Eurasian Watermilfoil

Understanding its Invasion Mechanisms and Management Case Studies

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Outline

- What is Eurasian Watermilfoil
- Dispersal Methods
- Optimal Conditions for Eurasian Watermilfoil
- Invasion Mechanisms
- Impacts of Eurasian Watermilfoil
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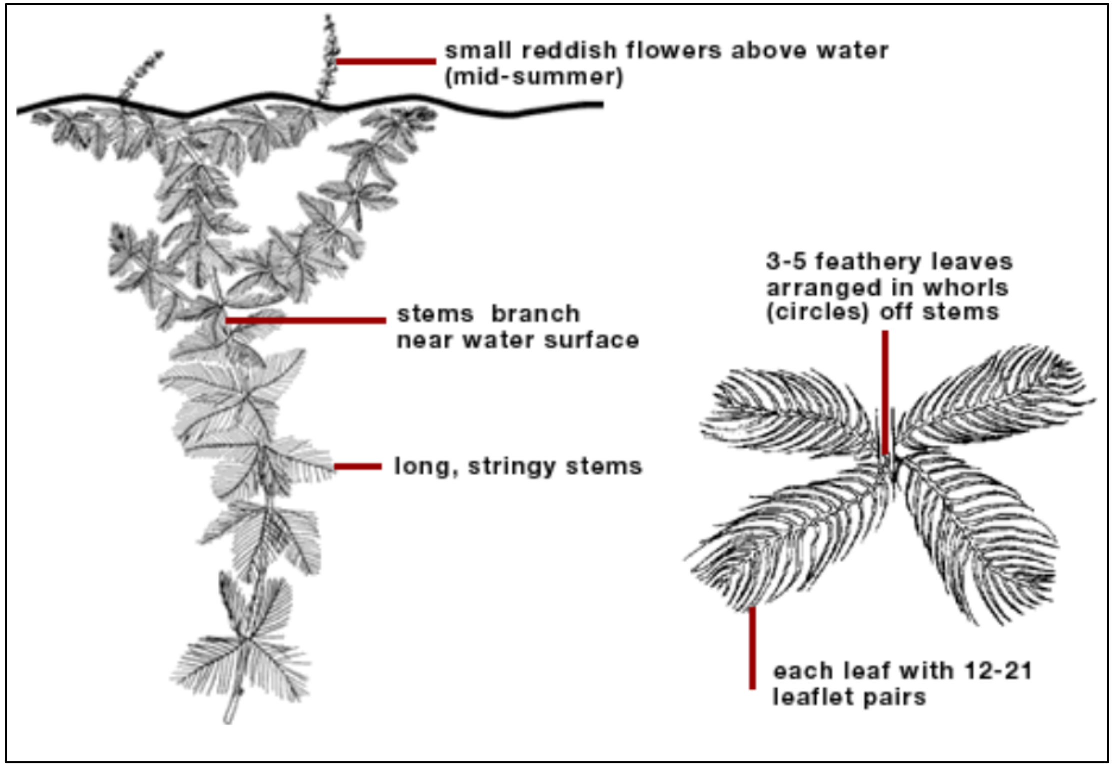
Eurasian Watermilfoil

- Rooted, long, and slender aquatic perennial plant
- Submerged leaves arranged in whorls of 3-5
- 12-21 featherlike leaflets on each leaf
- Blooms orange-red flowers in late July and August
- Can grow up to 6 ft or higher
- Grows to water surface and branches to form canopy
- Most abundant in 1 – 4 m of water, but can be found in up to 10 m



(Jensen, 2016)

(Menninger, 2011; Williams et al., 2018)

Dispersal Methods

Main methods of dispersal:

1) Stem fragmentation: Fragments breaking off plant
   - Break off naturally after flowering
   - Dispersed by water currents
   - Fragmentation and dispersal by recreational boating activities
2) Stolon formation: A stem that grows along the ground from a parent plant
   - A few centimetres away, the stolon allows for roots and vertical stems to develop
   - Allows for local expansion
3) Seed dispersal: insignificant contribution compared to the other two methods

(Borrowman, 2010 ; Menninger, 2011; Williams et al., 2018)

Optimal Conditions for Eurasian Watermilfoil

- Considered not unusually productive or reach unusually high levels of biomass
- Does best in areas of high nutrients and no cover
- Most growth occurs in water temperatures of 15°C and above
- Recedes to root crowns in winter
  - Maintains carbohydrate stores for the next growing season
- Highly adaptable, aiding in its spreading

Table 1: Factors influencing the growth and spread of Eurasian water-milfoil (Smith and Barko 1979, Alvarez 2016, Madsen 2013, Mossop and Bradford 2004).

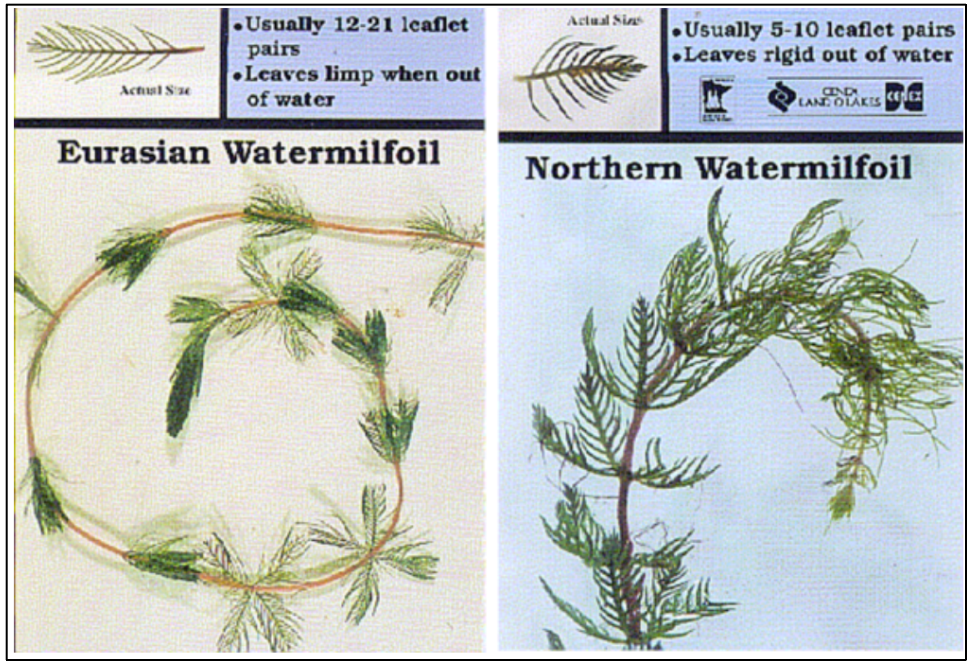
Factor	Influence on growth
Water Clarity	• Water clarity dictates the availability of light for photosynthesis, therefore controlling the depth and rate of growth • Low water clarity (high turbidity) limits EWM to shallow water, and leads to canopy / mat formation • High water clarity allows EWM to grow at greater depths, without necessarily reaching the surface
Water Temperature	• Plants photosynthesize and grow over a broad range: 15-35C • Maximum growth occurs at fairly high water temperatures: 30-35C • Growth is initiated at about 15C • Fragments do not propagate at water temperatures below 10C
Inorganic Carbon	• Plants grow best in relatively alkaline lakes (high pH) • Plants can grow in lakes of low alkalinity (low pH), but not as vigorously
Mineral Nutrients	• Nuisance growth is primarily an issue for moderately fertile and eutrophic lakes, or fertile locations within less fertile lakes • Uptake of nutrients from sediments by roots is an important source of P and N • Major cations and bicarbonate are mostly taken from the water
Carbon Dioxide	• Gases diffuse very slowly in water, with the rate of availability limiting photosynthesis
Sediment Texture	• Plants grow best on fine-textured inorganic sediments of intermediate density (such as clay or silty clay), due to apparently greater nutrient availability
Water Movement	• Vegetative spread of plant fragments is aided by water currents • The plant does not usually occur in high energy environments (strong currents) • Water level fluctuation may limit growth
Disturbance	• Disruption of lake bottom sediments or damage to existing vegetation will create 'gaps' in which the opportunistic EWM will take root.

(Williams et al., 2018)

(Menninger, 2011; Williams et al., 2018)

Invasion Mechanisms

- Native to Europe and Asia
- Introduced to Canada in 1960s
  - First reported in Lake Erie in 1961
  - Suggested initially introduced by shipping ballasts or aquarium releases
- Spreads within and between waterbodies via:
  - Boats, boat trailers, other equipment (I.e. fishing gear)
  - Water currents, wind, waterfowl
- Plant factors enabling Invasion:
  - highly adaptive growth structure, susceptibility to mechanical disruption, spread through fragmentation, low photosynthetic needs
- Can hybridize with native milfoil species, Northern Watermilfoil



(Minnesota Aquatic Invasive Species Research Center, 2020)

(Lui et al., 2010; Menninger, 2011; Williams et al., 2018)

Impacts of Eurasian Watermilfoil

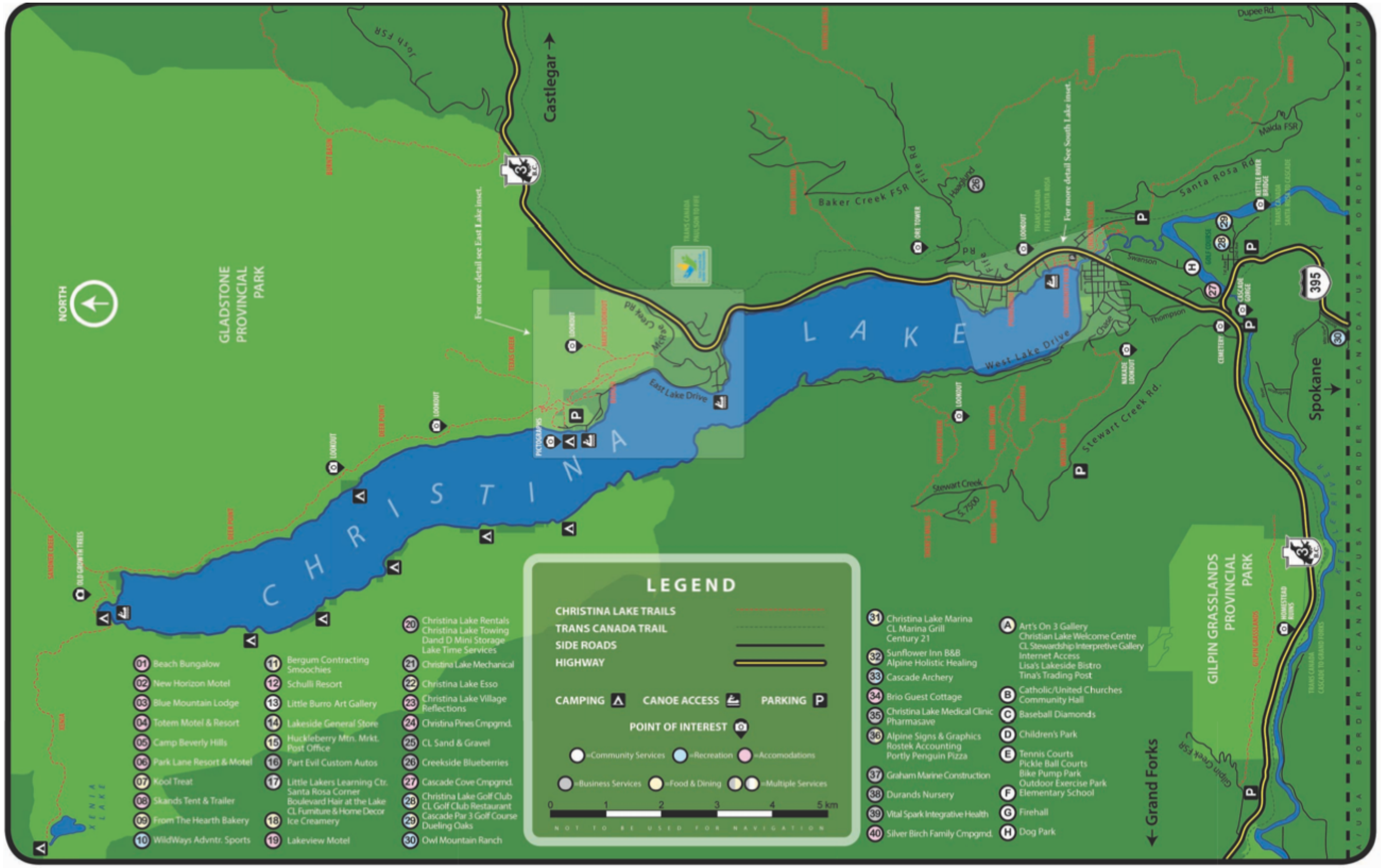
- Interferes with recreational water activity
  - Plant fragments and mats may decrease beach and facility usage
  - Dangerous for swimmers if become entangled in dense patches
  - Dense growth can negatively impact fisheries by obstructing space and disrupting feeding patterns of fish
- Interfered with water quality and resident wildlife
  - Can reduce oxygen levels and absorption in the water
  - Out compete native plant species
  - Alter invertebrate community, causing fewer species
  - Can create habitat for certain mosquitos
- Reduce property values in areas of heavy invasions

(Fox, 2018; Menninger, 2011; Williams et al., 2018)

Eurasian Watermilfoil Management Case Studies

#1: Christina Lake, BC – Lake Characteristics

- Home to approximately 1337 year-round residents plus seasonal visitors
- Surface area: approximately 27.3 km²
- Lake depth: average of 36m with a maximum depth of 54m
- Four months(June-September with temperatures above 15°C
- Low turbidity levels
- Nutrient rich



(Christina Lake Welcome Centre., 2020)

(Maki, 2018)

#1: Christina Lake, BC – Initial Control Management Program

- Eurasian Watermilfoil first detected in 1986
- Used diver surveys and bottom barriers from 1986-1989
- Effectiveness was determined through diver surveys each October
  - Number of Eurasian Watermilfoil decreased
  - Number of sites having Eurasian Watermilfoil increased
  - Total of 49 sites during 4-year period supported the plant species
  - In 1988, 7 out of the 21 sites found in 1987 found free of plants
  - 1989, 11 sites showed no Eurasian Watermilfoil
- Costs increased each year for control management

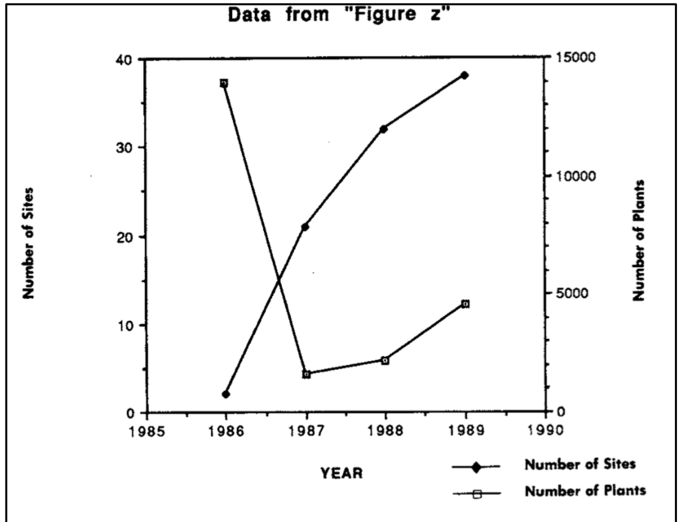


Figure 4.—Eurasian watermilfoil populations in Christina Lake.

Table 7.—Eurasian watermilfoil management in Christina Lake (from Wallis 1986 *a*, Wallis and Haberstock 1988, Retzer and Haberstock 1989, 1990).

Year	Number of EWM[1] sites	Number of EWM stems	Control effort[2]
1986	2	14,000	57 person-days 1132 m² b b[3] ($7000)
1987	21	1617	220 person-days 3040 m² b b ($40,000)
1988	32	2184	240 person-days 3055 m² b b ($47,000)
1989	38	4553	263 person-days 1760 m² b b ($58,000)

[1]EWM = Eurasian watermilfoil.
[2]Control effort includes the time required for surveys, control (bottom barrier installed), and public information; costs do not include Ministry of Environment supervision or report preparation.
[3]b b = bottom barrier.

(Newroth, 1993)

#1: Christina Lake, BC – 2018 Control Management Program Plan

- Marked the 32nd year of Eurasian Watermilfoil control for the Lake
- 575 sites of Eurasian Watermilfoil
- Control method used: hand harvesting by divers
  - Conducted for 23 weeks, April 30th-October 25th
  - 2 Crews composed of 7 members total using pontoon barge
  - Crews worked 4 days/week, 9hrs/day
  - Two shifts
    - Sunday-Wednesday
    - Wednesday-Sunday
    - "Supercrew" on Wednesday

(Maki, 2018)

The 2018 year-to-date (October 31) expenditure breakdown is as follows:

	Expenditure Value
Salaries and Benefits	$212,058.74
Travel and Training	$887.54
Communication Equipment	$1,538.64
Board Fee	$1,602.00
Diver Medicals	$611.00
Dive Equipment Repairs	$1,800.11
Boat Operating Costs	$11,818.70
Scuba Tank Refills	$6,290.00
Vehicle Operating Costs	$3,582.02
Dive Equipment Rental	$4,850.00
Contributions to Reserve	$32,600.00
JOP – MFA Vehicle Financing	$11,250.00
Contingencies	$82.00
Total Expenditures	**$288,970.85**
2018 Approved Budget	***$327,504.00***
Projected Surplus	*$38,533.15*

(Maki, 2018)

The 2016 year-to-date (November 7)expenditure breakdown is as follows:

Salaries and Benefits------------------- $173,817.77
Travel and Training-------------------- $809.26
Communication Equipment---------- $589.72
Board Fee---------------------------------- $1,390.00
Diver Medicals--------------------------- $766.75
Dive Equipment Repairs--------------- $681.27
Boat Operating Costs-------------------- $7,989.97
Scuba Tank Refills----------------------- $0.00 (so far)
Capital--------------------------------------$13,579.76
Vehicle Operating----------------------- $6,280.01
Dive Equipment Rental----------------- $4,615.00
Contribution to Reserve----------------$0.00 (Not yet allocated)
Contingencies---------------------------- $2,664.28

Total Expenditures:----------------$213,183.79

Total Surplus: $78,486.95

(Maki, 2016)

#1: Christina Lake, BC – Control Management Program Costs

- Program paid for by local taxpayers of Christina Lake since 1999

(Maki, 2016; Maki, 2018)

#1: Christina Lake, BC – 2018 Control Management Program Outcomes

- Low plant densities were recorded in comparison to the previous decade
- Some areas that were once large patches of milfoil back to being colonized by native species
- large portion of the lake is well under control, areas of south end need continued efforts
- Quoted as "under control, and trending towards fewer plants"
- Goals for 2019 season
  - Survey and remove milfoil plants multiple times at each of the sites
  - High plant density areas will continue to be treated
  - Maintaining a two-crew milfoil control

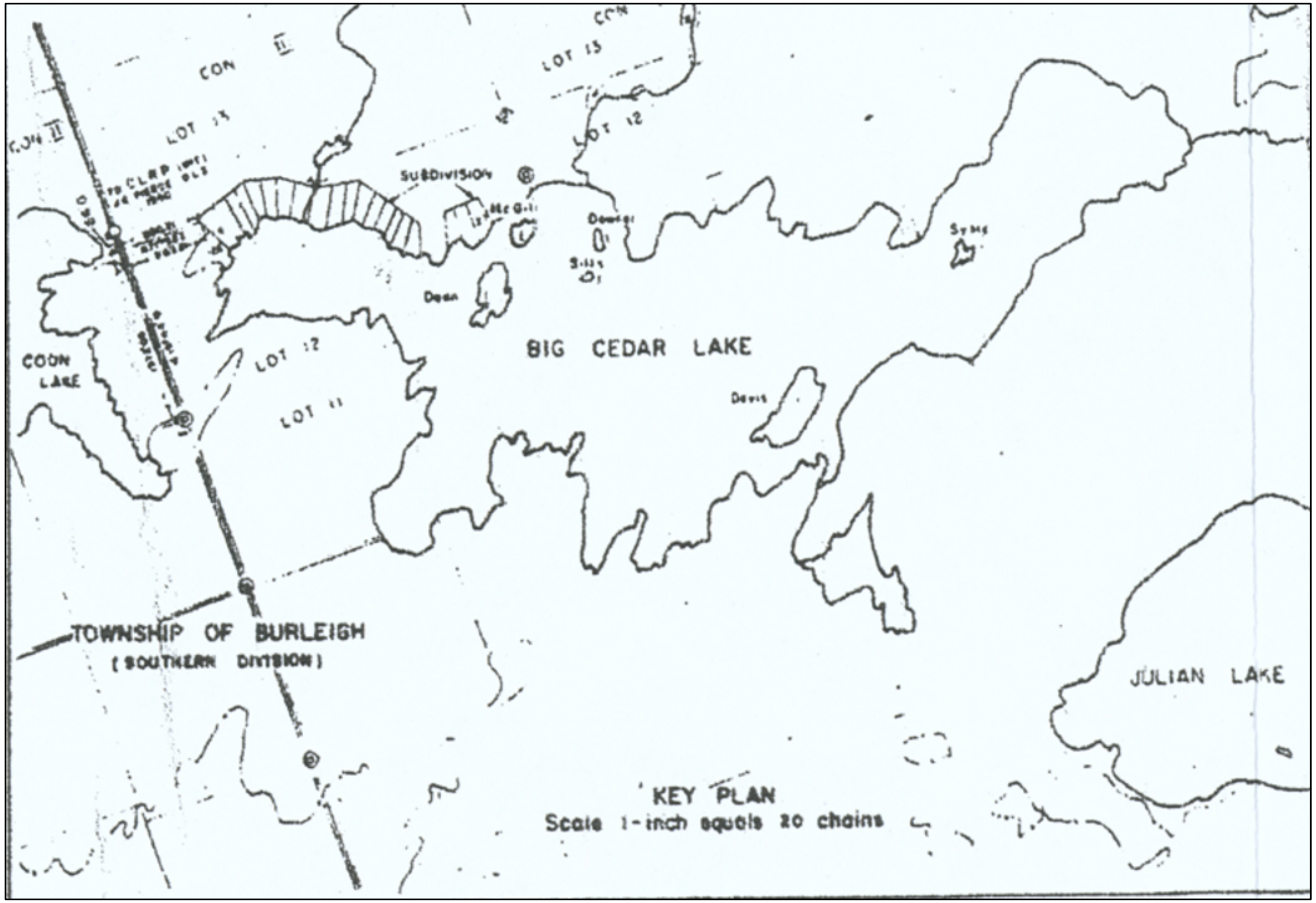
Number of Plants Removed/year

2018 Plant Count	2017 Plant Count	2016 Plant Count	2015 Plant Count
590,612	529,343	321,385	400,030

(Maki,2018)

#2: Big Cedar Lake, ON - Lake Characteristics

- Home to approximately 130 landowners
- Surface area: Approximately 550 acres
- Lake depth: Maximum depth of 18.5 m
- Average water temperature: 24.3°C
- pH: 8.3

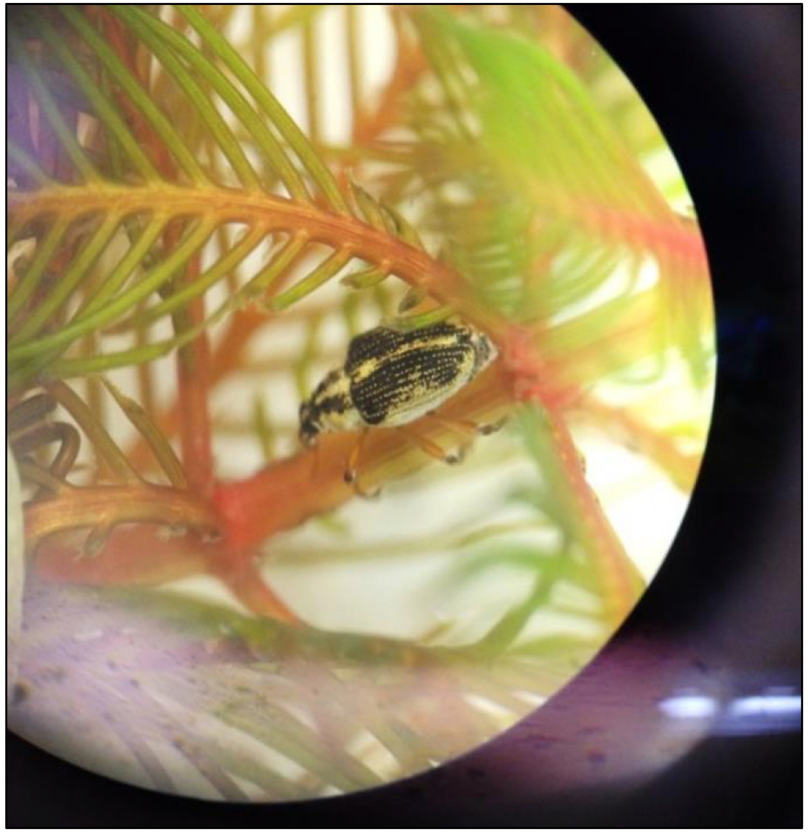


(Clutton Jr, 2009)

(Angler's Atlas, 2020; Big Cedar Lake Stewardship Association, 2020; Clutton Jr, 2009; May Trauzzi & Trauzzi, 2018)

#2: Big Cedar Lake, ON – Milfoil Weevil Control Program

- Eight-year Eurasian Watermilfoil control program using Milfoil Weevil (*Euhrychiopsis lecontei*)
- Implemented Milfoil Solution program by consulting company EnviroScience Inc.
  - Involved increasing native populations of milfoil weevils to reduce the abundance of milfoil
  - EnviroScience stocked the lake with 215,800 weevils and weevil eggs in over 15 different locations from 2011-2014
  - Dr. Eric Sager and students of Trent University continued stocking weevils from 2015-2018
  - 45,800 native weevil eggs and adults have been stocked since 2011
- Integrated management approach by stocking weevils along edges of biodegradable benthic mats planted with native plant species started in 2016



(Cooper et al., 2018)

#2: Big Cedar Lake, ON – 2018 Milfoil Weevil Control Program

- Approximately 25 patches of Eurasian Watermilfoil found at depths of 1.5-4.5m in 2017
- Stocked in 2018:
  - 25,000 weevil eggs
  - Weaved coconut fiber and jute netting five benthic mats (2.5m x 13.5m)
- 5 treatment patches and 5 control patches selected
  - Surveyed in late June (prior to weevil stocking), and in late August (after stocking) through rake throws
  - In June and July 2018, adult weevils were collected from locations across the Kawartha Lakes
  - Groups of 150 weevils were placed into aquariums filled with healthy milfoil stems from Big Cedar Lake
  - Patches of Eurasian Watermilfoil were systematically stocked with weevil eggs by securing them with egg-bearing stem bundles

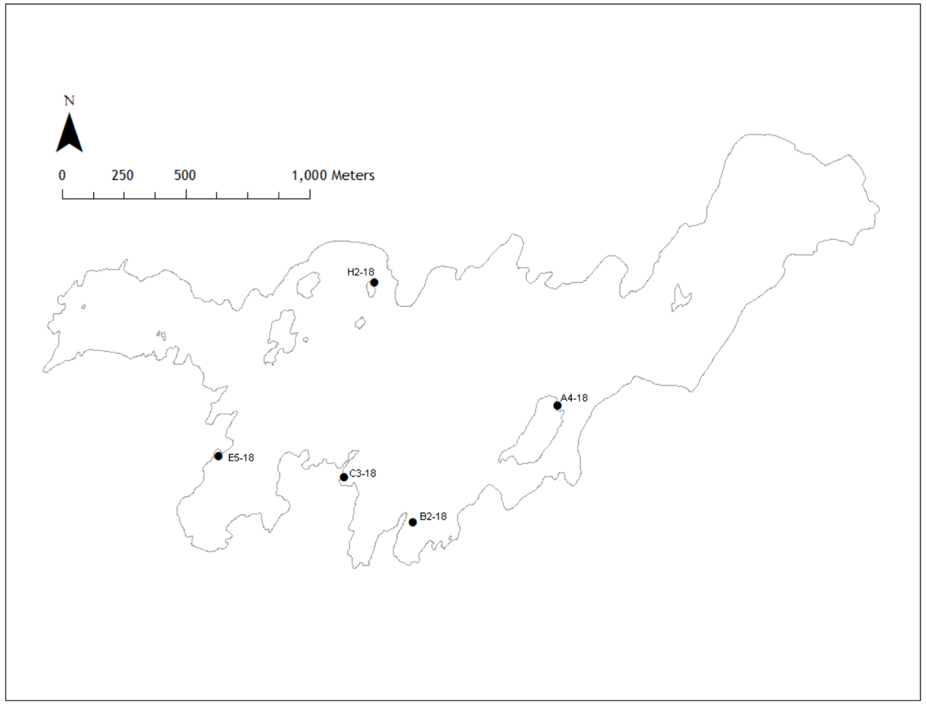


Figure 2.Locations of 2018 treatment sites at Big Cedar Lake

(Cooper et al., 2018)

#2: Big Cedar Lake, ON – 2018 Milfoil Weevil Control Program Costs

- $1.00 to $1.20/weevil
- Need minimum of 10,000 to 50,000 milfoil weevils to start introductory control program,
  - Weevils were sold in units of 1000 individuals
  - Typically 3,000/acre are needed to be effective
- Cost of lake surveying, weevil application and post application monitoring ranges from $1,000 to $3,000 per step for a typical lake project
- Total cost of a control project can be up to $95,000, leaving room for unexpected circumstances

(Cooper et al., 2018; Sandford Fleming College & Borrowman, 2011)

#2: Big Cedar Lake, ON – Milfoil Weevil Control Program Outcomes

- In 2015, saw large reductions in milfoil density
- In 2016 (addition of benthic mats), saw similar pattern as year prior
- In 2017, saw exceptional milfoil growth in both treatment and control sites
  - Densities were above the initial 2015 level
  - Treatment sites still had lower densities than control sites
- In 2018, saw densities decreased in both treatment and control sites, falling between 2015 and 2016 levels
- Eurasian Milfoil densities exhibited alternating pattern of higher to lower each year
- Data suggests unlikely that Milfoil Weevils will cause eradication of Eurasian Watermilfoil from Big Cedar Lake

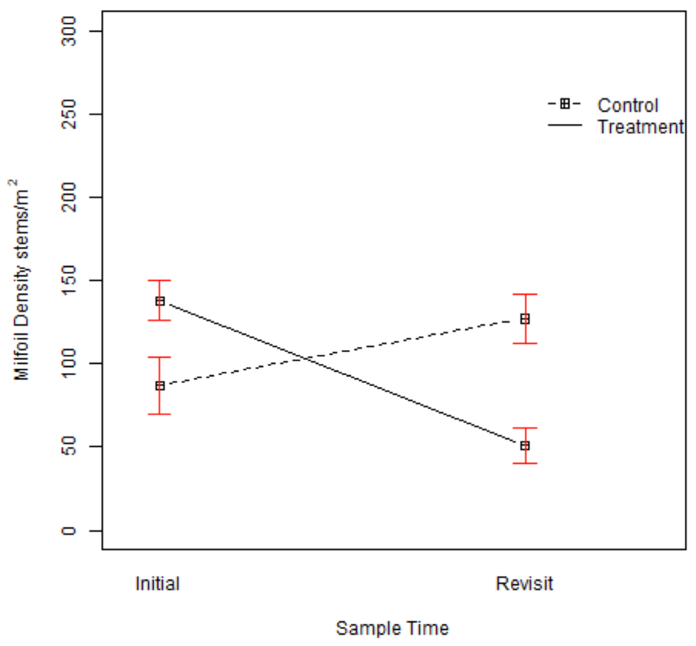


Figure 11. Milfoil density for the 2018 treatment sites observed initially in June and again in late August. This year had 5 control sites and 5 treatment sites.

(Cooper et al., 2018)

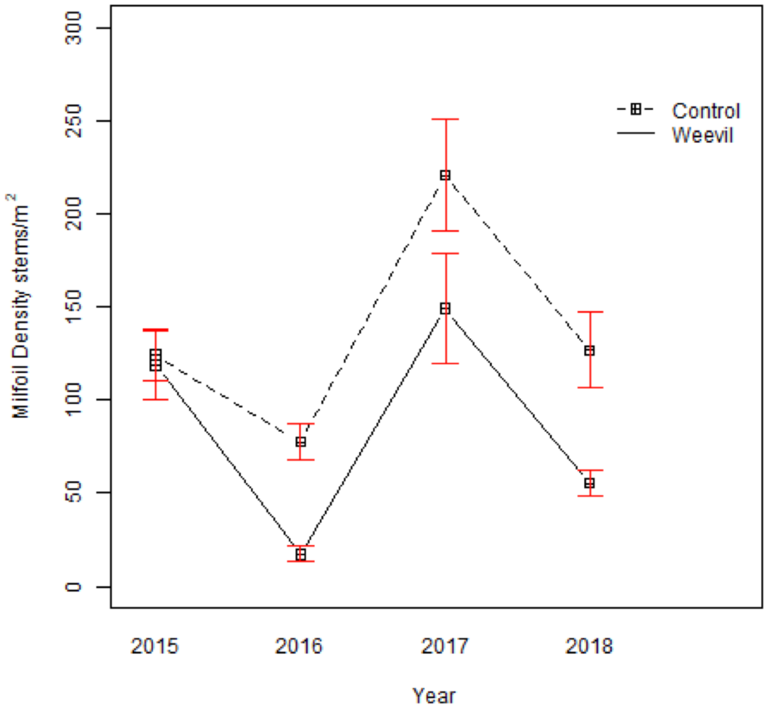


Figure 6.Milfoil density for the 2015 treatment season and observed for three years. This year had 4 control sites and 4 weevil sites.

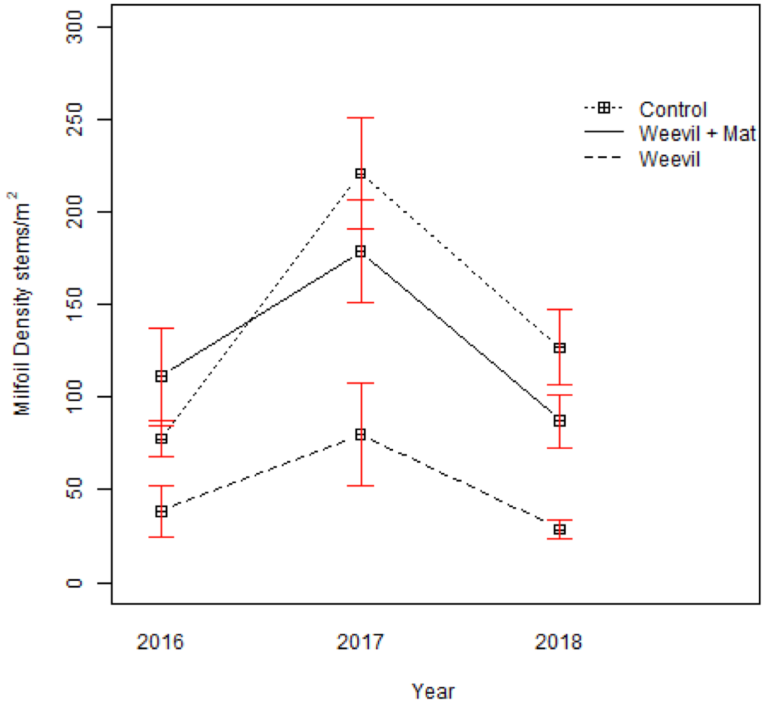


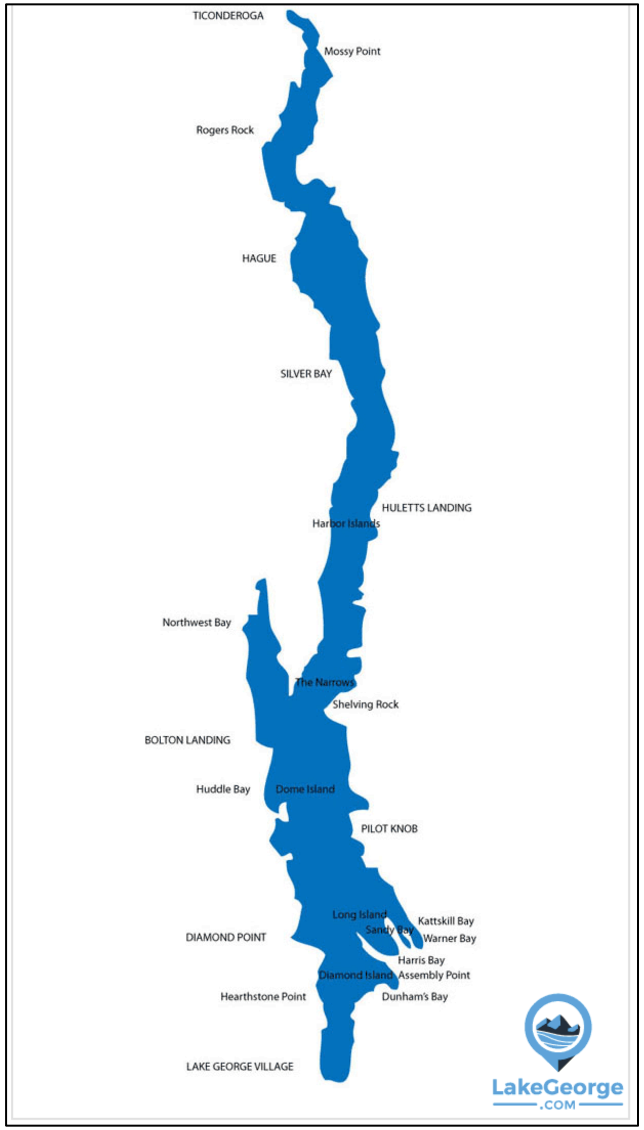
Figure 7.Milfoil density for the 2016 treatment season and observed for two years. This year had 4 control sites, 3 weevil + mat sites and 2 weevil sites.

#2: Big Cedar Lake, ON – Milfoil Weevil Control Program Outcomes Continued

(Cooper et al., 2018)

#3: Lake George, NY – Lake Characteristics

- Eurasian Watermilfoil first detected in 1985
- Area of Surface: 110km^2
- Lake depth: Average depth of 20 m
- Classified as an oligo-mesotrophic (limited productivity)
- Low in nutrients



(Mannix Marketing, 2020)

(Eichler et al., 1993; Boylen et al., 1996)

#3: Lake George, NY – Physical Control Management

- Hand Harvesting
  - Conducted at 14 sites
  - Sites with less than 1000 plants
- Diver Suction harvesting
  - Sites with scattered plants, < 50% cover
  - Conducted at 7 sites
  - Hydraulic vacuum system created by a diesel-powered venturi pump fixed to a a 9 m pontoon boat
- Benthic Barriers
  - Sites dominated by the plant species, > 50%
  - Conducted at four sites
  - Barriers were 2.2 m by 30 m sections of either Palco™ (solid polyvinyl chloride (PVC) sheeting 20 mm thick) or Aquascreen™ (open mesh)
  - Metal rods used to secure barriers
- Species presence and relative abundance determined at: grid installation, 30 days and 1 year later

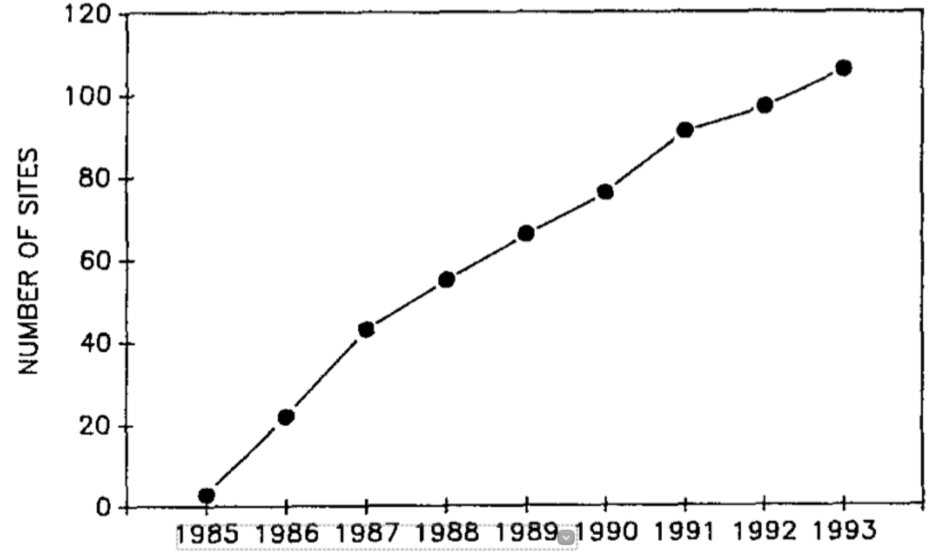


Figure 1. Yearly increase in the number of milfoil sites in Lake George.

(Boylen et al., 1996)

#3: Lake George, NY – Physical Control Management Outcomes

1) Hand Harvesting
   - Was over 80% effective in removal of milfoil from sites
   - Was a 56% reduction in the number of hours needed to harvest the following year
2) Diver Suction Harvesting
   - Reduced both the biomass and percent cover of milfoil
   - Average preharvest percent cover of more than 30% declined to <5%
   - Year later, percent coverage at an average of approximately 7%
3) Benthic Barriers
   - After removal, sites showed recolonization by native species
   - Year later, saw regrowth of milfoil was apparent in 71% grid quadrants

- Overall
  - Presence of native species occurs rapidly
  - Integrated program is needed as none of the techniques eliminate Eurasian Milfoil
  - Eurasian Milfoil management is long-term

Table 1. Summary of hand harvesting efforts for 1989 and 1990.

	1989			1990		
	Total number of plants	Dry wt (kg) of plants	Effort in person-days	Total number of plants	Dry wt (kg) of plants	Effort in person-days
Total of all sites (n = 14)	21,200	17.1	26.4	3953	3.2	12

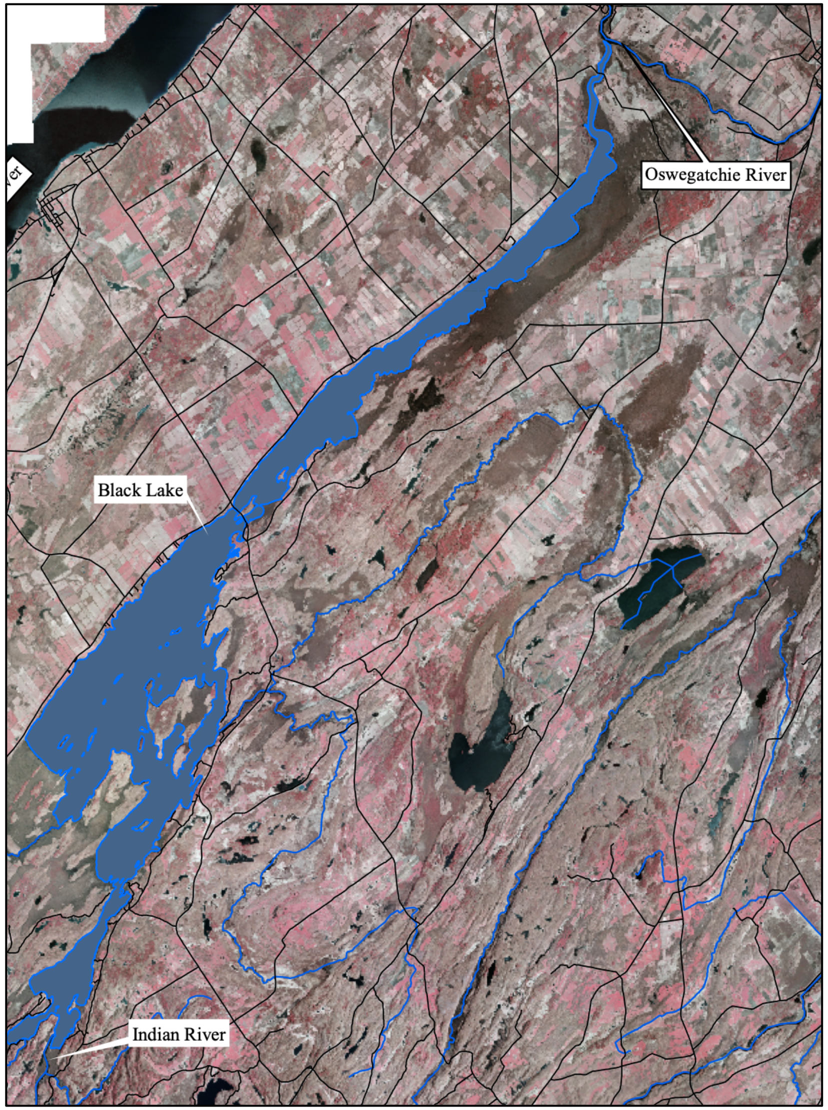
Table 2. Summary of suction harvesting efforts for 1990 and 1991.

	1990		1991	
	Dry wt (kg) of plants	Effort in person-days	Dry wt (kg) of plants	Effort in person-days
Total of all sites (n = 7)	710	28.0	49.6	5.7

(Boylen et al., 1996)

#4: Black Lake, NY- Lake Characteristics

- Lake occupied by seasonal camps and 27 tourist cottage, cabin, and campground businesses
- Surface area: 7,761 acres
- Lake depth: Average depth of 3 m, Maximum depth of 5m
- pH: Average of 8.1
- Average temperature: 23°C
- Classified as eutrophic (highly productive)



(Black Lake Association, 2016; Quantitative Environmental Analysis, 2008)

#4: Black Lake, NY- Integrated Management Prospect Plan of Action

- Hand harvesting for lower density beds, fewer than 500 plants/acre.
- Suction harvesting for intermediate density beds or dense beds needing to preserve non-target species
  - For beds less than 0.25 acres
  - Can be used as an aid hand harvesting with removal of pulled plants
- Benthic barriers for dense monospecific beds where non-target species are not a concern
- Follow-up hand harvesting may be needed for sites treated by benthic barriers or suction harvesting
- Removal efforts will need to take place over multiple years
- Effectiveness of the program should be assessed annually by plant monitoring methods

(Quantitative Environmental Analysis, 2008).

Table 3-2. Cost planning estimates for total removal of Eurasian watermilfoil from Black Lake, NY.

Treatment Method	Acres to be Treated	Cost per Acre Range	Assumed Cost per Acre	Estimated Cost[1]
Hand harvesting	932	$400 - $1,000	$700	$652,400
Suction harvesting	932	$1,000 - $25,000	$13,000	$12,116,000
Benthic barrier - professional installation	1371	$10,000 - $25,000	$10,000[2]	$13,710,000
Total	**3235**			**$26,478,400**
			Say	**$20-30 MM**

Notes:

[1]The cost per acre was estimated using the median cost for hand and suction harvesting and the lower end of the cost range for benthic barrier installation.

[2]The lower end of the cost range for benthic barrier was assumed because barrier materials can be reused, defraying some costs.

#4: Black Lake, NY- Estimated Costs

(Quantitative Environmental Analysis, 2008).

Concluding Remarks

- Integrated management is best option for Eurasian Watermilfoil
- Control methods used is determined by density of Eurasian Watermilfoil patches
- Eurasian Watermilfoil Management is a long-term commitment with annual follow-ups

See accompanied “Eurasian Watermilfoil Control Methods” chart for more information on Eurasian Watermilfoil control methods:

- Timing & application
- Effort
- Cost
- Effectiveness
- Advantages
- Disadvantages
- Permits & Regulations

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