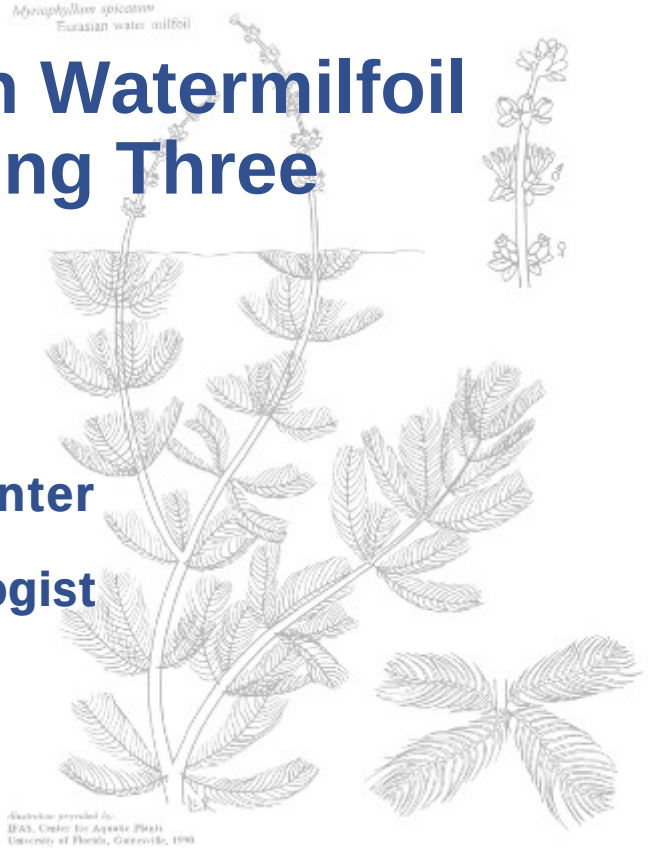
Selective Control of Eurasian Watermilfoil (*Myriophyllum spicatum*) Using Three Aquatic Herbicides



Marc Bellaud, ACT Senior Biologist – Presenter

Gerald Smith, ACT President / Aquatic Biologist

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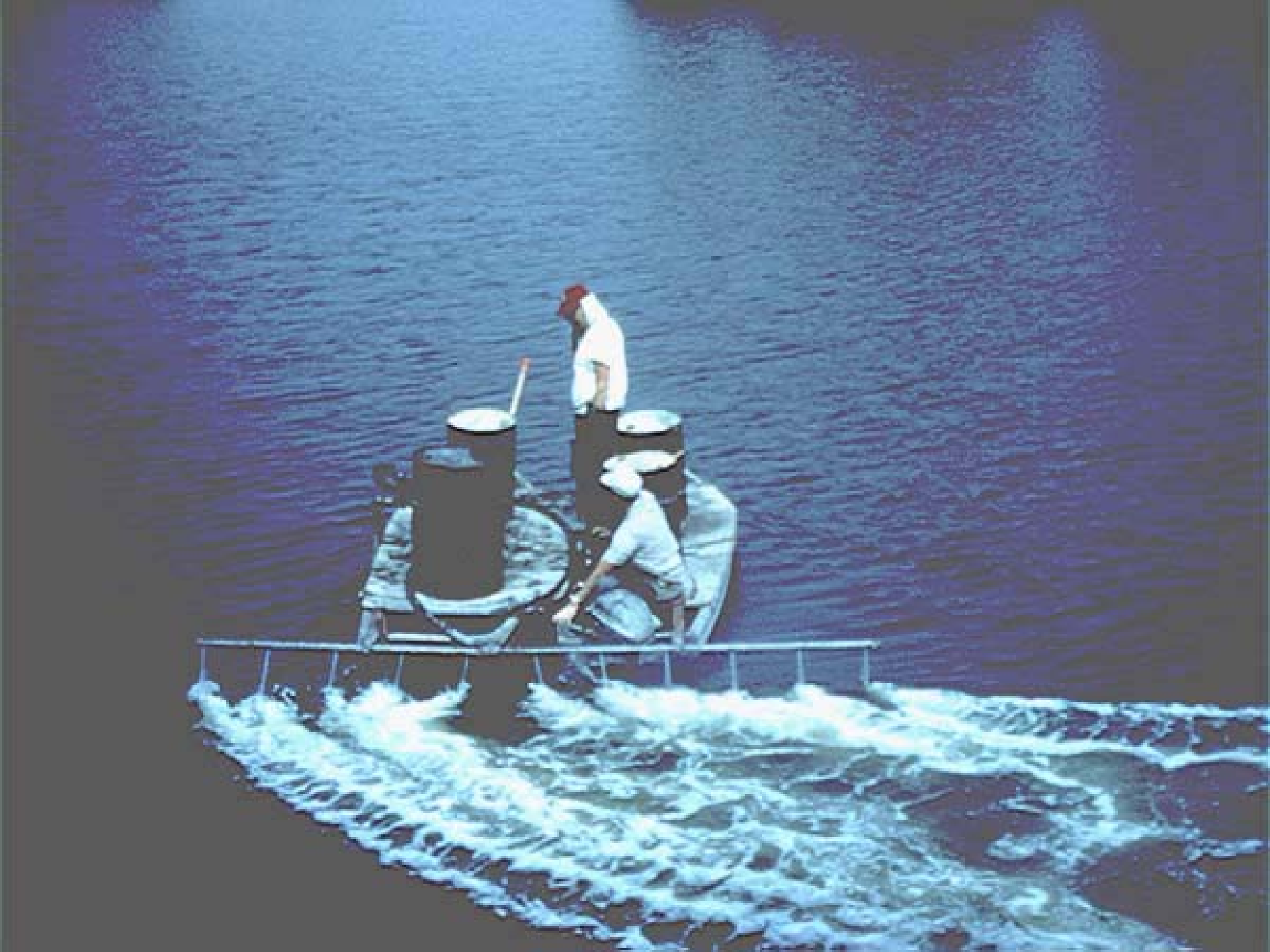


Aquatic Herbicides

- Risk = Toxicity x Exposure
- Products re-registered by EPA under FIFRA, also registered in each State
- 20 active ingredients for aquatics in 1976 – now only 8 in US
- Many target proteins or photosynthetic pathways
- No aquatic herbicides have a swimming restriction on the label

USEPA Herbicide Registration – what's involved?

- 120 toxicity tests required in every category minimum
- 8-13 years typically required from when a new compound is introduced to when it is registered
- $50-$80 million (or more) to register a product in aquatics

Aquatic Herbicides Currently Available

TRADE NAME	ACTIVE INGREDIENT	MANUFACTURER	
Navigate	2,4-D	Applied Biochemists	www.appliedbiochemists.com
Aquathol K	Endothall	United Phosphorus	www.upi-usa.com
Komeen / Nautique	Copper	SePRO	www.sepro.com
Renovate	Triclopyr	SePRO	www.sepro.com
Reward	Diquat	Syngenta	www.syngentaprofessional products.com
Rodeo & generics	Glyphosate	Dow AgroSciences	www.dowagro.com
Sonar	Fluridone	SePRO	www.sepro.com
Habitat	Imazapyr	BASF	www.vmanswers.com

Registered Aquatic Herbicides

Compound	Year Registered	Mode of Action
2,4-D Ester	1959	Auxin – Systemic
2,4-D Amine	1976	
Copper	1950's	Contact – phs – membrane
Diquat	1962	Contact – PSII – membrane
Endothall	1960	Contact – Resp. – membrane
Glyphosate	1982	Growth – protein synthesis
Fluridone	1986	Growth – Enzyme inhibitor
Triclopyr	2002	Auxin Systemic
Imazapyr	2003	Growth – AHAS inhibitor
Carfentrazone	2004	Contact – Enzyme- membrane

Source: USACE, ERDC

New Aquatic Herbicides…
Registration Pending or issued EUP

Compound	Company	Mode of Action
Penoxsulam	SePRO	Growth – ALS enzyme inhib.
Imazamox	BASF	Growth – AHAS enzyme inhib.
Flumioxazin	Valent	Contact- Protox Enzyme
Bis-pyrobac	Valent	Growth – ALS enzyme inhib.

Source: USACE, ERDC

Eurasian watermilfoil

- Perennial dicot
- Vegetative fragmentation and seeds
- Tolerates wide range of water quality
- Canopy forming
- Rapid growth

- Susceptible to several aquatic herbicides

Factors for herbicide selection

- Target species
- Non-target species trying to protect
- Size and configuration of treatment area – potential for dilution
- Water flow
- Concentration Exposure Time (CET)
- Water uses

Reward (Diquat)

- Formulation: Liquid
- Mode of Action: Contact – interferes with photosynthesis
- Environmental Fate: Sediment absorption, photolysis
- Water Use Restrictions: Drinking 1-3 days, Irrigation 1-5 days, Watering Livestock 1 day
- Advantages: Rapid action effective for partial lake or shoreline treatments
- Limitations: Annual control does not kill roots
- Plants Controlled: Milfoil, Curlyleaf Pondweed, Elodea, Hydrilla, Coontail, Pondweeds, Naiad, Duckweed, Bladderwort, Algae

Sonar (Fluridone)

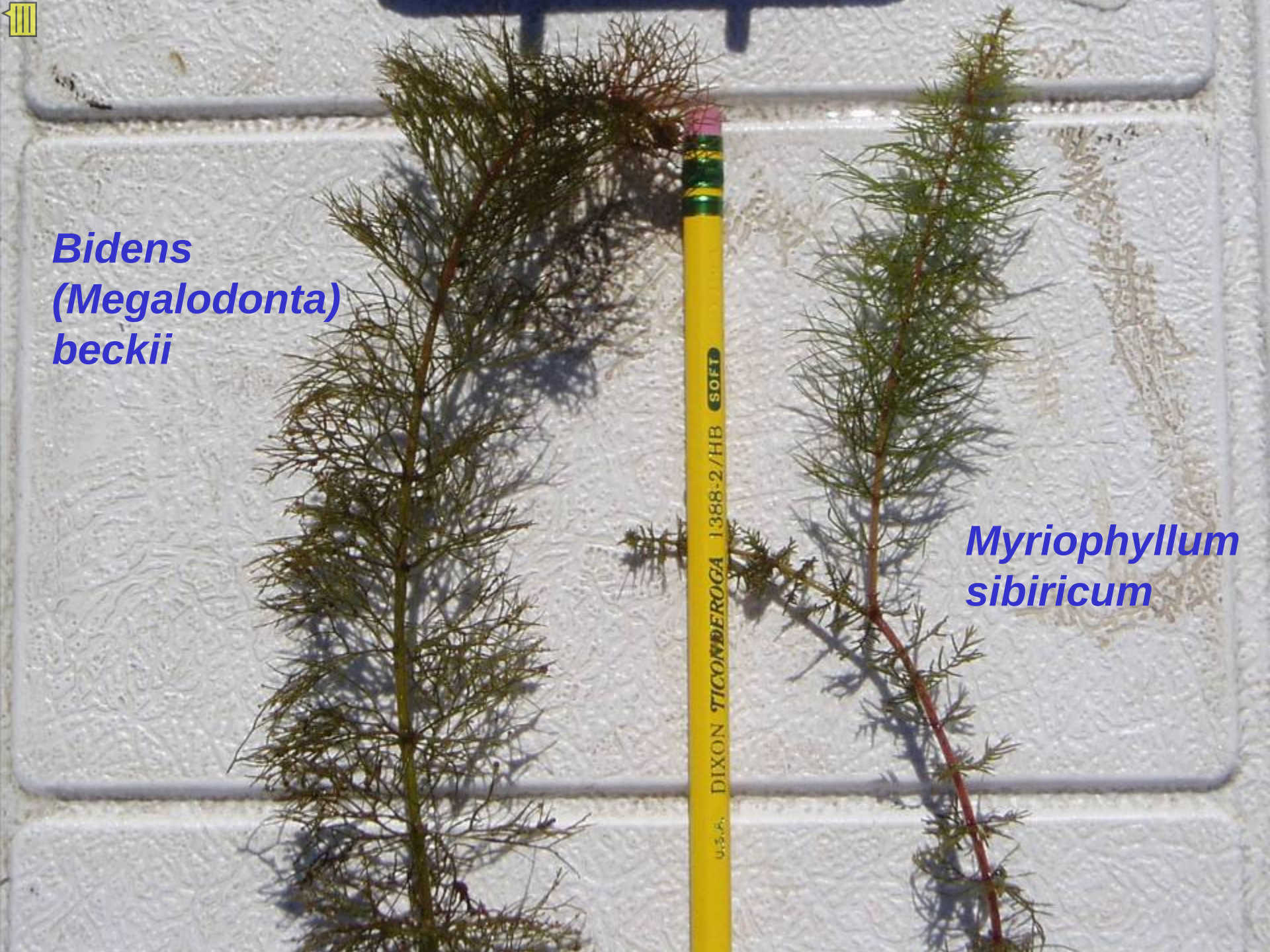
- Formulation: Liquid (AS) and Pellet (SRP, PR, Q, One)
- Mode of Action: Systemic – inhibits carotenoid synthesis
- Environmental Fate: phytolysis
- Water Use Restrictions: Irrigation 7-30 days or until <5-10 ppb
- Advantages: Systemic action kills entire plant including roots, provides multiple years of control, favorable toxicology profile, species selectivity at low doses
- Limitations: Highly soluble not effective for partial lake or shoreline treatments, requires long contact time
- Plants Controlled: Eurasian Watermilfoil, Fanwort, Curlyleaf Pondweed, Hydrilla, many others at higher doses

Renovate (Triclopyr)

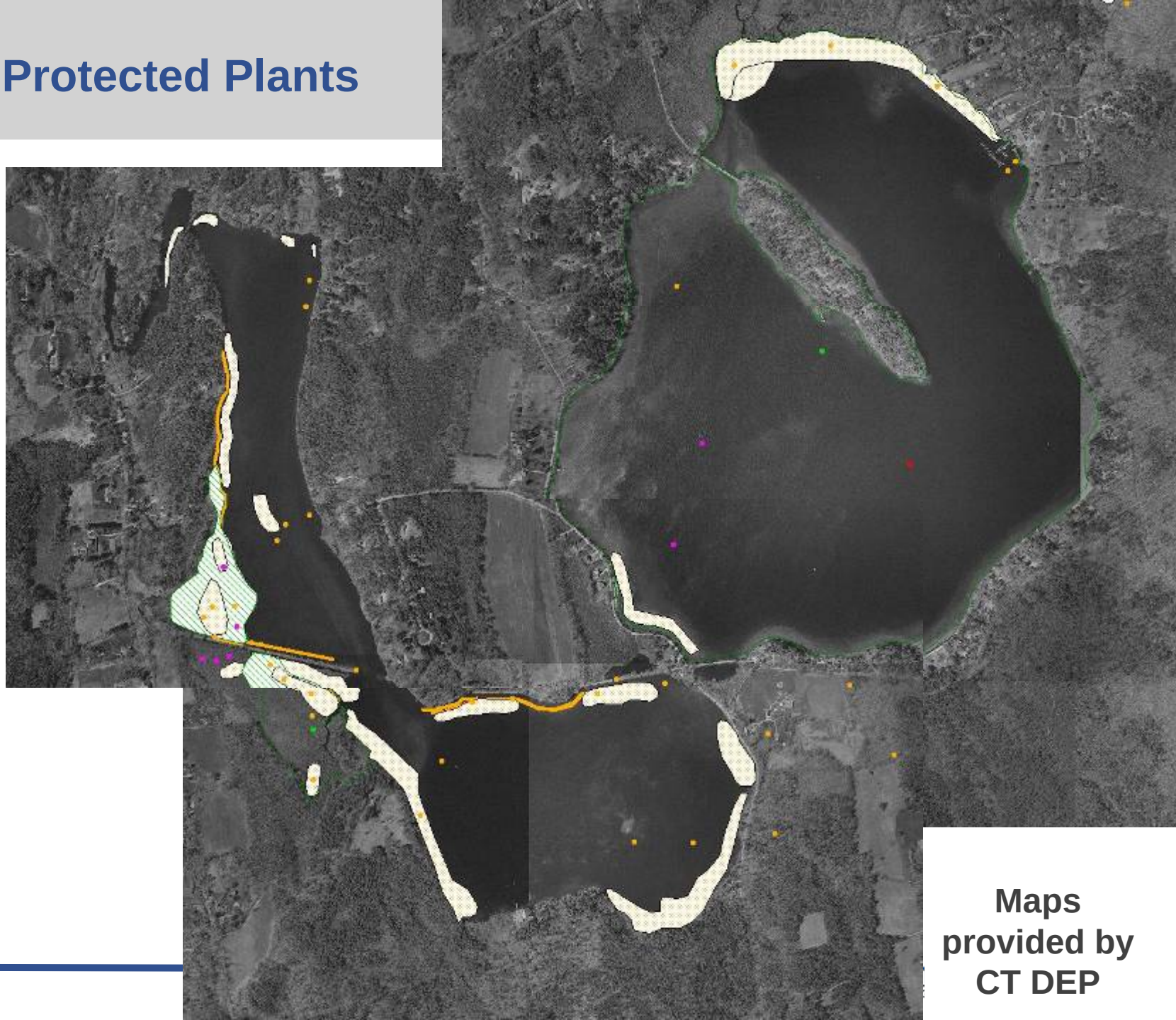
- Formulation: Liquid and Flake/Pellet (OTF)
- Mode of Action: Systemic – auxin mimic interferes with plant growth processes
- Environmental Fate: Phytolysis
- Water Use Restrictions: Irrigation 120 days or until non-detect, Drinking set-back distances based on dose
- Advantages: Rapid action effective for partial lake or shoreline treatments, Systemic kills entire plant including roots, multiple years of control
- Limitations: Expensive, Demonstrated effectiveness on only a few aquatic species
- Plants Controlled: Milfoil, Purple Loosestrife

CASE STUDY: Reward (Diquat)

- Twin Lakes (>800 acres) located in Salisbury in northwest CT in the “marble valley” (Canavan & Siver 1995)
- Considerable littoral zone EWM infestation
- Mechanical harvesting performed over throughout the 1990s was not providing effective control
- Several state protected aquatic plant populations in the lakes


Bidens (Megalodonta) beckii
Myriophyllum sibiricum
DIXON TICONDEROGA 1388-2/HB SOFT

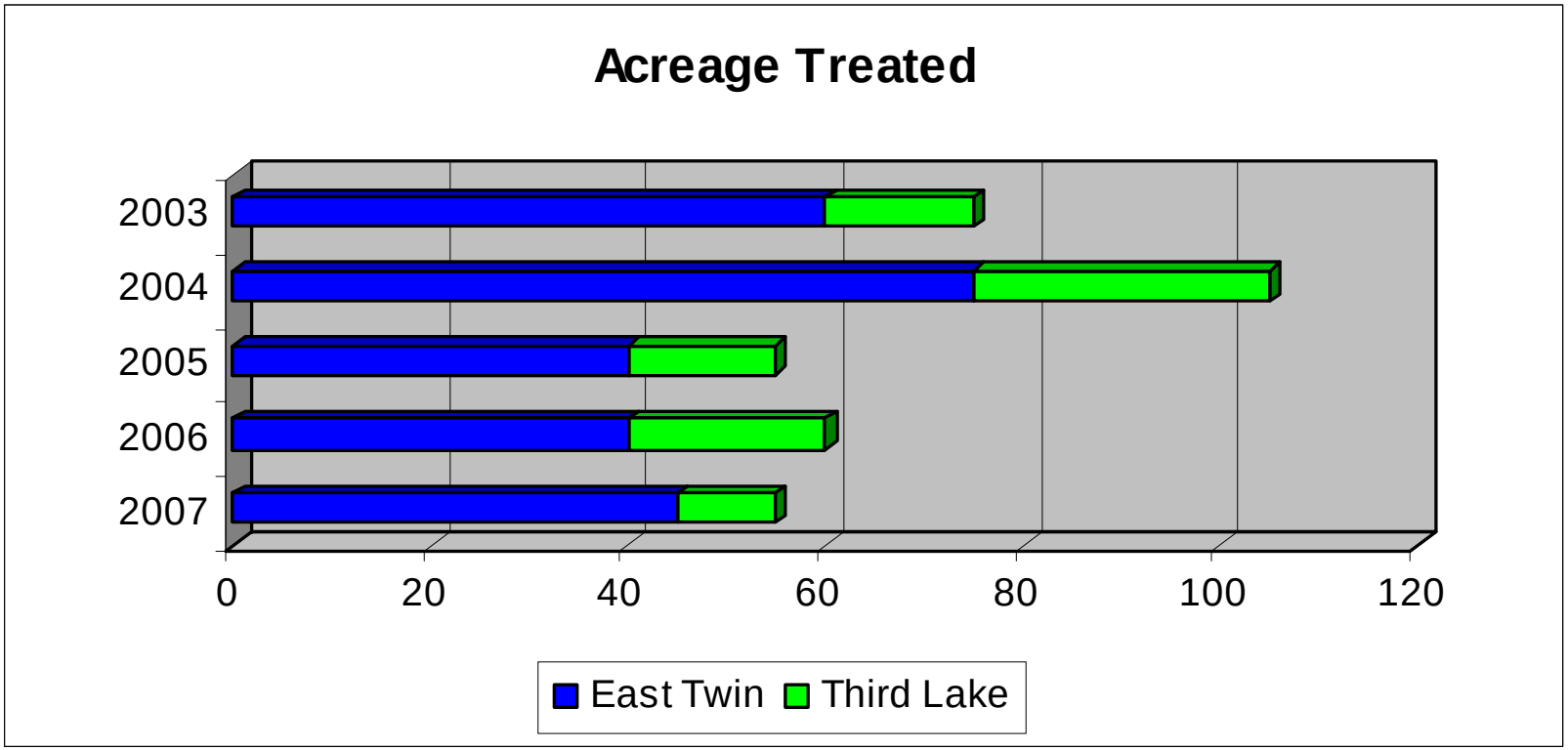
State Protected Plants



Maps provided by CT DEP

Treatment Program Summary (2003 – 2008)

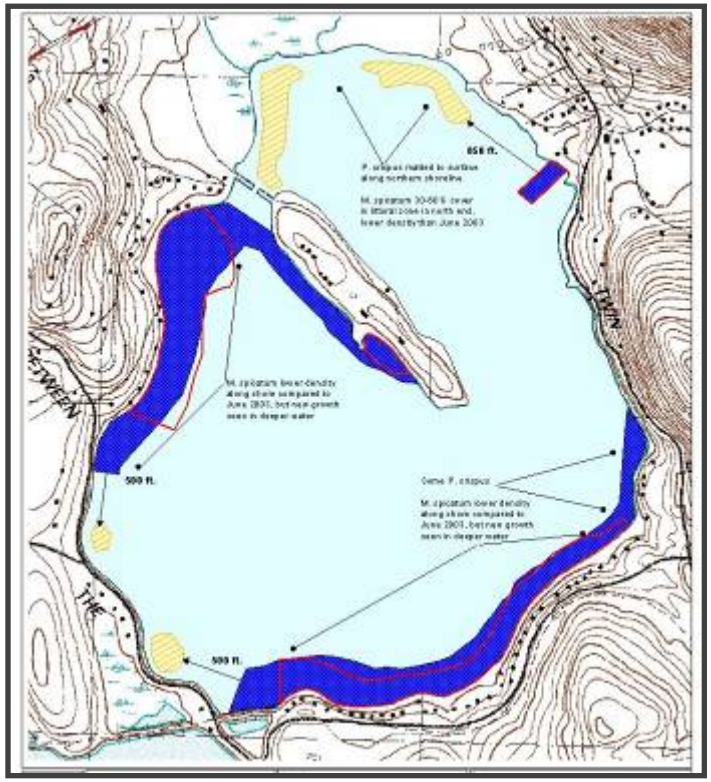
- Area-selective diquat treatment along high-use shorelines
- No-treatment buffers maintained around state protected plant populations



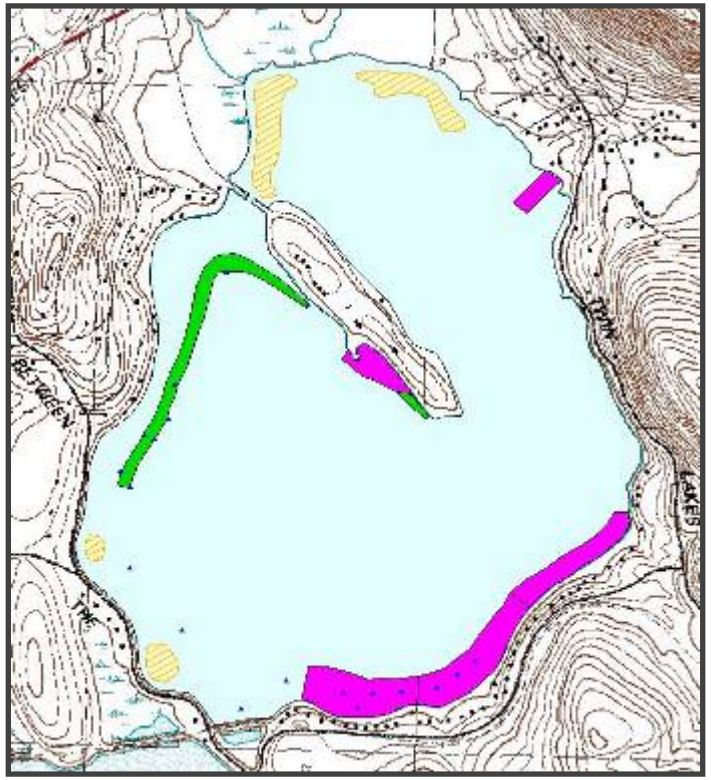
Program modifications…

- Redued treatment area by directly applying to EWM beds
- Lowered application rate from 1.5 gals/ac to 1.0-1.25 gals/ac
- Treated earlier in growing season

2004

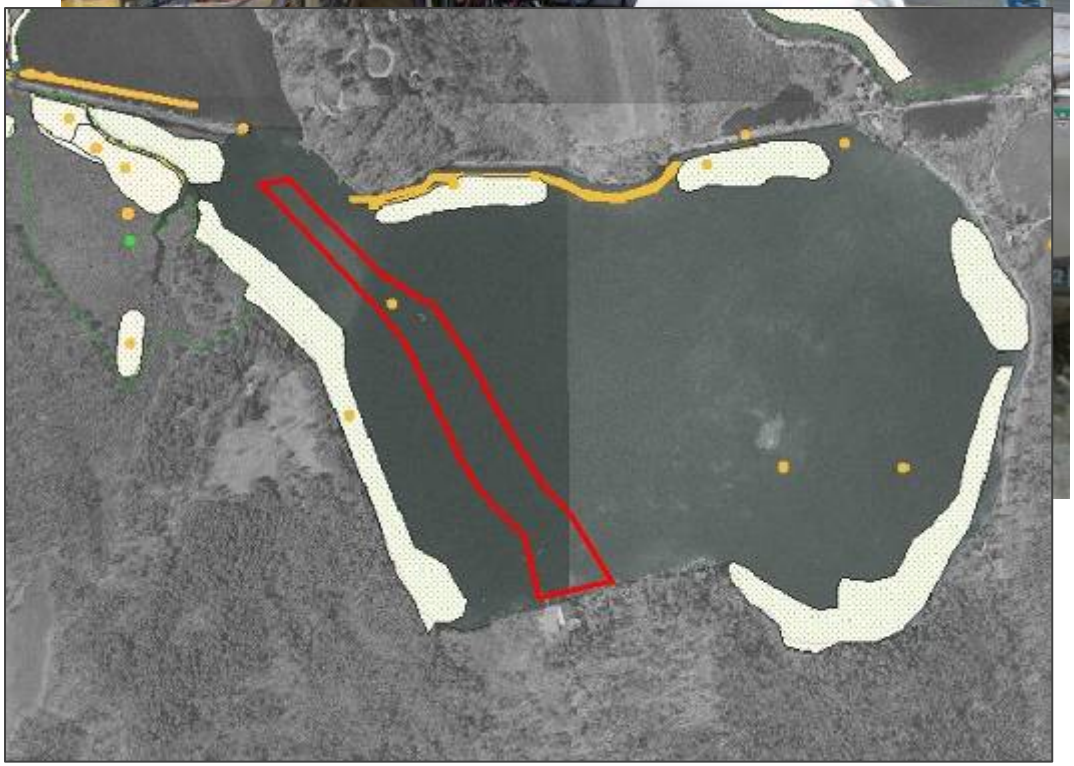


2005



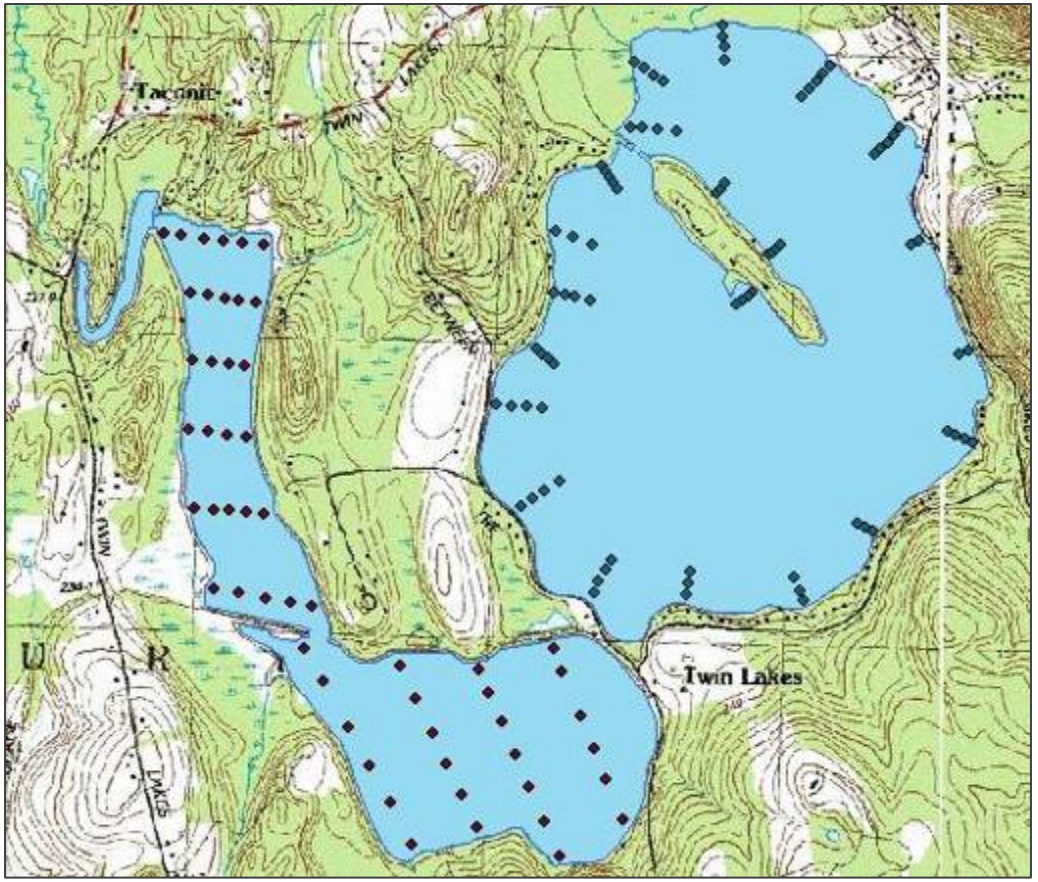
Second Lake CET treatment work performed in 2007

- 13 acre boat lane for Salisbury School Crew Teams along western shoreline
- Tried to limit impact to rare species by:
  - Treating early, in late May
  - Treating at 1 gallon per acre
  - Injecting herbicide 5-6 feet subsurface
  - Maintaining 100-200 foot buffers from known rare plant beds



Comprehensive Monitoring Program Required by DEP

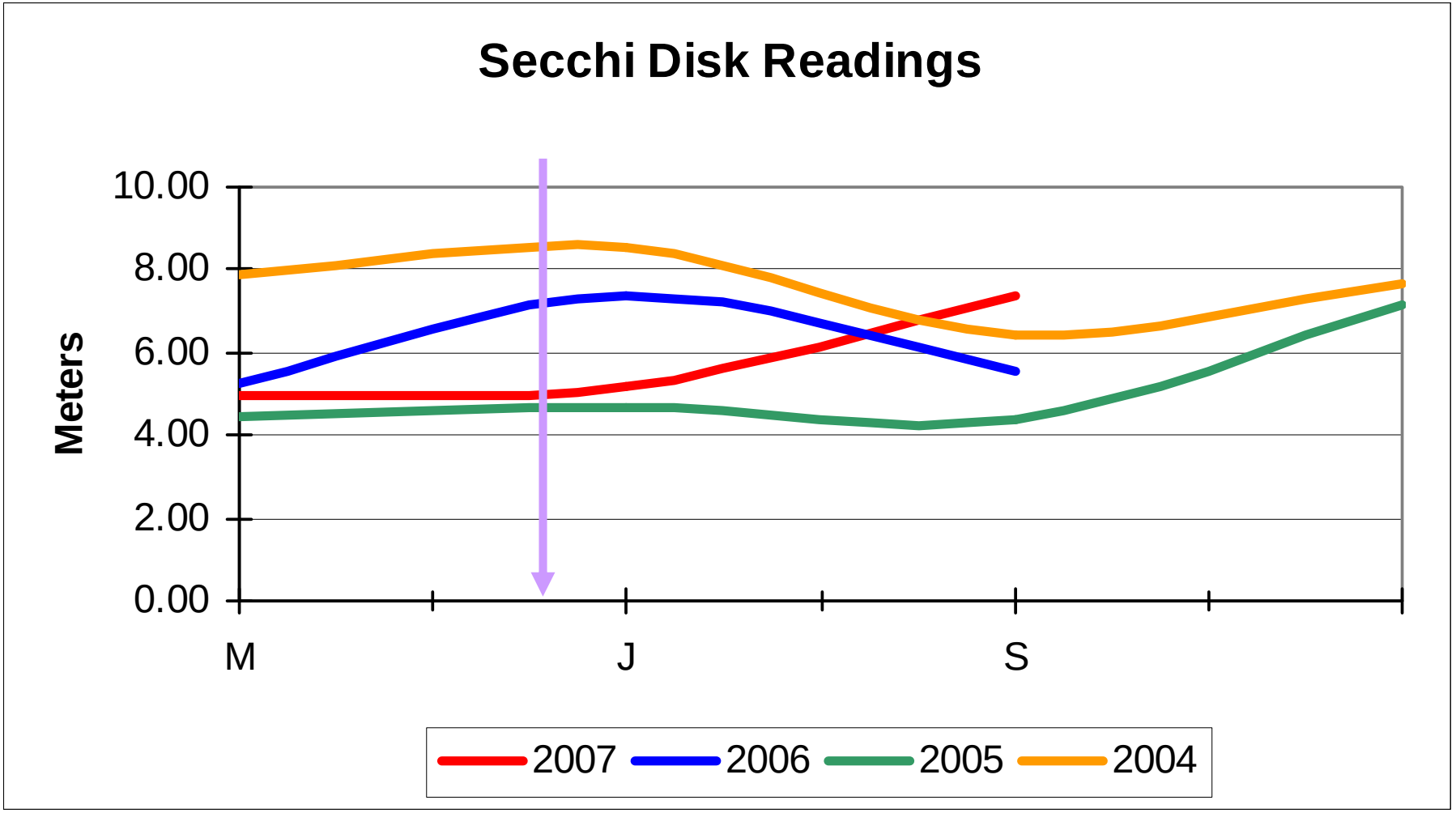
- **Early and late season vegetation surveys; DGPS located data points**
- **Water chemistry sampling monthly** [pH, alkalinity, TSS, turbidity, nitrogen series, total phosphorus, dissolved phosphorus, temp/do profiles, Secchi disk]
- **Phytoplankton and zooplankton sampling**

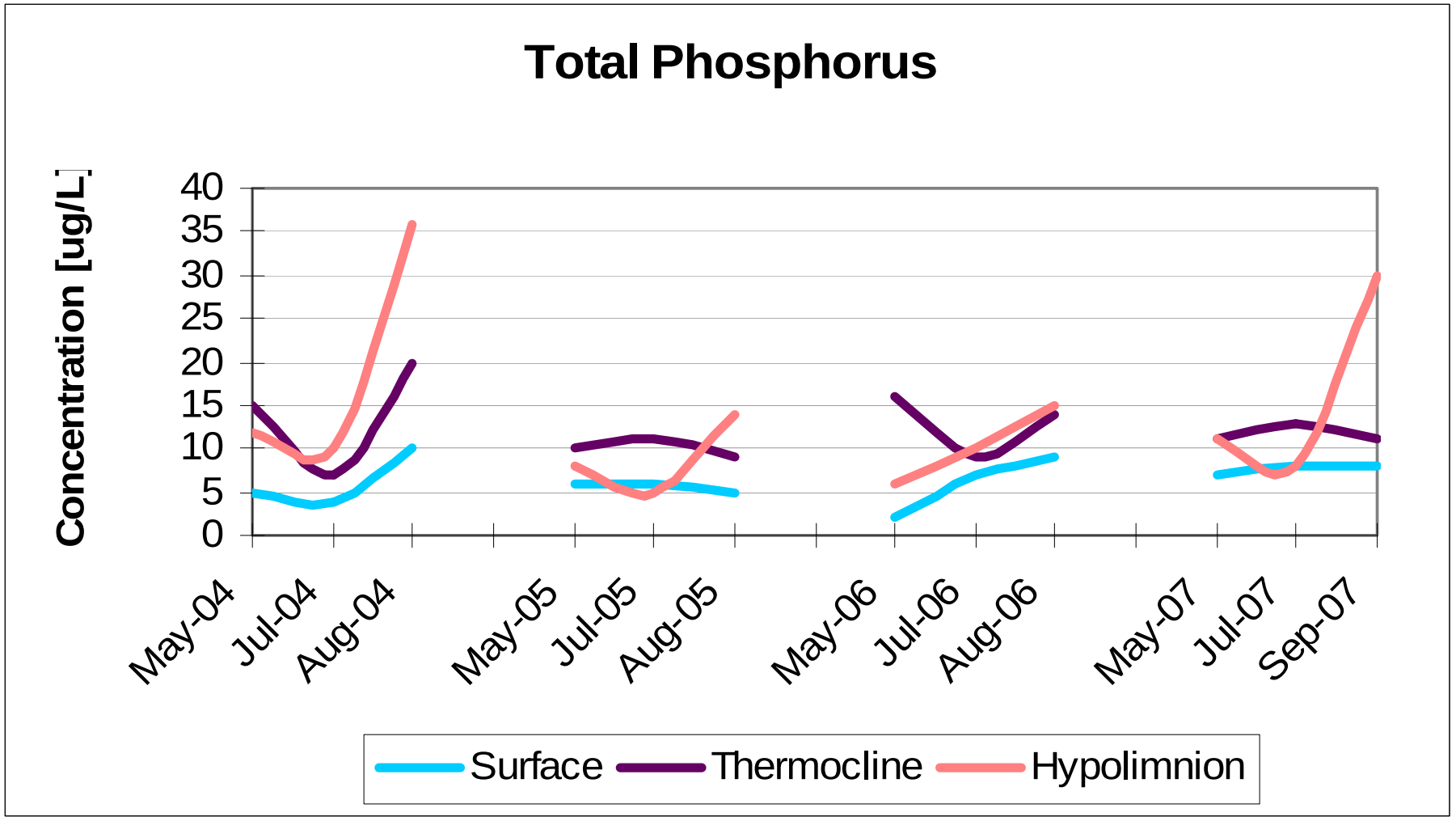


Water Quality Overview…

Typical Ranges – historic and observed between 2003 and 2008

➢ pH	7.9 – 8.5	(S.U.)
➢ Alkalinity	112 – 130	(mg CaCO3/L)
➢ Secchi disk clarity	5.0 – 6.5	(meters)
➢ Phytoplankton density	<2000	(cells/ml)
➢ Zooplankton density	20 – 40	(org/ml)





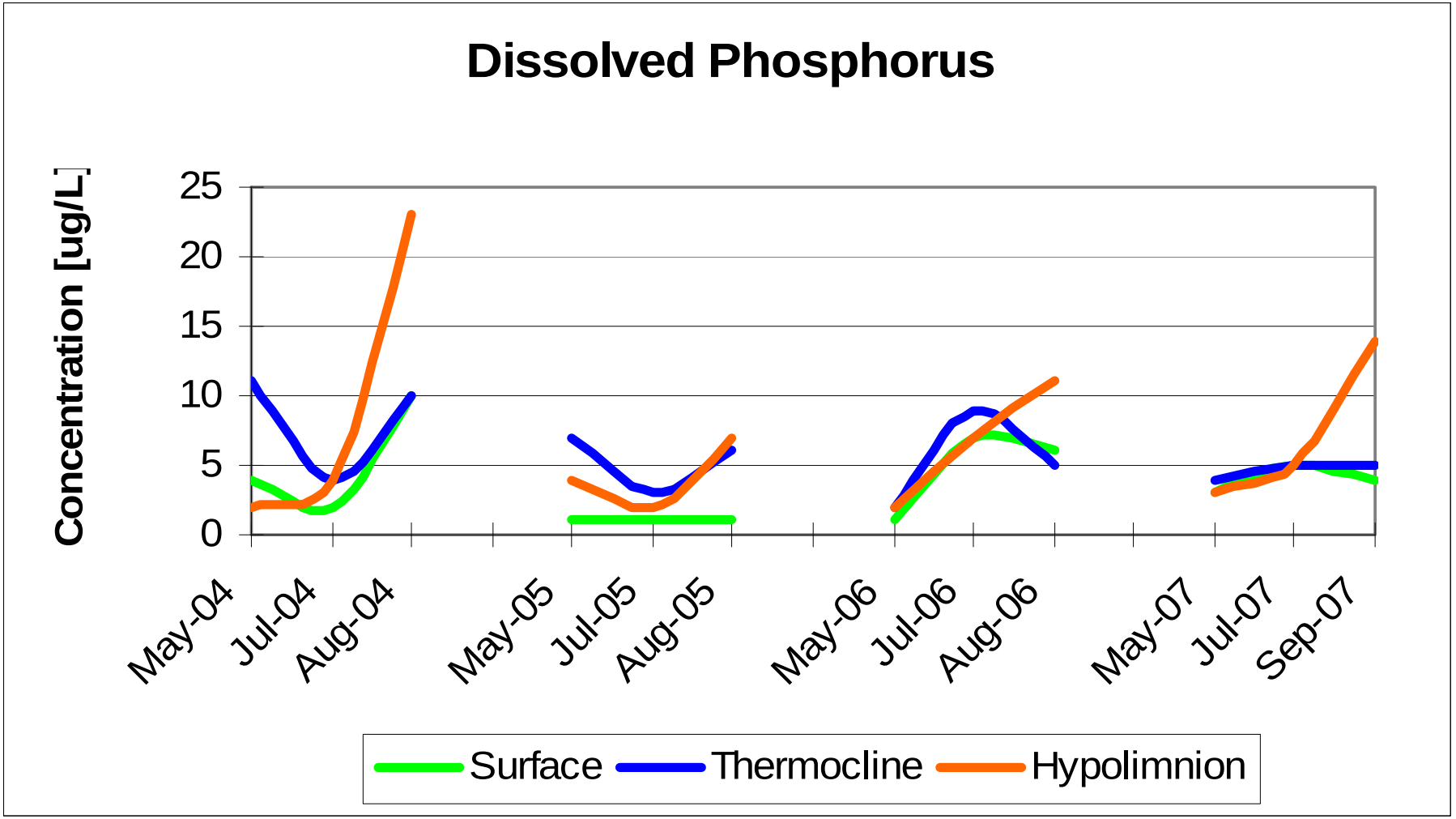


Chart 1: Site 1 - East Twin Deep Hole - 2006 Temperature Profile

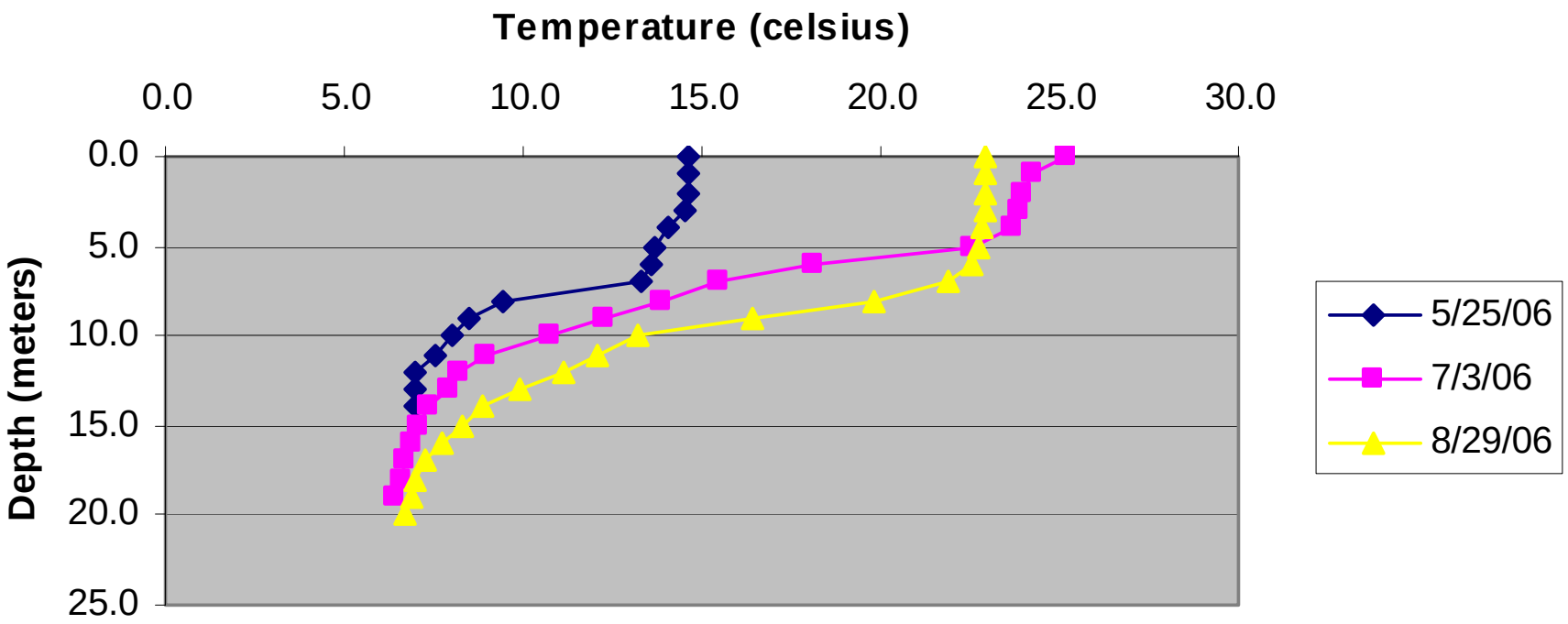
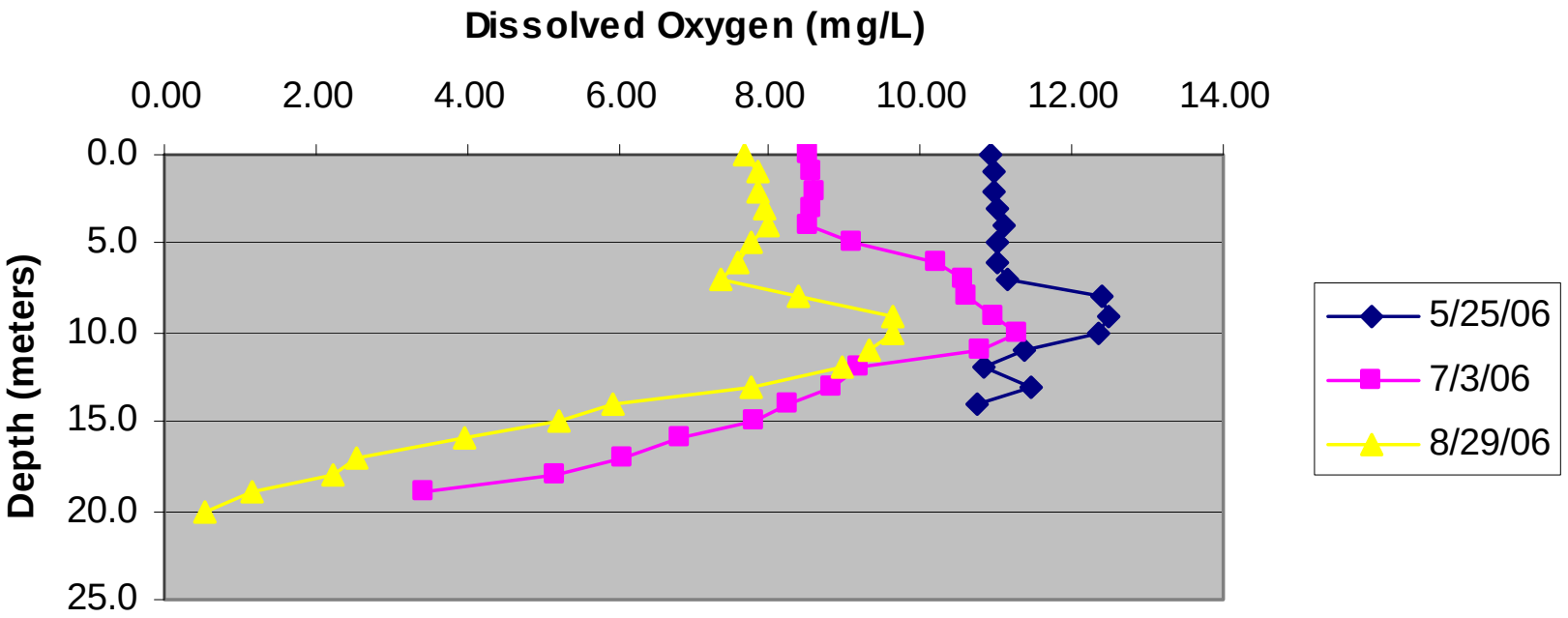


Chart 3: East Twin Deep Hole - 2006 Dissolved Oxygen Profile



Aquatic Plant Species List for Twin Lakes

Chara sp.

Ceratophyllum demersum

Eleocharis sp.

Elodea Canadensis

Heteranthea (Zosterella) dubia

Bidens (Megalodonta) beckii

Myriophyllum sibiricum

Myriophyllum spicatum

Najas flexilis

Nuphar luteum

Nymphaea odorata

Potamogeton amplifolius

Potamogeton crispus

Potamogeton gramineus

Potamogeton illinoensis

Potamogeton natans

Stuckenia (Potamogeton) pectinatus

Potamogeton robbinsii

Potamogeton zosteriformis

Utricularia purpurea

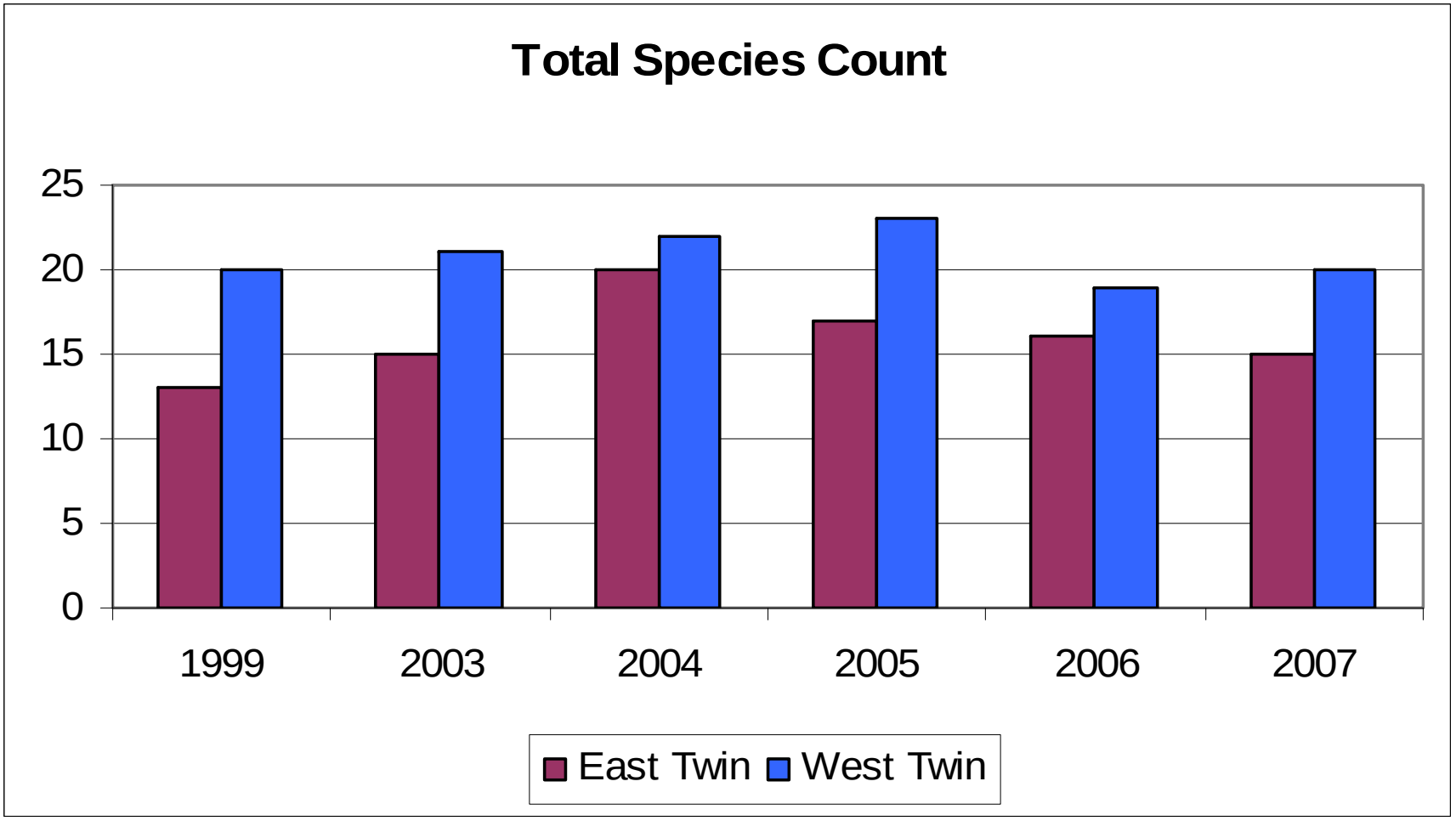
Utricularia sp.

Vallisneria americana

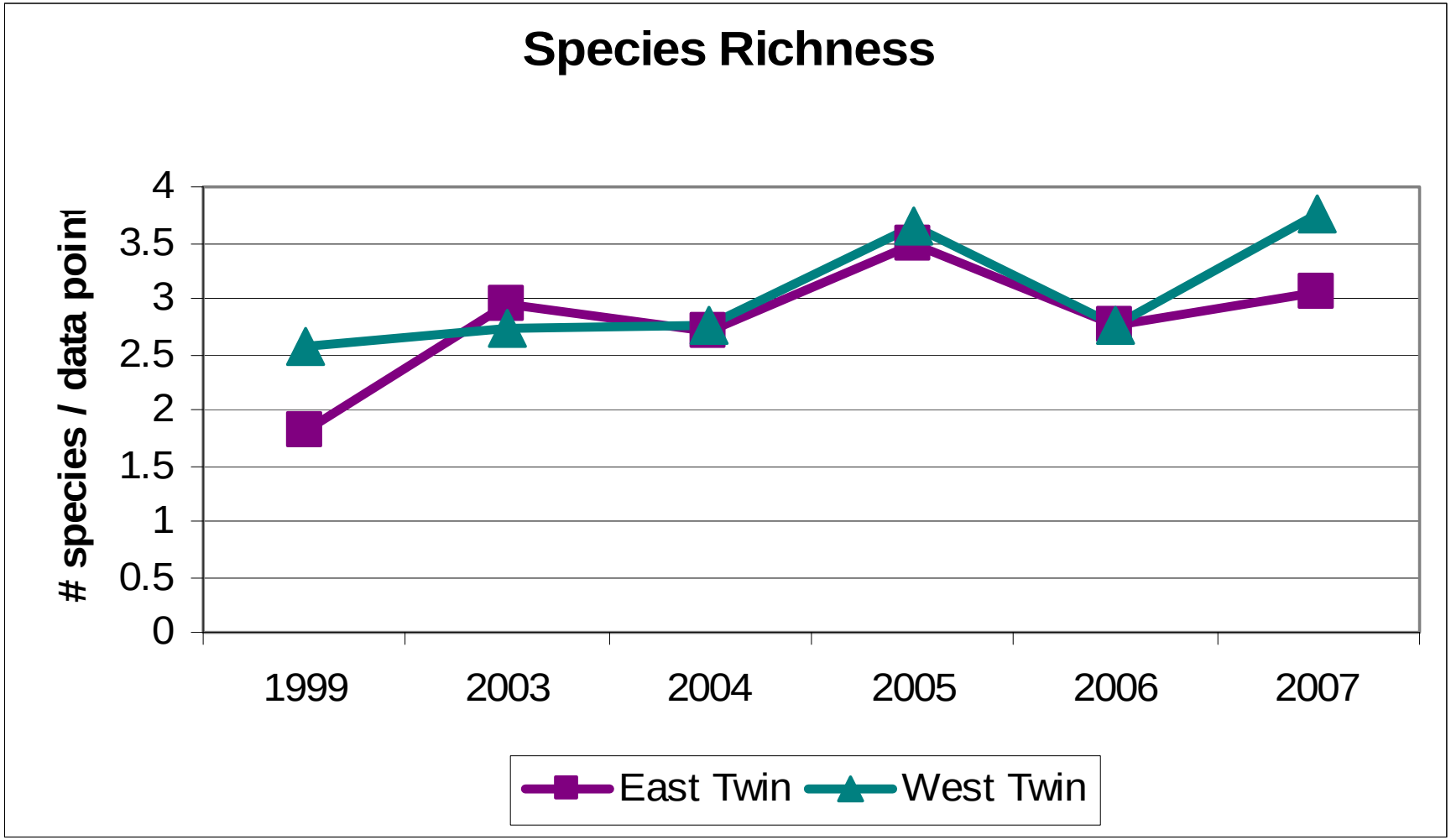
Potamogeton ogdenii (reported)

Numerous shoreline emergent species

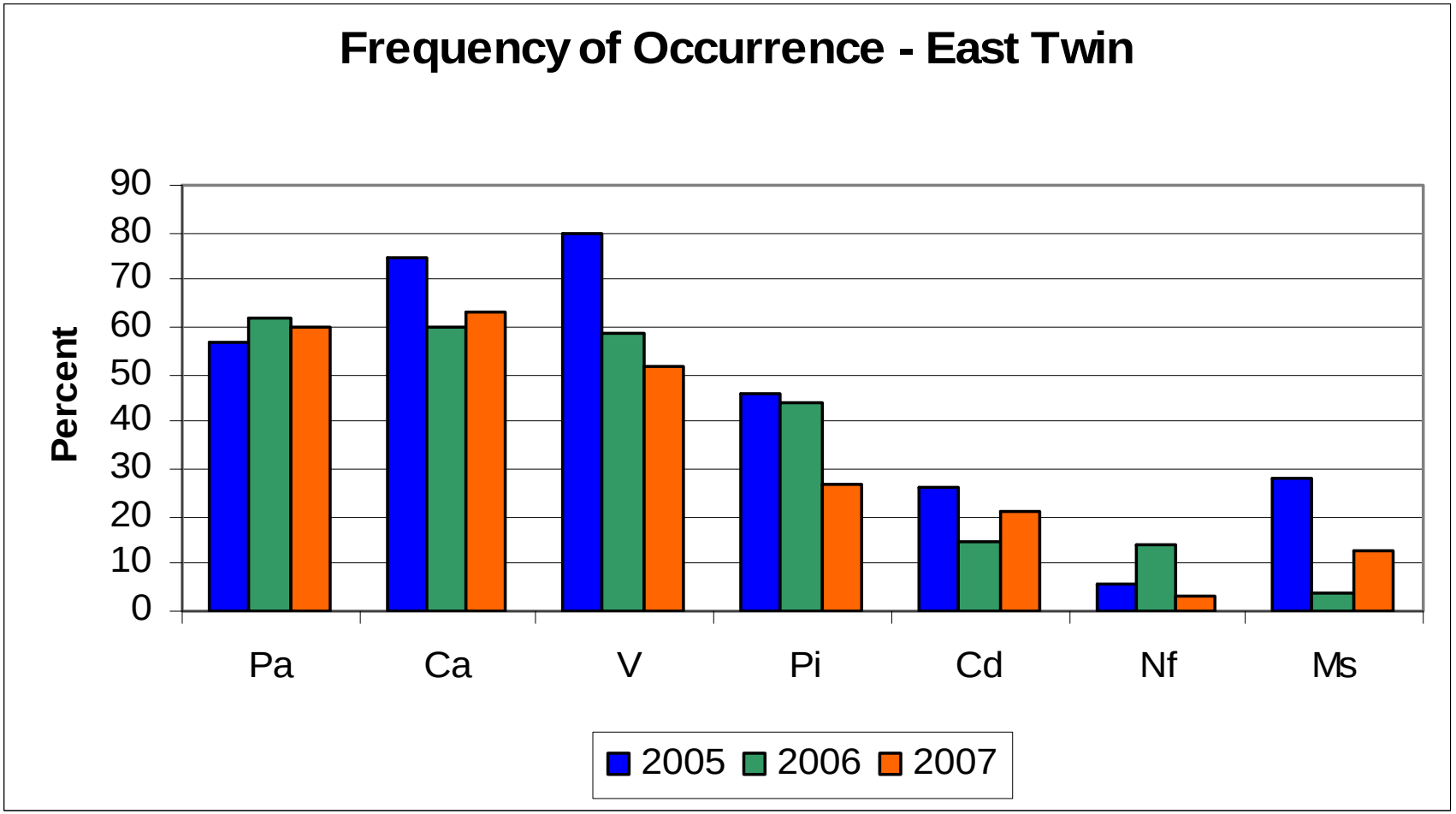
Pre and Post Vegetation Monitoring



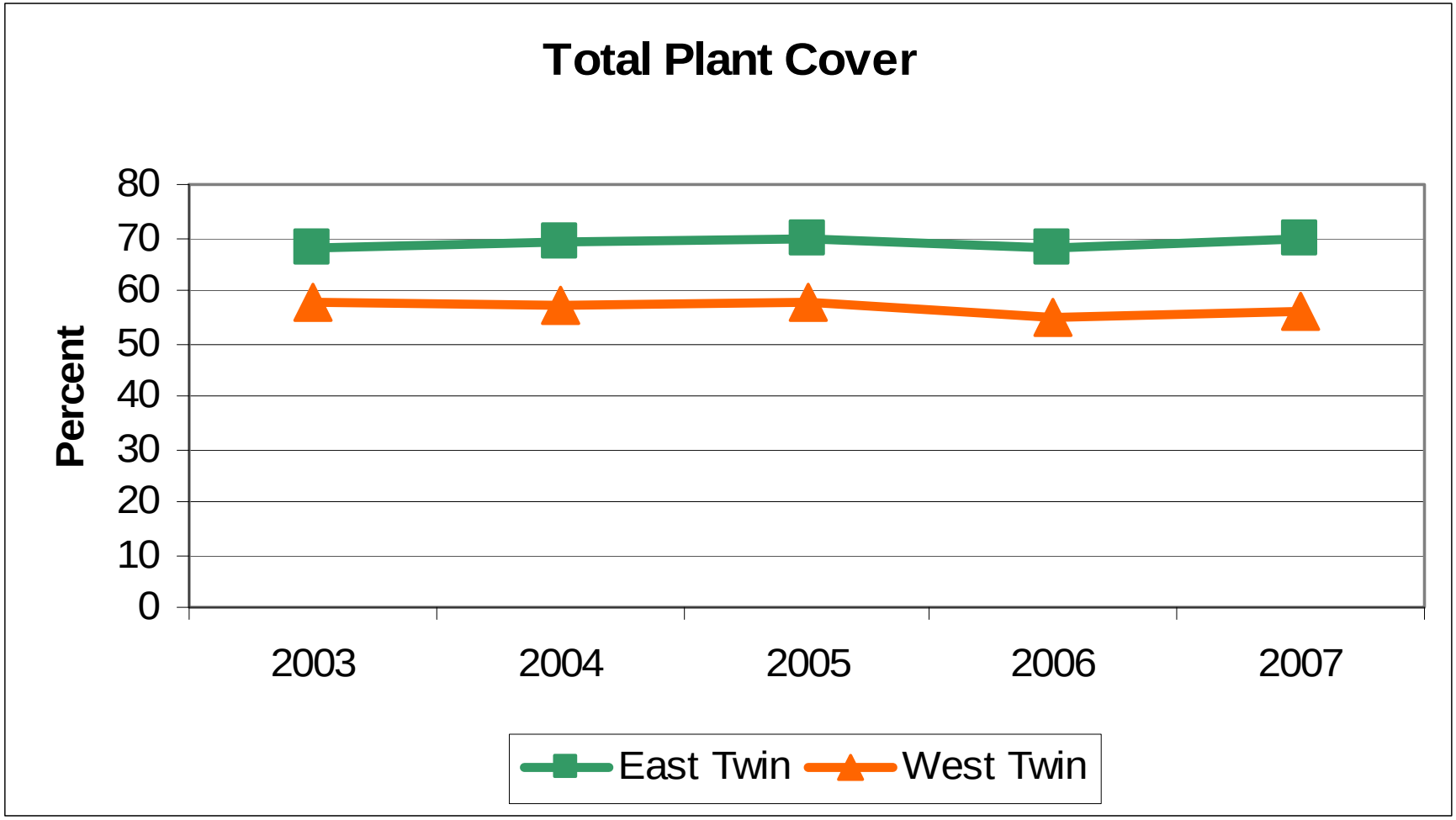
Pre and Post Vegetation Monitoring



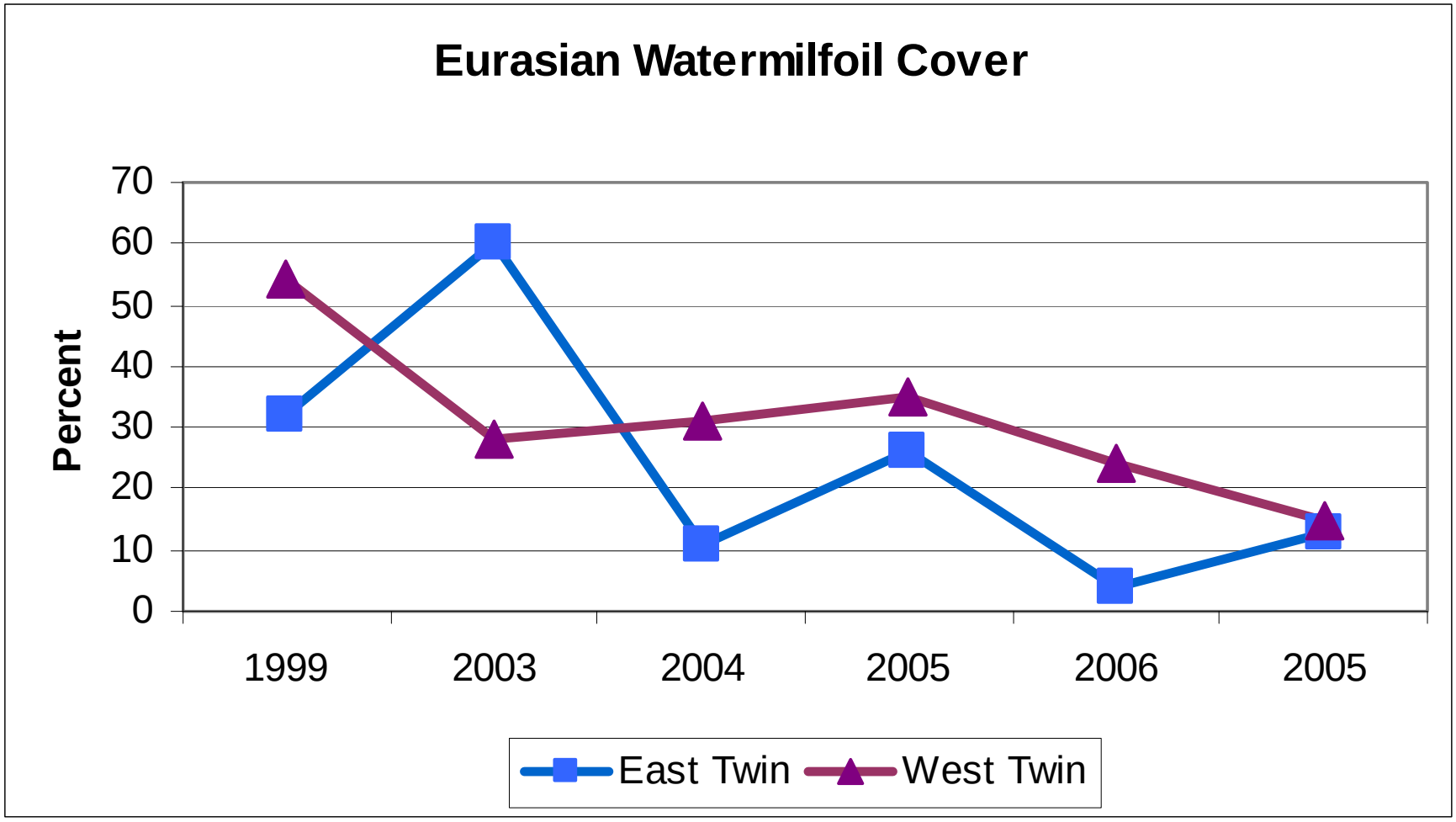
Pre and Post Vegetation Monitoring



Pre and Post Vegetation Monitoring

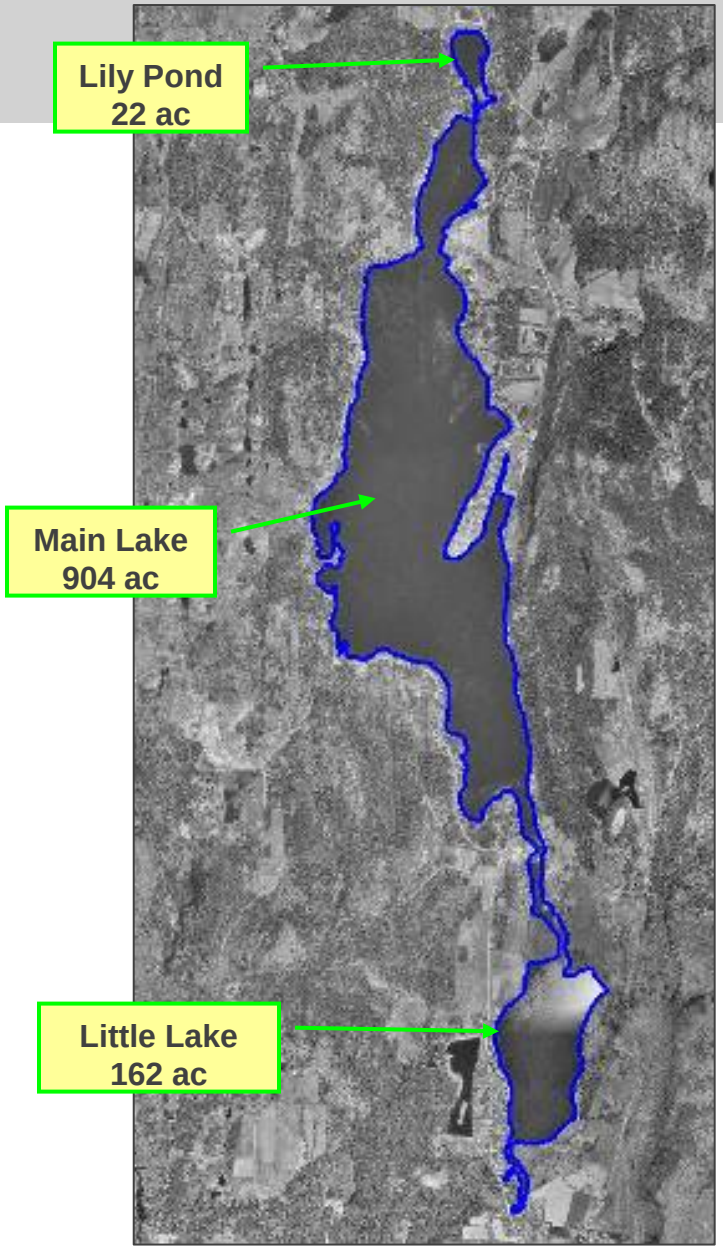


Pre and Post Vegetation Monitoring



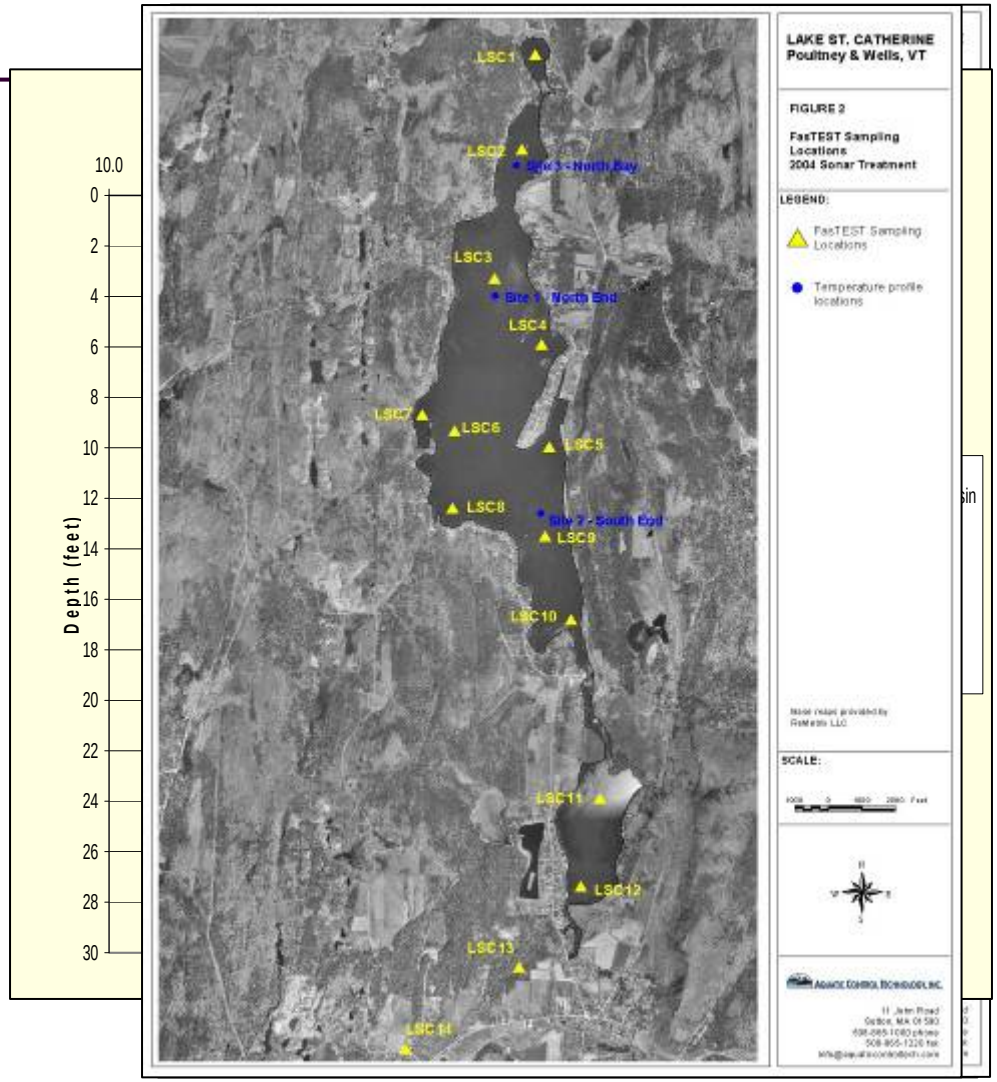
CASE STUDY:
Sonar (Fluridone)

- Lake St. Catherine: Poultney and Wells, VT
- 1088 acre lake system: 3-basins
- Total volume: 33,611 ac-ft
- Approximately 50% of lake volume below thermocline
- Thermocline depth 6-8 m
- Watershed 9000 acres
- Flushing rate 0.5 years
- EWM found throughout littoral zone estimated at over 300 acres
- Mechanical harvesting program over prior decade; ineffective

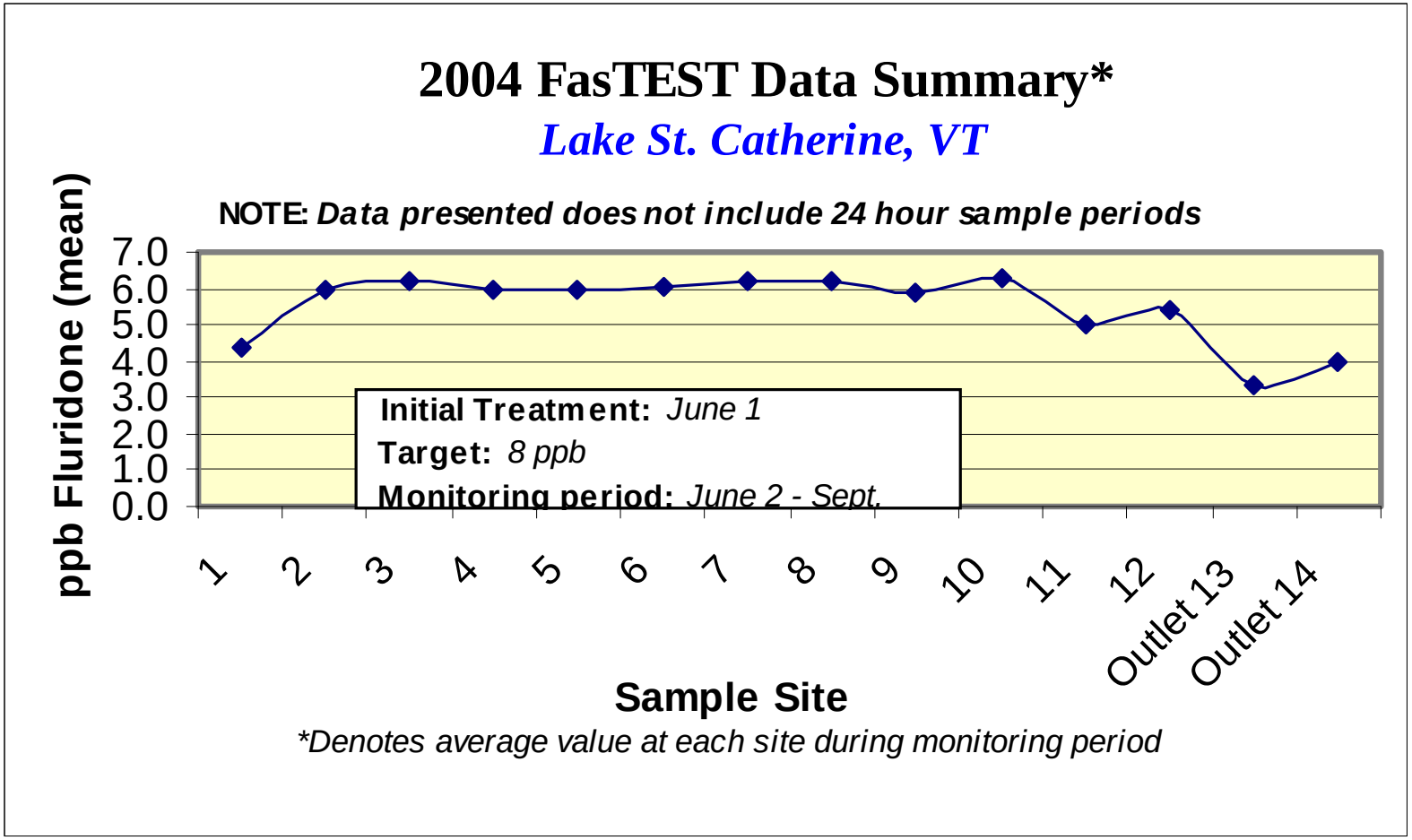


Sonar Treatment Protocol

- Whole-lake application of Sonar AS – initial dose 8 ppb, maintain 5-8 ppb for 90 days
- Use of Differential GPS for precision application
- 4 single-day applications performed by 2 airboats
- Weekly monitoring of thermocline depth
- FasTEST – 14 sites sampled 24-hours after each application and weekly until <5 ppb detected



Targeted fluridone concentrations maintained for >120 days



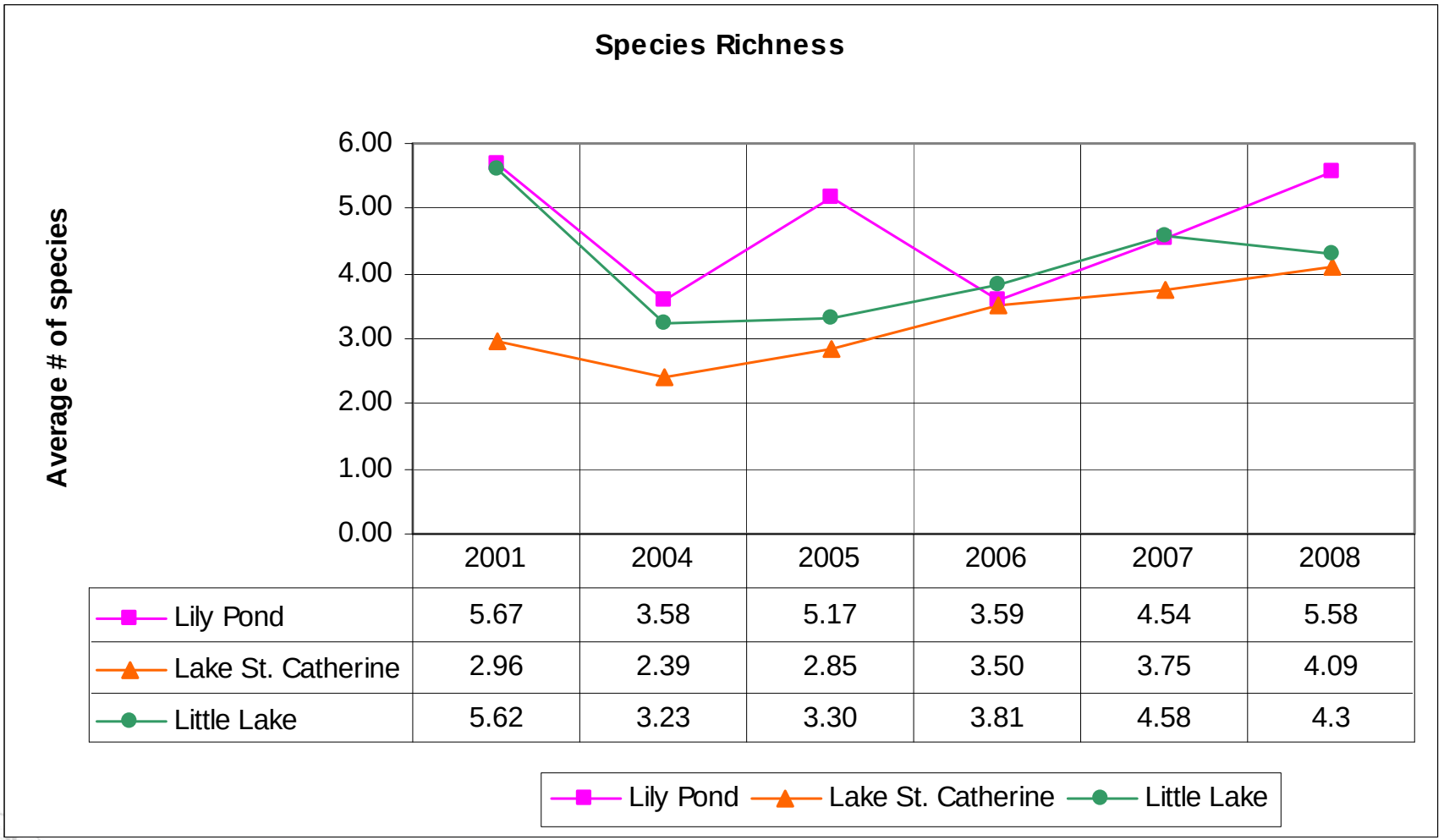
Year One – Program Results

- Good selectivity achieved
- But native species impacted

Years 2-5: Program Results

- **2005** - Late May inspection reveals widely scattered milfoil – main lake free of milfoil
- Diver hand pulling performed in selected areas
- **2006-2008** – Continued han-pulling, suction-harvesting and, spot-treatments with Renovate (triclopyr herbicide)
- Continued recolonization of native species

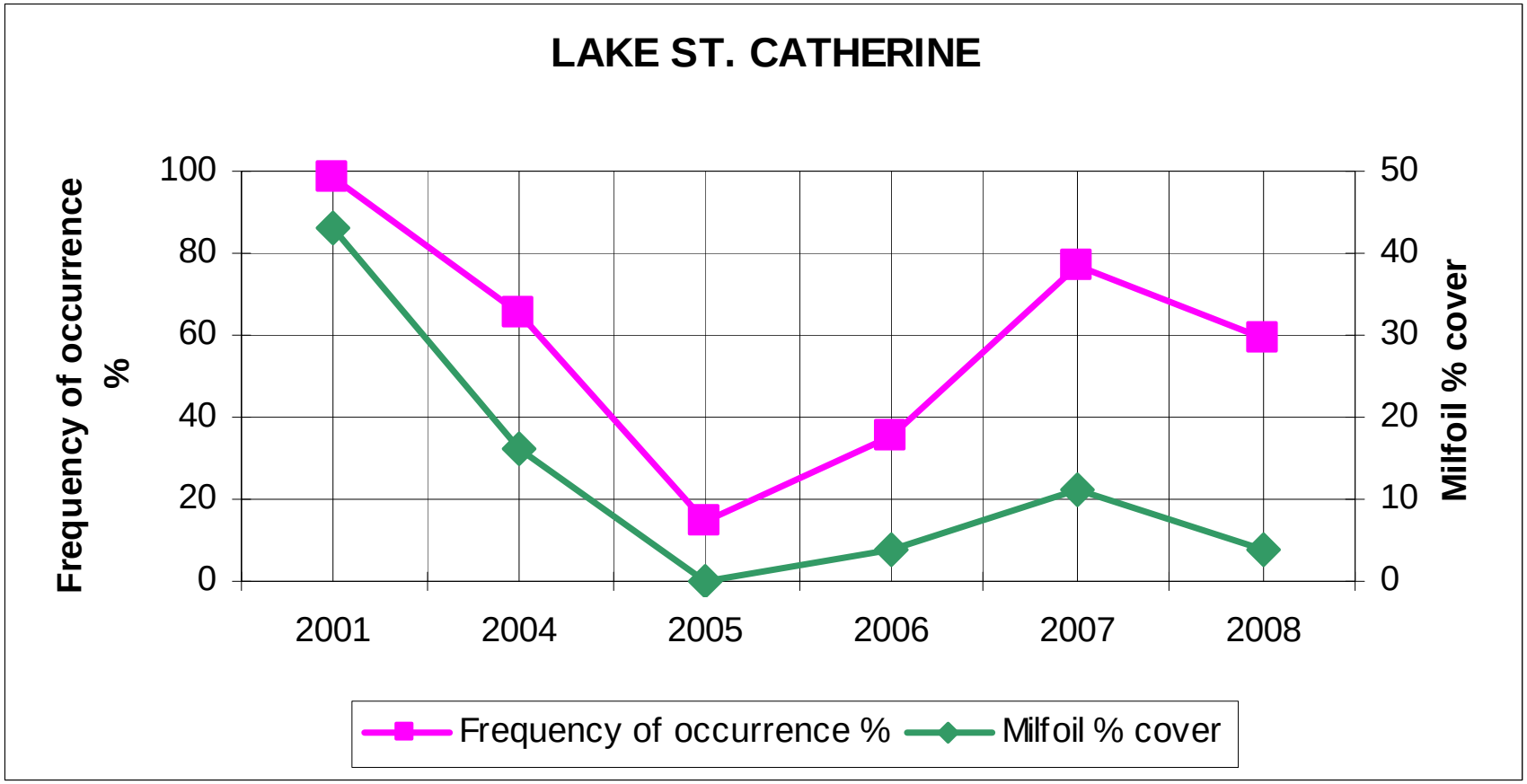
Pre and Post Vegetation Monitoring



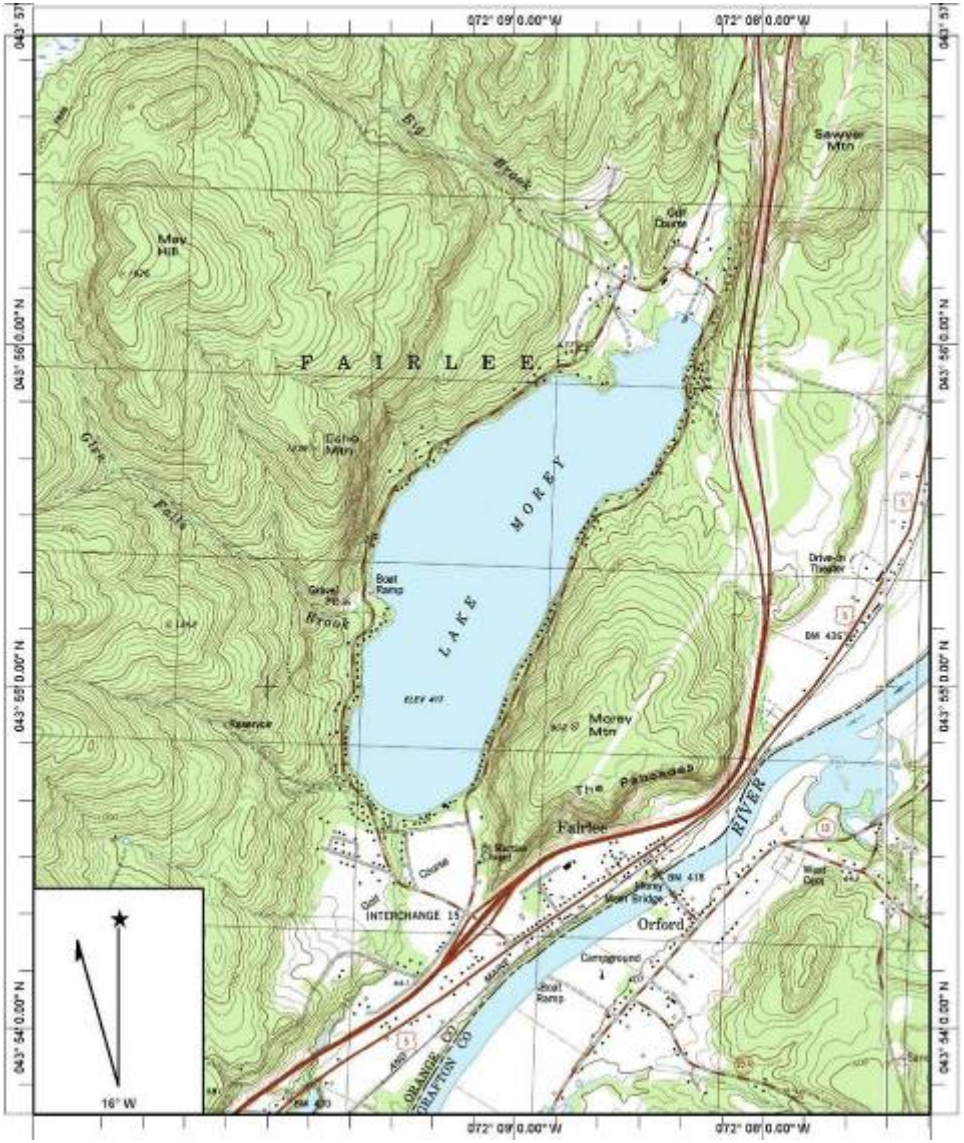
Pre and Post Vegetation Monitoring

Macrophyte Species	Common Name	2001 pre	2004 YOT	2005 YAT	2006 2YAT	2007 3YAT	2008 4YAT
Myriophyllum spicatum	Eurasian watermilfoil	94%	44%	17%	33%	74%	65%
Potamogeton robbinsii	Pondweed	52%	76%	88%	74%	77%	68%
Potamogeton amplifolius	Large-leaf	33%	38%	43%	49%	52%	53%
Elodea canadensis	Waterweed	32%	1%	1%	1%	5%	43%
Valisneria americana	Wild celery/Tapegrass	29%	13%	2%	4%	9%	8%
Potamogeton zosteriformis	Flat-stem pondweed	28%	3%	29%	29%	23%	19%
Potamogeton gramineus	Variable pondweed	23%	1%	6%	6%	2%	4%
Najas flexilis	Naiad	22%	0%	8%	39%	34%	22%
Ceratophyllum demersum	Coontail	20%	8%	11%	12%	21%	18%
Nitella / Chara	Stonewort	17%	6%	36%	40%	14%	14%
Nymphaea odorata	White waterlily	16%	5%	11%	10%	11%	11%
Utricularia vulgaris	Common bladderwort	8%	9%	2%	6%	7%	7%
Potamogeton illinoensis	Illinois pondweed	4%	1%	2%	9%	23%	39%
Zosterella dubia	Water stargrass	1%	1%	9%	8%	23%	17%

Pre and Post Vegetation Monitoring



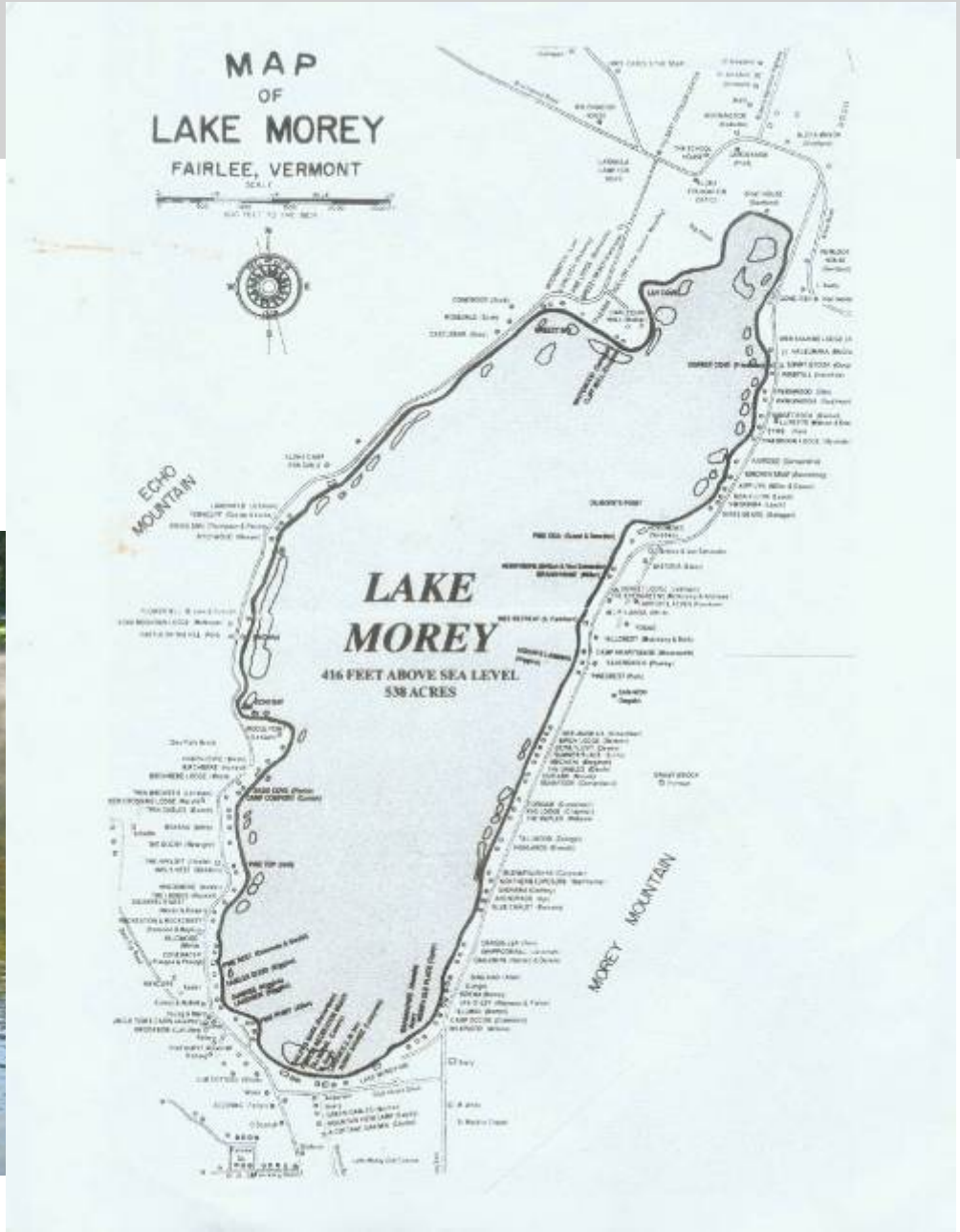
CASE STUDY: Renovate (Triclopyr)



- Lake Morey: Fairlee, VT
- Eurasian watermilfoil discovered in 1991
- DEC issued permit to apply Garlon 3A (triclopyr) in 1993; permit appealed then revoked
- Hand-pulling, suction harvesting, and bottom barrier installations employed since 1991
- Since 1991 over $1,000,000 expended on non-chemical controls, including in-kind

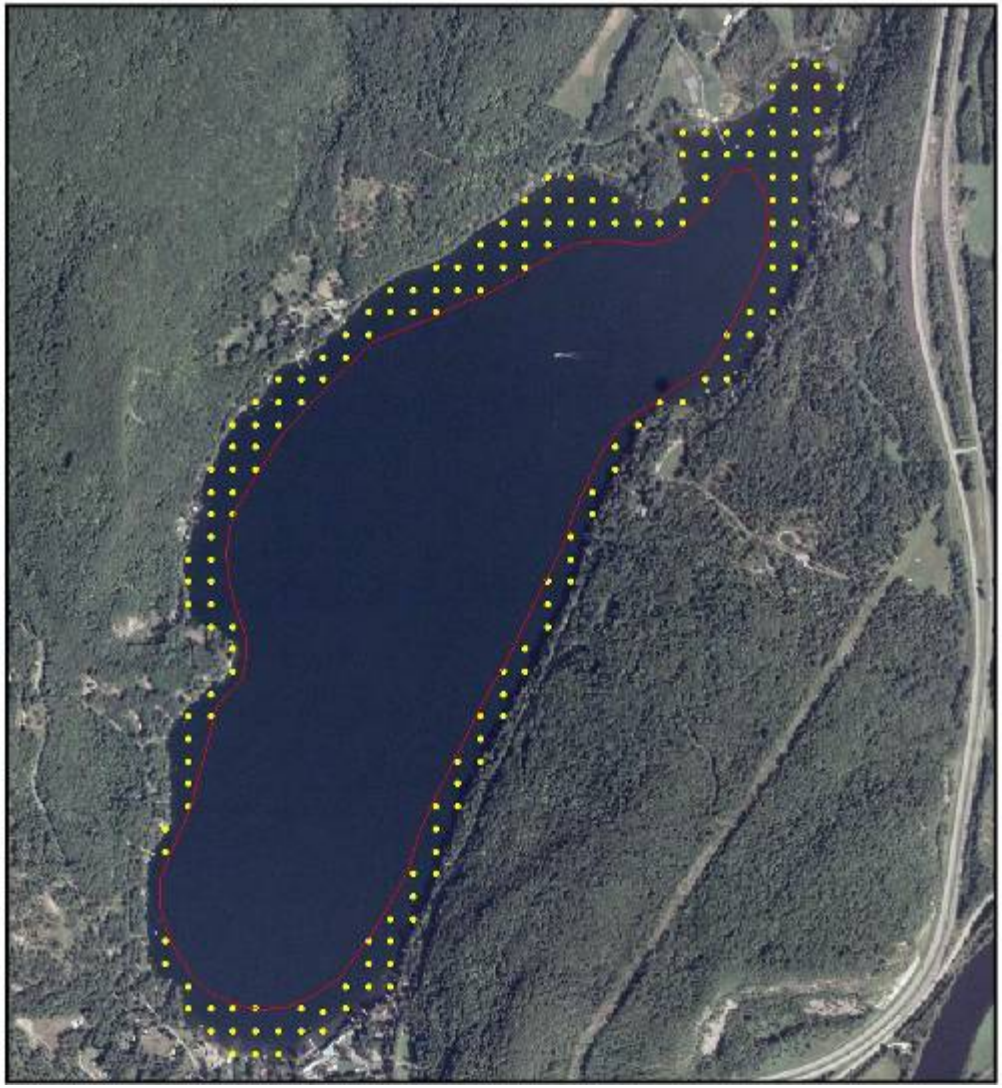
Association efforts…

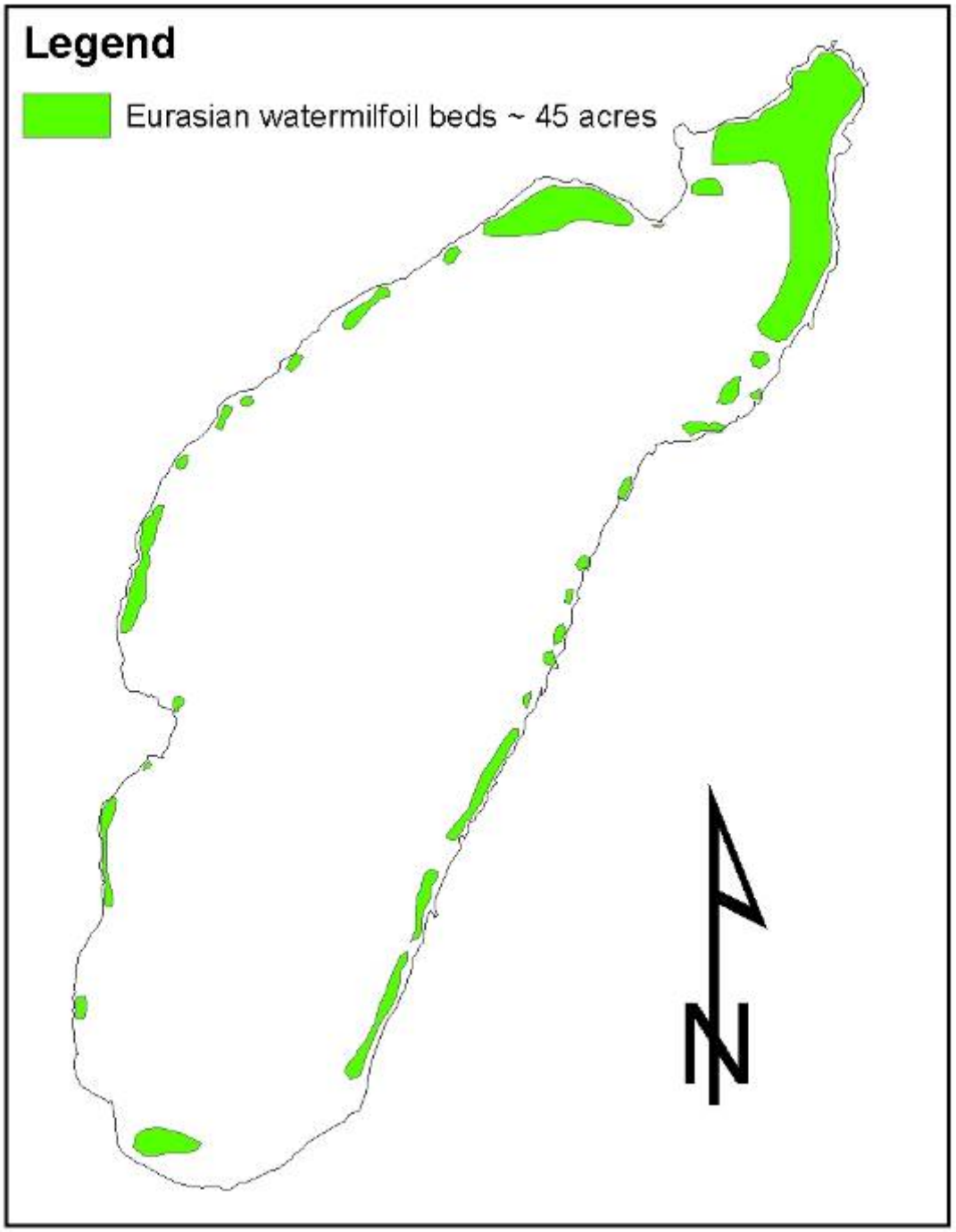
EWM growth pattern changed in 2004 and infestation rapidly expanded



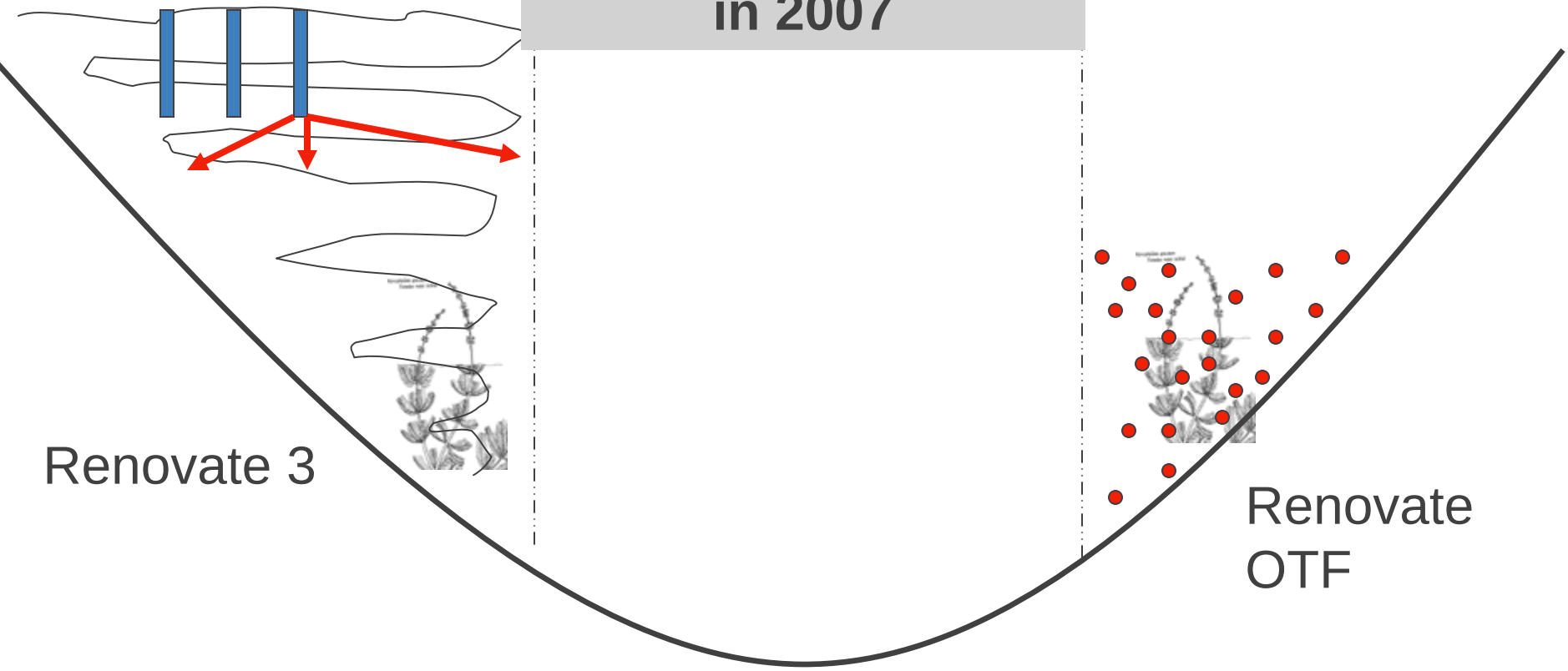
Point Intercept Survey

- DATA POINTS were randomly generated throughout littoral zone of lake on 80 m grid
- PRESENCE / ABSENCE sampling enabled creation of vegetation distribution maps
- Resulting data set used for statistical comparison pre and post-treatment
- GPS and GIS utilized




Legend
Eurasian watermilfoil beds ~ 45 acres
N

Two Formulations of Triclopyr Evaluated in 2007



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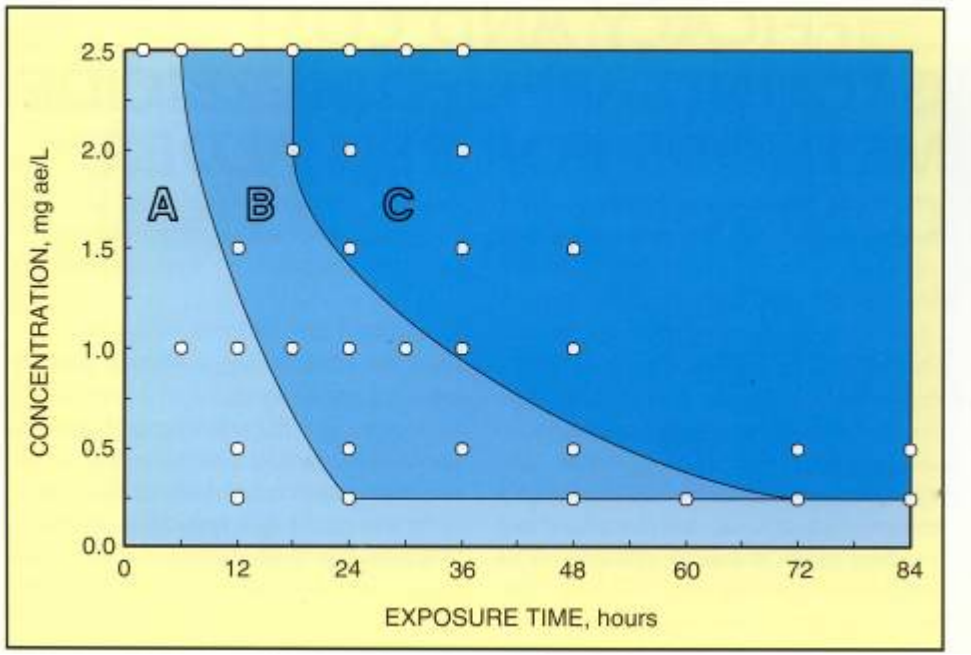
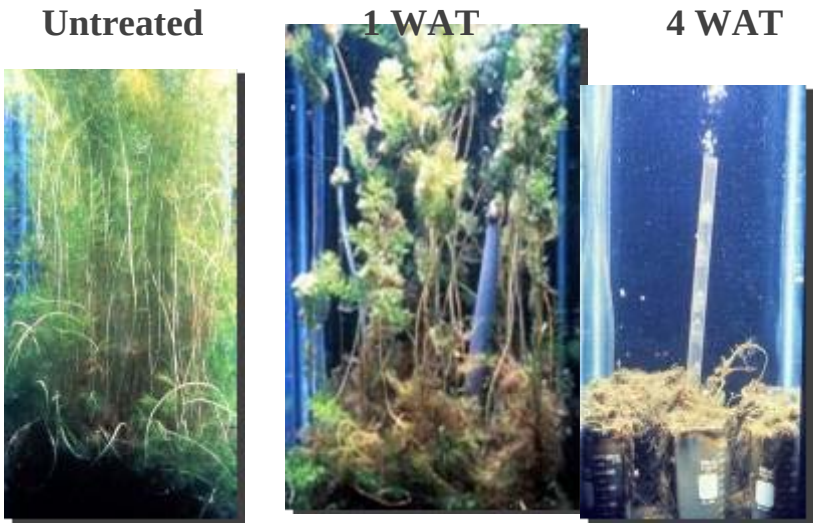
Renovate Concentration Exposure Time (CET)

Source: US Army Engineers – ERDC





Control Predictions

A: 0 - 70 % (regrowth likely)

B: 70 - 85 % (regrowth potential subject to site conditions)

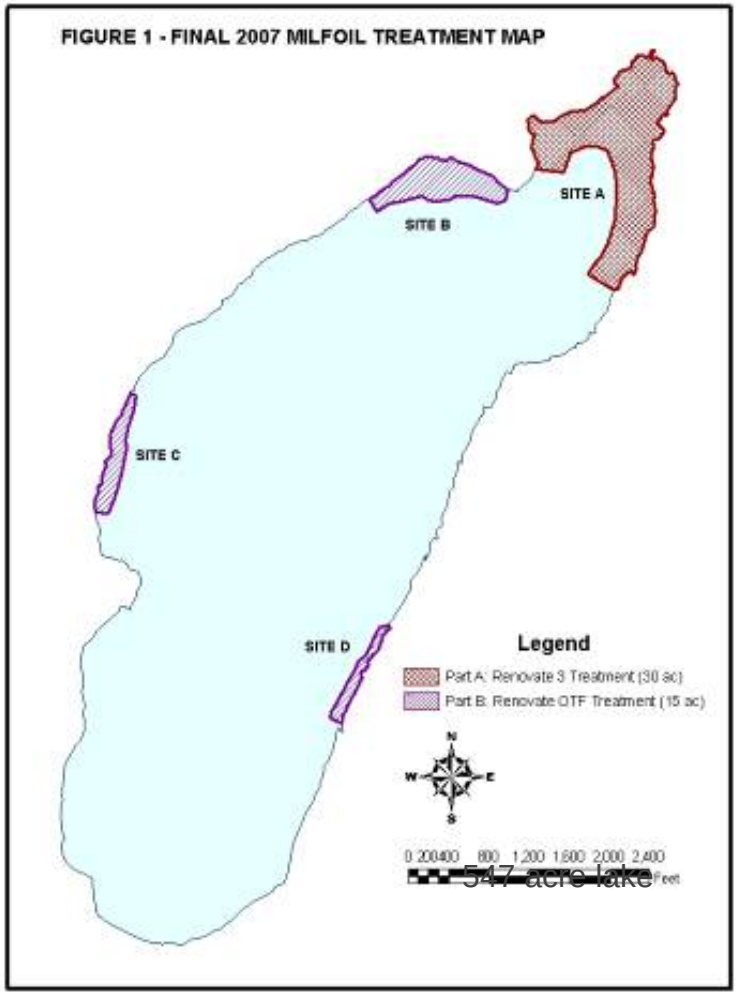
C: >85 % (limited regrowth potential)

2007 Treatment Program

- Site A: Renovate 3 (30 ac, 7 ft)
- Site B: Renovate OTF (8 acres, 8 ft)
- Site C: Renovate OTF (4 ac, 8 ft)
- Site D: Renovate OTF (3 ac, 8 ft)

June 24, 2007, Renovate OTF applied at 1.85 ppm and Renovate 3 applied at 1.5 ppm

EWM topped out or approaching surface in all sites



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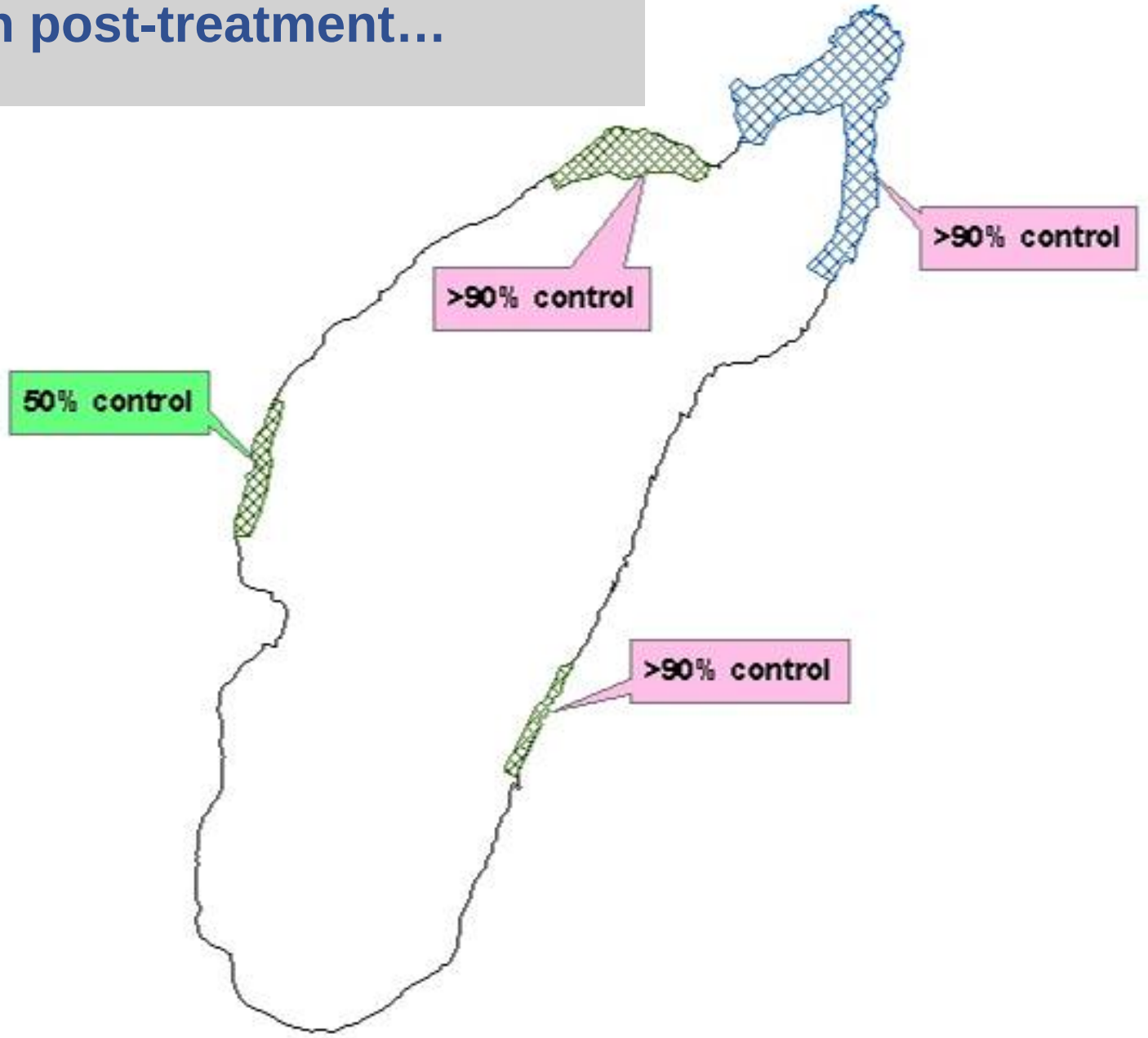
One month post-treatment…

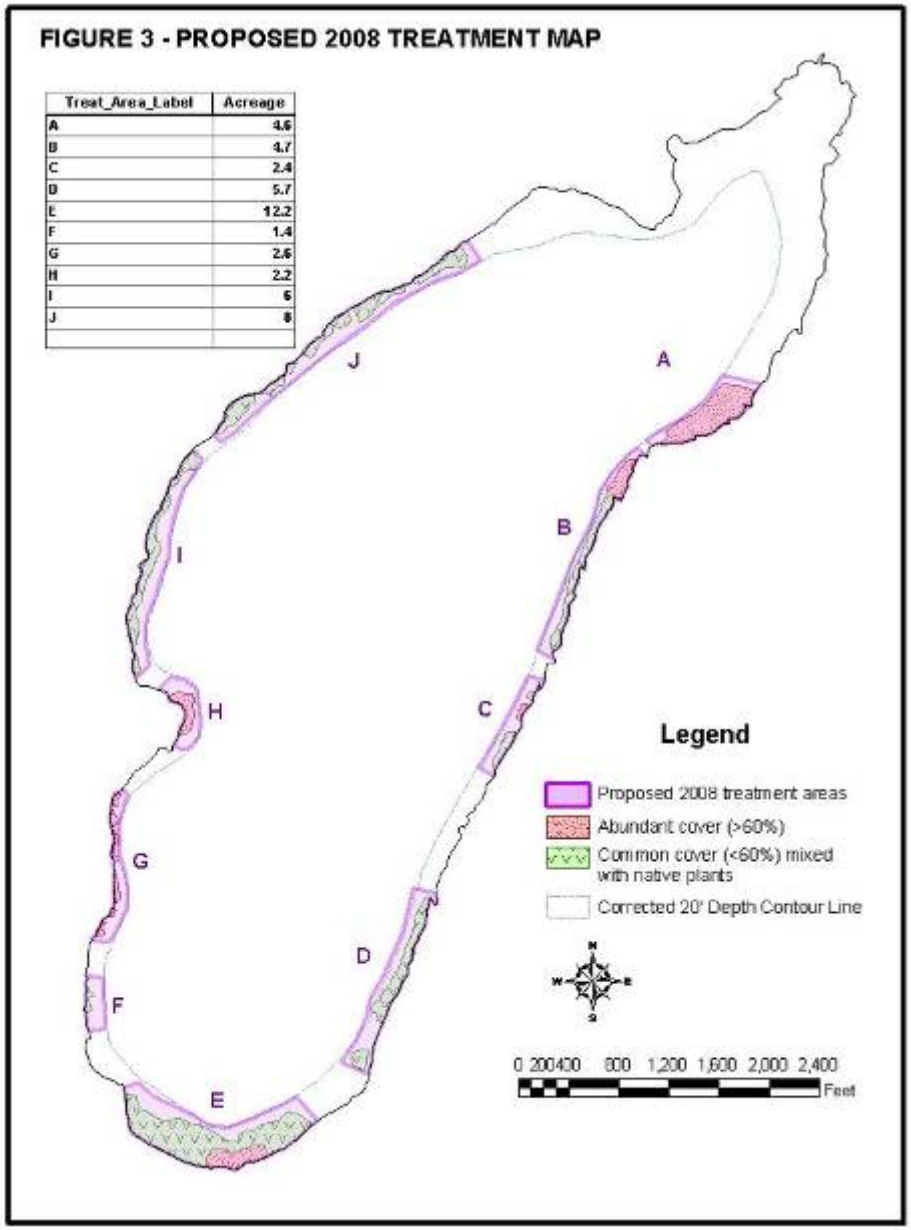



AUGUST 2006


AUGUST 2007

2008 Treatment Program

- ★Treated 50 acres with Renovate OTF
- ★All remaining EWM beds targeted
- ★Treated in mid-May to improve efficacy and reduce impairment to lake use
- ★Expanded treatment block size
- ★Continue hand-pulling to remove scattered EWM regrowth

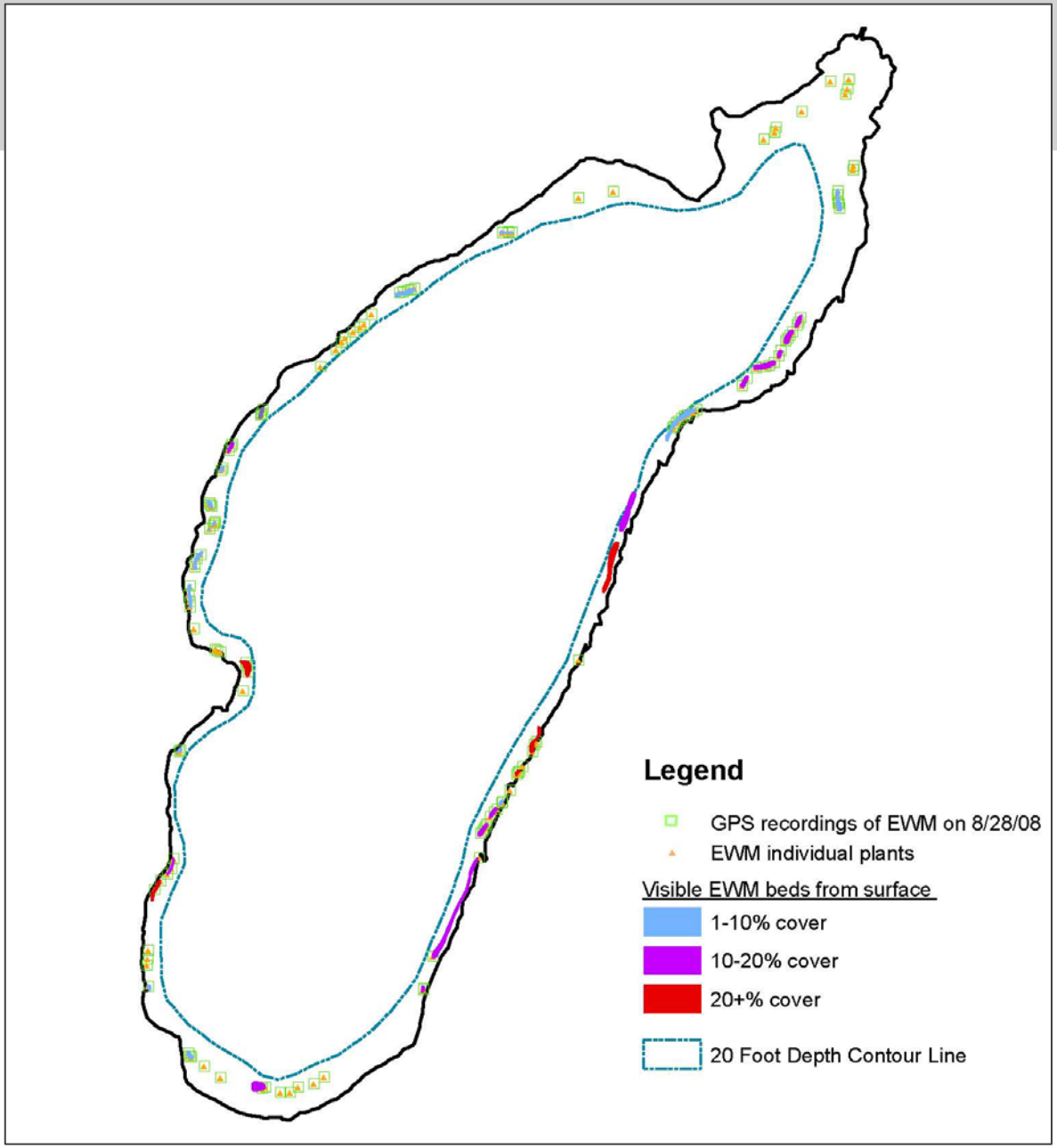



Classic

2008 Results…

EWM	2006	2007	2008
FOC	61%	43%	34%
Cover	30%	20%	3%

- Treatment timing
- Dose insufficient



Pre and Post Vegetation Monitoring

Species	Common Name	2006 Frequency of Occurrence	2007 Frequency of Occurrence	2008 Frequency of Occurrence
Myriophyllum spicatum	**Eurasian watermilfoil**	**61.2%**	**43.1%**	**33.6%**
Ceratophyllum demersum	**coontail**	**37.9%**	**47.4%**	**43.1%**
Najas flexilis	**bushy pondweed**	**30.2%**	**28.4%**	**28.4%**
Potamogeton amplifolius	**largeleaf pondweed**	**26.7%**	**23.3%**	**31.0%**
Vallisneria americana	**wild celery**	**26.7%**	**21.6%**	**24.1%**
Zosterella dubia	**water stargrass**	**18.1%**	**28.4%**	**25.0%**
Potamogeton robbinsii	**Robbins' pondweed**	**16.4%**	**27.6%**	**32.8%**
Potamogeton zosteriformis	**flat-stem pondweed**	**14.7%**	**5.2%**	**16.4%**
Potamogeton gramineus	**variable-leaf pondweed**	**13.8%**	**12.1%**	**15.5%**
Chlorophyta	**filamentous green algae**	**12.9%**	**23.3%**	**28.4%**
Megalodonta beckii	**water marigold**	**11.2%**	**19.0%**	**30.2%**
Elodea canadensis	**elodea**	**10.3%**	**3.4%**	**0.9%**
Potamogeton praelongus	**Whitestem pondweed**	**8.6%**	**11.2%**	**23.3%**
Potamogeton pusillus	**small pondweed**	**6.0%**	**12.1%**	**2.6%**
Nymphaea odorata	**white waterlily**	**1.7%**	**2.6%**	**4.3%**
Potamogeton illinoensis	**Illinois pondweed**	**0.9%**	**8.6%**	**19.8%**

Pre and Post Vegetation Monitoring

Data Point Depth Range (feet)	2006 Species Richness	2007 Species Richness	2008 Species Richness
Less than or equal to 5	5.6	5.1	5.3
Greater than 5 and less than or equal to 10	4.5	4.1	5.2
Greater than 10 and less than or equal to 20	3.1	3.6	4.0
Greater than 20	0.2	0.9	1.5
Total	3.1	3.4	3.8

Conclusions…

- Diquat, Fluridone and Triclopyr herbicides can be used to achieve highly-selective control of Eurasian watermilfoil
- No adverse changes to water chemistry, phytoplankton or zooplankton populations
- Very good non-target species selectivity achieved
- Quantitative post-treatment vegetation monitoring needed to evaluate treatment efficacy and document impacts to non-target species

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- Lake Morey Preservation Association

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