The Impact of Low Dose Fluridone Treatments on Non-Target Aquatic Plants

Ken Wagner, PhD, CLM, Water Resource Services

With Maxine Verteramo, Toni Stewart, Kathleen Burke, Erika Sawicki, and Amanda Carron

And special thanks to Pam Tyning

Fluridone as a herbicide

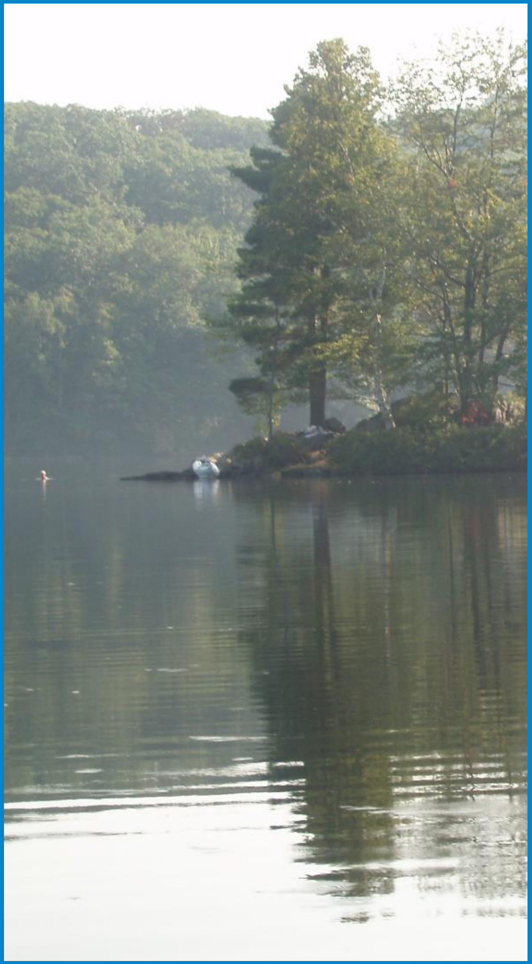
– Fluridone is $C_{19}H_{14}F_3NO$, or 1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]pyridin-4-one

– It inhibits the synthesis of certain pigments that both protect chlorophyll-a from photodegradation and transfer energy from different wavelengths of light to aid photosynthesis

– Susceptible plants die of a combination of starvation and sunburn

Low Dose Fluridone Treatments

- <10 ppb, often with boost treatments over time to maintain >2 ppb for extended period of time
- Prefer at >60 days exposure, 25 to 250 days in actual treatments
- Intended to selectively remove Eurasian watermilfoil in nearly all cases, a few attempts for hydrilla and fanwort control
- Nearly all liquid applications in this study, nearly all SePRO products
- All data here are from northeastern and north midwestern USA lakes



Non-target Plant Community

- Relative abundance assessed by frequency; stem counts and biomass data limited, semi-quantitative data hard to use
- Changes in low abundance species may be hard to quantify
- Which species are hurt and which are benefitted by low dose fluridone treatments?
- Direct vs indirect impacts

Study Design

- Using data from actual treatments (147 treatments of 64 lakes over last 20 years)
- Cannot have additional controls applied unevenly (annual drawdown before and after treatment OK, but not follow up treatments with another herbicide)
- Using frequency data for species from surveys

Lake or Pond	State	Treatment Year	Treatment Type	Formulation	Boosted?	Days After Initial Treatment Boosted	Initial target range (ppb)		Days of Exposure >15 ppb	Days of Exposure >10 ppb	Days of Exposure >6 ppb	Days of Exposure >2 ppb	Plant Data Type	Source
Highland #2	NJ	1999	whole lake	AS			8	8			27	35	map, list	Allied Biological
Hortonia	VT	2000	whole lake	AS	YES	35,106	6	6			12	120	frequency	Getsinger et al. 2002 and Eichler Report
Hortonia	VT	2004	whole lake	AS	YES	22,57,92	5	8		5	83	128	frequency	Aquatic Control Technology
Hortonia	VT	2010	whole lake	AS	YES	29,56,84	5	8		4	38	123	frequency	Aquatic Control Technology
Hortonia	VT	2015	whole lake	AS	YES	22,50,78	5	8		1	10	100	frequency	Solitude
Houghton	MI	2002	whole lake	AS	YES	20	6	6			5	137	frequency	ReMetrix 2003, 2006
Hutchins Lake	MI	2008	whole lake	AS	YES	18	6				4	73	frequency	P. Tyning
Indianhead Lake	MI	2010	whole lake	AS	YES	19	6				5	25	frequency	P. Tyning
Jehnsen Lake	MI	2009	whole lake	AS	YES	16	6					75	frequency	P. Tyning

Study Design

– Frequency data for one lake, variation among species and within species over time evident

Table 4: Frequency of Occurrence at Point-Intercept locations

Macrophyte Species	Common Name	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ceratophyllum demersum	Coontail	2	8	6	2	3	4	3	2	9
Chara / Nitella	Macro-algae	30	43	37	22	23	4	9	15	12
Elodea canadensis	Waterweed Elodea	48	15	14	12	16	10	16	24	33
Isoetes spp.	Quillwort	0	1	1	2	0	1	3	2	2
Myriophyllum spicatum	Eurasian watermilfoil	27	14	19	26	25	25	21	29	58
Najas flexilis	Slender naiad	21	19	20	21	25	14	0	1	7
Najas minor	European naiad	2	5	3	5	<1	0	0	0	0
Najas sp.	Naiad	0	<1	0	0	0	0	0	0	6
Potamogeton amplifolius	Large-leaf pondweed	4	<1	0	3	0	1	1	2	7
Potamogeton crispus	Curly-leaf pondweed	0	0	0	0	0	2	16	52	23
Potamogeton praelongus	White-stem pondweed	<1	0	2	0	2	4	3	4	13
Potamogeton pusillus	Thin-leaf pondweed	32	7	5	9	1	0	3	2	24
Potamogeton richardsonii	Richardson's pondweed	1	2	5	2	12	8	10	18	5
Potamogeton robbinsii	Robbin's Pondweed	0	3	5	1	2	1	5	3	6
Potamogeton zosteriformis	Flat-stem pondweed	12	8	9	5	<1	4	<1	8	5
Vallisneria americana	Wild celery	3	3	1	5	5	1	2	9	6
Zosterella dubia	Water stargrass	<1	0	0	0	0	0	<1	0	4

Results

– Data from 625 comparisons for 55 species from untreated lakes used to assess “natural” variation in frequency
– Grand mean and standard deviation approaching 5%, maximum individual species mean approaching 15%, all suggesting that +/- 15% can be expected without any treatment effect

	n	Mean	Median	Max	Min
Mean	11.4	4.8	3.3	14.8	0.3
Std Dev	5.3	4.6	3.9	12.9	0.8

Results

- Eurasian watermilfoil as example of plant we expect to show major decline; it was the target of the vast majority of treatments included in this evaluation
- Shaded central area indicates expected range of natural variation in frequency
- Percentage of all included treatments shown for each increment of increase or decrease in frequency relative to pre-treatment value

Taxon	Time After Treatment	# of Trtmts	-100 to -75	-75 to -50	-50 to -25	-25 to -15	-15 to -5	-5 to 5	5 to 15	15 to 25	25 to 50	50 to 75	75 to 100
Myriophyllum spicatum	YOT-LGS	99	31%	30%	21%	3%	7%	5%	2%				
	YAT1-EGS	14		50%	36%	7%				7%			
	YAT1-LGS	63		51%	32%	5%	5%	6%	2%				
	YAT2-LGS	52		21%	33%	4%	10%	17%	8%	8%			
	YAT3-LGS	20		5%	30%		30%	20%		5%	5%	5%	
	YAT4-LGS	16		13%	38%	19%	6%	6%	6%	6%			6%
	YAT5-LGS	8			25%	25%	13%	13%	13%	13%			
	YAT6-LGS	2			100%								

Results

- Arrow arum as example of a species for which no impact would be expected; emergent species does not take up much fluridone
- Indeed shows no decrease outside expected natural range, some increases later, possibly due to open habitat

Taxon	Time After Treatment	# of Trtmts	-100 to -75	-75 to -50	-50 to -25	-25 to -15	-15 to -5	-5 to 5	5 to 15	15 to 25	25 to 50	50 to 75	75 to 100
Peltandra virginica	YOT-LGS	10					10%	90%					
	YAT1-EGS	1						100%					
	YAT1-LGS	8					13%	75%		13%			
	YAT2-LGS	8					13%	75%	13%				
	YAT3-LGS	4						75%		25%			
	YAT4-LGS	3						100%					
	YAT5-LGS	2						50%			50%		
	YAT6-LGS	1						100%					

Results

- Robbins' pondweed is a highly desirable species for both habitat, minimal recreational impairment, and prevention of invader colonization; would not want to harm extant populations by treatment
- Very little decrease exhibited, some increases, but largely unaffected
- Use of low dose fluridone to get at colonizing Eurasian watermilfoil in beds of P. robbinsii appears to be quite workable

Taxon	Time After Treatment	# of Trtmts	-100 to -75	-75 to -50	-50 to -25	-25 to -15	-15 to -5	-5 to 5	5 to 15	15 to 25	25 to 50	50 to 75	75 to 100
Potamogeton robbinsii	YOT-LGS	33					3%	61%	21%	6%	9%		
	YAT1-EGS	5						60%	40%				
	YAT1-LGS	31				3%	3%	61%	23%	3%	6%		
	YAT2-LGS	21			5%		5%	71%	5%	10%	5%		
	YAT3-LGS	10						90%			10%		
	YAT4-LGS	9					11%	78%	11%				
	YAT5-LGS	3					33%	33%	33%				

Results

- A common thin-leaved pondweed, P. pusillus shows variable response, including declines and increases
- Known colonizer, with seed banks lasting a long time
- Should recover after treatment, but may be impacted initially
- Possible issues with species identification

Taxon	Time After Treatment	# of Trtmts	-100 to -75	-75 to -50	-50 to -25	-25 to -15	-15 to -5	-5 to 5	5 to 15	15 to 25	25 to 50	50 to 75	75 to 100
Potamogeton pusillus	YOT-LGS	65		5%	9%	5%	12%	37%	9%	11%	9%	2%	2%
	YAT1-EGS	6			17%			33%			50%		
	YAT1-LGS	60		3%	10%	7%	12%	22%	8%	15%	17%	7%	
	YAT2-LGS	51		6%	16%	4%	14%	14%	8%	8%	27%	2%	2%
	YAT3-LGS	18		6%	6%	11%	11%	22%		28%	6%	11%	
	YAT4-LGS	15		13%		7%	20%	27%		13%	20%		
	YAT5-LGS	8			25%		13%	13%	13%	13%	25%		

Results

- Macroalga with many desirable properties, Chara is often observed to increase after fluridone treatments
- Some decreases observed, however, mostly well after treatment when other species regrow and outcompete Chara (losses not necessarily a direct treatment effect)

Taxon	Time After Treatment	# of Trtmts	-100 to -75	-75 to -50	-50 to -25	-25 to -15	-15 to -5	-5 to 5	5 to 15	15 to 25	25 to 50	50 to 75	75 to 100
Chara sp.	YOT-LGS	76	1%	1%	4%	5%	9%	22%	17%	20%	16%	3%	1%
	YAT1-EGS	12			8%	8%		33%	25%	17%		8%	
	YAT1-LGS	66		3%	9%	5%	11%	21%	23%	14%	9%	2%	5%
	YAT2-LGS	55		2%	16%	5%	16%	27%	9%	9%	11%	2%	2%
	YAT3-LGS	23		4%	4%	13%	13%	17%	22%	4%	13%	4%	4%
	YAT4-LGS	17		6%		6%	29%	24%	6%	18%	6%	6%	
	YAT5-LGS	6					33%	33%			17%	17%	
	YAT6-LGS	1					100%						

Results

- Waterweed known to be susceptible to fluridone, question of whether low dose and extended exposure is less detrimental
- Some declines, but most treatments show limited impact
- Low dose fluridone results are encouraging for preservation of this species in treated lakes

Taxon	Time After Treatment	# of Trtmts	-100 to -75	-75 to -50	-50 to -25	-25 to -15	-15 to -5	-5 to 5	5 to 15	15 to 25	25 to 50	50 to 75	75 to 100
Elodea spp.	YOT-LGS	43		2%	7%	9%	14%	67%					
	YAT1-EGS	10		10%		10%	30%	50%					
	YAT1-LGS	41			5%	10%	20%	61%			5%		
	YAT2-LGS	30		3%	7%	13%	7%	57%	3%		3%	7%	
	YAT3-LGS	15				7%	27%	53%	7%		7%		
	YAT4-LGS	13					15%	69%	15%				
	YAT5-LGS	6						83%	17%				
	YAT6-LGS	2				50%		50%					

Results

- All the assessed naiads seem to respond similarly, lumped for overall comparison here
- Wide range of response; may decline substantially in YOT, but tends to be a colonizer too
- Central tendency is to get back to pre-treatment conditions in 3-4 years

Taxon	Time After Treatment	# of Trtmts	-100 to -75	-75 to -50	-50 to -25	-25 to -15	-15 to -5	-5 to 5	5 to 15	15 to 25	25 to 50	50 to 75	75 to 100
Najas spp.	YOT-LGS	93	4%	1%	10%	9%	19%	46%	4%	3%	3%		
	YAT1-EGS	23			9%		9%	78%			4%		
	YAT1-LGS	81		1%	5%	4%	16%	46%	6%	14%	6%	2%	
	YAT2-LGS	57		2%	4%	9%	9%	39%	12%	5%	18%	4%	
	YAT3-LGS	33		3%	6%	6%	12%	42%	12%	9%	6%		3%
	YAT4-LGS	22			5%	5%	9%	55%	9%	5%	9%		5%
	YAT5-LGS	6			17%	17%		33%		33%			
	YAT6-LGS	2			50%			50%					

Results

- Coontail known to have wide response to treatment
- Low dose fluridone data verify this expectation
- Central tendency is to get back to pre-treatment condition after about 3 years
- Reasons for variation not understood

Taxon	Time After Treatment	# of Trtmts	-100 to -75	-75 to -50	-50 to -25	-25 to -15	-15 to -5	-5 to 5	5 to 15	15 to 25	25 to 50	50 to 75	75 to 100
Ceratophyllum demersum	YOT-LGS	69		1%	7%	10%	16%	45%	7%	6%	7%		
	YAT1-EGS	13		8%	15%		8%	69%					
	YAT1-LGS	65		3%	2%	9%	22%	42%	12%	9%	2%		
	YAT2-LGS	54		4%	6%	7%	17%	39%	15%	9%	2%	2%	
	YAT3-LGS	23			9%	4%	22%	52%	9%	4%			
	YAT4-LGS	16		6%	6%		13%	38%	31%	6%			
	YAT5-LGS	8			25%		13%	25%	13%	13%	13%		
	YAT6-LGS	3			33%		33%	33%					

Results

- Problem with methodology in that non-abundant species (<10% freq) can disappear and still be within range of "natural" variation
- Identified species that tend to decrease, based on presence before treatment and 0 values for 2 years afterward in >50% of cases

Taxa at >0% but <10% before trtmt	# of 0% in YOT through YAT2	# obs over 2 yrs	0% through 2 yrs after trtmt
Bidens beckii	8	11	72.7%
Brasenia schreberi	9	18	50.0%
Decodon verticillatus	12	23	52.2%
Elodea spp.	42	57	73.7%
Iris sp.	15	24	62.5%
Myriophyllum sibiricum	27	35	77.1%
Myriophyllum spicatum	6	12	50.0%
Myriophyllum verticillatum	8	10	80.0%
Najas spp.	27	62	43.5%
Potamogeton crispus	32	57	56.1%
Potamogeton nodosus	14	19	73.7%
Potamogeton praelongus	33	52	63.5%
Ranunculus spp.	10	14	71.4%
Sagittaria spp.	30	51	58.8%
Based on 515 cases over 50 taxa			

Results

- Another issue is taxa not being present before treatment then appearing (colonizers)
- Evaluated as species with 0 value for pre-treatment but increasing in 1st 2 years after treatment with max >50% or mean >10% freq

Taxa not present before trtmt but appearing within 2 yrs after trtmnt	# obs	2 yr Max Freq	2 yr Mean Freq
Elodea spp.	30	56.4	4.9
Najas spp.	38	75.0	7.7
Najas flexilis	29	63.0	7.3
Najas guadalupensis	39	75.0	10.7
Nuphar variegata	16	56.3	8.1
Nymphaea odorata	26	61.5	4.6
Potamogeton crispus	68	97.6	4.7
Potamogeton gramineus	48	61.9	3.5
Potamogeton illinoensis	39	64.3	5.2
Potamogeton pusillus	31	67.9	21.2
Potamogeton richardsonii	29	50.0	3.7
Stuckenia pectinata	19	83.0	16.5
Vallisneria americana	33	100.0	14.9
Zosterella dubia	75	71.0	12.7
Based on 493 cases over 60 species			

Conclusions for non-target plants

– There is substantial variation in the response of individual species to low dose fluridone treatment

– Most non-target species are nominally impacted on average and recover within 2 years, but some species show a wide range of intraspecific variation in response

– Natural variation in frequency of occurrence makes it hard to discern changes <15%

– A list of species most likely to decline has been developed (14 of 50 taxa with adequate data)

– A list of species most likely to colonize after treatment has been developed (14 out of 60 species with adequate data)

Taxonomic richness

– Number of species present, without regard for relative abundance
– Depends to some extent on survey effort, nature of habitat
– May be affected by fluridone treatment
– Common statements:
  • Herbicides reduce richness
  • Herbicides restore a richer plant assemblage

Results without treatment

- How do untreated lakes behave?
- Richness varies with survey effort
- Richness does not vary greatly between years on average, but any 2 years could differ substantially

Basic Richness Features of 3 Untreated Lakes

Attribute	Indian	Laurel	Morses
Survey points	30	119	306
Mean richness	14.4	19.1	23.5
Max richness	16	26	33
Min richness	13	16	16
Std Dev	1.07	3.18	6.26
Coeff. of Variation	0.07	0.17	0.27

Comparison of Richness in Consecutive Years

Attribute	Indian	Laurel	Morses
Survey Pts	30	119	306
n	9	6	7
Mean	-0.1	-0.2	-0.6
Median	-1.0	-0.5	1.0
Max	2.0	8.0	7.0
Min	-2.0	-7.0	-17.0
Std Dev	1.62	5.04	7.66

Results with treatment

- Data decrease with time after treatment, reasonable approximation through YAT4
- Average loss of 1.3 species in YOT, but high variation among treatments and lakes
- Minimal loss on average after YAT1
- 95% confidence interval is high, roughly +/- 6 to10 species

Attribute	YOT(LGS)-Pre(Avg)	YAT1(EGS)-Pre	YAT1(LGS)-Pre	YAT2-Pre	YAT3-Pre	YAT4-Pre	YAT5-Pre
n	77	14	73	60	25	19	8
Mean	-1.3	-0.1	0.4	0.6	-0.1	1.7	0.7
Median	-1.0	0.8	-1.0	0.0	-1.0	1.0	0.5
Max	8.0	8.0	11.0	9.0	10.0	13.0	5.0
Min	-11.0	-13.0	-7.0	-10.0	-9.0	-4.0	-3.0
Std Dev	3.87	5.25	3.78	3.80	4.37	3.68	2.73

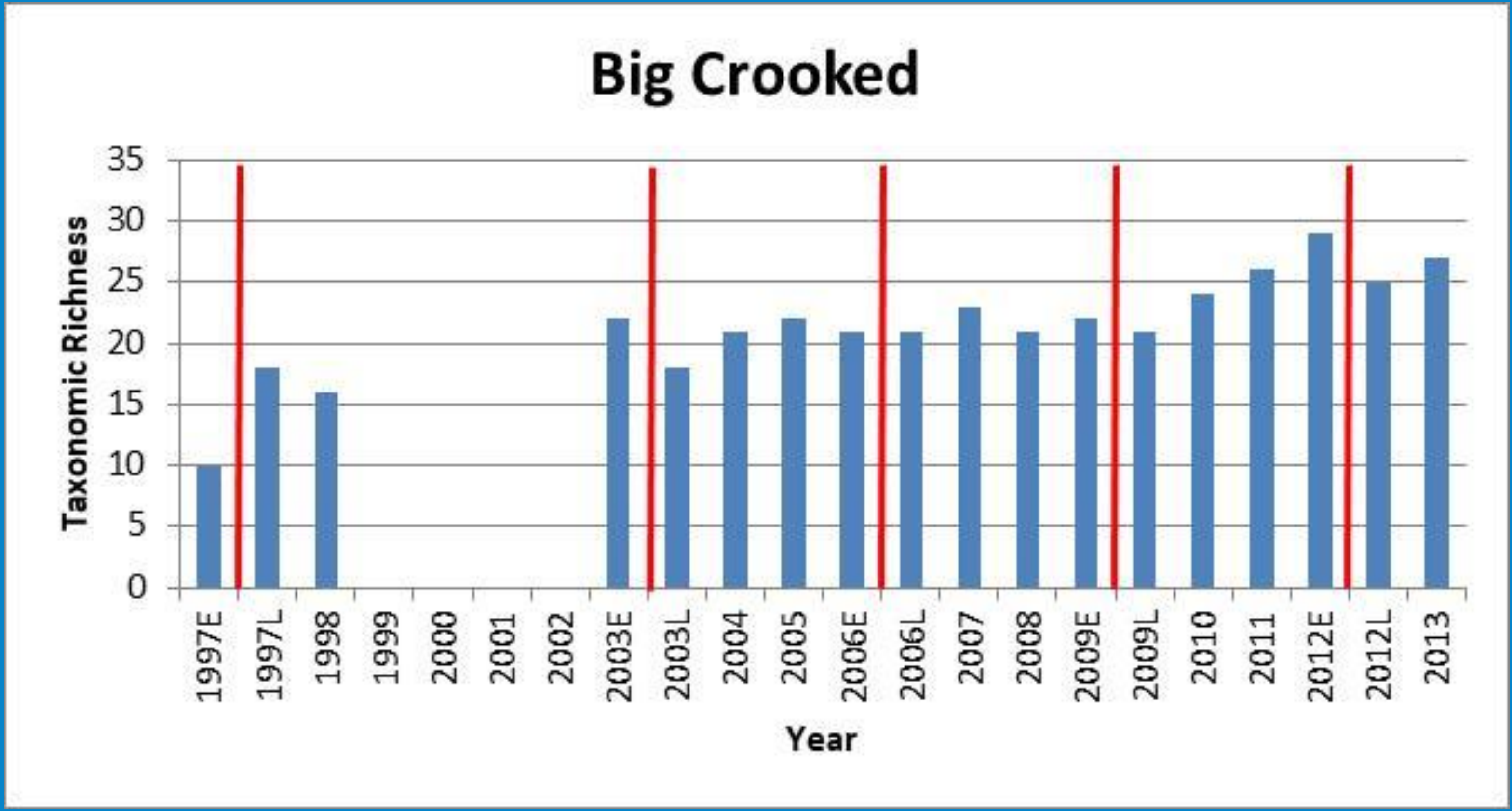
Results with treatment

- Subdividing by pre-treatment richness (low, medium, high), more of a pattern emerges
- Treatment of lakes with low richness leads to increases in species over multiple years
- Treatment of lakes with high richness leads to initial loss of species but recovery over 2-4 years
- Treatment at intermediate richness has limited effect on average, although variation can be high

Mean	YOT(LGS)-Pre(Avg)	YAT1(EGS)-Pre	YAT1(LGS)-Pre	YAT2-Pre	YAT3-Pre	YAT4-Pre
<10 spp	0.6	2.1	2.8	1.6	1.8	0.8
11-20 spp	-1.2	1.0	0.2	0.6	-0.3	2.1
>20 spp	-3.2	-7.0	-1.6	-1.0	-2.0	0.5

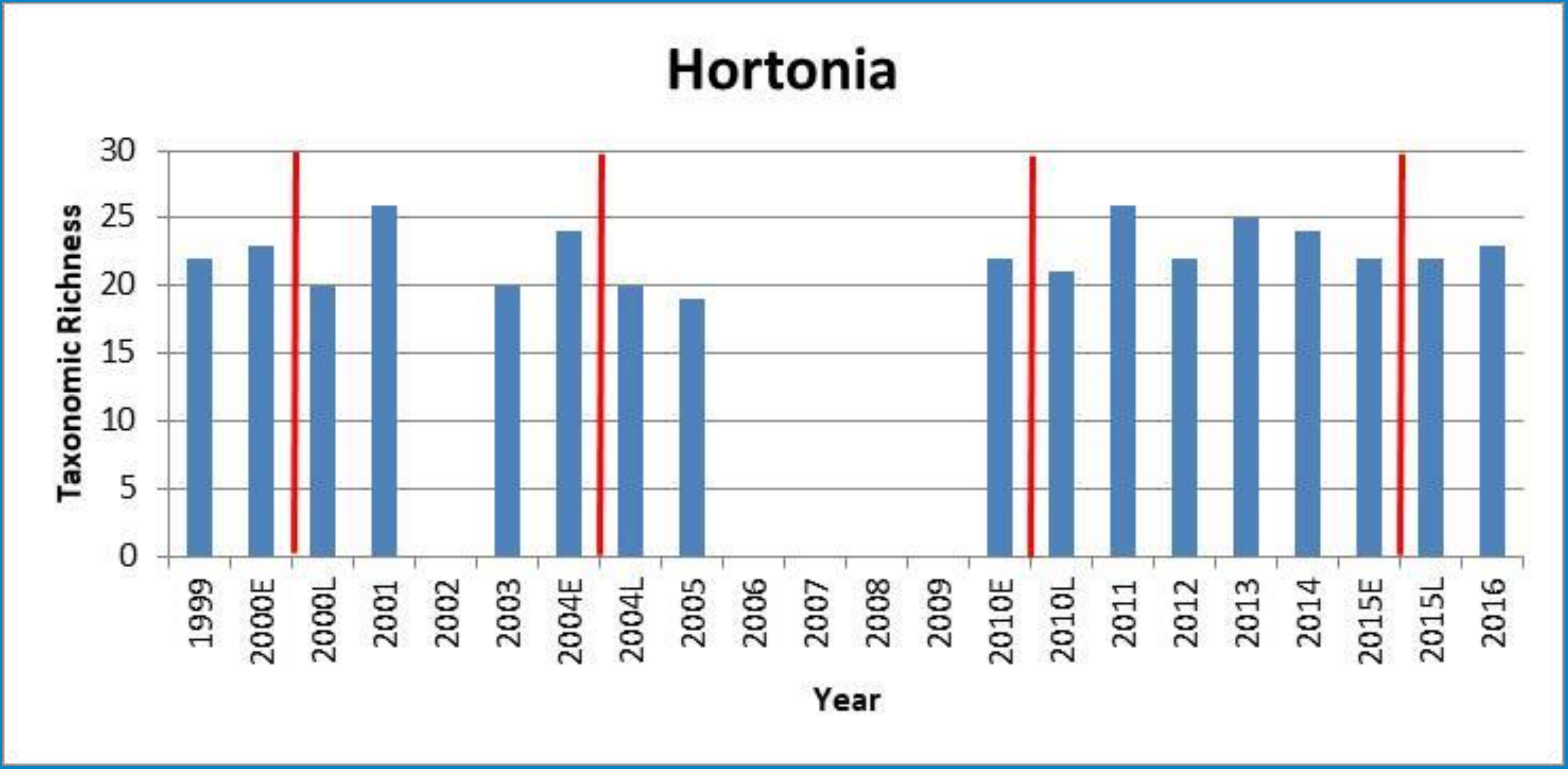
Results

– Big Crooked in MI exhibits overall increase in richness from low level before treatment over multiple fluridone treatments, going from 10 to >20 species



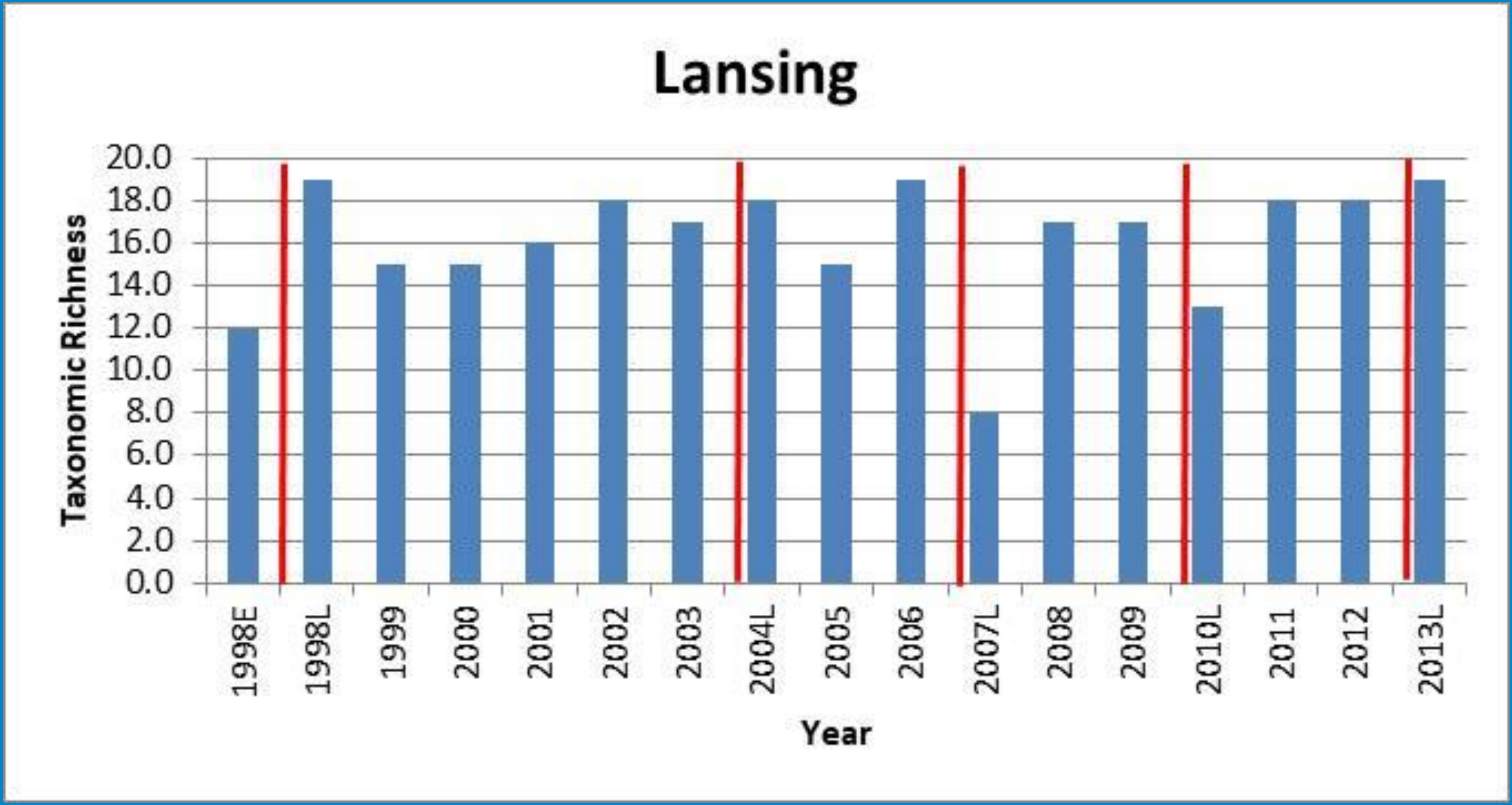
Results

– Hortonia Lake in VT exhibits fluctuations over time, possibly in response to multiple fluridone treatments, but richness is generally stable at 20-25 species



Results

– Lansing in MI shows substantial variation, especially in the year of treatment, and richness ranges from 8 to 19 species



Conclusions

- Richness varies in lakes, even without low dose fluridone treatments, at levels that may obscure treatment impacts
- Richness varies with survey effort; consistency is important to valid comparisons within and among lakes
- Richness declines slightly in the year of treatment in many cases, but rebounds within a couple of years
- Low dose fluridone treatment can be expected to increase richness when pre-treatment richness is low (<10 species), but will not likely increase richness from initially high levels (>20 species)

The End

One more and that will all make sense…

QUESTIONS?