emerging suite of sensitive native plant species
  - NWM, Bidens, Coontail, dicots

Lake Name	County	Target	Site	Acres	PDU/ acre-foot	Treatment Date
North Twin	Vilas	EWM	B-19	14.3	8.0	6/17/2019
		EWM	C-20	10.0	7.0	6/17/2020
South Twin	Vilas	EWM	X-21	5.4	4.5	6/9/2021
		EWM	Y-21	22.5	4.0	6/9/2021
		EWM	Z-21	30.1	4.0	6/9/2021
Kawaguesaga	Oneida	EWM	K1-19	4.3	4.0	7/16/2019
		EWM	K2-19		4.0	7/16/2019
		EWM	K3-19		5.0	7/16/2019
		EWM	E-20	15.2	3.5	6/30/2020
		EWM	F-20	12.9	5.0	6/30/2020
		EWM	P-21	3.6	3.5	6/22/2021
		EWM	Q-21	3.3	3.5	6/22/2021
		EWM	R-21	3.4	3.5	6/22/2021
Minocqua	Oneida	EWM*	M1-19	9.3	3.5	6/8/2019
		EWM*	M2-19		3.5	6/8/2019
		EWM*	B-20	17.7	4.5	6/15/2020
		EWM*	C-20	10.2	4.5	6/15/2020
		EWM*	D-20	12.8	3.0	6/15/2020
		EWM*	G-20	7.4	5.0	6/30/2020
		EWM*	O-21	13.4	4.0	6/22/2021
Berry	Oconto-Menominee	HWM	A-20	10.0	4.0	6/12/2020
Crooked	Oconto	EWM	A-20	7.9	3.0/5.0	7/6/2020
Little Saint Germain	Vilas	EWM	A-20	11.1	4.0	6/12/2020
		EWM	C-20	5.1	4.0	6/12/2020
		EWM	D-20	15.9	3.0	6/12/2020
Long	Vilas	EWM*	B-20	15.9	4.0	6/17/2020
[Big] Silver	Waushara	HWM	A-20	11.6	3.5	6/8/2020
Hatch	Waupaca	EWM?	A-21	3.0	4.0	6/17/2021
Kettle Moraine	Fond du Lac	EWM	A-21	10.0	4.0	6/10/2021
Boulder	Oconto	EWM	A-21	1.4	5.0	6/18/2021
		EWM	B-21	1.0	5.0	6/18/2021
Silver	Forest	EWM	A-21	15.0	3.0	6/23/2021
Grass (Cloverleaf Lakes)	Shawano	HWM	A-21	3.5	4.0	6/22/2021
		HWM	B-21	3.3	3.5	6/22/2021

*Presumably EWM although HWM has been documented from system

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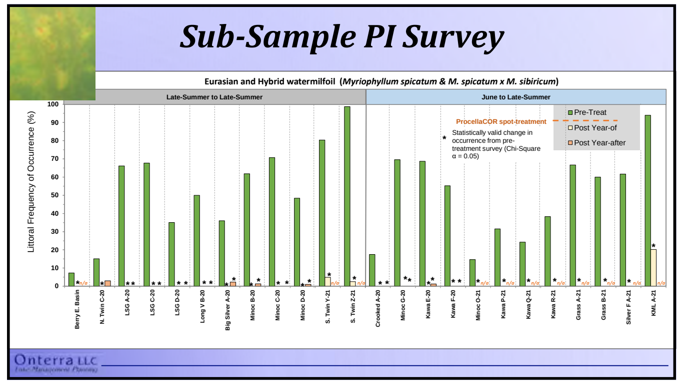

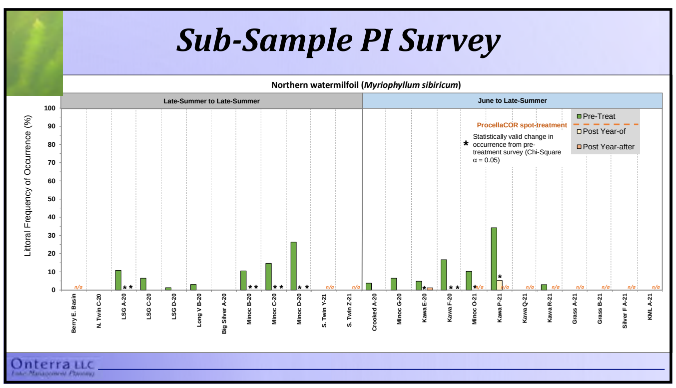

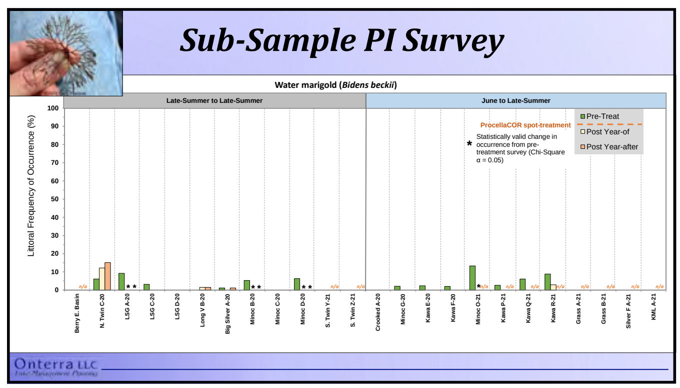

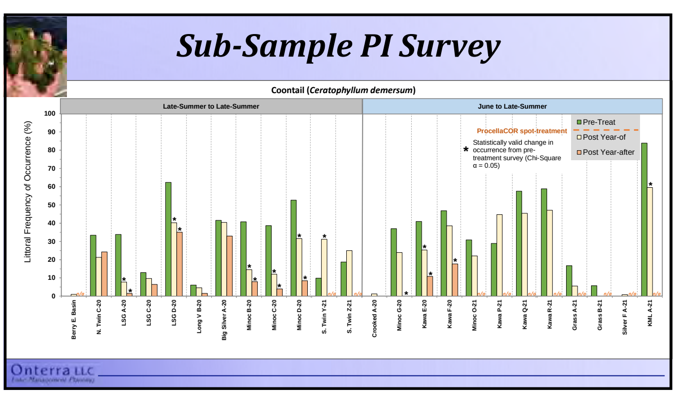

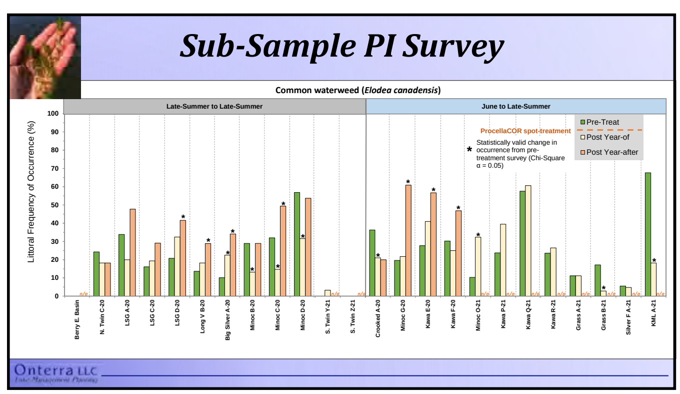

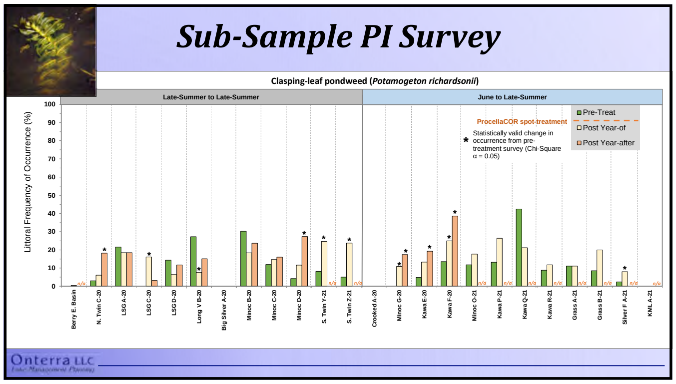
Sub-Sample PI Survey
Clasping-leaf pondweed (Potamogeton richardsonii)
Late-Summer to Late-Summer
June to Late-Summer
Littoral Frequency of Occurrence (%)
ProcellaCOR spot-treatment
Statistically valid change in occurrence from pre-treatment survey (Chi-Square α = 0.05)
Pre-Treat
Post Year-of
Post Year-after
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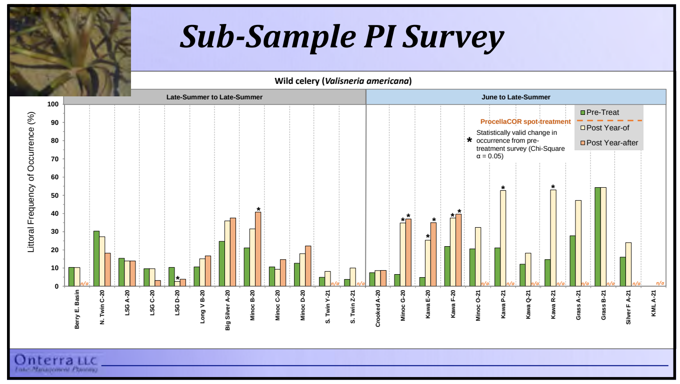
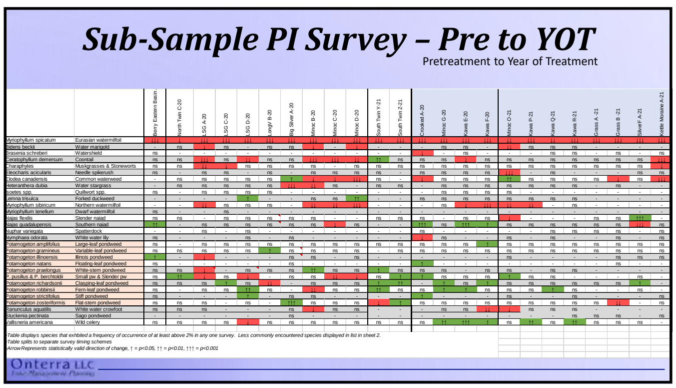
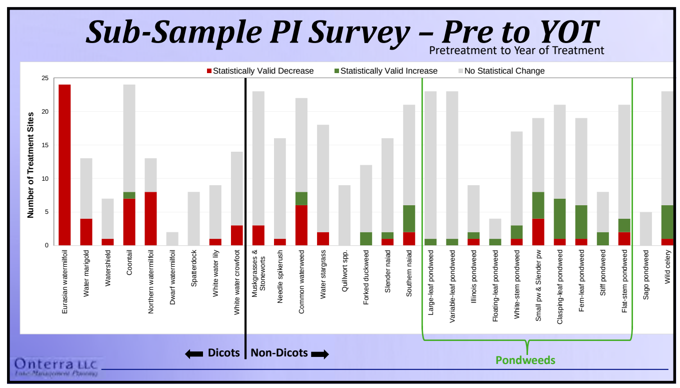
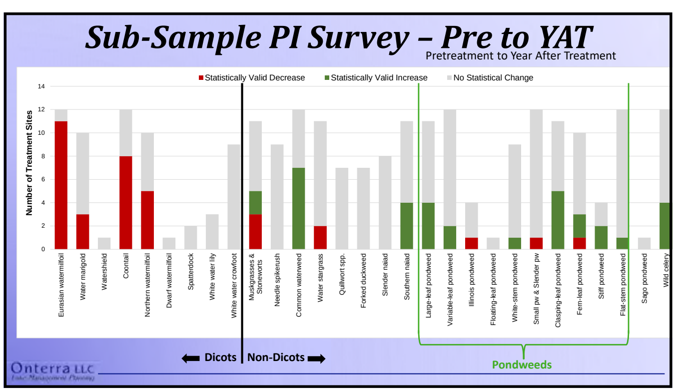
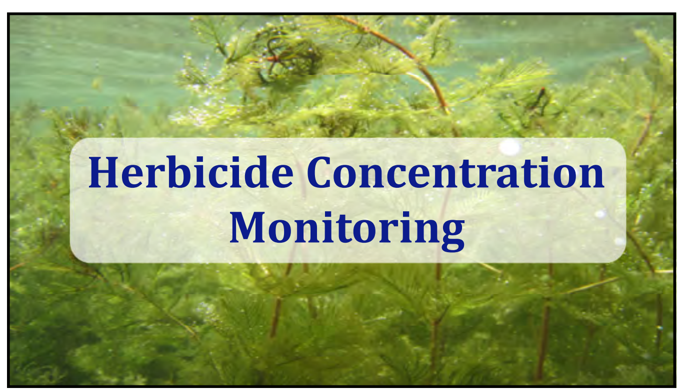

Sub-Sample PI Survey
Wild celery (Valisneria americana)
Late-Summer to Late-Summer
June to Late-Summer
Littoral Frequency of Occurrence (%)
ProcellaCOR spot-treatment
Statistically valid change in occurrence from pre-treatment survey (Chi-Square α = 0.05)
Pre-Treat
Post Year-of
Post Year-after
Onterra LLC


Sub-Sample PI Survey – Pre to YOT
Pretreatment to Year of Treatment
Onterra LLC


Sub-Sample PI Survey – Pre to YOT
Pretreatment to Year of Treatment
Statistically Valid Decrease
Statistically Valid Increase
No Statistical Change
Number of Treatment Sites
Dicots
Non-Dicots
Pondweeds
Onterra LLC


Sub-Sample PI Survey – Pre to YAT
Pretreatment to Year After Treatment
Statistically Valid Decrease
Statistically Valid Increase
No Statistical Change
Number of Treatment Sites
Dicots
Non-Dicots
Pondweeds
Onterra LLC


Herbicide Concentration Monitoring

Herbicide Concentration Monitoring

2019
- SePRO Lab
- Most data below detection limits

2020
- EPL Lab
- Aimed at CET w/in application areas

2021
- EPL Lab
- Aimed at CET w/in AOPI

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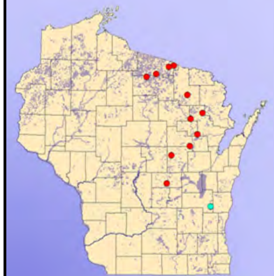
2021 Onterra-Monitored Lakes



Lake Name	County	pH
Kettle Moraine	Fond du Lac	9.08
Hatch	Waupaca	8.73
Boulder	Oconto	8.54
Berry	Oconto-Meno	8.22
Grass	Shawano	8.21
[Big] Silver	Waushara	8.20
North Twin	Vilas	8.13
Crooked	Oconto	8.12
South Twin	Vilas	8.09
Silver	Forest	7.79
Little Saint Germain	Vilas	7.76
Kawaguesaga	Oneida	7.74
Minocqua	Oneida	7.55
Long	Vilas	7.10

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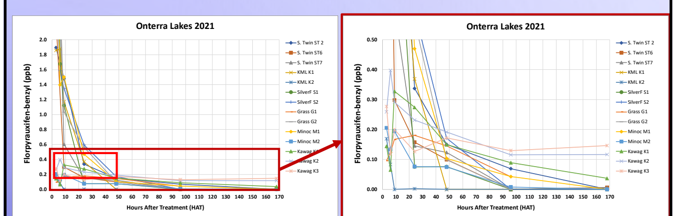
2021 Onterra-Monitored Lakes

Florpyrauxifen-benzyl



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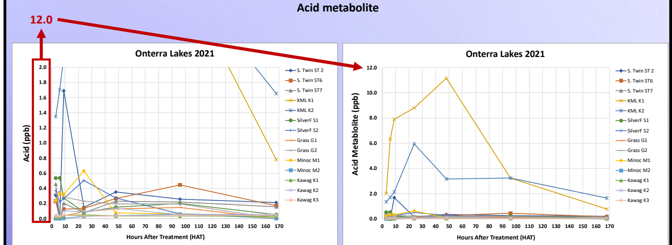
2021 Onterra-Monitored Lakes

Acid metabolite



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EWM *Kawaguesaga Lake 2021– Concentration Monitoring*

Sample Interval Matrix (X indicates sample to be collected)						
Interval	Treatment Application Areas K1	K2	K3	West Bay (QR Bay) K4	South Bay AOPI (P-Bay) K5	SW Basin AOPI K6
Pre-Treatment						x
3 HAT	x	x	x			
6 HAT	x	x	x			
9 HAT	x	x	x	x	x	x
24 HAT	x	x	x	x	x	x
48 HAT	x	x	x	x	x	x
96 HAT	x	x	x	x	x	x
7 DAT	x	x	x	x	x	x

HAT = Hours After Treatment, DAT= Days After Treatment

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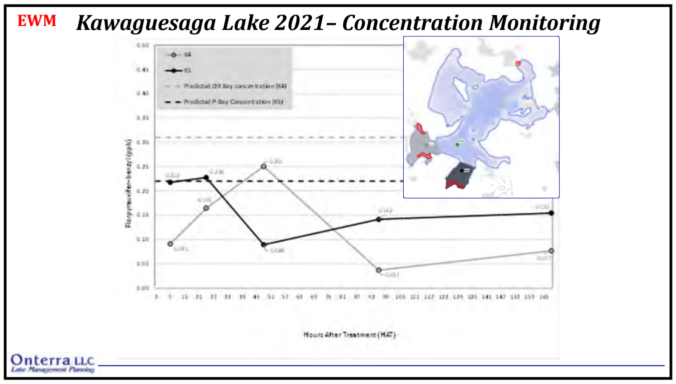
EWM
Kawaguesaga Lake 2021– Concentration Monitoring
Hours After Treatment (HAT)
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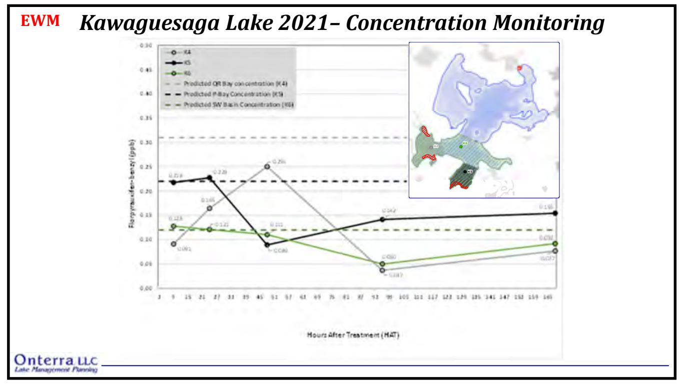
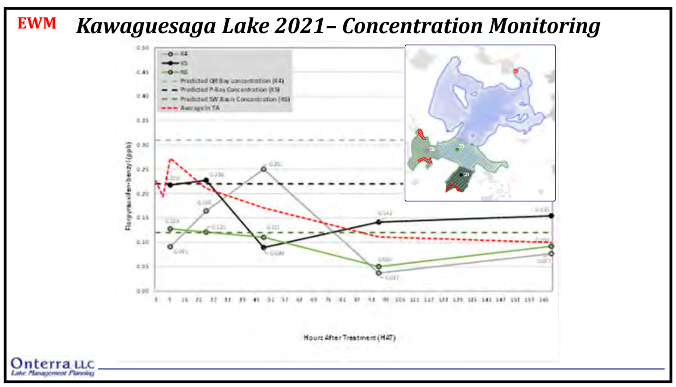
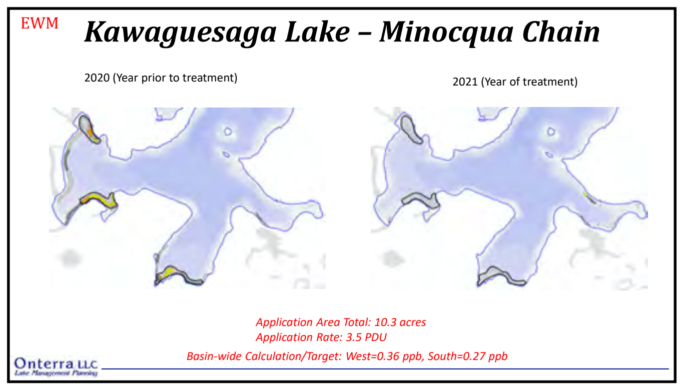
Lake Management Planning


EWM
Kawaguesaga Lake 2021– Concentration Monitoring
Hours After Treatment (HAT)
Onterra LLC
Lake Management Planning


EWM
Kawaguesaga Lake 2021– Concentration Monitoring
Hours After Treatment (HAT)
Onterra LLC
Lake Management Planning


EWM
Kawaguesaga Lake – Minocqua Chain
2020 (Year prior to treatment)
2021 (Year of treatment)
Application Area Total: 10.3 acres
Application Rate: 3.5 PDU
Basin-wide Calculation/Target: West=0.36 ppb, South=0.27 ppb
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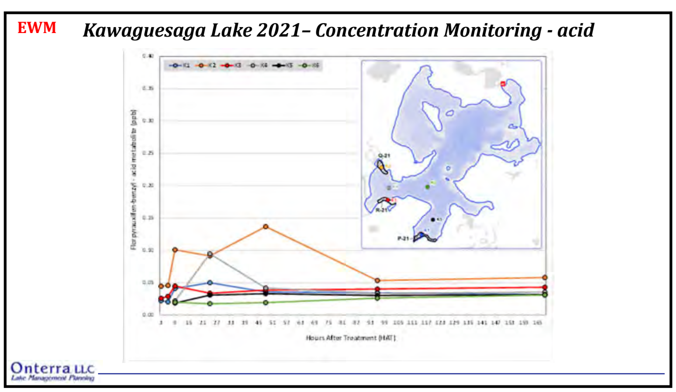
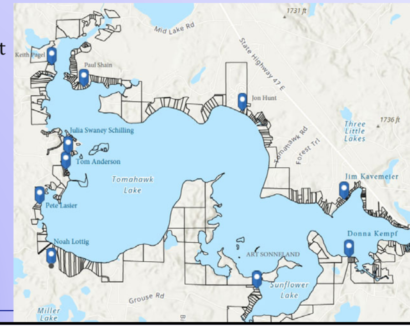
Lake Management Planning


EWM
Kawaguesaga Lake 2021– Concentration Monitoring - acid
Hours After Treatment (HAT)
Onterra LLC
Lake Management Planning


Thank You
Onterra LLC
Lake Management Planning

TLA Planning Committee

- Jim Kavemeier – Chair
- Noah Lottig – TLA President
- Tom Anderson
- Jon Hunt
- Donna Kempf
- Pete Lasier
- Keith Pagel
- Julia Swaney Schilling
- Paul Shain
- Art Sonneland



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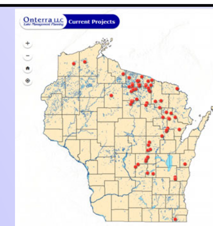
Presentation Outline

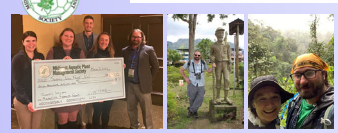
- Introduction to Onterra
- Lake Management Planning
- Implementation Plan
  - 6 goals, 10 actions

Onterra LLC

Onterra, LLC

- Founded in 2005, HQ in De Pere, WI
- Staff
  - Four full-time ecologists
  - One part-time paleoecologist
  - Three full-time field technicians
  - Five summer interns
- Services
  - Science and planning
- Philosophy
  - Promote realistic planning
  - Assist, not direct





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Why Create a Lake Management Plan?

- Preserve/restore ecological function
- To create a better understanding of lake's positive and negative attributes.
- To discover ways to minimize the negative attributes and maximize the positive attributes.
- Consider ecological function and human-use needs
- Snapshot of lake's current status or health.
- Foster realistic expectations and dispel any misconceptions.

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2016 CLMP Implementation Plan

- Study Components
  - Water Quality
  - Watershed
  - Shoreland Condition ← 2020 w/ NOVA
  - Aquatic Plants
  - General AIS
  - Fishery/Wildlife
- Stakeholder Perceptions
- Management Objectives/Goals/Actions


Tomahawk Lake System
Comprehensive Lake Management Plan
Oneida County, Wisconsin
July 2015
Sponsored by
TOMAHAWK LAKE

Onterra LLC

Management Plan, Grants, & Permits

WDNR recommends *Comprehensive Lake Management Plans* generally get updated every 10 years (implementation grants)

- Slightly longer if a plan has been actively implemented and updated during its lifespan

WDNR recommends lakes conducting active management update *Aquatic Plant Management* aspects every 5 years (AIS control grants)

- Slightly longer if a plan has been actively implemented and updated during its lifespan and whole-lake PI survey is within 5 years

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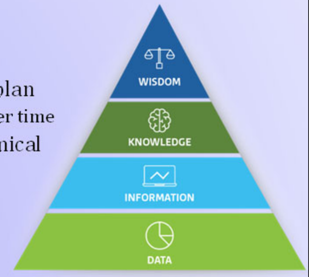
Onterra Planning Project Overview

- Collect & analyze data
  - Technical & sociological
- Make the data understandable
- Construct long-term & useable plan
  - Living plan subject to revision over time
- Onterra's role is to provide technical direction
  - Not really recommendations



Management Planning Project Overview

Collect and compile information

Includes both environmental & sociological data
Historical & current information
Past management actions

Create a realistic and implementable management plan

Challenges facing lakes and lake group
Create goals that will address challenges
Develop actions that will meet goals
Assign timeframes & facilitators

OFD Currently Seeking Public Comment

TABLE OF CONTENTS

16-page "APM Plan"

Implementation Plan

Goal 1: Ensure the TLA has a Functioning and Up-to-Date Management Plan

Goal 2: Monitor Aquatic Vegetation

Goal 3: Prevent Establishment of New Aquatic Invasive Species

Goal 4: Promote Education of Aquatic Invasive Species & AIS Management

Goal 5: Actively manage EWM to keep the population from negatively impacting recreation, navigation, and aesthetics

Goal 6: Promote Lake Stewardship and Conservation Ethics to TLA Members and Tomahawk Lake Riparians

Implementation Plan – Goal 1

Goal 1: Ensure the TLA has a Functioning and Up-to-Date Management Plan

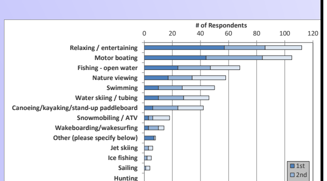
Action: Periodically update plans

- *CLM Plan every 10 yrs, APM Plan every 5 years, Annual Control & Monitoring Plan*

Action: Conduct periodic riparian stakeholder surveys

- *Every 5 years during Plan update*

Please rank up to three activities that are important reasons for owning or renting your property on or near the Tomahawk Lake system.



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Implementation Plan – Goal 2

Goal 2: Monitor Aquatic Vegetation

Action: Coordinate Periodic Point-Intercept Surveys

Frequency: Once every 5 yrs, particularly to maintain grant eligibility

Action: Periodically monitor the Eurasian watermilfoil population

Frequency: Every 2-3 yrs, potentially focused in scope

Action: Coordinate Periodic Community Mapping (floating-leaf and emergent) Surveys

Frequency: 10 year intervals or if need arises such as population changes or high/low water levels

Action: Periodically monitor the non-native emergent plant population

Frequency: Every 5yrs, potentially volunteer-based

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Implementation Plan – Goal 2

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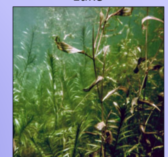
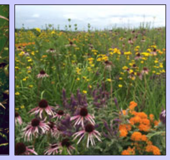
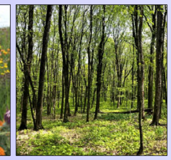
- Frequency: Every 5yrs, potentially volunteer-based

Onterra LLC Lake Management Planning

Native Aquatic Plants

- Foundation of the lake ecosystem
- Provide oxygen, food, and shelter
- Play a role in water quality
- Stabilize bottom and shoreline sediments

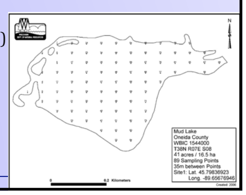
Lake

Grasslands

Forest


Onterra LLC Lake Management Planning

Point-Intercept Surveys

- Systematic approach to collecting aquatic plant information from a waterbody
- Using established protocol, WDNR dictates grid spacing
  - Snapshot of current plant community
  - Trend analysis (2007, 2014, 2021)
  - Allows comparisons between lakes (state, ecoregion)

Lake	Distance Between Sampling Points (meters)	Number of Sampling Locations
Tomahawk Lake	58	4149
Little Tomahawk Lake	35	536
Tomahawk Thoroughfare	58	134
Mud Lake	35	89
Paddle Pond	25	27
Inkwell Lake	35	43

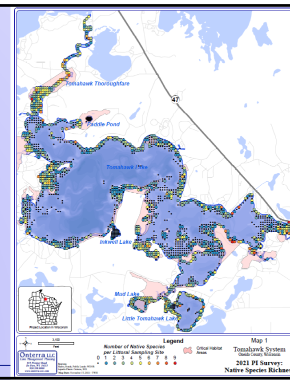


Onterra LLC Lake Management Planning

2021 Species List

- ~62 total species within/around Tomahawk Lake system during PI
  - Minimal aquatic plants found within Paddle Pond and Inkwell Lake
  - Natural Heritage Inventory:
    - Vasey's pondweed (Special Concern)

  - Non-native Plants:
    - Eurasian watermilfoil
    - Curly-leaf pondweed



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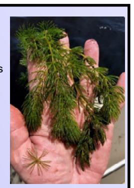
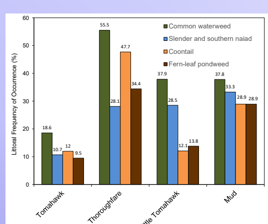
Dominant Species

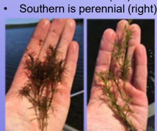
Common waterweed
- No true-roots

Coontail
- No true-roots





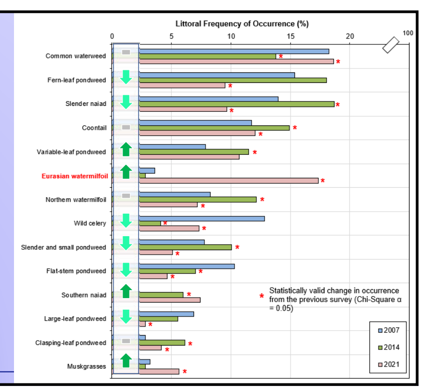
Slender & southern naiad
- Slender is annual (left)
- Southern is perennial (right)



Fern Pondweed
- Low-growing
- Year round

Onterra LLC Lake Management Planning

Tomahawk Lake Littoral Frequency Of Occurence



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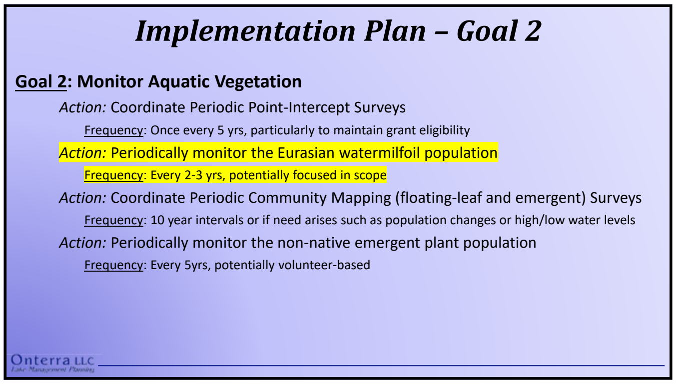
Implementation Plan – Goal 2
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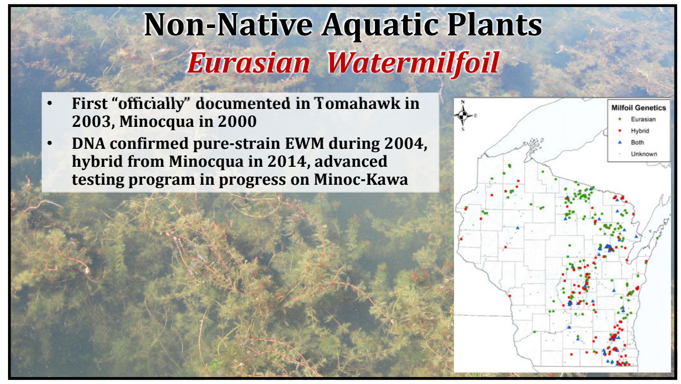
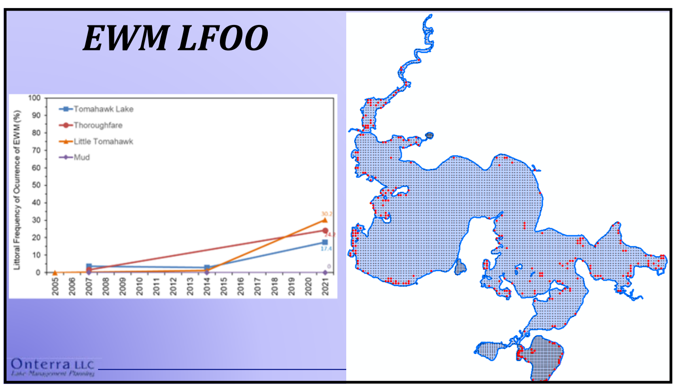
Lake Management Planning


Non-Native Aquatic Plants
Eurasian Watermilfoil
• First "officially" documented in Tomahawk in 2003, Minocqua in 2000
• DNA confirmed pure-strain EWM during 2004, hybrid from Minocqua in 2014, advanced testing program in progress on Minoc-Kawa
Milfoil Genetics
Eurasian
Hybrid
Both
Unknown


EWM LFOO
Littoral Frequency of Ocurrence of EWM (%)
Tomahawk Lake
Thoroughfare
Little Tomahawk
Mud
30.2
17.4
0
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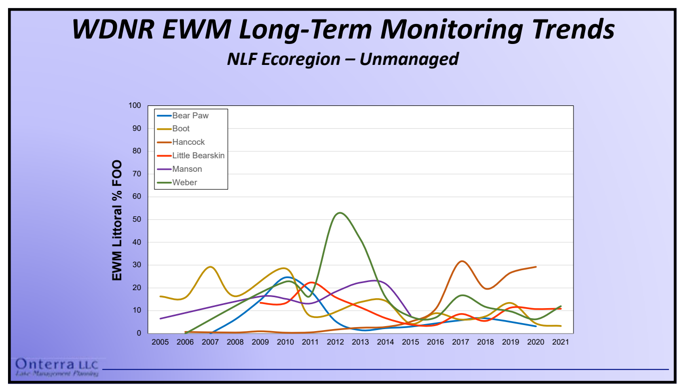
Lake Management Planning


WDNR EWM Long-Term Monitoring Trends
NLF Ecoregion – Unmanaged
EWM Littoral % FOO
Bear Paw
Boot
Hancock
Little Bearskin
Manson
Weber
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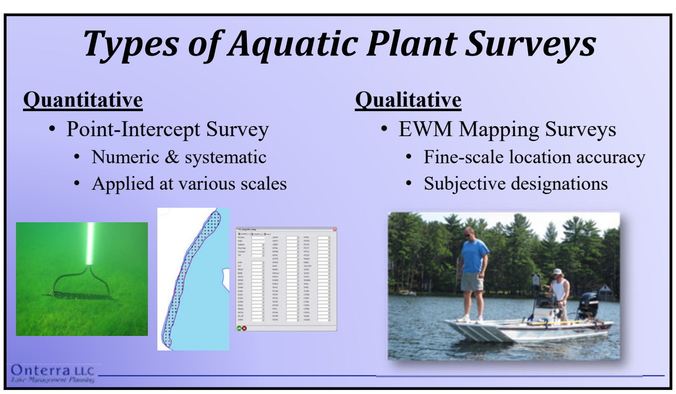
Types of Aquatic Plant Surveys
Quantitative
• Point-Intercept Survey
• Numeric & systematic
• Applied at various scales
Qualitative
• EWM Mapping Surveys
• Fine-scale location accuracy
• Subjective designations
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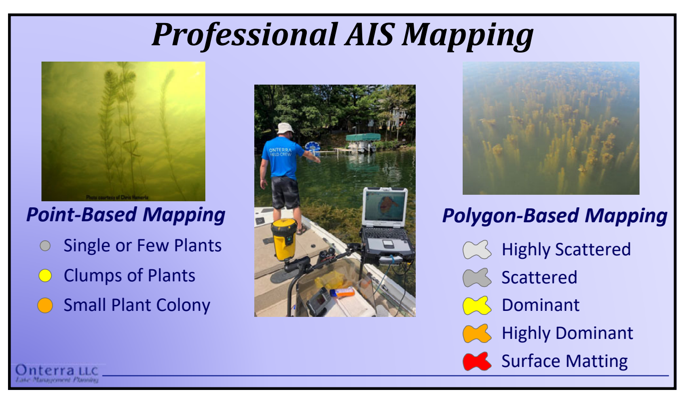
Professional AIS Mapping
Point-Based Mapping
Single or Few Plants
Clumps of Plants
Small Plant Colony
Polygon-Based Mapping
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting
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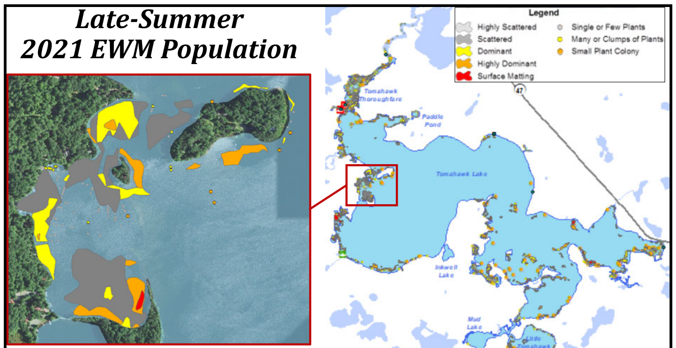
Lake Management Planning

Late-Summer 2021 EWM Population



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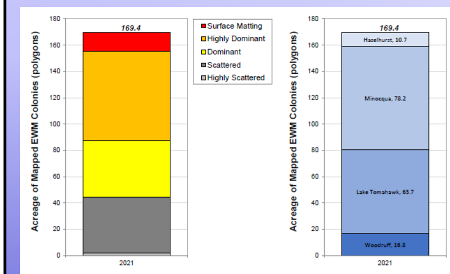
Late-Summer EWM Mapping



TLA Interactive Web App EWM Mapping

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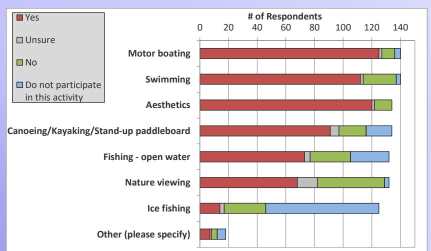
Riparian Perceptions on EWM Impacts

41.3% Response Rate

Has the EWM population ever had a negative impact on your enjoyment of Tomahawk Lake?



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Implementation Plan – Goal 2

Goal 2: Monitor Aquatic Vegetation

- *Action:* Coordinate Periodic Point-Intercept Surveys
  - Frequency: Once every 5 yrs, particularly to maintain grant eligibility
- *Action:* Periodically monitor the Eurasian watermilfoil population
  - Frequency: Every 2-3 yrs, potentially focused in scope
- *Action:* Coordinate Periodic Community Mapping (floating-leaf and emergent) Surveys
  - Frequency: 10 year intervals or if need arises such as population changes or high/low water levels
- *Action:* Periodically monitor the non-native emergent plant population
  - Frequency: Every 5 yrs, potentially volunteer-based

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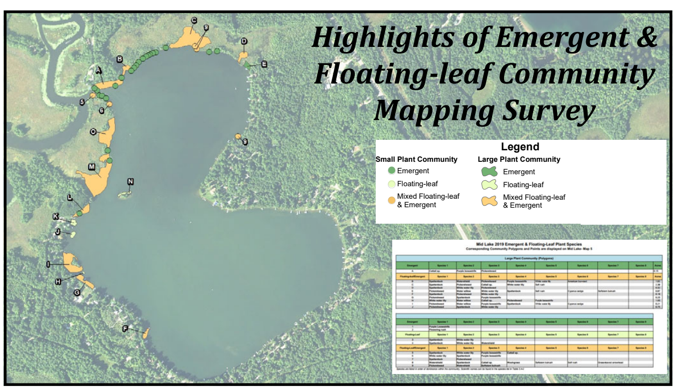
Highlights of Emergent & Floating-leaf Community Mapping Survey

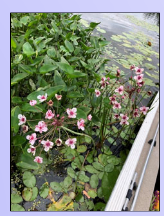


Non-Native Emergent Aquatic Plants

Pale Yellow Iris

Purple Loosestrife

Flowering Rush



Narrow-leaf Cattail

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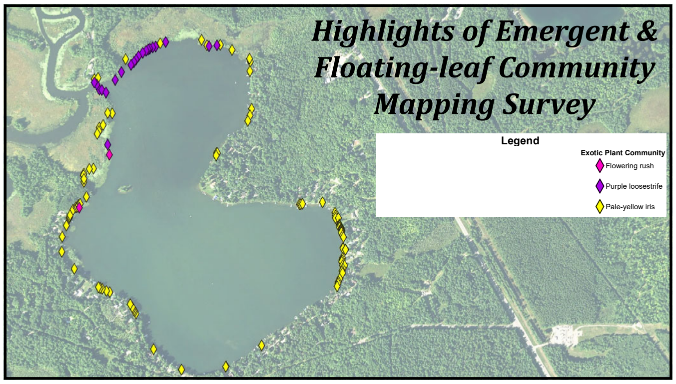
Highlights of Emergent & Floating-leaf Community Mapping Survey



Implementation Plan – Goal 3

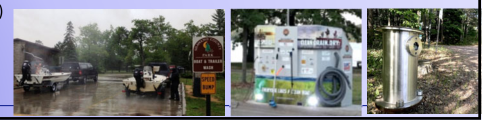
Goal 3: Prevent Establishment of New Aquatic Invasive Species

Action: Monitor Tomahawk entry points for AIS (CBCW)

Indian Mounds Campground	2015	2016	2017	2018	2019	2020
Boats Inspected	132	347	453	785	816	759
Hours Spent	36	229	350	182	268	181
Boats Inspected/Hrs Spent	0.27	0.66	0.77	0.23	0.33	0.24

Coffen Ln off Hwy 47	2015	2016	2017	2018	2019	2020
Boats Inspected	1,783	1,971	1,734	1,900	1,883	2,021
Hours Spent	304	322	319	332	340	356
Boats Inspected/Hrs Spent	0.17	0.16	0.18	0.17	0.18	0.18

Action: Investigate supplemental aquatic invasive species prevention and containment methods (pressure washing stations, water-less cleaning stations, remove video surveillance)



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Implementation Plan – Goal 4

Goal 4: Promote Education of Aquatic Invasive Species & AIS Management

Action: Convey updated aquatic invasive species information and messaging to TLA members and Tomahawk Lake riparians

- *Fragmentation concern*
- *Population management vs nuisance management*
- *Conservation ethics*
- *EWM hybridity*
- *EWM herbicide resistance*
- *Unrealistic expectations (e.g. eradication)*
- *Silver-bullet strategies*
- *Role of native aquatic plants*
- *Importance of nutrient management*
- *Safety concerns related to dense EWM*
- *Human tolerance to EWM conditions (surface-matting)*

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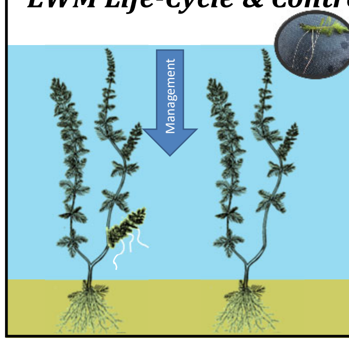
EWM Life-Cycle & Control Strategy Philosophy



- Strategy is straight-forward compared to those w/ seed or turion base
- Herbicide needs to translocate to root crown (*hard to kill with herbicides*)
- Hand-harvesting is analogous to single treatment (*extremely time intensive)*
- Winter drawdown can be effective if completely de-water and desiccate/freeze roots.

EWM Management Perspectives

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 rely on herbicide treatment (risk assessment)
   - Will not "eradicate" EWM
3. **Minimize navigation and recreation impediment (Nuisance Control)**
   - May be accomplished through herbicide treatment, hand-harvesting, and/or mechanical harvesting
   - Set triggers (thresholds) of implementation and tolerance

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Implementation Plan – Goal 5

Goal 5: Actively manage EWM to keep the population from negatively impacting recreation, navigation, and aesthetics

Action: Conduct Integrated Pest Management Program towards EWM

Mechanical Harvesting – primary tool. 2-year trial (2022-2023) to better learn how to integrate and develop success expectations.

Herbicide Treatment – planning for first trial in 2023. Sites conducive to holding effective herbicide concentrations and exposure times (protected/confined areas) as well as high-use areas that may be less compatible with mechanical harvesting (shallow, docks, obstacles, far from off-load sites, history of quick EWM rebound)

Hand-Harvesting/DASH – elective activity for riparians. TLA would assist with permitting, but costs would be borne by benefiting riparian

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Integrated Pest Management (IPM)

Using a combination of methods that are more effective when applied collectively as part of defined strategy than when conducted separately

- Conduct mechanical harvest as primary method
- Areas difficult for mechanical harvest are those likely to be effective for herbicides
- Opportunity for HH/DASH by riparians

- Support nutrient management
- Human tolerance to EWM conditions

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Implementation Plan – Goal 5

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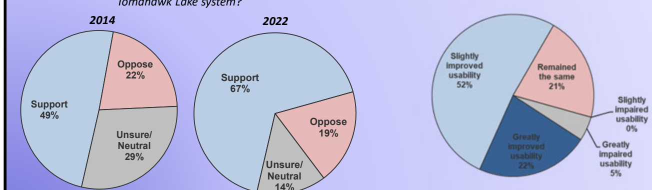
Riparian Perceptions of Mechanical Harvesting *41.3% Response Rate*

What is your level of support for the use of the following Eurasian watermilfoil management techniques (mechanical harvesting [i.e. weed cutter]) in the Tomahawk Lake system?

In 2021, to what extent would you say the outcome of harvesting in front of your property altered the usability of the lake?



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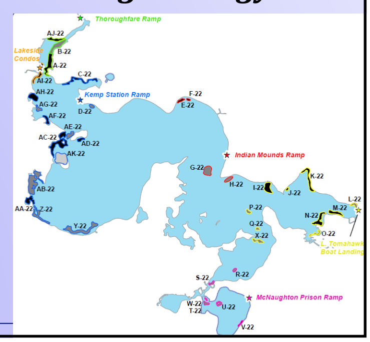
Mechanical Harvesting Strategy

- WDNR Grant secured for 2022-2023 trial program
- Larger & newer equipment secured for 2022-2023
- Efficiency program in place
- Professional monitoring for changes in aquatic plants
- Volunteer monitoring of longevity of nuisance relief



Onterra LLC Lake Management Planning

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EWM Best Management Practices (BMPs)

- **BMP is a "placeholder" term to represent the management option that is currently supported by that latest science and policy**
- **Definition evolves over time**
  - Pre 2010 - small spot treatments with granular products (ester formulations)
  - Early 2010s - larger spot treatments with liquid products (amine formulations)
  - Mid 2010s – whole-lake treatments, spot treatments with herbicide combos, hand-harvesting/DASH
  - Current– whole-lake/basin approaches, nuisance maintenance vs population management, scale-appropriate HH/DASH, mechanical harvesting, increasing human tolerance, new chemistries such as ProcellaCOR, barrier curtains (enclosure/exclosure)

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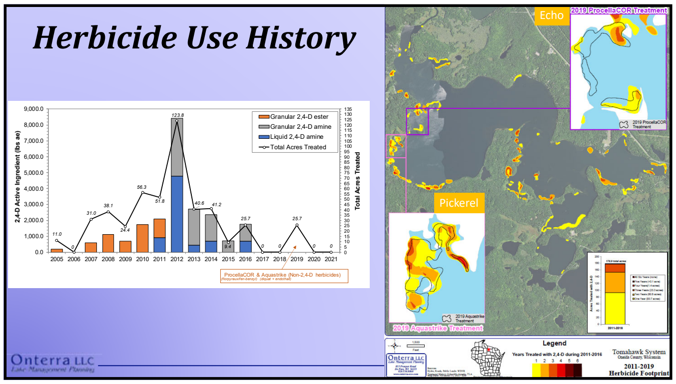
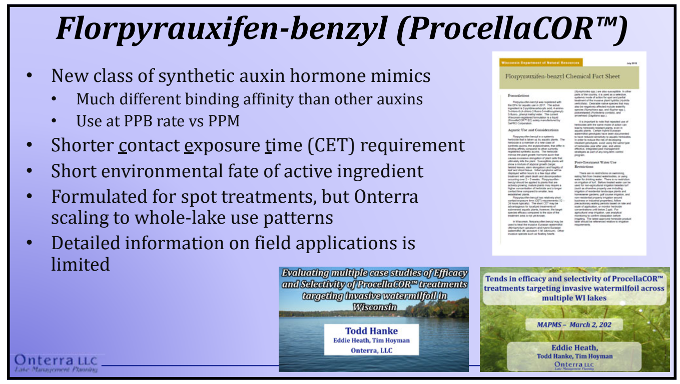
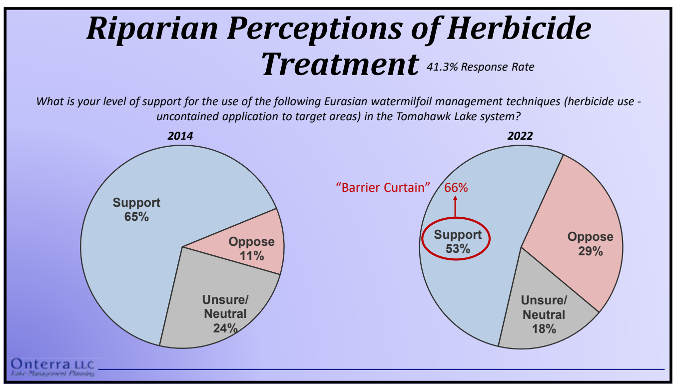
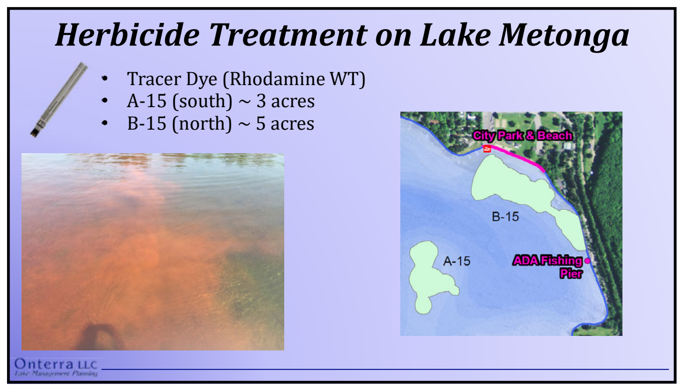
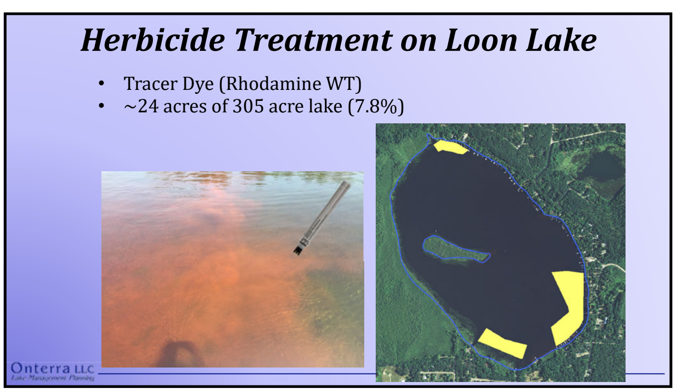
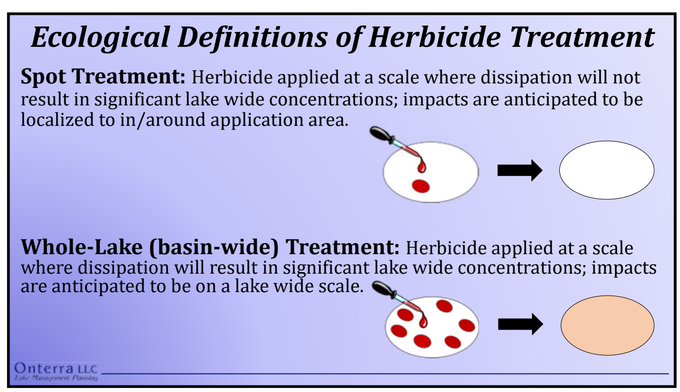

Herbicide Use History
Granular 2,4-D ester
Granular 2,4-D amine
Liquid 2,4-D amine
Total Acres Treated
2,4-D Active Ingredient (lbs ae)
Total Acres Treated
Echo
2019 ProcellaCOR Treatment
Pickerel
2019 Aquastrike Treatment
Legend
Tomahawk System
2011-2019
Herbicide Footprint
Onterra LLC


Florpyrauxifen-benzyl (ProcellaCOR™)
New class of synthetic auxin hormone mimics
Much different binding affinity than other auxins
Use at PPB rate vs PPM
Shorter contact exposure time (CET) requirement
Short environmental fate of active ingredient
Formulated for spot treatments, but Onterra scaling to whole-lake use patterns
Detailed information on field applications is limited
Evaluating multiple case studies of Efficacy and Selectivity of ProcellaCOR™ treatments targeting invasive watermilfoil in Wisconsin
Todd Hanke
Eddie Heath, Tim Hoyman
Onterra, LLC
Tends in efficacy and selectivity of ProcellaCOR™ treatments targeting invasive watermilfoil across multiple WI lakes
Eddie Heath,
Todd Hanke, Tim Hoyman
Onterra LLC


Riparian Perceptions of Herbicide Treatment
41.3% Response Rate
What is your level of support for the use of the following Eurasian watermilfoil management techniques (herbicide use - uncontained application to target areas) in the Tomahawk Lake system?
2014
Support 65%
Oppose 11%
Unsure/ Neutral 24%
2022
"Barrier Curtain" 66%
Support 53%
Oppose 29%
Unsure/ Neutral 18%
Onterra LLC


Herbicide Treatment on Lake Metonga
Tracer Dye (Rhodamine WT)
A-15 (south) ~ 3 acres
B-15 (north) ~ 5 acres
City Park & Beach
B-15
A-15
ADA Fishing Pier
Onterra LLC


Herbicide Treatment on Loon Lake
Tracer Dye (Rhodamine WT)
~24 acres of 305 acre lake (7.8%)
Onterra LLC


Ecological Definitions of Herbicide Treatment
Spot Treatment: 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.
Whole-Lake (basin-wide) Treatment: Herbicide applied at a scale where dissipation will result in significant lake wide concentrations; impacts are anticipated to be on a lake wide scale.
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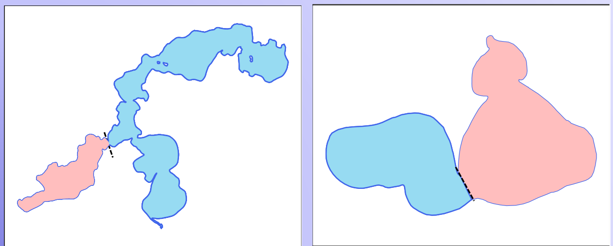
Area of Potential Impact (AOPI)

- Mixing area, reaches equilibrium - basin or bay of a lake



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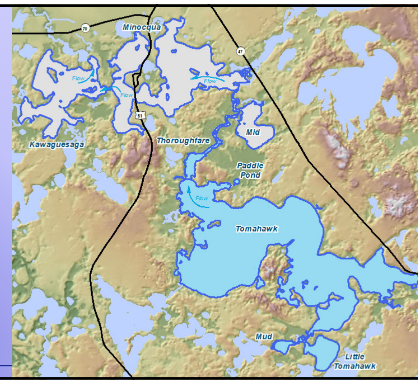

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Implementation Plan – Goal 5

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Hand-Harvesting/DASH – elective activity for riparians. TLA would assist with permitting, but costs would be borne by benefiting riparian

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Hand-Harvesting/DASH for Riparians

Before

After

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Implementation Plan

Goal 6: Promote Lake Stewardship and Conservation Ethics to TLA Members and Tomahawk Lake Riparians

Action: Educate stakeholders on the importance of shoreland condition and shoreland restoration and protection

Action: Facilitate connecting riparians with Healthy Lakes & River Grants

Action: Promote long-term protections for private property on the Tomahawk Lake System

Healthy Lakes & Rivers

TLA Interactive Web App Shoreland Surveys

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Thank You

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B

APPENDIX B

Stakeholder Survey Response Charts and Comments

Tomahawk Lakes - Anonymous Stakeholder Survey

Surveys Distributed: *446*
Surveys Returned: *184*
Response Rate: *41.3%*

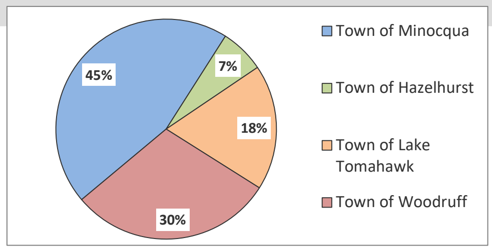
Tomahawk Lakes Property

1. Which of the Tomahawk Lakes is your property on?

Answer Options	Response Percent	Response Count
Tomahawk Lake	97.3%	178
Little Tomahawk Lake	0.5%	1
Mud Lake	0.0%	0
Inkwell Lake	0.0%	0
Paddle Pond	0.0%	0
Tomahawk Thoroughfare	1.1%	2
Not a riparian property owner (non-shoreline property)	1.1%	2
	answered question	**183**
	skipped question	**1**

2. In which municipality do you pay property taxes?

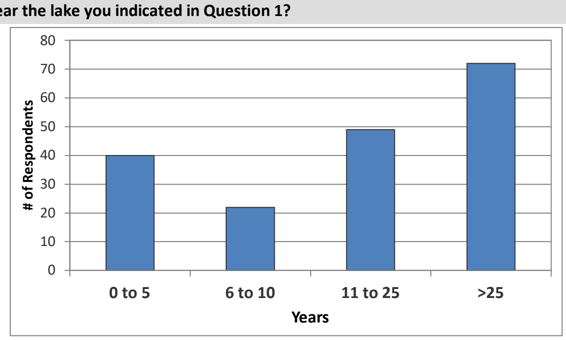
Answer Options	Response Percent	Response Count
Town of Minocqua	45.1%	83
Town of Hazelhurst	6.5%	12
Town of Lake Tomahawk	18.5%	34
Town of Woodruff	29.9%	55
Do not pay property tax (i.e. renter)	0.0%	0
	answered question	**184**
	skipped question	**0**



3. How many years have you owned or rented your property on or near the lake you indicated in Question 1?

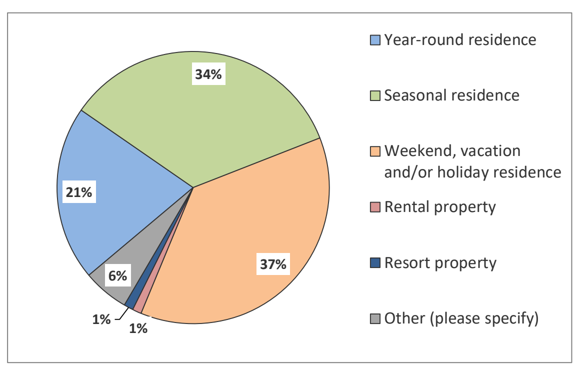
Answer Options	Response Count
	183
answered question	**183**
skipped question	**1**

Category (# of years)	Responses	% Response
0 to 5	**40**	**22%**
6 to 10	**22**	**12%**
11 to 25	**49**	**27%**
>25	**72**	**39%**



4. How is your property on or near the lake used?

Answer Options	Response Percent	Response Count
Year-round residence	20.8%	38
Seasonal residence	34.4%	63
Weekend, vacation and/or holiday residence	37.2%	68
Rental property	1.1%	2
Resort property	1.1%	2
Other (please specify)	5.5%	10
	answered question	**183**
	skipped question	**1**

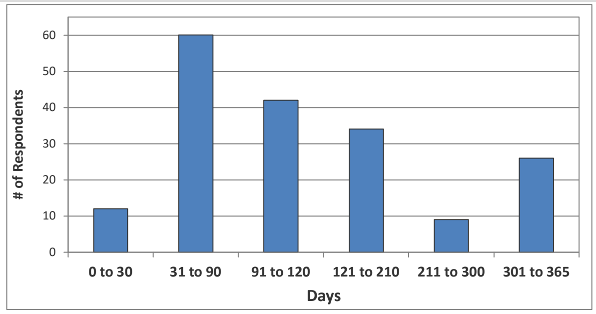


Number	Other (please specify)
1	Seasonal use for a 3-generation family of 18 people; multiple cottages
2	Used year around averaging about one week per month
3	Year-round vacation/weekend residence
4	Seasonal from late April until mid October
5	Part of Indian Shores Resort
6	Campground used mainly summer vacation weekend holiday
7	Many times of the year, not permanent residence
8	live nearby so use it througout the summer but never for a full month at a t
9	Own property at Indian Shores Campground
10	We rent it approximately 10 weeks throughout the entire year. Then we use it as much as possible.

5. Considering the past three years, how many days each year is your property used by you or others?

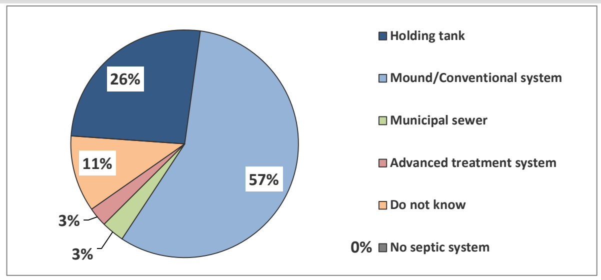
	Response Count
answered question	183
skipped question	1

Category (# of days)	Responses	%
0 to 30	12	7%
31 to 90	60	33%
91 to 120	42	23%
121 to 210	34	19%
211 to 300	9	5%
301 to 365	26	14%



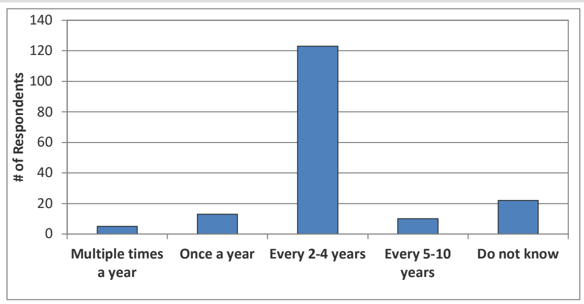
6. What type of septic system does your property have?

Answer Options	Response Percent	Response Count
Holding tank	26.1%	48
Mound/Conventional system	57.1%	105
Municipal sewer	3.3%	6
Advanced treatment system	2.7%	5
Do not know	10.9%	20
No septic system	0.0%	0
answered question		184
skipped question		0



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

Answer Options	Response Percent	Response Count
Multiple times a year	2.9%	5
Once a year	7.5%	13
Every 2-4 years	71.1%	123
Every 5-10 years	5.8%	10
Do not know	12.7%	22
answered question		173
skipped question		11

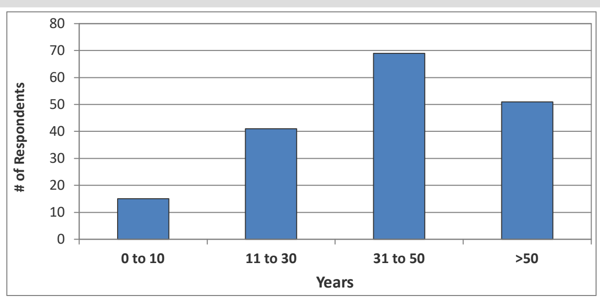


Recreational Activity on Tomahawk Lakes

8. How many years ago did you first visit the Tomahawk Lake system?

Answer Options	Response Count
answered question	176
skipped question	8

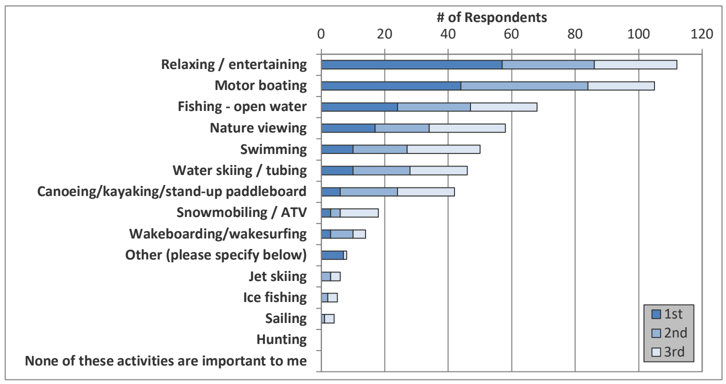
Category (# of years)	Response Percent	Response Count
0 to 10	8.5%	15
11 to 30	23.3%	41
31 to 50	39.2%	69
>50	29.0%	51



9. Please rank up to three activities that are important reasons for owning your property on or near the Tomahawk Lake system, with 1 being the most important.

Answer Options	1st	2nd	3rd	Weighted Average	Response Count
Relaxing / entertaining	57	29	26	1.72	112
Motor boating	44	40	21	1.78	105
Fishing - open water	24	23	21	1.96	68
Nature viewing	17	17	24	2.12	58
Swimming	10	17	23	2.26	50
Water skiing / tubing	10	18	18	2.17	46
Canoeing/kayaking/stand-up paddleboard	6	18	18	2.29	42
Snowmobiling / ATV	3	3	12	2.5	18
Wakeboarding/wakesurfing	3	7	4	2.07	14
Other (please specify below)	7	0	1	1.25	8
Jet skiing	0	3	3	2.5	6
Ice fishing	0	2	3	2.6	5
Sailing	0	1	3	2.75	4
Hunting	0	0	0	0	0
None of these activities are important to me	0	0	0	0	0
				answered question	**181**
				skipped question	**3**

Number	"Other" responses
1	X-C Skiing in Winter and Biking in Summer
2	Mushrooming
3	Being on a clean and clear body of water for all activities including relaxing, observing wildlife, swimming, and other water sports
4	Near family
5	Family History
6	grandchildren swimming
7	Enjoying the natural beauty and peace and quiet
8	Boating
9	Summer residence
10	Living
11	Crystal clear water, sand bottom, uncrowded lake

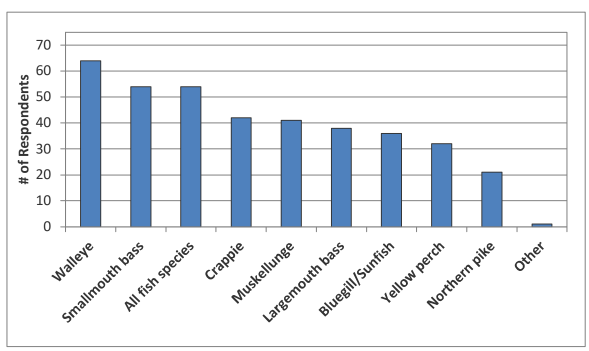


10. Have you personally fished on any of the Tomahawk Lakes in the past three years?

Answer Options	Response Percent	Response Count
Yes	72.6%	130
No	27.4%	49
	answered question	**179**
	skipped question	**5**

11. What species of fish are you interested in catching on the Tomahawk Lakes?

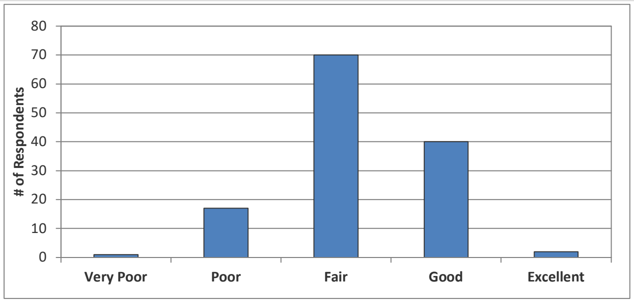
Answer Options	Response Percent	Response Count
Walleye	49.6%	64
Smallmouth bass	41.9%	54
All fish species	41.9%	54
Crappie	32.6%	42
Muskellunge	31.8%	41
Largemouth bass	29.5%	38
Bluegill/Sunfish	27.9%	36
Yellow perch	24.8%	32
Northern pike	16.3%	21
Other	0.8%	1
	answered question	
	skipped question	



Number	Other (please specify)
1	disappointed in the Walleye ban

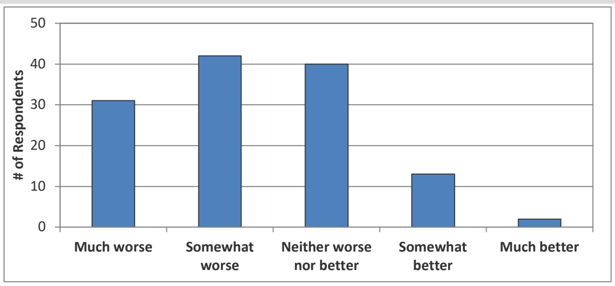
12. How would you describe the current quality of fishing on the Tomahawk Lakes?

Answer Options	Very Poor	Poor	Fair	Good	Excellent	Response Count
	1	17	70	40	2	130
					answered question	**130**
					skipped question	**54**



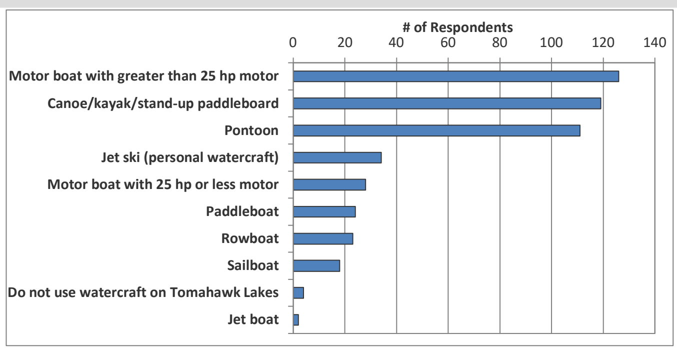
13. How has the quality of fishing changed on the Tomahawk Lake system since you have started fishing there?

Answer Options	Much worse	Somewhat worse	Neither worse nor better	Somewhat better	Much better	Response Count
	31	42	40	13	2	128
					answered question	**128**
					skipped question	**56**



14. What types of watercraft do you currently use on the Tomahawk Lake system?

Answer Options	Response Percent	Response Count
Motor boat with greater than 25 hp motor	71.2%	126
Canoe/kayak/stand-up paddleboard	67.2%	119
Pontoon	62.7%	111
Jet ski (personal watercraft)	19.2%	34
Motor boat with 25 hp or less motor	15.8%	28
Paddleboat	13.6%	24
Rowboat	13.0%	23
Sailboat	10.2%	18
Do not use watercraft on Tomahawk Lakes	2.3%	4
Jet boat	1.1%	2
	answered question	**177**
	skipped question	**7**



15. Do you use your watercraft on waters other than the Tomahawk/Minocqua Chain of Lakes?

Answer Options	Response Percent	Response Count
Yes	14.9%	26
No	85.1%	148
	answered question	**174**
	skipped question	**10**

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

Answer Options	Response Percent	Response Count
Remove aquatic hitch-hikers (ex. - plant material, clams, mussels)	75.0%	24
Drain bilge	68.8%	22
Rinse boat	34.4%	11
Power wash boat	12.5%	4
Apply bleach	0.0%	0
Air dry boat for 5 or more days	21.9%	7
Do not clean boat	15.6%	5
Other (please specify)		5
	answered question	**32**
	skipped question	**152**

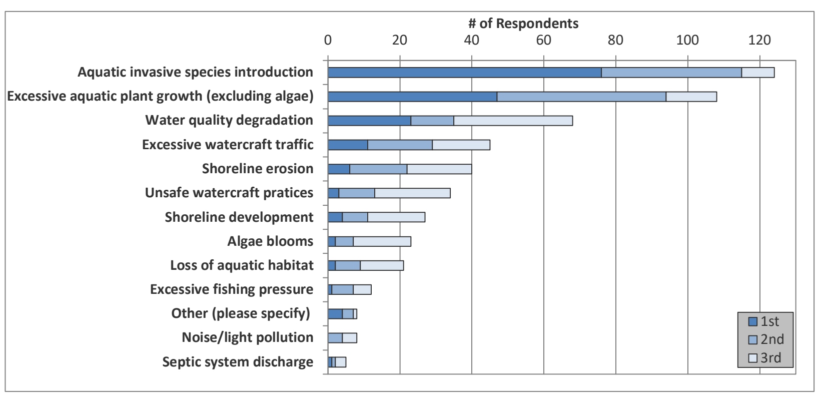
Number	Other (please specify)
1	Just use on lake system
2	We only use the kayak elsewhere (rarely); we empty water out of the passe
3	It is clean when we put it in at beginning and we do not take it out until enc
4	boating in Florida on Atlantic Ocean inlet
5	wipe the boat down with special cleaning sauce and towel

Tomahawk Lakes Current and Historic Condition, Health and Management

17. From the list below, please rank your top three concerns regarding the Tomahawk Lake system, with 1 being your top concern.

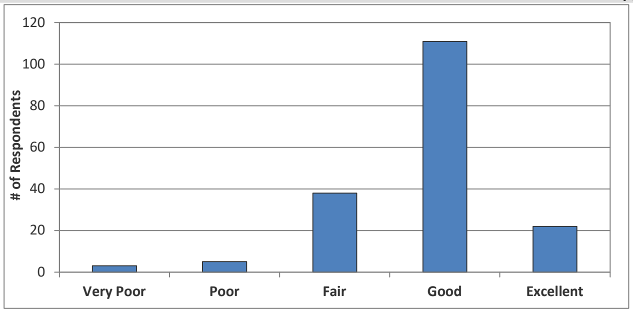
Answer Options	1st	2nd	3rd	Response Count
Aquatic invasive species introduction	76	39	9	124
Excessive aquatic plant growth (excluding algae)	47	47	14	108
Water quality degradation	23	12	33	68
Excessive watercraft traffic	11	18	16	45
Shoreline erosion	6	16	18	40
Unsafe watercraft pratices	3	10	21	34
Shoreline development	4	7	16	27
Algae blooms	2	5	16	23
Loss of aquatic habitat	2	7	12	21
Excessive fishing pressure	1	6	5	12
Other (please specify)	4	3	1	8
Noise/light pollution	0	4	4	8
Septic system discharge	1	1	3	5
			answered question	**180**
			skipped question	**4**

Number	"Other" responses
1	Lawn fertilization
2	Jet skiers and wake boats abusing the lake
3	Poor fishing
4	INDIANS SPEARING
5	The incredible increase of Milfoil is concerning
6	Milfol
7	Massive amts of milfoil!!! Affecting all aspects of life on Lake.
8	Milfoil
9	Wake Surf Boat shoreline damage
10	EWM infestation
11	In my opinion the only thing we should be focused on is the destructive invasion of Milfoil
12	So called "harvesting" of milfoil which spreads the plant all over the lake and round the lakeshore on the windward shire
13	efforts by some members of TLA to restrict boat traffic to slow-no-wake all the way to Lakeside Landing. Don't do this! It is self serving and damages the good reputation of TLA



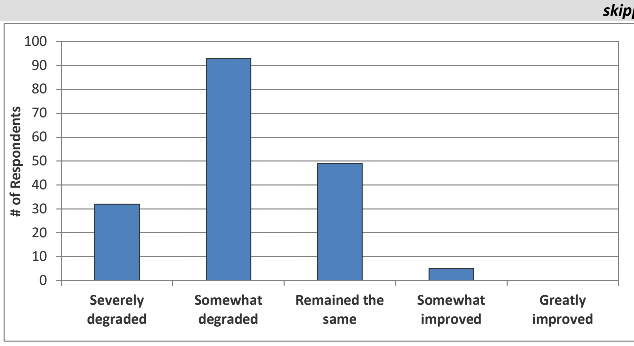
18. How would you describe the overall current water quality of the Tomahawk Lakes?

Answer Options	Very Poor	Poor	Fair	Good	Excellent	Response Count
	3	5	38	111	22	179
					answered question	179
					skipped question	5



19. How has the overall water quality changed in the Tomahawk Lakes since you first visited?

Answer Options	Severely degraded	Somewhat degraded	Remained the same	Somewhat improved	Greatly improved	Response Count
	32	93	49	5	0	179
					answered question	179
					skipped question	5



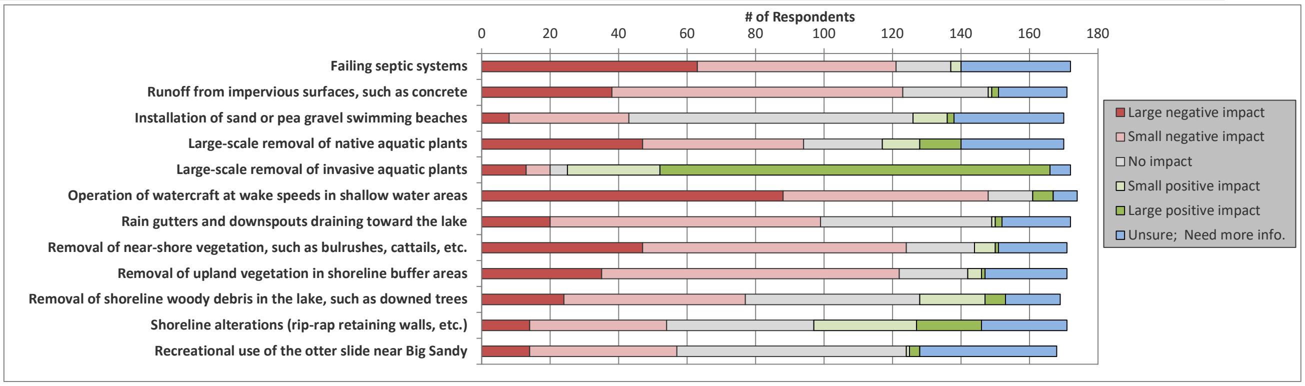
20. Which of the following would you say is the single most important aspect when considering water quality?

Answer Options	Response Percent	Response Count
Water clarity (clearness of water)	48.3%	86
Water color	0.6%	1
Aquatic plant growth (not including algae blooms)	41.0%	73
Algae blooms	3.9%	7
Smell/odors	1.7%	3
Water level	0.0%	0
Fish kills	0.6%	1
Other	3.9%	7
	answered question	178
	skipped question	6

Number	"Other" responses
1	Milfoil!
2	Not sure
3	Sustain Aquatic Species
4	Invasive aquatic plant growth
5	Eurasian Water Millfoil
6	excessive milfoil affects clarity and use of lake
7	Milfoil invasion has destroyed my shoreline

21. Using the following scale, what impact, if any, do you believe each of the following practices have on the water quality of the Tomahawk Lake system?

Answer Options	Large negative impact	Small negative impact	No impact	Small positive impact	Large positive impact	Unsure/ Need more info.	Response Count	Weighted Average
Failing septic systems	63	58	16	3	0	32	172	1.39
Runoff from impervious surfaces, such as concrete	38	85	25	1	2	20	171	1.74
Installation of sand or pea gravel swimming beaches	8	35	83	10	2	32	170	2.22
Large-scale removal of native aquatic plants	47	47	23	11	12	30	170	1.85
Large-scale removal of invasive aquatic plants	13	7	5	27	114	6	172	4.19
Operation of watercraft at wake speeds in shallow water areas	88	60	13	0	6	7	174	1.59
Rain gutters and downspouts draining toward the lake	20	79	50	1	2	20	172	1.99
Removal of near-shore vegetation, such as bulrushes, cattails, etc.	47	77	20	6	1	20	171	1.7
Removal of upland vegetation in shoreline buffer areas	35	87	20	4	1	24	171	1.7
Removal of shoreline woody debris in the lake, such as downed trees	24	53	51	19	6	16	169	2.3
Shoreline alterations (rip-rap retaining walls, etc.)	14	40	43	30	19	25	171	2.56
Recreational use of the otter slide near Big Sandy	14	43	67	1	3	40	168	1.9
						answered question	**175**	
						skipped question	**9**	



22. Which of the following descriptions do you believe most accurately describes the development (residential and commercial) of the Tomahawk Lake system shoreline?

Answer Options	Response Percent	Response Count
Under-developed	0.6%	1
Just right	68.0%	119
Over-developed	24.6%	43
Other (please specify)	6.9%	12
	answered question	**175**
	skipped question	**9**

Number	"Other" responses
1	What development?
2	Do not know
3	some areas are overdeveloped
4	varies depending on area
5	violation of # of piers and shore stations per footage of frontage.
6	slightly over developed
7	I think it is just right...there is...wonderfully, a good mix of undeveloped/state/NHAL lands to those that are developed.
8	Who determines that??
9	Just right, at this point in time.
10	Relaxing of shoreline zoning rules county wide.
11	Unsure
12	TOMAHAWK LAKE JUST RIGHT (NO MORE MULTI FAMILY PLEASE!)

Aquatic invasive species (AIS) are non-native plants and animals that are introduced into our lakes and streams and can potentially upset the natural balance of a lake ecosystem while decreasing recreational opportunities. Examples of AIS include animals such as carp, zebra mussels, rusty crayfish, round goby, and spiny waterflea; and plants such as Eurasian watermilfoil, purple loosestrife, and curly-leaf pondweed.

23. Before reading the statement provided, had you ever heard of aquatic invasive species?

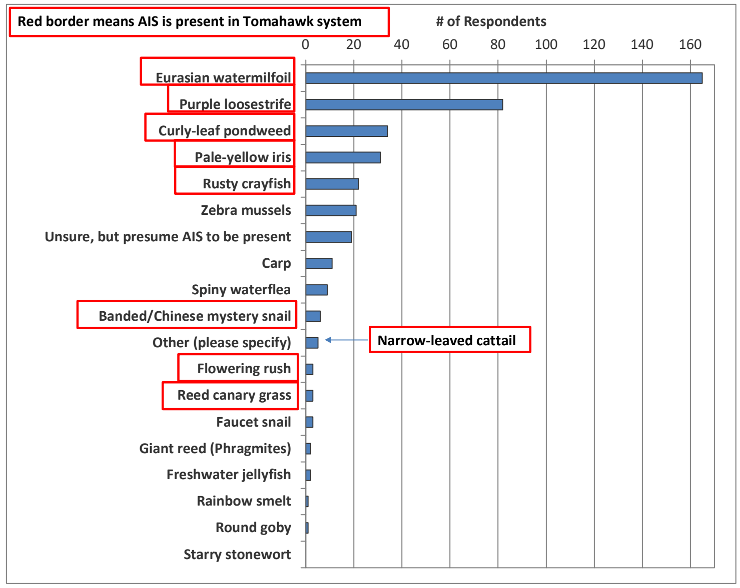
Answer Options	Response Percent	Response Count
Yes	99.4%	173
No	0.6%	1
	answered question	**174**
	skipped question	**10**

24. Do you believe aquatic invasive species are present within the Tomahawk Lake system?

Answer Options	Response Percent	Response Count
Yes	97.7%	169
No	2.3%	4
	answered question	**173**
	skipped question	**11**

25. Which aquatic invasive species do you believe are present in or immediately around the Tomahawk Lakes?

Answer Options	Response Percent	Response Count
Eurasian watermilfoil	97.6%	165
Purple loosestrife	48.5%	82
Curly-leaf pondweed	20.1%	34
Pale-yellow iris	18.3%	31
Rusty crayfish	13.0%	22
Zebra mussels	12.4%	21
Unsure, but presume AIS to be present	11.2%	19
Carp	6.5%	11
Spiny waterflea	5.3%	9
Banded/Chinese mystery snail	3.6%	6
Other (please specify)	3.0%	5
Flowering rush	1.8%	3
Reed canary grass	1.8%	3
Faucet snail	1.8%	3
Giant reed (Phragmites)	1.2%	2
Freshwater jellyfish	1.2%	2
Rainbow smelt	0.6%	1
Round goby	0.6%	1
Starry stonewort	0.0%	0
	answered question	169
	skipped question	15



Number	"Other" responses
1	Narrow Leafed cattails
2	not familiar with the water creatures
3	There are many, the names I am not sure of.
4	could be more of which I'm not aware
5	Unsure of other specific species

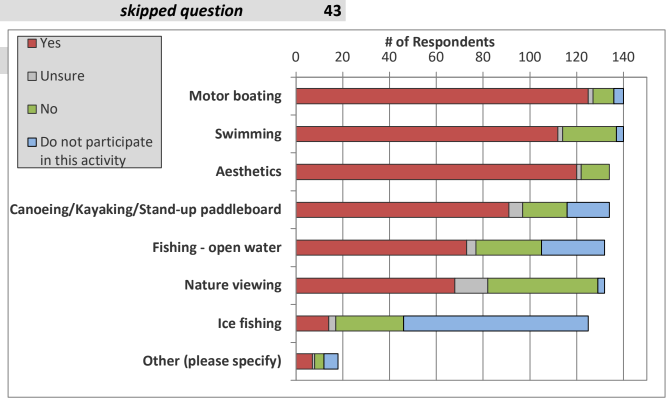
26. How confident are you that you could accurately identify Eurasian watermilfoil?

Answer Options	Not at all confident	Not too confident	Unsure	Fairly confident	Very confident	Response Count
	10	15	9	77	65	176
					answered question	176
					skipped question	8

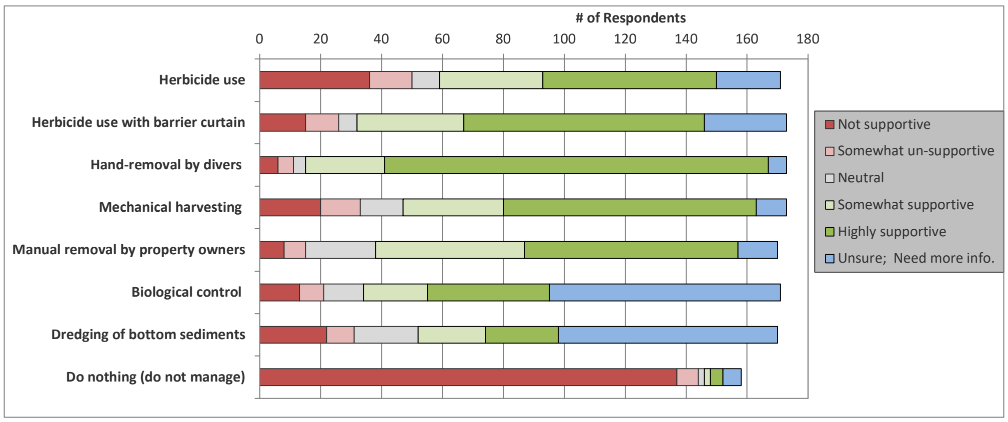
27. If you answered "fairly confident" or "very confident" in the previous question, has the Eurasian watermilfoil population ever had a negative impact on your enjoyment of Tomahawk Lake?

Answer Options	Yes	Unsure	No	Do not participate in this activity	Response Count
Motor boating	125	2	9	4	140
Swimming	112	2	23	3	140
Aesthetics	120	2	12	0	134
Canoeing/Kayaking/Stand-up paddleboard	91	6	19	18	134
Fishing - open water	73	4	28	27	132
Nature viewing	68	14	47	3	132
Ice fishing	14	3	29	79	125
Other (please specify)	7	1	4	6	18
				answered question	141
				skipped question	43

Number	"Other" responses
1	Greatest problem of Lake
2	We can't even get our boats to the boathouse!
3	heaps of milfoil washing on our shore after mowing of milfoil.
4	Milfoil is a major issue
5	water skiing
6	hydrobike cannot get through it!!
7	Live on a channel, fragment from boats & cutting are burying our frontage.
8	Has destroyed my shoreline.
9	Shallow areas filling up with EWM
10	MAJOR PROBLEM
11	Cut milfoil washes up on our shoreline.

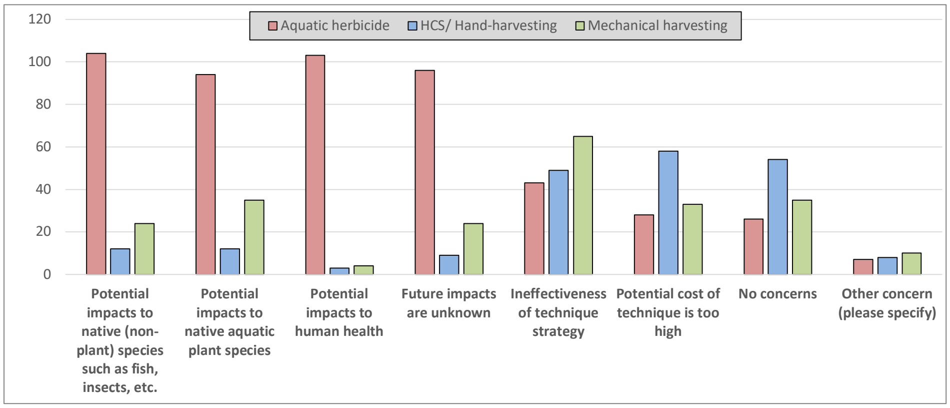


28. Eurasian watermilfoil can be controlled using many techniques. What is your level of support for the use of the following Eurasian watermilfoil management techniques in the Tomahawk Lake system?								
Answer Options	**Not supportive**	**Somewhat un-supportive**	**Neutral**	**Somewhat supportive**	**Highly supportive**	**Unsure; Need more info.**	**Response Count**	**Weighted Average**
Herbicide use - uncontained application to target areas	36	14	9	34	57	21	171	2.99
Herbicide use with a barrier curtain to help contain the chemical within the treatment area (newer technique)	15	11	6	35	79	27	173	3.41
Hand-removal by divers (includes HCS - hydraulic conveyor system)	6	5	4	26	126	6	173	4.4
Mechanical harvesting (i.e. weed cutter)	20	13	14	33	83	10	173	3.67
Manual removal by property owners	8	7	23	49	70	13	170	3.75
Biological control (milfoil weevil)	13	8	13	21	40	76	171	2.06
Dredging of bottom sediments	22	9	21	22	24	72	170	1.83
Do nothing (do not manage plants)	137	7	2	2	4	6	158	1.17
				answered question			**174**	
				skipped question			**10**	



29. What concerns, if any, do you have for the future use of aquatic herbicides, HCS/hand-harvesting, and/or mechanical harvesting to target Eurasian watermilfoil in the Tomahawk Lake system?

Answer Options	Aquatic herbicide	HCS/ Hand-harvesting	Mechanical harvesting	Response Count
Potential impacts to native (non-plant) species such as fish, insects, etc	104	12	24	108
Potential impacts to native aquatic plant species	94	12	35	105
Potential impacts to human health	103	3	4	104
Future impacts are unknown	96	9	24	103
Ineffectiveness of technique strategy	43	49	65	103
Potential cost of technique is too high	28	58	33	79
No concerns	26	54	35	62
Other concern (please specify)	7	8	10	16
			answered question	**154**
			skipped question	**30**



Number	"Other" responses
1	I have no knowledge of treatment risks!
2	Consider the Eco harvester
3	will pollute lake
4	Not concerned but want us to do what we can to eliminate it!!!!
5	no cost is too high for the best quality to our lake waters
6	Affect on aquatic plant & animal species
7	how often will the technique need to be repeated to control AIS
8	we need a new harvest company
9	New formulas don't have studies of long term health implications
10	Herbicides should not be used, negatively impacts lake
11	Do not use Herbicide, it will damage the lake. Do not turn Lake Tomahawk into an underwater desert where the fish have no place to live and die. Manage the current weeds DO NOT USE A CHEMICAL TO KILL THE LAKE.
12	Cost is high, impact only temporary of mechanical harvesting
13	don't know enough
14	harvesting, mechanical and otherwise has only propagated the species on my waterfror
15	stupid questions
16	breaks up the plant and it re-roots
17	I'm also concerned some methods may make the problem worse. We educate boaters to check their boats and trailers for invasive species before putting in the water and yet we encourage homeowners to remove invasive species around their docks on their own. If the loose milfoil, for example, isn't gathered do we know it's not floating off and settling in other areas making the problem even worse?
18	Spreading it more
19	I don't know enough about it to comment
20	Herbicide treatments should be targeted to specific heavily infested areas. Mechanical Harvesting only thickens current beds, widens EWM bed size and contributes to establishment of new beds.
21	HARVESTING NOT ADEQUATE TO CONTROL WEEDS ON OUR LAKE
22	weed debris drifts towards and litters my shoreline

30. From what source(s) do you draw the majority of your information for each of the three listed aquatic plant management techniques?

Answer Options	Aquatic herbicide	HCS/ Hand-harvesting	Mechanical harvesting	
TLA Newsletter articles/ TLA Facebook page	119	117	120	
Personal communications with friends, family, or community members	77	70	76	
First-hand observation of management techniques and their efficacy	41	67	76	
WI DNR website/presentations/publications	56	37	41	
Other lake association communications (excluding TLA)	41	33	41	
Web search and/or social media	37	28	32	
Scientific literature	34	21	19	
I do not follow/read any of these	12	12	9	
Other (please specify)	2	1	2	
			answered question	**166**
			skipped question	**18**

Number	"Other" responses
1	I don't remember being given any authoritative information from any of these sources.
2	Sorry to leave so much blank-I have heard concerns about the lake and I am supportive of doing everything possible to help improve the quality of the water and general health of the lake and surrounding areas in whatever manner is best for the environment.
3	UW lectures on PBS-Wisconsin
4	Lakeland Times
5	TLA newsletter/facebook page disseminates the TLA agenda - lots of questionable / false info.

During the summer of 2021, Tomahawk Lake Association (TLA) managed Eurasian watermilfoil (EWM) by contracting with a mechanical harvesting boat ("weed cutter") to minimize the nuisance levels of Eurasian watermilfoil and provide recreational access in areas with dense EWM colonies.

31. Has Eurasian watermilfoil been mechanically harvested in front of your property?

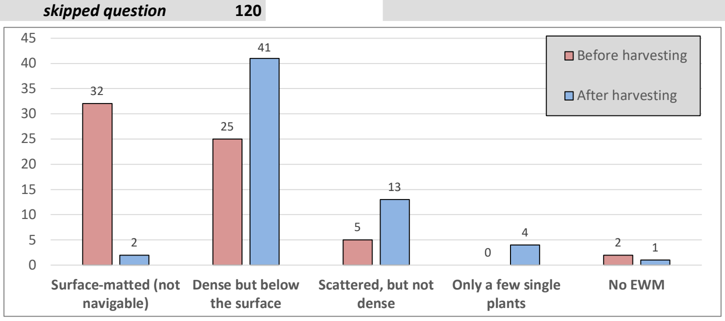
Answer Options	Response Percent	Response Count
Yes	36.1%	62
Unsure/Do not recall	20.9%	36
No	43.0%	74
	answered question	**172**
	skipped question	**12**

32. What was the density of the Eurasian watermilfoil prior to the harvesting in front of your property?

Answer Options	Response Percent	Response Count
Surface-matted (not navigable)	50.0%	32
Dense but below the surface	39.1%	25
Scattered, but not dense	7.8%	5
Only a few single plants	0.0%	0
No Eurasian watermilfoil was there	3.1%	2
	answered question	**64**
	skipped question	**120**

33. What was the density of the Eurasian watermilfoil AFTER being harvesting in front of your property?

Answer Options	Response Percent	Response Count
Surface-matted (not navigable)	3.3%	2
Dense but below the surface	67.2%	41
Scattered, but not dense	21.3%	13
Only a few single plants	6.6%	4
Completely gone/ no EWM remaining	1.6%	1
	answered question	**61**
	skipped question	**123**



34. To what extent would you say the outcome of harvesting in front of your property altered the usability of the lake?

Answer Options	Response Percent	Response Count
Greatly improved usability	22.6%	14
Slightly improved usability	51.6%	32
Remained the same	21.0%	13
Slightly impaired usability	0.0%	0
Greatly impaired usability	4.8%	3
answered question		62
skipped question		122

35. Did the harvesting in front of your property pose any challenges to you?

Answer Options	Response Percent	Response Count
Harvesting created fragments of EWM	48.4%	30
Did not remove enough EWM	51.6%	32
Water turbidity (cloudy water)	11.3%	7
No negative impacts	30.7%	19
Other (please specify	12.9%	8
answered question		62
skipped question		122

Number	"Other" responses
1	The cutting of EWM is detrimental to our shoreline - it collects in our bay and is extremely problematic to dispose of all of the cuttings.
2	I have observed the harvest but have no idea how effective it has been.
3	I did not witness directly. I would expect improvement but it is not harvested frequently enough.
4	lots of weed fragments-few to none were EWM
5	The impact is greatly seen the next year, it is like they seeded a brand new crop for fall harvest.
6	Harvesting missed a great deal of EWM in beds near our dock
7	Massive fragmentation that then blew on our shoreline and made the dock unusable
8	6-9 feet of matted rotting vegetation that ruined enjoyment of our shoreline and could not be physically removed due to volume and weight. I resorted to throwing it back into the lake on windy days where it dispersed somewhat

Tomahawk Lake Association (TLA)

The Tomahawk Lake Association (TLA) was formed in 1989. It is the only special interest organization representing the Tomahawk Lake System and represents an organization of people united by the passion to protect our lake for generations to come. TLA's mission is to promote and enhance the health of the Tomahawk Lake system and its watershed through careful stewardship of both the lake and its surrounding riparian (watershed) areas.

36. Before reading the above, had you ever heard of the TLA?

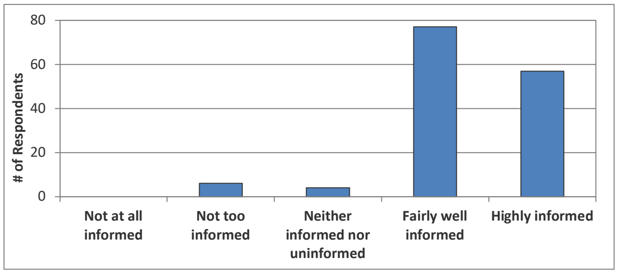
Answer Options	Response Percent	Response Count
Yes	94.8%	163
No	5.2%	9
answered question		172
skipped question		12

37. What is your membership status with the TLA?

Answer Options	Response Percent	Response Count
Current member	84.2%	138
Former member	3.7%	6
Never been a member	12.2%	20
answered question		164
skipped question		20

38. How informed has (or had) the TLA kept you regarding issues with the Tomahawk Lake system and its management?

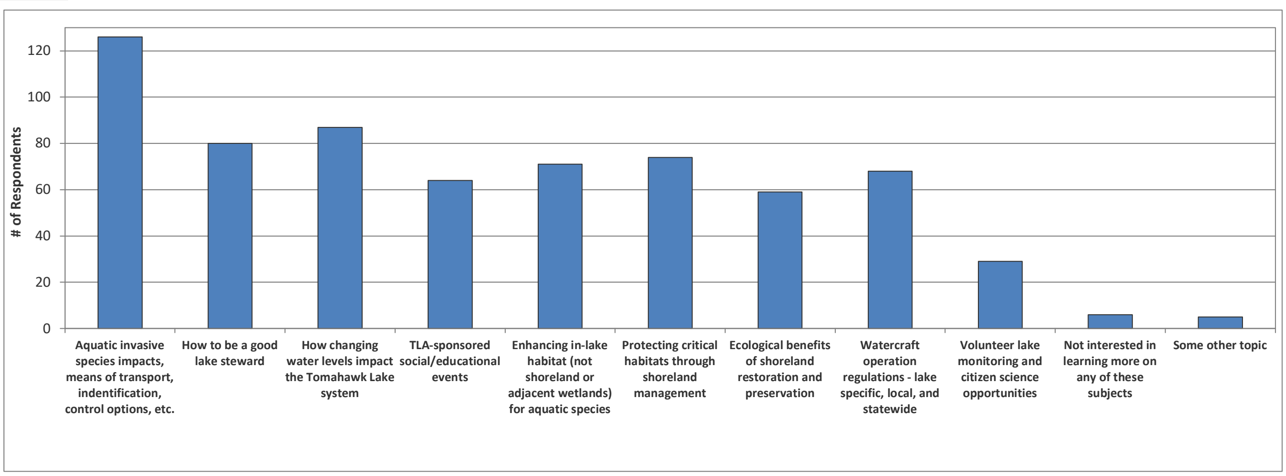
Answer Options	Not at all informed	Not too informed	Neither informed nor uninformed	Fairly well informed	Highly informed	Response Count
	0	6	4	77	57	144
					answered question	**144**
					skipped question	**40**



39. 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, indentification, control options, etc.	77.8%	126
How to be a good lake steward	49.4%	80
How changing water levels impact the Tomahawk Lake system	53.7%	87
TLA-sponsored social/educational events	39.5%	64
Enhancing in-lake habitat (not shoreland or adjacent wetlands) for aquatic species	43.8%	71
Protecting critical habitats through shoreland management	45.7%	74
Ecological benefits of shoreland restoration and preservation	36.4%	59
Watercraft operation regulations - lake specific, local, and statewide	42.0%	68
Volunteer lake monitoring and citizen science opportunities	17.9%	29
Not interested in learning more on any of these subjects	3.7%	6
Some other topic	3.1%	5
	answered question	**162**
	skipped question	**22**

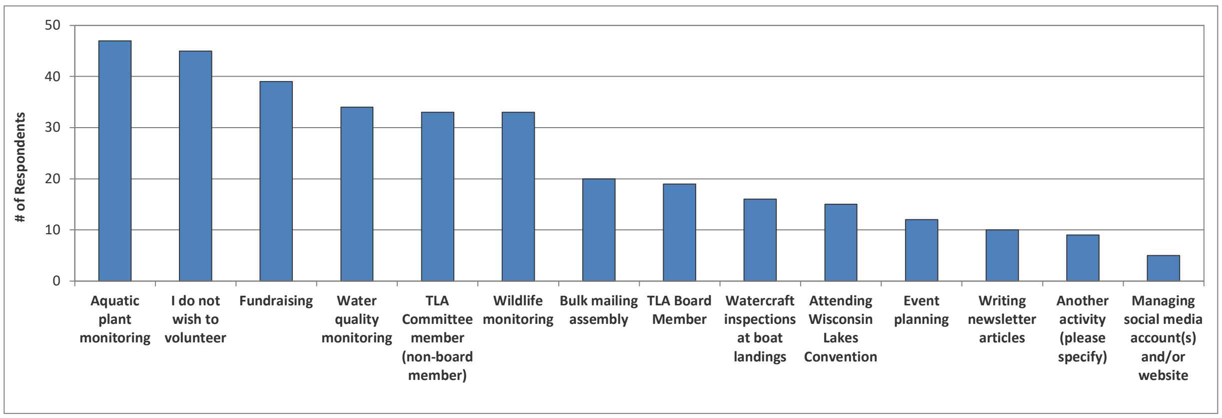
Number	Other (please specify)
1	Would like designated fishing times with prohibited recreatational boating. example early morning and late evening. Hard to fish with skiers and tubers making laps around the fishing boats and creating waves.
2	mainly in getting rid of Milfoil PROMPTLY
3	Do
4	Light and soundscape management
5	update on walleye stocking initiative/info on fish health in lake



40. The effective management of the Tomahawk Lake system will require the cooperative efforts of numerous volunteers. Please circle the activities you would be willing to participate in if the TLA requires additional assistance.

Answer Options	Response Percent	Response Count
Aquatic plant monitoring	30.5%	47
I do not wish to volunteer	29.2%	45
Fundraising	25.3%	39
Water quality monitoring	22.1%	34
TLA Committee member (non-board member	21.4%	33
Wildlife monitoring	21.4%	33
Bulk mailing assembly	13.0%	20
TLA Board Member	12.3%	19
Watercraft inspections at boat landings	10.4%	16
Attending Wisconsin Lakes Convention	9.7%	15
Event planning	7.8%	12
Writing newsletter articles	6.5%	10
Another activity (please specify)	5.8%	9
Managing social media account(s) and/or wel	3.3%	5
answered question		154
skipped question		30

Number	Another Activity (please specify)
1	I am not at the Lake for long enough periods to volunteer.
2	Donations, word-of-mouth awareness
3	clearing aquatic plants from my bay
4	Volunteered plant monitoring
5	Participation in events, clean up efforts
6	I am a board and committee member and do many of the above
7	In any fashion I am capable of.
8	Financial support
9	If I spent more time up there I'd definitely volunteer for some activities.. I intend to once I retire.



41. Would you be willing to contribute funds, or additional funds beyond what you may currently pay as a member, to support additional Eurasian watermilfoil management?

Answer Options	Response Percent	Response Count
Yes	58.1%	100
No	8.7%	15
Would need more information to make the decision	33.1%	57
answered question		172
skipped question		12

42. Please feel free to provide written comments concerning Tomahawk Lakes, its current and/or historic condition and its management.

Answer Options	Response Count
answered question	71
skipped question	113

Number	Response Text
1	New home owner who is very concerned with Lake management and willing to help/contribute
2	We are very concerned about is eurasian milfoil. We think TLA should give up on divers and herbicides, and buy a large mechanical harvester. Property owners would contribute to that. The one that was on the lake last summer was too small and didn't accomplish much.
3	EWM is a challenge/problem that continues to concern me quite a bit.
4	See comment above. Some lakes have designated times for fishing so that waves from recreational boats don't swamp the fishing boats. Early am and late evening for example. Bring the walley fishing back!!
5	I love Lake Tomahawk and appreciate what the TLA does to protect and improve it. I am quite concerned by the action of specific member(s) who live in close proximity to Lakeside Landing and wish to make that stretch of water slow-no-wake for reasons that appear self serving to me. As a fellow resident of this stretch of water I strongly object to this measure as it would devalue my own property, devalue my experience boating and fishing on the lake, and eliminate the single best stretch of waterskiing on the entire chain.
6	TLA must convince non-member Tomahawk Lake residents to join in!
7	Thanks for all your work towards maintaining a healthy lake system
8	UW-Madison sponsored Science on Tap, Jan.5, 2022, addressed aquatic invasive species, specifically EWM. The presentation indicated that efforts to eradicate it have not been demonstrated to be effective or safe. 2-4D herbicides rarely reach minimum effective levels of 2 ppm and its long-term effect on other aquatic life is unknown. Mechanical and other forms of "harvesting" may actually aid in dispersing EWM by fragmenting the plant. Hybridization of EWM with native milfoils compounds the problem. Noninterventional monitoring of EWM in a number of Wisconsin lakes (including Oneida County) shows that its distribution within a given lake generally stabilizes and even declines over time. So these efforts that are being promoted to eradicate EWM may be, as it is said in the Ozarks, "pissing into the wind."
9	Thank you for your hard work in preserving our lake.
10	I donate money, however, the milfoil removal in my location in Kemps Bay hasn't occurred. The maps of the mechanical removal stopped short and the my dock was barely accessible by boat due to milfoil overgrowth.
11	I thank you all for the efforts to hear our voices and to take actions to keep our lake clean, clear, free from milfoil, and sustainable.
12	PLEASE put in lake specific controls/restrictions for wake boat operation close to shore and radio volume/music playing on boats!!
13	Must be more aggressive to remove EWM. Skeptical that cutting best option. Consider ecoharvester and use chemicals
14	Would be happy to contribute providing services would impact my property. Services are non existence
15	The TLA website contains more information on *<name removed>* overinflated perception of himself is, versus relevant and meaningful updates on the progress of controlling milfoil.
16	I am grateful that we have a strong and active lake association. Fishing quality on our lake is important, and I am an active fisherman. But fishing quality fluctuates from year to year and is nowhere near as important to me as the catastrophic growth and effects of Eurasian milfoil over the last two seasons. I chose a property on Lake Tomahawk over 25 years ago over all other lakes in the area specifically because of the pristine nature of the lake and its water quality. For the first time in all the years we have been on the lake, I actually had my enjoyment of the lake impaired by the degradation from milfoil. Controlling milfoil and other exotic species has to, in my opinion, be the primary focus of the Lake Tomahawk association.
17	Disappointed that what we have been doing does not seem to work and that grant money is no longer available to the extent we need it. Unsure about the best long-term strategy at this point.
18	Chemicals for controlling EWM did not work and negatively affected animal and possibly human life. Would it be helpful to train property owners how to harvest EWM themselves if they want to? Or can they volunteer to help with the mechanical harvesting?
19	It seems that the weed conditions in the lake are getting worse based upon observation and discussions with neighbors.
20	most of the owners are great stewards of the lake and shore line. I am worried that the new people will want to change the dynamics of this beautiful yet fun lake. I think that people who use the lake for day visits should be given opportunity to contribute the continued quality of the lake by asking or putting a collection box at each launch area.
21	Thank you for caring and getting involved
22	thank you for all you do to keep our lake beautiful!
23	Communication about EWM has drastically been reduced in the last year.
24	TLA is the worst at invasive species plant management in the whole Minocqua chain. It is an extremely concerning issue.
25	Been fishing on the chain, mostly lake tomahawk, for 40 years. Walleyes have improved markedly in the last 5 years under the keep moratorium and it seems like the most logical path forward would be to institute a permanent catch and release policy on the Minocqua Chain turning our wonderful lakes into a “destination” or “must fish” spot for the State of Wisconsin and surrounding states. As an avid Lake Link member many people dream about their bucket list vacation trips to Ontario and the Northwest Angle just for the chance to catch a trophy Walleye. My family and I have caught several trophy walleye both on the boat and through the ice. Musky fishing: We think that the 50 inch limit was a fantastic move toward creating a trophy fishery. The cooperation between the lake association the state/DNR/and local stakeholders should be commended. We also hope Musky stocking continues. Imagine having a trophy musky and walleye fishery. Largemouth bass are an enemy that we should talk about more. They aren’t supposed to be here (in this volume anyway), since the lake is mostly a deep basin with a cisco forage base suitable for cool-water fish like walleye, pike, musky, smallmouth bass, and even lake trout. But largemouth bass are here, and they’ve gotten white-glove treatment with the catch and release movement among our tourist visitors. Compare that to walleye, where every keep-able fish is kept. There are selection pressures that are at odds with the best-case scenario of a walleye lake with a few bass in the weedy bays. Other big fisheries with largemouth bass problems, like Lac du Flambeau’s Fence Lake and Crawling Stone Lake chain have caught onto this. The tribes have started trapping out the exploding stunted largemouth population. Why haven’t we? Please keep lake development to a minimum. All of the guests we have comment about how wild the lake is and how the undeveloped shoreline reminds them of being in a very remote location. We need to learn from the mistakes of popular Southern Wisconsin Lakes who have sold every piece of possible shoreline, causing dangerous waterways that people avoid during nice sunny days. Development of shoreline will bring more boaters, pollution, and a less enjoyable location for everyone.
26	Weed cutter spent a lot of time in our area last summer. We have a lot of weeds but not EWM. Seemed like weed cutter was not targeting high concentration areas of EWM. Are there options to add several hand removal pontoon units?
27	Last summer was the first time I've personally seen the growth and problem with Eurasian Milfoil, and I was truly amazed at its growth from the year before, and worried about it. It is not in front of my property, but how long until it will be? We must eradicate it.
28	It has been appalling what has happened to our lake over the last number of years.

29	TLA needs to counsel with Lake Associations who have effectively cut the DNR out of the process and protected their lake. Catfish lake in Vilas county is a good example.
30	We don't believe chemicals should be a milfoil mgmt option, particularly for any new chemical that has not been studied for at least 20 years. We don't believe TLA even has jurisdiction to dump chemicals in the lake.
31	Let's please keep the lake natural and clean for future generations to enjoy. I'd like to see TLA take a more aggressive stance on the increased boat traffic and wake boats and the shoreline erosion that is happening because of it.
32	I believe the past chemical treatment of the weeds caused harm to the lakes ecosystem. I* have seen fish with growths floating dead.
33	The TLA aboard needs to continue to be open to and do careful research on ALL options for invasive species management and elimination before committing to both short and long term strategies.
34	Thank you for reaching out! We love our lake and all it provides. Due to space consideration , I will make my comments brief and to the point. We all supported TLA and its "original" mission. It was welcomed and supported by many of us over the "fair share" amount. TLA has morphed and took on more than it should have. While these endeavors are important they allowed the board to take their eye off the ball (original mission). The board is now consumed with many issues. Eurasian Milfoil is everything period!! All other matters can wait as your resources are splattered. When significant dollars are spent on executive director salary we were all surprised and questioned the logic. When the hand removal system was implemented we all knew it was a band-aid and did not address the issues. The employees were less "on task" as we observed often. So over time we and many I know said enough is enough and we withdrew our support to TLA. In the latest newsletter, Noah Lottig comments finally gave a "we get it" approach. I believe the board has great love for Lake Tomahawk, but needs to put all of its resources and efforts toward Milfoil. You will then see a re-newed participation and enthusiasm.
35	Thanks to TLA Board for all your efforts! Fully support generation of monies to deal with lake issues to maintain or improve our Treasure!
36	Something has to be done to control EWM, the cutting seems to make it worse in managing the cuttings. The timing of having the divers come remove is an issue as well as they simply don't have the manpower to remove all in the spring and by the time they get done the summer is over.
37	The TLA is doing a good job to protect our lake.
38	Have we tried weevils to manage Eurasion milfoil? I support aggressive Milfoil mitigation actions.
39	Thanks for all your efforts on the TLA, we appreciate you!
40	EWM is presently the biggest issue effecting the Tomahawk Lake system. The roll out of the Mechanical Harvestor (cutting) was poorly executed, not completely the fault of TLA communications, of when and where areas would be harvested. Some of the worst areas were not addressed until the end of the summer...if at all. If the Mechanical Harvestor is continue, the implementation of the harvesting must be executed equitably and address the worst areas first. A schedule of when areas will be cut should be put out at the beginning of the season and any changes communicated when they occur. Communication should be through an email blast.
41	The lake seems to be ok except for the invasive species.
42	Could the number and size of boats on the lake be limited?
43	Sunflower Bay is very reduced by weeds for hydrobike props, compared to several years ago!
44	Thanks TLA for all you do!
45	Our property taxes are based on the value of our property, specifically the lake. Our taxes escalate every year because the assessors believe our lake value appreciates, The opposite is true, the lake has depreciated in value because of these problems. We can't swim, the fish population has deteriorated to all time lows, and navigating the boat in areas is a real challenge. Part of our taxes should go to these causes.
46	I am so proud to live on Tomahawk Lake. Protecting the lake and being a donor is critical. Thank you TLA.
47	Since we bought our property in 2014, EWM has become an overwhelming nuisance to our recreational use of the lake. More needs to be done quickly to control the spread of it.
48	Fished Tomahawk in the mid 1950's. Outstanding Walleye fishery, no invasive issues of any sort, and of course much less boat traffic. Heavy fishing pressure(summer and winter) along with spring harvest regulations have taken its toll. I stop to think when I was 10, and how it's all changed in 65 years. I have a Grandson who is 10, loves to fish, and thinks it is a awesome lake. I only wonder what his feelings and answers to these questions will be in 65 years?
49	I appreciate the hard work of Noah and the TLA board in managing EWM this past year. Thank you.
50	TLA operating budget is not specific enough. I'm skeptical of how my fair share is being spent. How do you operate with a negative budget? Is there a positive balance somewhere? Glad to see APM going to be used. Your description of dock in and dock out is poor. I don't like that so much is being spent on "mapping" of existing weeds as it doesn't take an independent source to identify where our EWM is. Was/is Onterra able to sell their data to a third party ? They looked to be doing a rather in depth analysis of our water depths in areas that have no EWM. Are you planning to share the updated APM plan with us ? Tomahawk Lake is a gem and hopefully will continue to be for a long time! Much love, see you at a meeting soon.
51	My family has been boating and skiing on Tomahawk Lake and the Minocqua chain for 56 years and the aquatic weed growth this past season and the past few years has been much worse than I have ever seen. I think we need swift action with all hands on deck.
52	Appreciate all that you have been doing in the fight against Eurasian Milfoil. It feels we are losing the battle. But I have hope. Would love to see the milfoil areas that are in the middle of the lake areas (sunken island in Sunflower bay or between seagull island and Indian Mounds be marked with a buoy to flag boaters to avoid operating through these areas and spreading it more. Also would like to see Wakeboarding or wake surfing done in deeper water to safe our shoreline and prevent erosion of lake bottom. We do these activites and ALWAYS try to stay in deep water away from the shoreline.
53	The increased plant production on TL & other lakes in the area is sad. Not sure this will be eradicated ever. I fear cutting only spreads it to every nook & cranny because of fluctuating water level & boating activity.
54	Thanks for all you do to keep the lake beautiful. I appreciated your question about sound and light scape around the lake. It seems some of the bigger houses that have gone up recently are using A LOT of lights outside. In addition, removal of trees from properties along HWY 47 has increased traffic sound exponentially. It stands out radically in contrast to the existing homes on the lake. Not sure what can be done about it but would like to see discussion of good soundscape and lightscape practices.
55	Milfoil has made our shoreline unswimmable, huge change from almost none present to unusable in past few years. need to do something.
56	Please continue to work with all land owners and keep our lake strong and healthy. Thanks for all you do.
57	Very worried about milfoil concentrations growing beyond control
58	keep up the good work, worried about commercial development for example Indian Shores 50 plus boat slips in small concentrated area
59	EWM is out of control and has gotten significantly worse over the past 2 years. TLA has suggested there is no concern related to future spread since it has already established itself in the areas where it will grow. This is untrue and we have 2 large new EWM beds in front of our property that developed last summer. It may only grow in 10% of the lake, but that now appears to be the entire shoreline. Using the HCS dive boats for removal is ineffective and expensive and has very minimal impact. TLA communication related to chemical treatment with ProcellaCor that it works in Minocqua/Kawagasaga, but not Lake Tom because our lake is so different is hard to believe. A number of us have contacted TLA leadership and inquired about the purchase and use of the EcoHarvester which pulls EWM from the roots as an alternative solution, but it seems this option was never given serious consideration. When looking at potential solutions it is essential to consider all options. And finally, why has TLA not worked in partnership with Minocqua/Kawaga association in addressing the milfoil issue?

60	lake front lawn fertilization needs to be addressed
61	Keep up the good work
62	EWM management / reduction is the primary area of concern. There are many projects that are good for the health of the lake and I support them, but the over arching priority should be reducing EWM. In my view, mechanical harvesting is a terrible process as it is ineffective at Removing EWM, and spreads it over time. TLA needs to use site specific herbicide applications to reduce the EWM areas in the lake. Other lake systems are using ProcelaCore with great success. we should too.
63	Appreciate all that has and is currently being done to keep the system available for years to come
64	We want the TLA leaders to remain open to the limited, prudent use of chemical control of Eurasian Milfoil. Mechanical control only will not be enough to control it, we believe.
65	Appreciate all your efforts to keep the good quality of our lake.
66	I am very surprised that our newsletter compared current EWM coverage with historic, and determined EWM has not spread. I am an Avid fisherman. In my opinion, EWM has greatly increased it's coverage area and density during the past 2-3 years.
67	Concerned with amount of boat traffic, specifically large wake created by surf boats. Want to see undeveloped shoreline to remain that way. Would like to see fishing improve
68	This past summer was clearly the worst AIS situation that I've seen on Lake Tomahawk. The situation seems to have gotten well beyond what can be managed using the current diver approach.
69	The milfoil was very bad this year and the worst I have seen it in 10 years. Lake traffic also is at its highest level ever. Most traffic appears to be coming in from chain of lakes. Seeing a lot more garbage on shorelines and in the water near big sandy and the islands.
70	I have been a fishing guide for over 20 years as well as a professional tournament fisherman. I guide full time in South eastern WI and fish every friday-saturday-sunday on lake tom. The milfoil on lake Tom has dramatically improved the fishing over the last 10 years on this lake, same as eagle River chain. due to the depths of the lake, I believe this weed with keep creeping towards shorelines, but will never get out past 17' water, just as all SE Wisconsin lakes have. I am also not confident that it can ever be controlled unless all pleasure boating is banned from the public launches. the wake boat ballasts are what has spread it so quickly in SE WI.
71	Family has been property owner on mid lake/tomahawk lake since 1955, my wife and I on Tomahawk since 1985. Overuse of shoreline and lake in addition to milfoil problems are our biggest concerns.

C

APPENDIX C

Whole-Lake Point-Intercept Data Matrix

Scientific Name	Common Name	LFOO (%) 2007	2014	2021
Elodea canadensis	Common waterweed	18.2	13.8	18.6
Potamogeton robbinsii	Fern-leaf pondweed	15.3	18.0	9.5
Najas flexilis	Slender naiad	14.0	18.7	9.6
Ceratophyllum demersum	Coontail	11.8	14.9	12.0
Potamogeton gramineus	Variable-leaf pondweed	7.9	11.5	10.7
Myriophyllum spicatum	Eurasian watermilfoil	3.6	2.8	17.4
Myriophyllum sibiricum	Northern watermilfoil	8.2	12.1	7.2
Vallisneria americana	Wild celery	12.8	4.1	7.3
Potamogeton berchtoldii & P. pusillus	Slender and small pondweed	7.8	10.1	5.1
Potamogeton zosteriformis	Flat-stem pondweed	10.3	7.0	4.6
Potamogeton pusillus	Small pondweed	7.8	10.1	1.4
Najas guadalupensis	Southern naiad	0.0	6.0	7.4
Potamogeton amplifolius	Large-leaf pondweed	6.9	5.5	2.8
Potamogeton richardsonii	Clasping-leaf pondweed	2.8	6.1	4.1
Chara spp.	Muskgrasses	3.2	2.8	5.7
Bidens beckii	Water marigold	4.0	4.0	3.1
Eleocharis acicularis	Needle spikerush	0.9	1.7	4.9
Potamogeton praelongus	White-stem pondweed	3.2	3.9	2.4
Ranunculus aquatilis	White water crowfoot	0.0	2.0	3.9
Potamogeton illinoensis	Illinois pondweed	0.1	1.3	4.2
Nitella spp.	Stoneworts	5.3	1.6	0.5
Potamogeton berchtoldii	Slender pondweed	0.0	0.0	3.7
Isoetes spp.	Quillwort spp.	0.0	0.5	2.6
Heteranthera dubia	Water stargrass	0.5	1.7	1.6
Myriophyllum tenellum	Dwarf watermilfoil	1.8	0.5	1.4
Nymphaea odorata	White water lily	1.3	1.6	1.0
Elodea nuttallii	Slender waterweed	0.0	3.8	0.2
Juncus pelocarpus	Brown-fruited rush	2.4	0.5	0.4
Brasenia schreberi	Watershield	0.8	1.1	0.7
Lemna trisulca	Forked duckweed	0.0	0.8	1.2
Potamogeton spirillus	Spiral-fruited pondweed	1.5	1.1	0.2
Fissidens spp. & Fontinalis spp.	Aquatic Moss	0.1	1.2	0.8
Nuphar variegata	Spatterdock	0.6	0.8	0.6
Pontederia cordata	Pickerelweed	0.4	0.8	0.5
Sagittaria cristata	Crested arrowhead	0.5	0.8	0.2
Elatine minima	Waterwort	0.3	0.5	0.4
Potamogeton strictifolius	Stiff pondweed	0.0	0.2	0.6
Potamogeton friesii	Fries' pondweed	0.0	0.8	0.2
Potamogeton hybrid	Pondweed Hybrid	0.0	0.0	0.6
Utricularia vulgaris	Common bladderwort	0.0	0.8	0.1
Potamogeton foliosus	Leafy pondweed	0.0	0.3	0.2
Myriophyllum alterniflorum	Alternate-flowered watermilfoil	0.1	0.5	0.1
Schoenoplectus subterminalis	Water bulrush	0.3	0.0	0.2
Stuckenia pectinata	Sago pondweed	0.0	0.0	0.2
Sparganium sp.	Bur-reed sp.	0.5	0.0	0.0
Typha latifolia	Broad-leaved cattail	0.0	0.4	0.0
Spirodela polyrhiza	Greater duckweed	0.0	0.0	0.2
Sparganium fluctuans	Floating-leaf bur-reed	0.0	0.0	0.2
Sparganium emersum var. acaule	Short-stemmed bur-reed	0.0	0.3	0.0
Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	0.0	0.0	0.2
Potamogeton natans	Floating-leaf pondweed	0.1	0.2	0.0
Myriophyllum verticillatum	Whorled watermilfoil	0.0	0.3	0.0
Potamogeton epihydrus	Ribbon-leaf pondweed	0.1	0.2	0.0
Lythrum salicaria	Purple loosestrife	0.0	0.2	0.0
Utricularia intermedia	Flat-leaf bladderwort	0.0	0.2	0.0
Typha angustifolia	Narrow-leaved cattail	0.0	0.2	0.0
Stuckenia filiformis	Thread-leaf pondweed	0.0	0.2	0.0
Sparganium angustifolium	Narrow-leaf bur-reed	0.0	0.2	0.0
Lemna minor	Lesser duckweed	0.0	0.0	0.1
Sparganium eurycarpum	Common bur-reed	0.0	0.1	0.0
Sagittaria rigida	Stiff arrowhead	0.0	0.1	0.0
Sagittaria latifolia	Common arrowhead	0.0	0.1	0.0
Potamogeton perfoliatus	Perfoliate pondweed	0.0	0.1	0.0
Potamogeton obtusifolius	Blunt-leaved pondweed	0.0	0.1	0.0
Potamogeton alpinus	Alpine pondweed	0.0	0.1	0.0
Myriophyllum farwellii	Farwell's watermilfoil	0.0	0.1	0.0
Eleocharis palustris	Creeping spikerush	0.0	0.1	0.0

Scientific Name	Common Name	LFOO (%)		
		2005	2014	2021
Najas flexilis	Slender naiad	41.9	33.6	19.0
Elodea canadensis	Common waterweed	19.4	14.5	37.9
Potamogeton gramineus	Variable-leaf pondweed	10.8	31.3	23.3
Myriophyllum sibiricum	Northern watermilfoil	25.8	27.5	13.8
Vallisneria americana	Wild celery	31.2	13.7	17.2
Potamogeton robbinsii	Fern-leaf pondweed	29.0	16.8	13.8
Myriophyllum spicatum	Eurasian watermilfoil	0.0	3.1	30.2
Potamogeton berchtoldii & P. pusillus	Slender and small pondweed	4.3	15.3	20.7
Potamogeton pusillus	Small pondweed	4.3	15.3	20.7
Potamogeton zosteriformis	Flat-stem pondweed	18.3	12.2	10.3
Heteranthera dubia	Water stargrass	19.4	14.5	5.2
Ceratophyllum demersum	Coontail	9.7	6.1	12.1
Bidens beckii	Water marigold	22.6	9.2	5.2
Potamogeton richardsonii	Clasping-leaf pondweed	7.5	8.4	6.0
Potamogeton amplifolius	Large-leaf pondweed	12.9	6.1	3.4
Najas guadalupensis	Southern naiad	0.0	1.5	9.5
Potamogeton foliosus	Leafy pondweed	21.5	0.0	0.9
Ranunculus aquatilis	White water crowfoot	0.0	1.5	6.9
Chara spp.	Muskgrasses	2.2	3.1	5.2
Potamogeton illinoensis	Illinois pondweed	8.6	1.5	2.6
Brasenia schreberi	Watershield	2.2	5.3	2.6
Potamogeton praelongus	White-stem pondweed	3.2	0.0	3.4
Fissidens spp. & Fontinalis spp.	Aquatic Moss	0.0	1.5	3.4
Utricularia purpurea	Large purple bladderwort	0.0	0.8	3.4
Potamogeton strictifolius	Stiff pondweed	0.0	6.9	0.0
Lemna trisulca	Forked duckweed	0.0	0.0	3.4
Potamogeton friesii	Fries' pondweed	0.0	2.3	1.7
Sparganium angustifolium	Narrow-leaf bur-reed	2.2	1.5	0.9
Nymphaea odorata	White water lily	2.2	0.0	1.7
Eleocharis acicularis	Needle spikerush	2.2	0.0	1.7
Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	1.1	0.0	1.7
Pontederia cordata	Pickerelweed	0.0	2.3	0.9
Stuckenia pectinata	Sago pondweed	1.1	0.8	0.9
Potamogeton natans	Floating-leaf pondweed	1.1	2.3	0.0
Nitella spp.	Stoneworts	1.1	2.3	0.0
Sagittaria cristata	Crested arrowhead	0.0	2.3	0.0
Nuphar variegata	Spatterdock	1.1	1.5	0.0
Utricularia vulgaris	Common bladderwort	0.0	1.5	0.0
Myriophyllum tenellum	Dwarf watermilfoil	0.0	0.0	0.9
Isoetes spp.	Quillwort spp.	1.1	0.8	0.0
Myriophyllum alterniflorum	Alternate-flowered watermilfoil	0.0	0.8	0.0
Juncus pelocarpus	Brown-fruited rush	0.0	0.8	0.0

D

APPENDIX D

Strategic Analysis of Aquatic Plant Management in Wisconsin (June 2019).

Extracted Supplemental Chapters:

- 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.

Toxicology

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).

<u>Species Susceptibility</u>

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.

<u>Species Susceptibility</u>

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

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

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

Florpyrauxifen-benzyl

Registration and Formulations

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

Mode of Action and Degradation

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

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

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

Toxicology

No adverse human health effects were observed in toxicological studies submitted for EPA herbicide registration, regardless of the route of exposure (Heilman et al. 2017). There are no drinking water or recreational use restrictions, including swimming and fishing. There are no restrictions on irrigating turf, and a short waiting period (dependent on application rate) for other non-agricultural irrigation purposes.

Florpyrauxifen-benzyl showed a good environmental profile for use in water, and is "practically non-toxic" to birds, bees, reptiles, amphibians, and mammals (Heilman et al. 2017). No ecotoxicological effects were observed on freshwater mussel or juvenile chinook salmon (Heilman et al. 2017). Florpyrauxifen-benzyl will temporarily bioaccumulate in freshwater organisms but is rapidly depurated and/or metabolized within 1 to 3 days after exposure to high (>150 ppb) concentrations (WSDE 2017).

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

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

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

Species Susceptibility

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

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

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

S.3.3.3. Emergent and Wetland Herbicides

Glyphosate

Registration and Formulations

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

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

Mode of Action and Degradation

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

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

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

Toxicology

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

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

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

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

Species Susceptibility

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

Imazapyr

Registration and Formulations

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

Mode of Action and Degradation

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

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

Toxicology

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

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

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

Species Susceptibility

The imazapyr herbicide label is listed to control the invasive plants phragmites (*Phragmites australis* subsp. *australis*), purple loosestrife (*Lythrum salicaria*), reed canary grass (*Phalaris arundinacea*), non-native cattails (*Typha* spp.) and Japanese knotweed (*Fallopia japonica*) in Wisconsin. Native species that are also controlled include cattails (*Typha* spp.), waterlilies (*Nymphaea* sp.), pickerelweed (*Pontederia cordata*), duckweeds (*Lemna* spp.), and arrowhead (*Sagittaria* spp.).

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

S.3.3.4. Herbicides Used for Submersed and Emergent Plants

Triclopyr

Registration and Formulations

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

Mode of Action and Degradation

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

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

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

Toxicology

Based upon the triclopyr herbicide label, there are no restrictions on swimming, eating fish from treated waterbodies, or pet/livestock drinking water use. Before treated water can be used for irrigation, the concentration must be below 0.001 ppm (1 ppb), or at least 120 days must pass. Treated water should not be used for drinking water until concentrations of triclopyr are less than

0.4 ppm (400 ppb). There is a least one case of direct human ingestion of triclopyr TEA which resulted in metabolic acidosis and coma with cardiovascular impairment (Kyong et al. 2010).

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

Species susceptibility

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

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

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

Penoxsulam

Registration and Formulations

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

Mode of Action and Degradation

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

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

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

Toxicology

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

Species Susceptibility

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

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

S.3.4. Physical Removal Techniques

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

S.3.4.1. Manual and Mechanical Cutting

Manual and Mechanical Cutting

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

<u>Ecological Impacts of Manual and Mechanical Cutting</u>

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.

<u>Ecological effects of Dredging</u>

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.

<u>Ecological Impacts of Water-level Drawdown</u>

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).

E

APPENDIX E

Comment Response Document for the Official First Draft

Comments to Tomahawk Lake OFD Aquatic Plan Management Plan (6/17/2022)

Response by Eddie Heath (Onterra, LLC)

WDNR Official Comments: Scott Van Egeren (Lakes Biologist) – Received 10/19/2022

I have reviewed the first draft of the Tomahawk Lake System Aquatic Plant Management Plan and determined that the education, monitoring, and management activities identified in the Implementation Plan are eligible for Surface Water Grants funding subject to the eligibility and application requirements of the Surface Water Grants program and specifically to the comments below.

I would note that under Management Goal 5 (and associated management actions) that the approval of a specific EWM control proposal for grant eligibility and permitting will depend on DNR review of and discussions with Tomahawk Lake Association about the annual control and monitoring strategy. DNR and TLA should consider the likelihood of effective management, the need for management, and also any unintended, non-target impacts. An annual meeting to discuss the specific control and monitoring strategy for the coming year will facilitate DNR decisions on annual EWM control plans, however DNR cannot guarantee that a treatment proposal will always be approved for grant funding and/or permitted.

Also at this point I largely reviewed your draft management plan with grant eligibility (for 2023) in mind, but have not provided substantial editorial comments on the entire plan narrative. I hope to provide additional feedback on the remainder of your management plan within the next few weeks.

WDNR Official Comments: Scott Van Egeren (Lakes Biologist) – Received 12/14/2022

I looked through your first draft aquatic plant management plan and only had a few minor editorial comments. I also forwarded the plan to DNR Fisheries, Wildlife, and AIS staff, but haven't heard back from them. These programs were involved in the planning meeting and were also provided this draft back in June. I don't expect that they will have additional comments at this point.

I would suggest that the minor comments below be addressed in the language of the plan. You have already supplied DNR with the other deliverables for the two planning grants (AEPP64021 and AEPP64121). Once we have a version of the APM plan without the draft watermarks you are approved for final grant reimbursement.

Comments

- Any comments that came in during the 21 day public comment period should be summarized in a plan appendix. This could be the same as the comment response document if you like. The draft Plan has been posted on the TLA's website for 180 days. No comments were received from the pubic nor from agencies other than

WDNR lakes biologist. This information is presented within the final plan in Section 2.2.

- Page 64 (and other locations referencing grant deadlines) - DNR surface water grant application deadlines are now Sept 15 for pre-application and Nov 15 for final application. Change has been made.
- Page 73 - The DNR *Draft Aquatic Plant Treatment Evaluation Protocol* recommends that quantitative point-intercept data is collected the year before (pre) and the summer after the treatment (post). Collecting the pre-treatment data the year before treatment allows the data collection to be conducted in late summer when the majority of aquatic plants are at peak biomass. If collected the year before treatment the seasonal timing of the pre-survey will also match the timing of the post-survey. I would strongly recommend that if quantitative plant data is being collected that it be done following the protocol above. If not I cannot guarantee the DNR grant program will fund this monitoring activity. Sentiment understood and the language in the report was modified accordingly. Additional discussion of monitoring needs likely required on a case-by-case basis.
- Page 76 - The new DNR Fisheries Biologist is Nathan Lederman and he can be reached at Nathaniel.Lederman@wi.gov Change has been made.