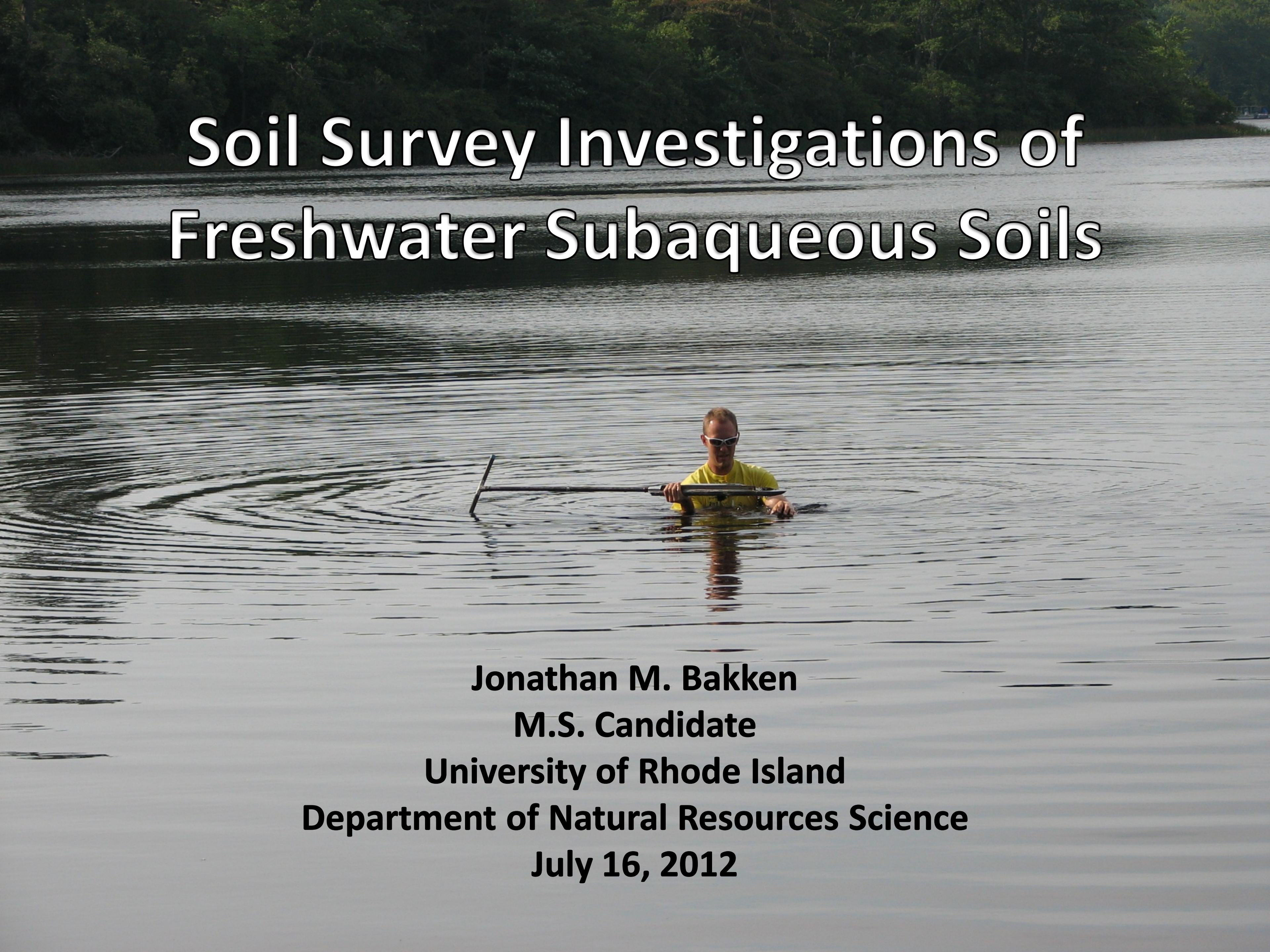

Soil Survey Investigations of Freshwater Subaqueous Soils

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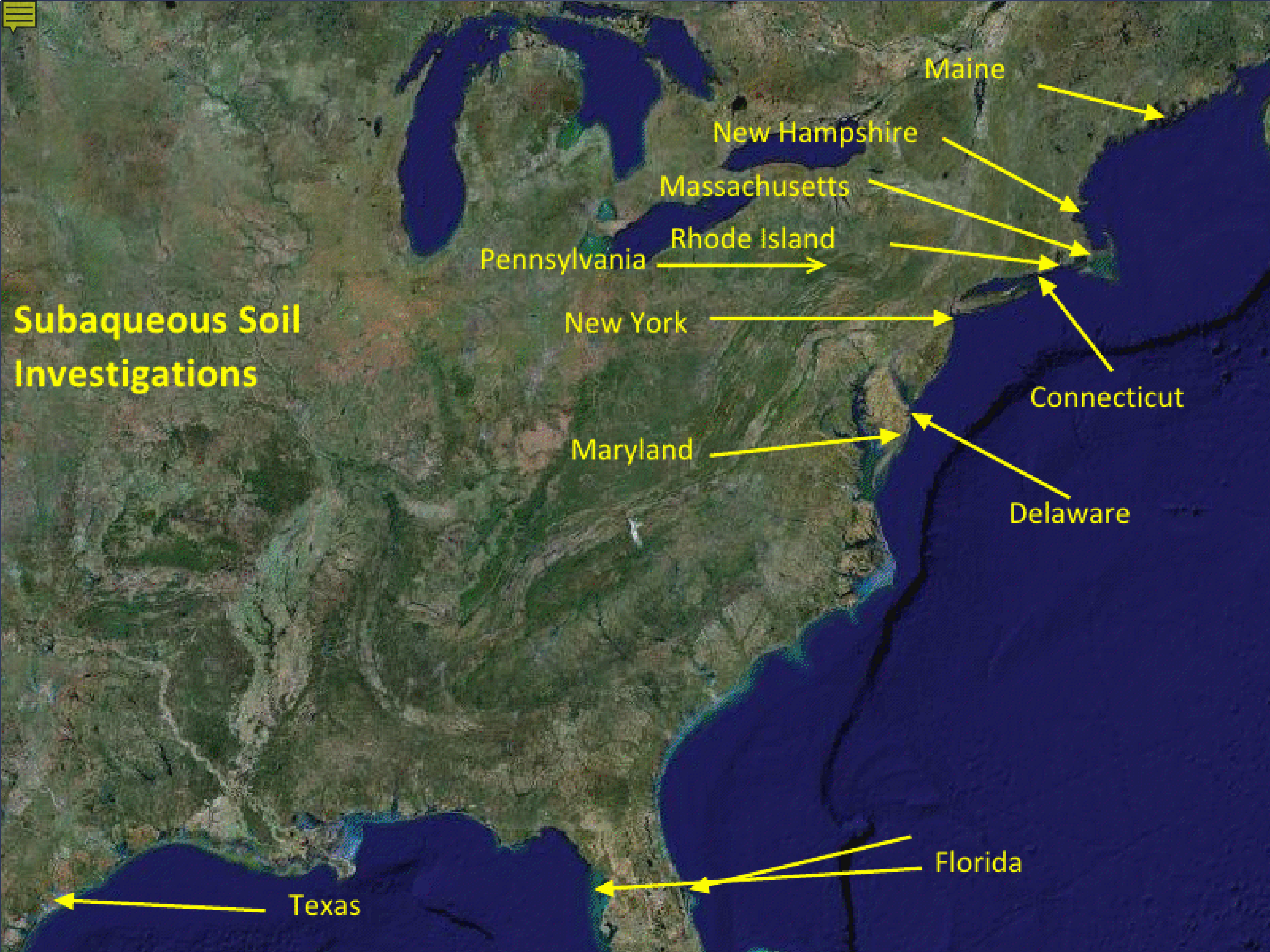
Outline

- Introduction to subaqueous soils
- Chapter 1 - Characterization and mapping of freshwater subaqueous soil resources
- Chapter 2 - Freshwater subaqueous soils: accumulation of metals (arsenic and lead) and the determination of sedimentation rates
- Chapter 3 – Freshwater subaqueous soils and carbon accounting
- Chapter 4 – Aquatic invasive plants, total extractable phosphorus, and freshwater subaqueous soil relationships

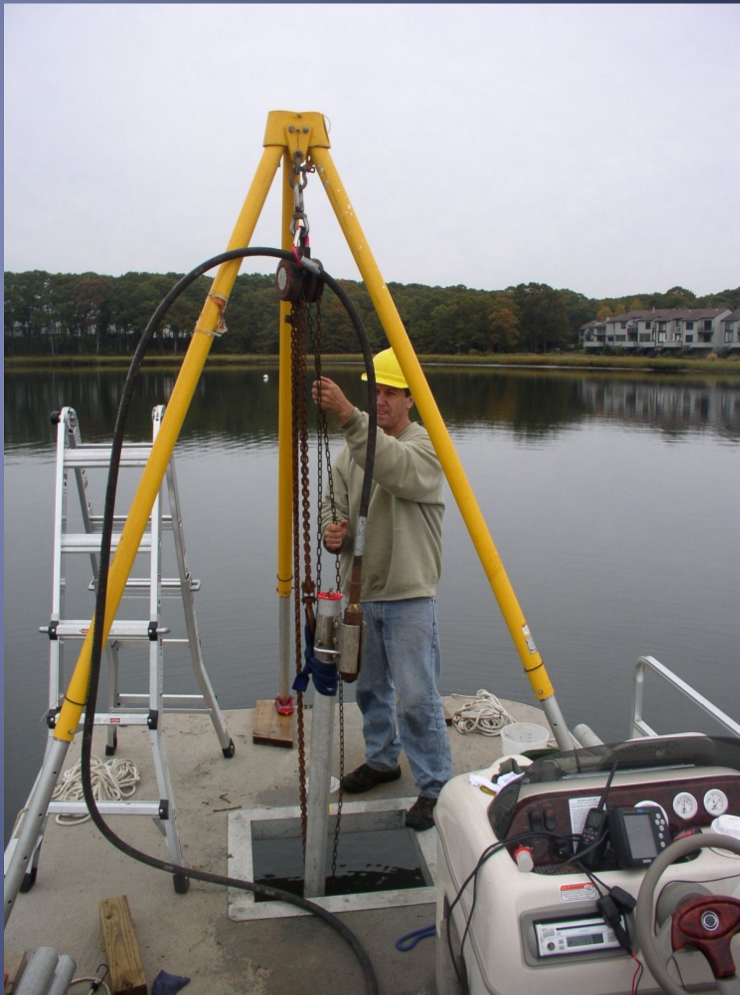
Subaqueous Soil

- Investigated as soil for the past 10-15 years
- Occur in water that is generally <2.5 m deep
- Support submerged aquatic vegetation
- Undergoes pedogenesis (soil forming processes)
- Incorporated in Soil Taxonomy (2010)
- Little work has been completed in freshwater systems


Subaqueous Soil Investigations
Maine
New Hampshire
Massachusetts
Rhode Island
Pennsylvania
New York
Connecticut
Maryland
Delaware
Florida
Texas

Previous Subaqueous Soil Mapping in Rhode Island

- NRCS, Mapcoast, URI
- Coastal ponds and embayments
- Bathymetry data were used to create landform base maps
- Delineation of landscape units
- Vibracoring and field descriptions
- Mapping and interpretations (i.e. shellfish management, dredged materials, eelgrass restoration, and carbon accounting)



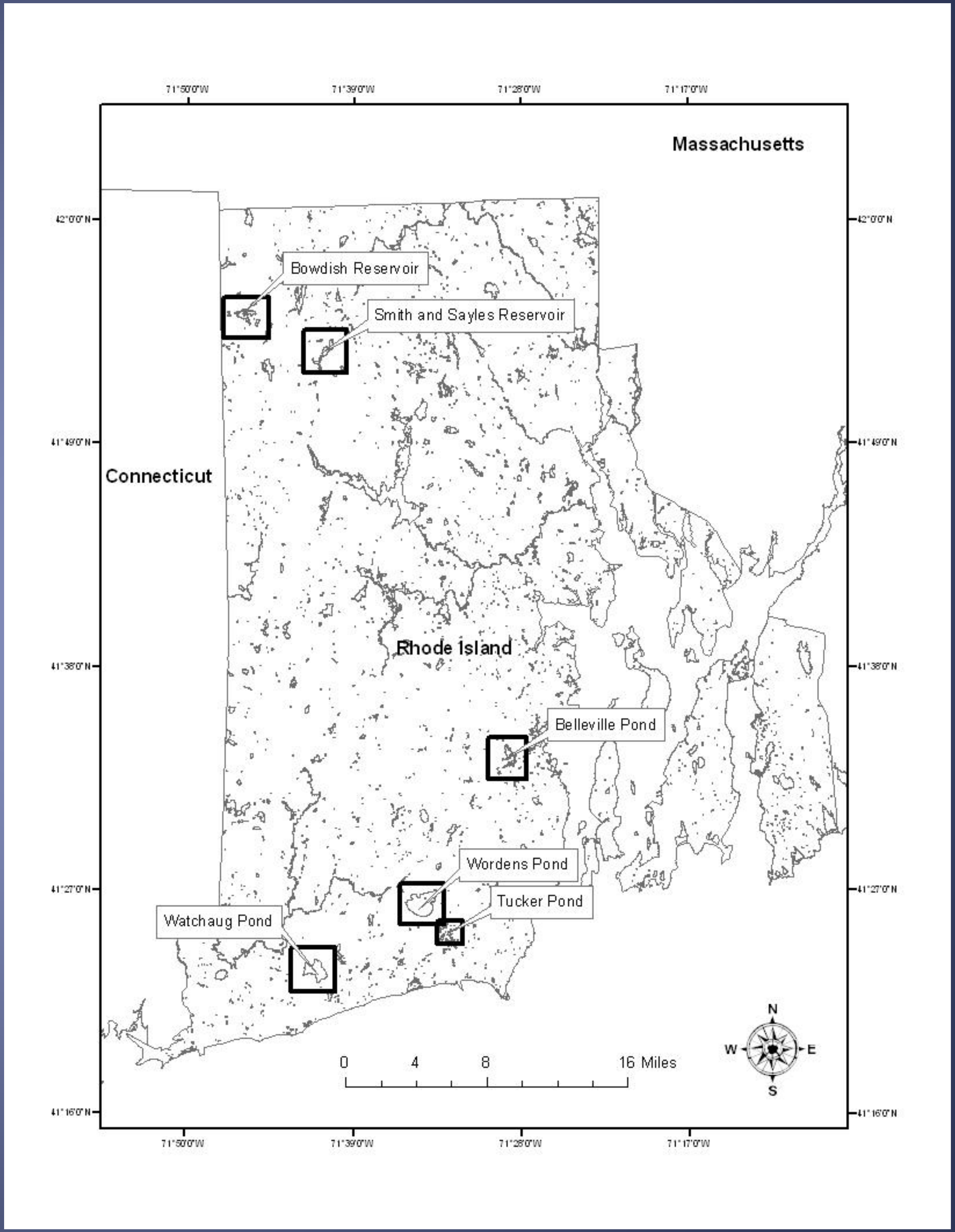
Study Sites

3 natural ponds:

Worden Pond
Watchaug Pond
Tucker Pond

3 created ponds:

Belleville Pond
Bowdish Reservoir
Smith & Sayles Reservoir



Summary Table of Study Sites

Name	**Bowdish Reservoir**	**Smith and Sayles Reservoir**	**Belleville Pond**	**Tucker Pond**	**Worden Pond**	**Watchaug Pond**
Area (ha)	103	75	48	39	444	231
Watershed Size (mi^2)	1478	640	1366	317	317	317
Maximum Depth (m)	3.0	3.4	2.7	9.8	2.1	13.1
Average Depth (m)	1.8	1.5	1.5	3.4	1.2	2.4
Year Impounded	1850	1865	1800	N/A	N/A	N/A

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Chapter 1 – Characterization and mapping of freshwater subaqueous soil resources

Objectives:

- Evaluate the effectiveness of bathymetric maps and ground-penetrating radar (GPR) for establishing soil-landscape relationships in freshwater subaqueous soils

- Characterize, classify, and map freshwater subaqueous soil resources

Methods

1) Fathometer - bathymetry

2) Ground-penetrating radar (GPR)

3) Development of landscape units

4) Soil sampling

5) Soil descriptions

6) Numerous lab methods: bulk density, rubbed fiber content, Na-pyrophosphate color, 5:1 soil conductivity, 1:1 water and 1:2 $CaCl_2$ pH, loss-on-ignition (LOI) SOM, CHN analyzer

7) Creation of soil map units (classified at the series level)

8) National Soil Survey Database

Results – Bathymetry and landscape delineations

Percent cover of landscape units by water body:

	Bowdish Reservoir	Smith and Sayles Reservoir	Belleville Pond	Tucker Pond	Worden Pond	Watchaug Pond
Cove	4	14	24	6	6	13
Shoal	7	2	3	na	4	5
Lakebed	79	63	58	43	64	64
Shoreline	10	22	16	29	26	7
Deepwater	na	na	na	23	na	10

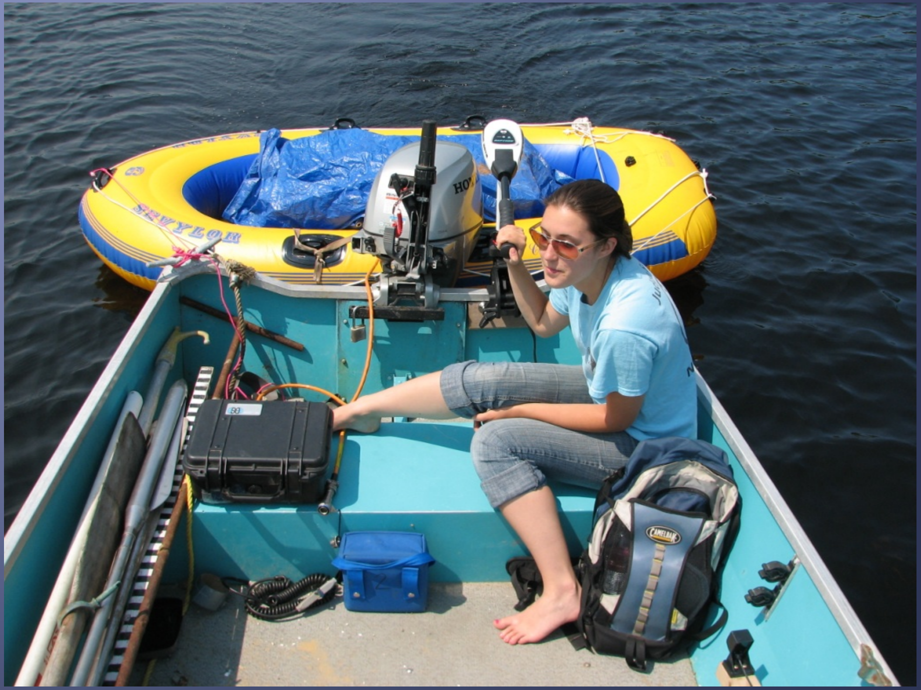
Note: na indicates that these landscape units were not present in this water body

Ground-penetrating radar (GPR)

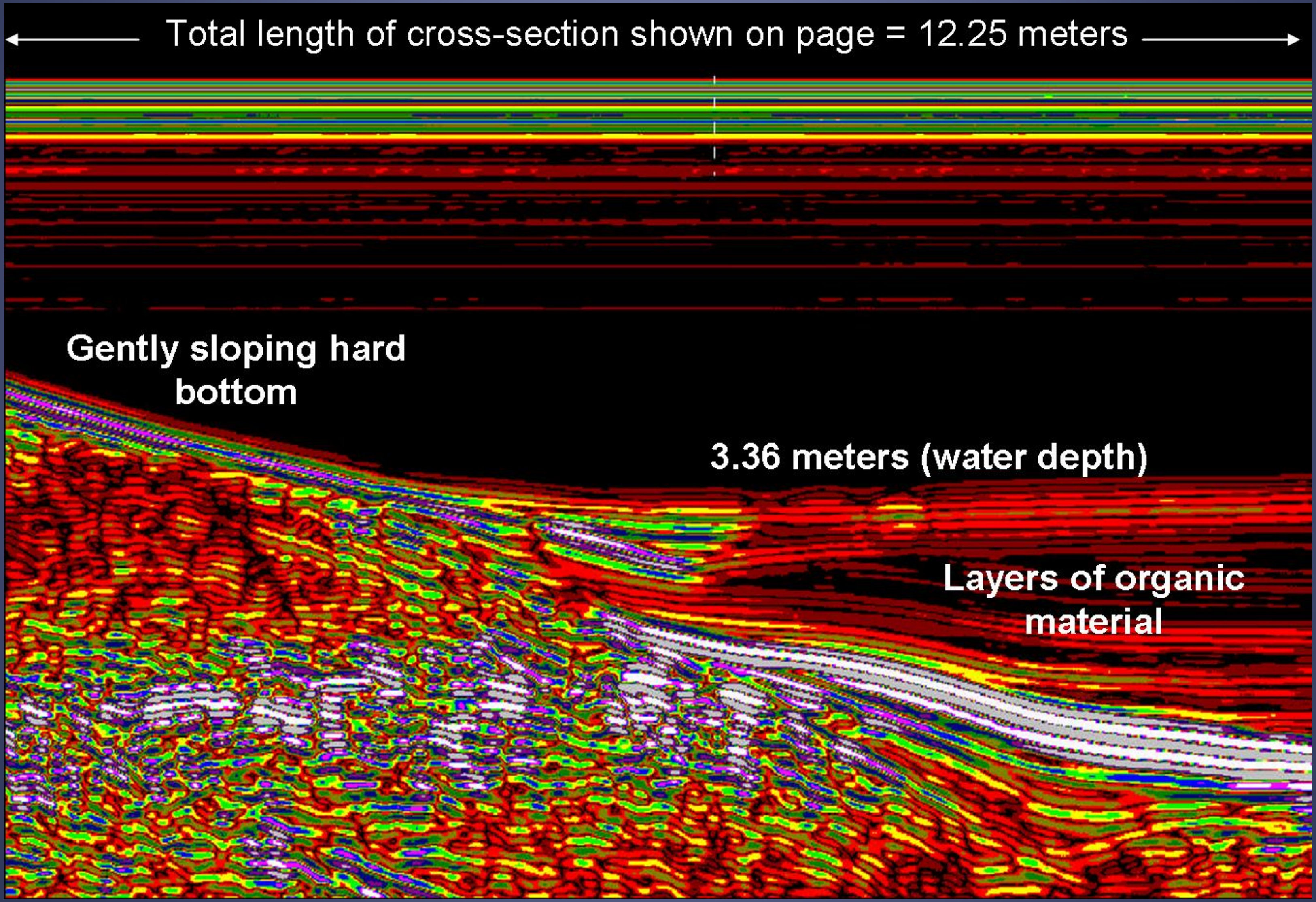
- Ground penetrating radar utilizes radio frequency waves to detect subsurface features

- Waves reflect when they encounter a change in the electrical properties of sediment

- The unit can be pulled across the ice (a flat surface) or behind a boat



Results – GPR



Total length of cross-section shown on page = 12.25 meters
Gently sloping hard bottom
3.36 meters (water depth)
Layers of organic material

Characterization and Classification – Organic and mineral soil profile descriptions

Wassists (9023):

Oa1--0 to 50 centimeters; muck

Oa2--50 to 72 centimeters; muck

Oa3--72 to 86 centimeters; muck

Oe1--86 to 114 centimeters; mucky peat

Oe2--114 to 144 centimeters; woody mucky peat

Wassents (9028):

A1--0 to 11 centimeters; loamy sand

A2--11 to 23 centimeters; mucky sandy loam

CA--23 to 41 centimeters; sand

Cg1--41 to 87 centimeters; sand

Cg2--87 to 132 centimeters; fine sand

Cg3--132 to 200 centimeters; fine sand

Cg4--200 to 257 centimeters; loamy fine sand

Summary of Family Classifications

Family Classification	Number of Pedons
Loamy, dysic, mesic (Terric) Sapric Frasiwassists***	7
Sandy, dysic, mesic (Terric) Sapric Frasiwassists***	2
Sandy, Mixed, mesic Histic Humaquept	2
Sandy, mixed, mesic, Typic Humaquepts	6
Sandy over Loamy, mixed, mesic Typic Humaquepts	1
Coarse-loamy, mesic Typic Humaquepts	1
Coarse-loamy over sandy-skeletal, mesic Typic Humaquepts	2
Coarse-loamy, Mixed, mesic Typic Frasiwassents	14
Coarse-loamy, Mixed, mesic Fluventic Frasiwassent	4
Dysic, mesic, Sapric Frasiwassists	25
Mixed, mesic Psammentic Frasiwassents	9
Siliceous, mesic Psammentic Frasiwassents	3
Coarse-loamy, Mixed, mesic Thapto-histic Frasiwassents	2
Sandy, Mixed, mesic, Fluvaquentic Humaquept	2
Coarse-loamy, Mixed, mesic Fluvaquentic Humaquept	1
	81

*Any additional pedons were classified to the subgroup level

**All mineralogy classes (i.e. mixed or siliceous) were assumed

***The Terric designation is currently being proposed as an addition to *Soil Taxonomy*

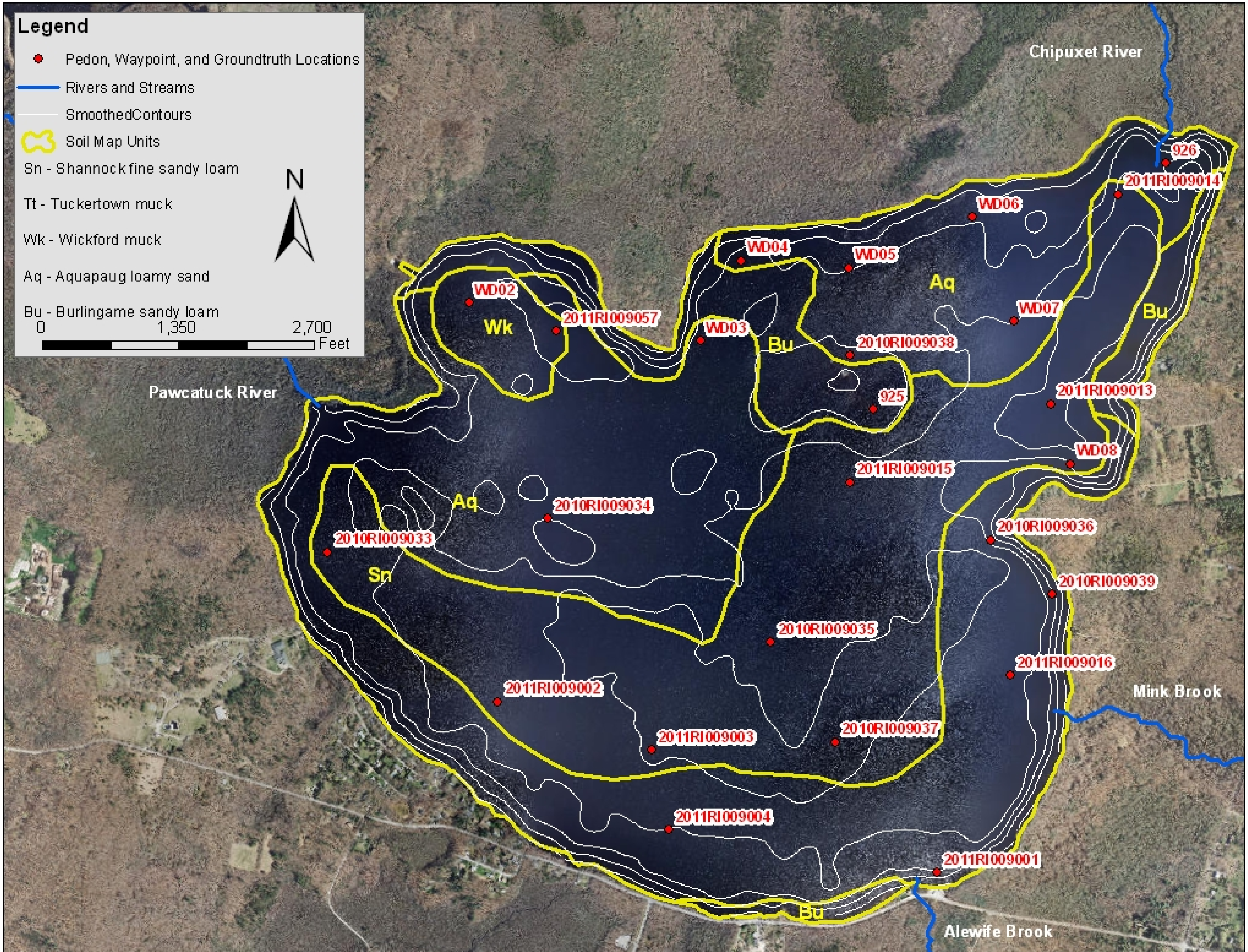
Aquapaug (Psammentic Frasiwassent)

Shannock (Typic Humaquept)

Burlingame (Aeric Frasiwassent)

Wickford muck (Sapric (Terric) Frasiwassist)

Tuckertown muck (Sapric Frasiwassist)



Legend
Pedon, Waypoint, and Groundtruth Locations
Rivers and Streams
SmoothedContours
Soil Map Units
Sn - Shannock fine sandy loam
Tt - Tuckertown muck
Wk - Wickford muck
Aq - Aquapaug loamy sand
Bu - Burlingame sandy loam
0 1,350 2,700
Feet
N
Chipuxet River
Pawcatuck River
Mink Brook
Alewife Brook
926
2011RI009014
WD06
WD04
WD05
Aq
WD02
Wk
2011RI009057
WD03
Bu
WD07
Bu
2010RI009038
925
2011RI009013
WD08
2011RI009015
Aq
2010RI009034
2010RI009033
Sn
2010RI009036
2010RI009039
2010RI009035
2011RI009016
2011RI009002
2011RI009003
2010RI009037
2011RI009004
2011RI009001
Bu

Web Soil Survey

Distribution of soil series by water-body (ha)

	Bowdish Reservoir	Smith and Sayles Reservoir	Belleville Pond	Worden Pond	Watchaug Pond	Tucker Pond
Shannock	na	na	5	142	89	1
Tuckertown	70	na	12	na	37	26
Wickford	na	35	29	11	15	2
Aquapaug	11	6	1	251	33	na
Burlingame	22	34	na	39	56	10
Total (ha)	**103**	**75**	**48**	**444**	**231**	**39**

Note: na indicates that these soil series were not present in this water body.

Characterization and Classification – Soil map units

Soil classifications to the subgroup level with acreages:

Subgroup Classification	Soil Series Name	Acreage of Classifications (ha) (and number of Map Unit Symbols)*	Percent Coverage Within Combined Sample Areas
Sapric Frasiwassist	Tuckertown muck	146 (6)	16%
Terric Frasiwassist	Wickford muck	92 (7)	10%
Typic Humaquept	Shannock fine sandy loam	238 (5)	25%
Psammentic Frasiwassent	Aquapaug loamy sand	303 (8)	**32%**
Aeric Frasiwassent	Burlingame sandy loam	161 (16)	17%

Soil Genesis (reasons for these soils)

- The history and background of each individual water body is important
- Flooded wetland systems (i.e. Belleville Pond)
- Formation of ice-block lakes (natural ponds)
- Histic epipedons in the created water bodies (true subaqueous Inceptisols?)
- Presence of umbric epipedons
- Histosols and Inceptisols were commonly found (differs from estuarine systems)

Histic epipedon from S&S

Key Results and Conclusions

• Bathymetry, GPR, ground-truthing, sample collection, and soil characterization were used to map freshwater subaqueous soils

• Bathymetric data were used to identify five landscape units (fewer than coastal systems) which included Lakebed, Shoals, Shoreline, Coves, and Deepwater.

• GPR technology (which can't be used in estuarine systems) was invaluable allowing for quick and accurate analysis of water depth, substrate type, and substrate thickness.

• The most commonly found soil was the Psammentic Frasiwassents (32% of the total area mapped).

• Five new soil series were developed for the soils that commonly occur on these subaqueous landscapes.

Chapter 2 – Freshwater subaqueous soils: accumulation of metals (arsenic and lead) and the determination of sedimentation rates

Objectives:

- Better understand As and Pb accumulation and distribution in the freshwater systems
- Use As and Pb as stratigraphic markers to estimate the sedimentation rates of lakes over the last ~100 years

Materials and Methods

- Samples were collected from select vibracores (from the surface to 25 cm every 2.5 cm, and between 25 and 75 cm every 5 cm)

- Total concentrations (ug g^{-1}) determined for both As and Pb

- Enrichment factors:
EF = (X/Y)sample / (X/Y)background

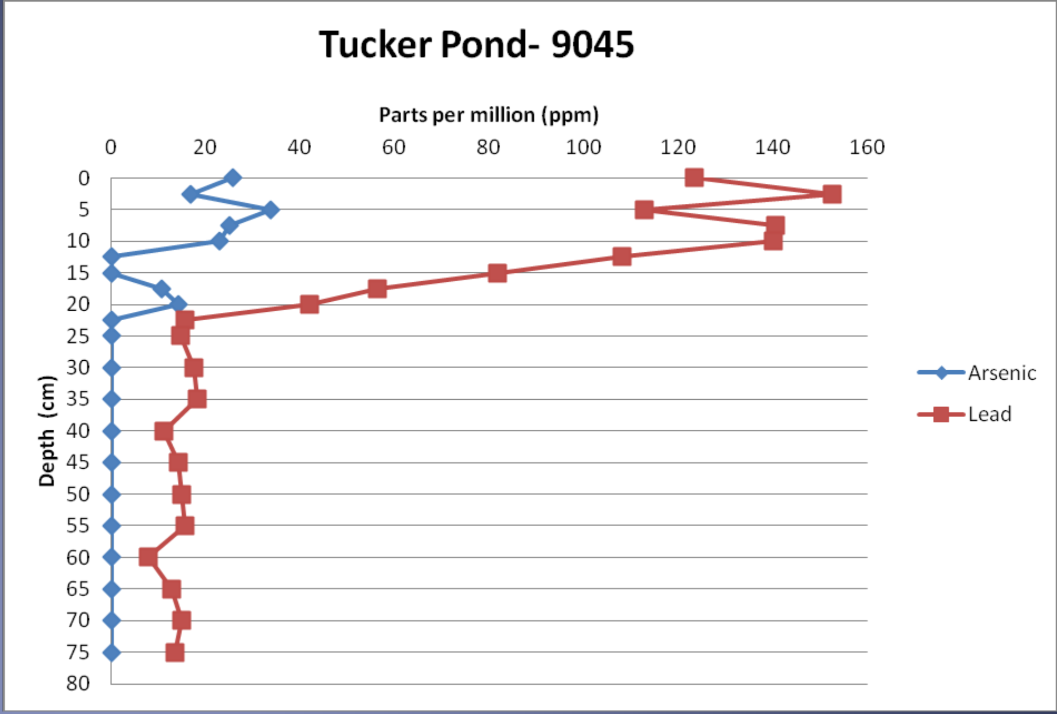
- NOAA guideline comparisons (ERL and ERM limits)

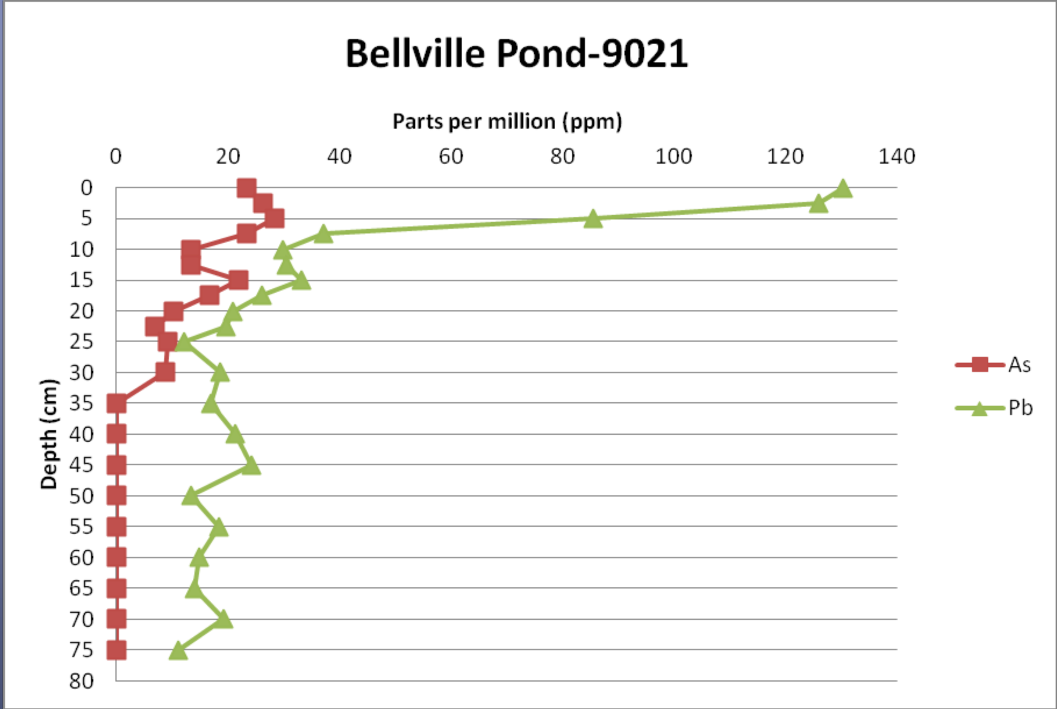
- Sedimentation rates (cm yr^{-1})

NITON XL3t XRF analyzer

Concentrations

- ➢ Upper 20-30 cm
- ➢ Limits of Detection (LOD) for the XRF analyzer (zeros)
- ➢ Possible sources of As and Pb include mining, manufacturing, fossil fuel combustion, and other uses in agriculture and forestry

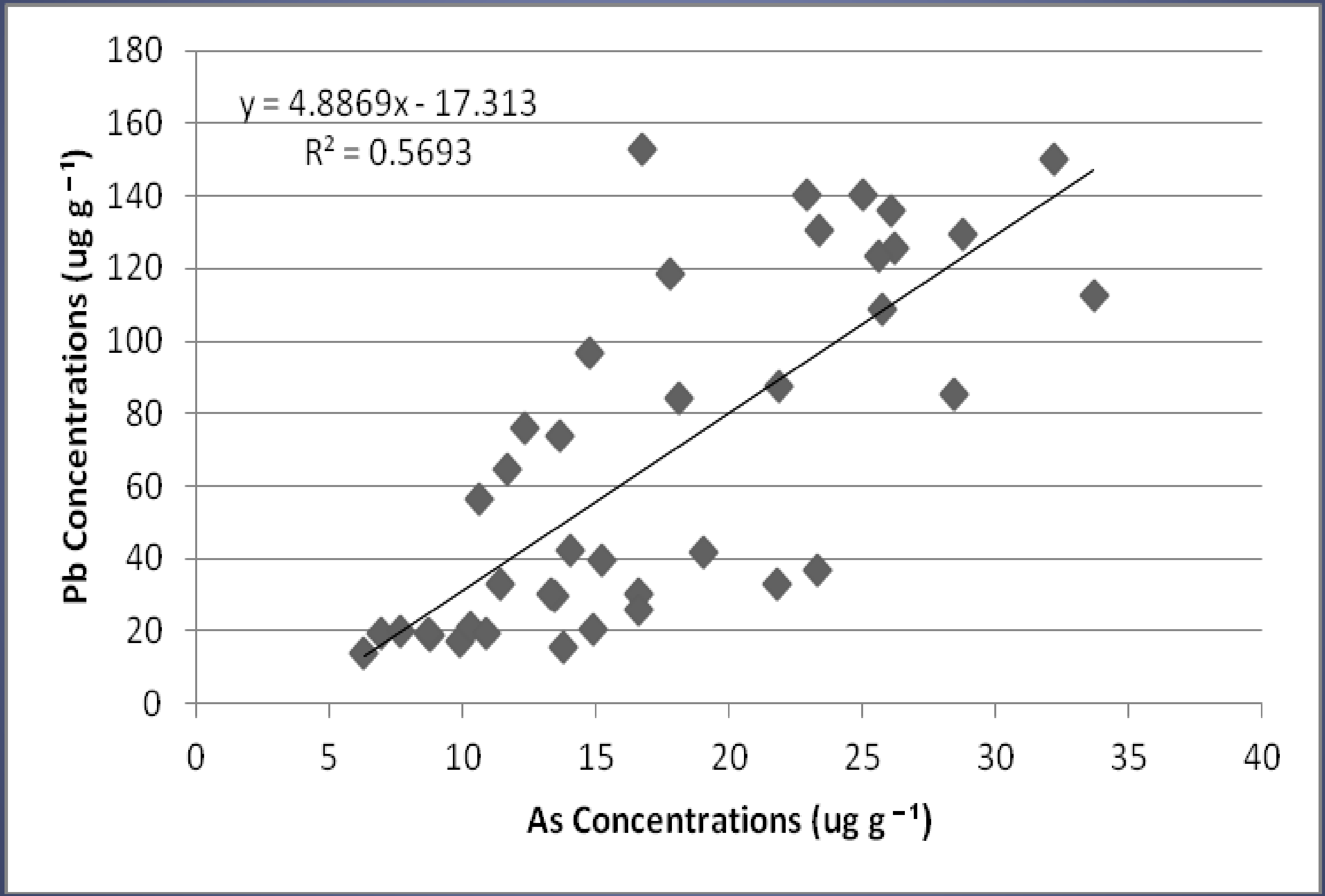


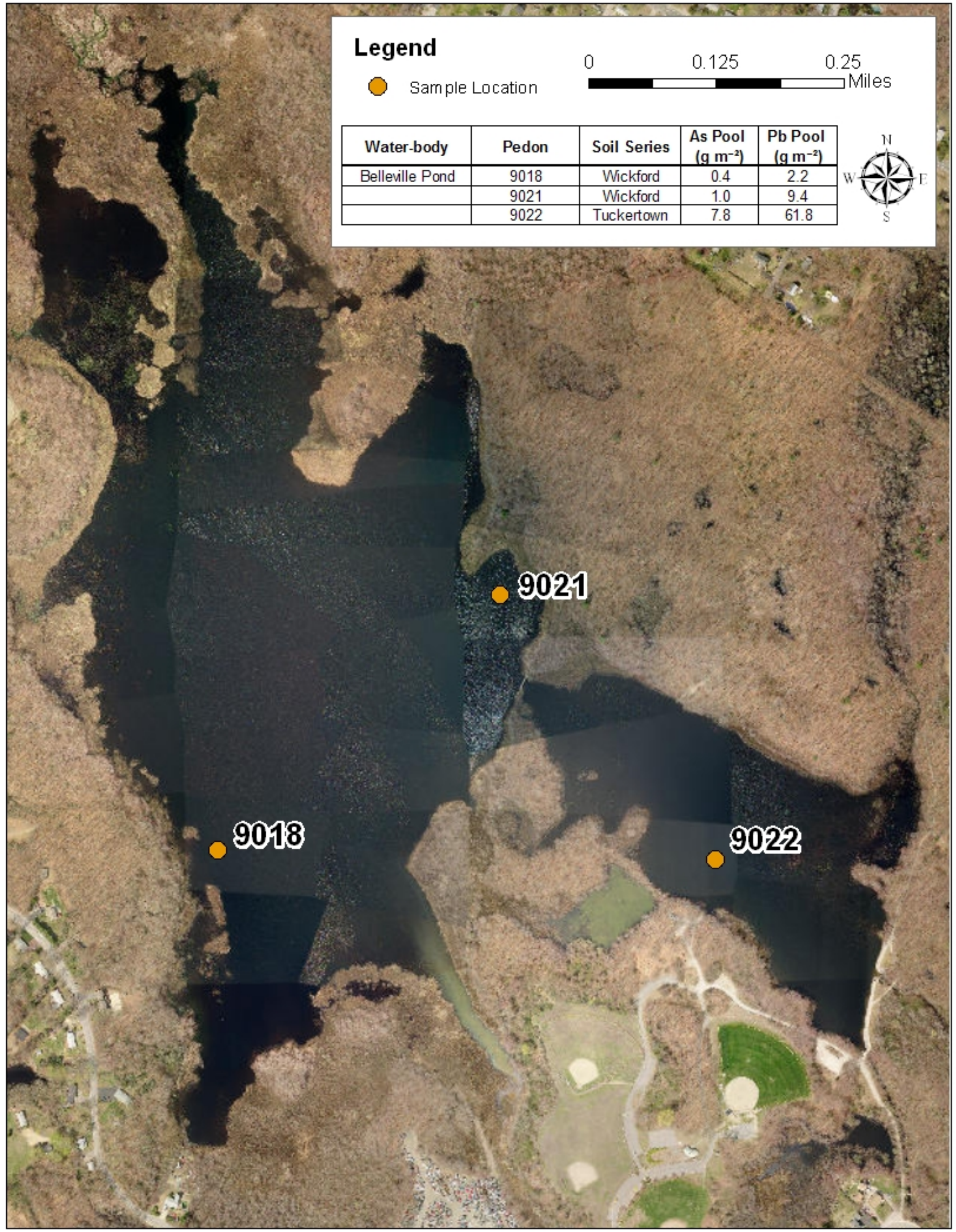


Enrichment factors

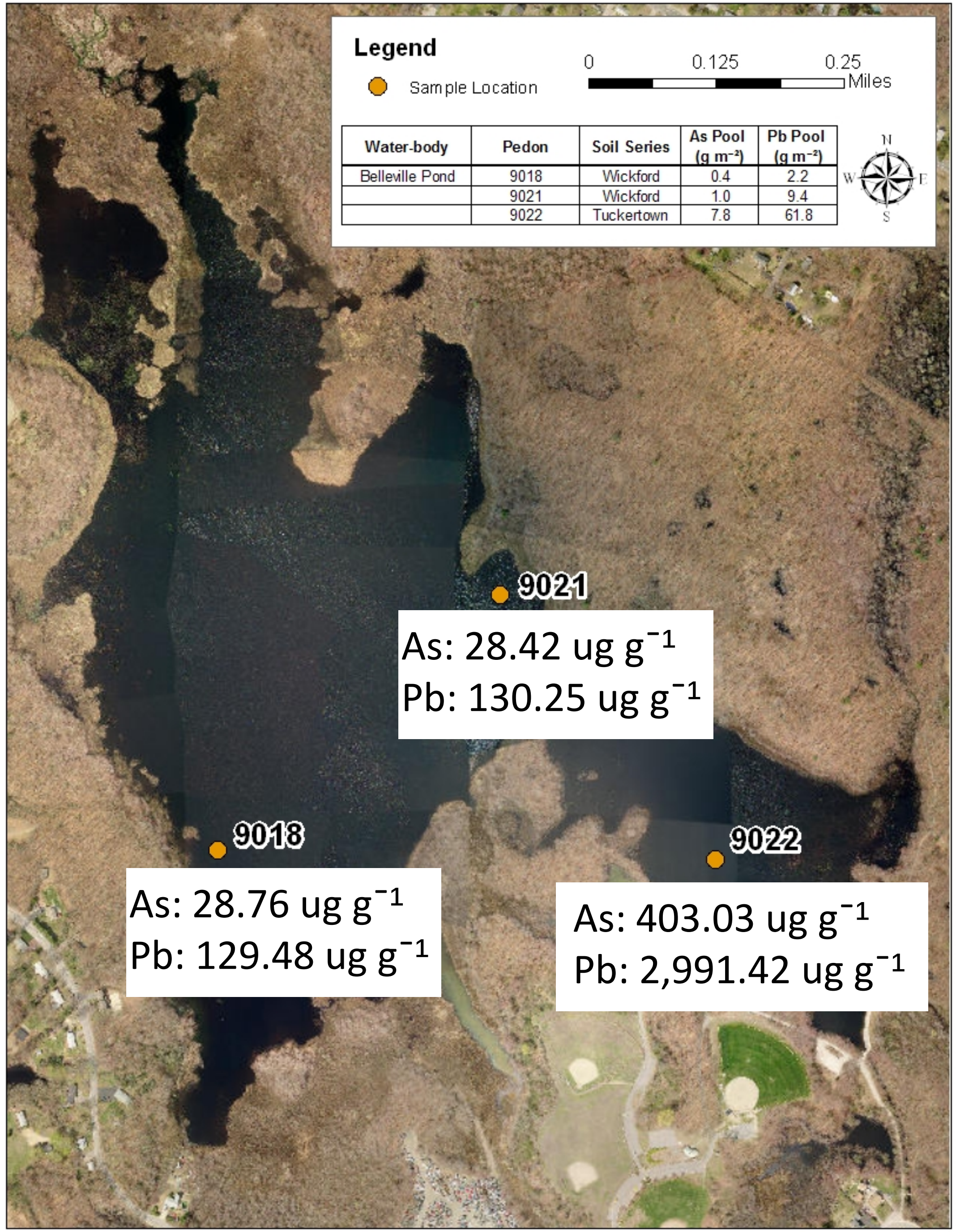
Water-Body	Pedon	Soil Series	**As Enrichment Factor Range	**Pb Enrichment Factor Range
Belleville Pond	9018	Wickford	5.0 - 13.4	1.1 - 7.5
Belleville Pond	9021	Wickford	4.3 - 14.1	1.1 - 6.5
Belleville Pond	9022	Tuckertown	9.2 - 152.9	1.1 - 138.8
Smith and Sayles	7003	Wickford	4.4	1.2 - 5.2
Smith and Sayles	7005	Wickford	5.4 - 10.1	1.0 - 5.7
Smith and Sayles	7007	Burlingame	N/A	1.1 - 5.1
Tucker Pond	9041	Burlingame	3.0 - 7.8	1.1 - 5.1
Tucker Pond	9044	Tuckertown	4.2 - 8.3	1.3 - 5.3
Tucker Pond	9045	Tuckertown	2.7 – 7.0	1.0 - 4.2
Watchaug Pond	9026	Shannock	25.4	1.2 - 8.4
Watchaug Pond	9029	Burlingame	2.47	1.4 - 6.7
Watchaug Pond	9032	Burlingame	N/A	1.6 - 13.4
Worden Pond	9003	Shannock	2.5 - 5.2	1.0 - 4.1
Worden Pond	9013	Shannock	5.6 - 9.2	1.1 - 4.1
Worden Pond	9014	Shannock	6.8 - 7.8	1.2 - 5.2

As and Pb relationships





Water-body	Pedon	Soil Series	As Pool (g m⁻²)	Pb Pool (g m⁻²)
Belleville Pond	9018	Wickford	0.4	2.2
	9021	Wickford	1.0	9.4
	9022	Tuckertown	7.8	61.8



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Belleville Pond	9018	Wickford	0.4	2.2
	9021	Wickford	1.0	9.4
	9022	Tuckertown	7.8	61.8

NOAA biological effects limits

Water-Body	*ID	Soil Series	# of Pb Values > Background Levels (and below ERL)**	# of As Values > Background Levels (and below ERL)**	# of Pb Values between ERL and ERM Limits***	# of As Values between ERL and ERM Limits***	# of Pb Values > ERM Limits ****	# of As Values > ERM Limits ****	Range in Pb Concentration (ppm)	Range in As Concentration (ppm)
Belleville	9018	Wickford	3	2	2	4	0	0	<LOD - 129	<LOD - 29
Belleville	9021	Wickford	15	1	3	11	0	0	11 - 130	<LOD - 28
Belleville	9022	Tuckertown	5	0	4	3	6	5	8 - 2991	<LOD - 403
S&S	7003	Wickford	13	1	7	0	0	0	11 - 66	<LOD - 6
S&S	7005	Wickford	10	1	3	3	0	0	8 - 119	<LOD - 18
S&S	7007	Burlingame	9	0	4	0	0	0	10 - 69	<LOD
Tucker	9041	Burlingame	13	0	3	3	0	0	10 - 97	<LOD - 18
Tucker	9044	Tuckertown	3	0	2	4	0	0	<LOD - 136	<LOD - 26
Tucker	9045	Tuckertown	9	0	8	7	0	0	8 - 153	<LOD - 34
Watchaug	9026	Shannock	2	1	0	0	0	0	<LOD - 16	<LOD - 6
Watchaug	9029	Burlingame	4	1	0	0	0	0	8 - 19	<LOD - 7
Watchaug	9032	Burlingame	11	0	0	0	0	0	7 - 22	<LOD
Worden	9003	Shannock	18	1	0	4	0	0	9 - 30	<LOD - 16
Worden	9013	Shannock	3	2	0	6	0	0	<LOD - 19	<LOD - 51
Worden	9014	Shannock	3	0	0	3	0	0	<LOD - 20	<LOD - 15

*All pedons were collected in Rhode Island in 2011 (i.e. 2011RI00). 21 samples were collected for each pedon sampled.
**RIDEM soil background levels = 1.7 ug/g for As; 13.9 ug/g for Pb
***NOAA Effects Range Low (ERL) guideline thresholds for biological effects = 8 for As; 47 for Pb
****NOAA Effects Range Median (ERM) guideline thresholds for biological effects = 70 for As; 218 for Pb

Results – NOAA biological effects limits

Water-Body	*ID		# of Pb	# of As	# of Pb	# of As	# of Pb	# of As	Pb ation)	Range in As Concentration (ppm)
Belleville	9018								129	<LOD - 29
Belleville	9021								0	<LOD - 28
Belleville	9022								1	<LOD - 403
S&S	7003								5	<LOD - 6
S&S	7005								9	<LOD - 18
S&S	7007								9	<LOD
Tucker	9041								7	<LOD - 18
Tucker	9044								136	<LOD - 26
Tucker	9045								3	<LOD - 34
Watchaug	9026								16	<LOD - 6
Watchaug	9029									<LOD - 7
Watchaug	9032									<LOD
Worden	9003									<LOD - 16
Worden	9013	Shannock	3	2	0	0	0	0	<LOD - 19	<LOD - 51
Worden	9014	Shannock	3	0	0	3	0	0	<LOD - 20	<LOD - 15

(n = 315)	**As**	**Pb**
Soil Background Level	1.7 ug g^{-1}	13.9 ug g^{-1}
NOAA "possible effects"	8 ug g^{-1}	47 ug g^{-1}
NOAA "probable effects"	70 ug g^{-1}	218 ug g^{-1}
# that have possible effects	48	36
# that have probable effects	5	6

*All pedons were collected in Rhode Island in 2011 (i.e. 2011RI00). 21 samples were collected for each pedon sampled.
**RIDEM soil background levels = 1.7 ug/g for As; 13.9 ug/g for Pb
***NOAA Effects Range Low (ERL) guideline thresholds for biological effects = 8 for As; 47 for Pb
****NOAA Effects Range Median (ERM) guideline thresholds for biological effects = 70 for As; 218 for Pb

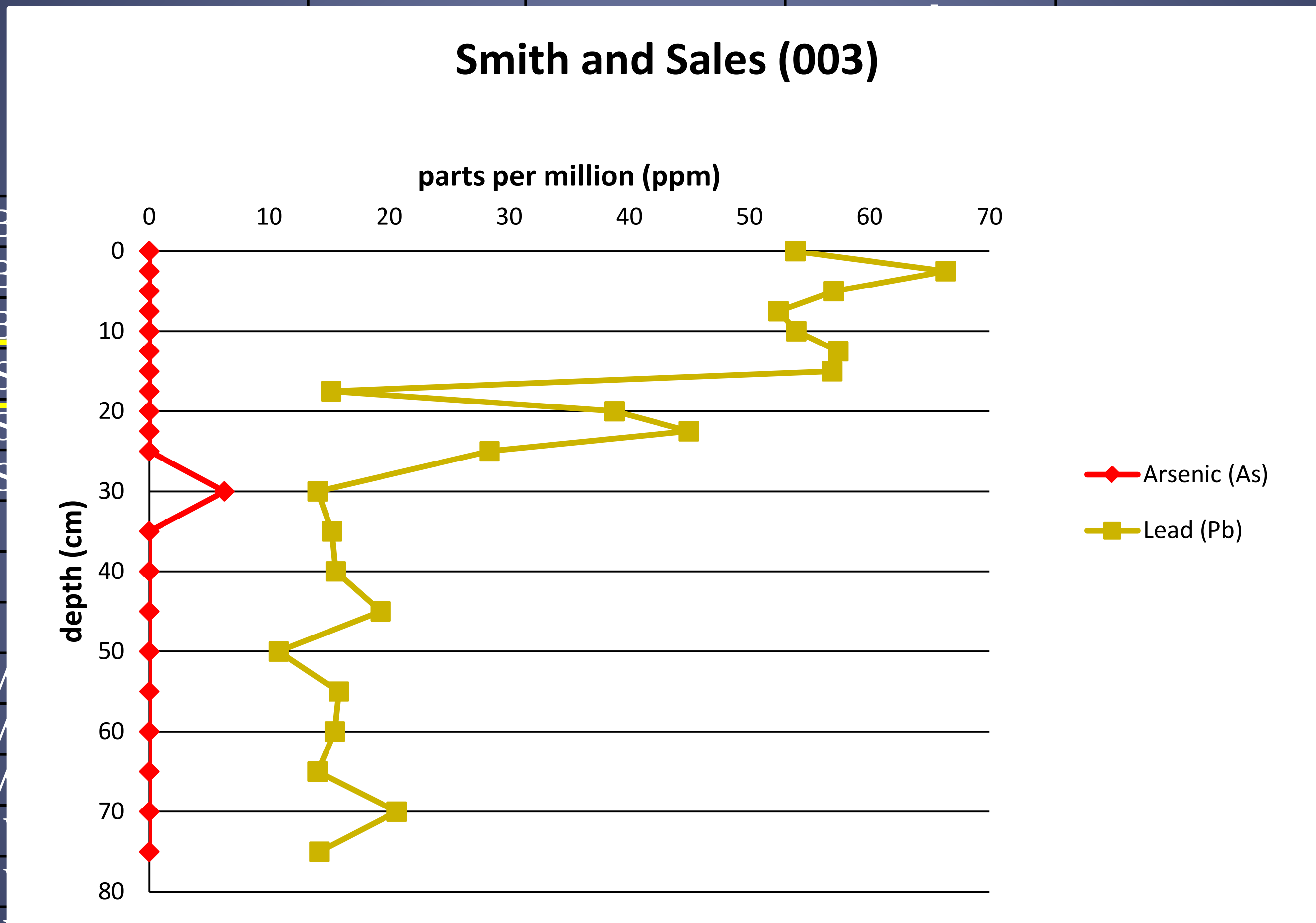
Results - Sedimentation rates

Water-body	Sampling ID	Year Impounded	Depth to background levels of Pb and As	Sedimentation Rate (cm yr^{-1}) based on 1920*
Belleville Pond	9018	1800	15	0.16
Belleville Pond	9021	1800	25	0.27
Belleville Pond	9022	1800	20	0.22
S&S Reservoir	7003	1865	30	0.33
S&S Reservoir	7005	1865	20	0.22
S&S Reservoir	7007	1865	25	0.27
Tucker Pond	9041	Natural Pond	17	0.19
Tucker Pond	9044	Natural Pond	12	0.13
Tucker Pond	9045	Natural Pond	22.5	0.25
Watchaug Pond	9026	Natural Pond	2.5	0.03
Watchaug Pond	9029	Natural Pond	2.5	0.03
Watchaug Pond	9032	Natural Pond	5	0.05
Worden Pond	9003	Natural Pond	7.5	0.08
Worden Pond	9013	Natural Pond	20	0.22
Worden Pond	9014	Natural Pond	2.5	0.03

Natural vs. Created Comparison:

Source of Variation	DF	SS	MS	F	P
Between Groups	1	0.0661	0.0661	11.011	**0.006**
Residual	13	0.0781	0.00601		
Total	14	0.144			

Sedimentation rates



Worden Pond	9014	Natural Pond	2.5	0.03

Natural vs. Created Comparison:

Source of Variation	DF	SS	MS	F	P
Between Groups	1	0.0661	0.0661	11.011	0.006
Residual	13	0.0781	0.00601		
Total	14	0.144			

Key Results and Conclusions

- Elevated concentrations of As and Pb were generally found in the upper 20-30 cm of each pedon.

- The source of these metals was likely lead-arsenate pesticide and leaded gasoline that began to show up in the environment around 1920.

- Proximity to contaminant sources, as well as dam location in the reservoirs, were both found to be important determinants in regards to the spatial distribution of As and Pb concentrations.

- Reservoirs had significantly higher sedimentation rates.

Chapter 3 – Freshwater subaqueous soils and carbon accounting

Objectives:

- Elucidate the magnitude and distribution of SOC in three natural and three created freshwater lakes in Rhode Island

- Estimate SOC pools, providing a useful interpretation to aid in the accounting of subaqueous SOC pools

Materials and Methods

- Forty-six pedons (Macaulay peat sampler or a vibracorer)

- Loss-on-ignition and CHN analyzer (Costech ECS 4010) results

- Soil organic carbon pools were calculated for each horizon using the equation:

SOC = Cs*L*Db

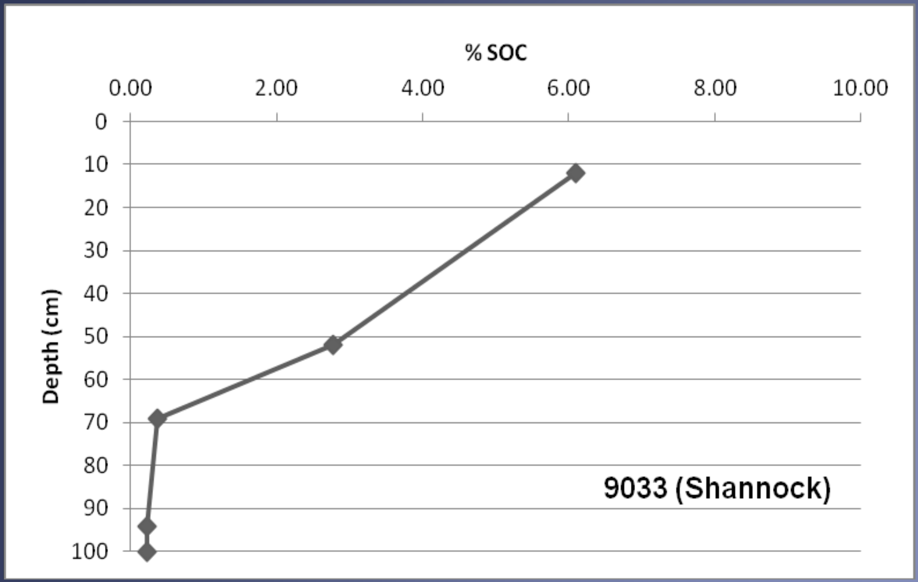
Where Cs = soil organic carbon content (kg C kg^{-1} soil)

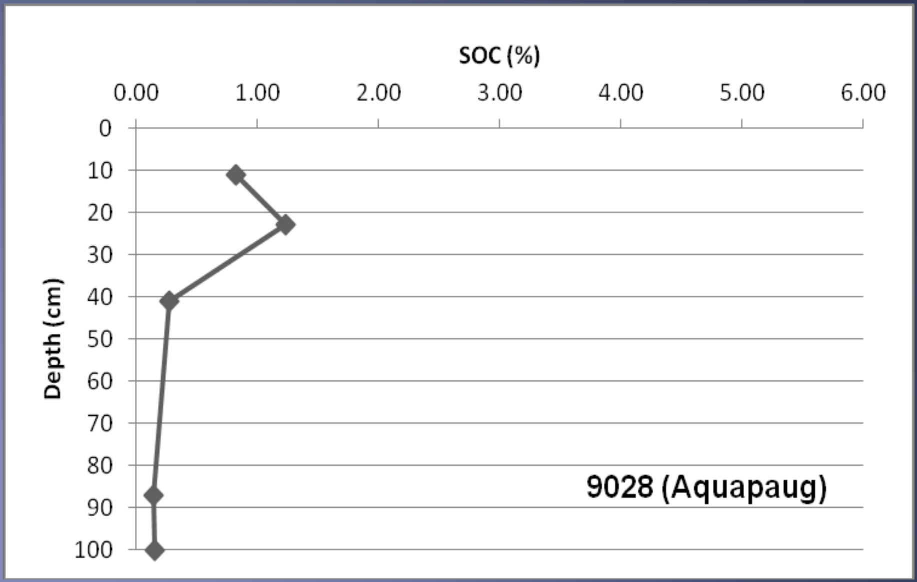
L = soil horizon thickness (m)

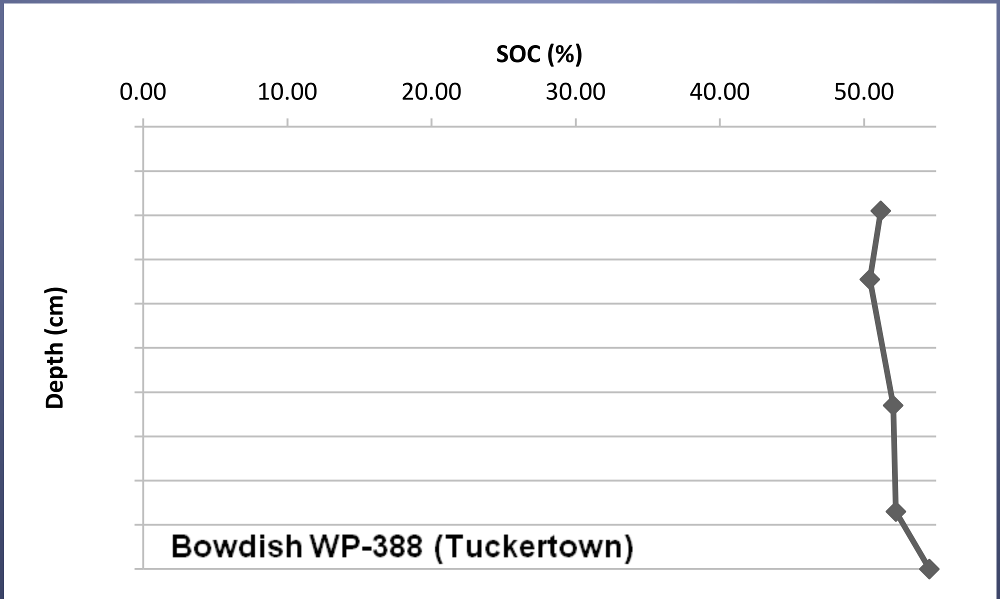
Db = bulk density of soil ($g\ cm^{-3}$)

Sapric Frasiwassist

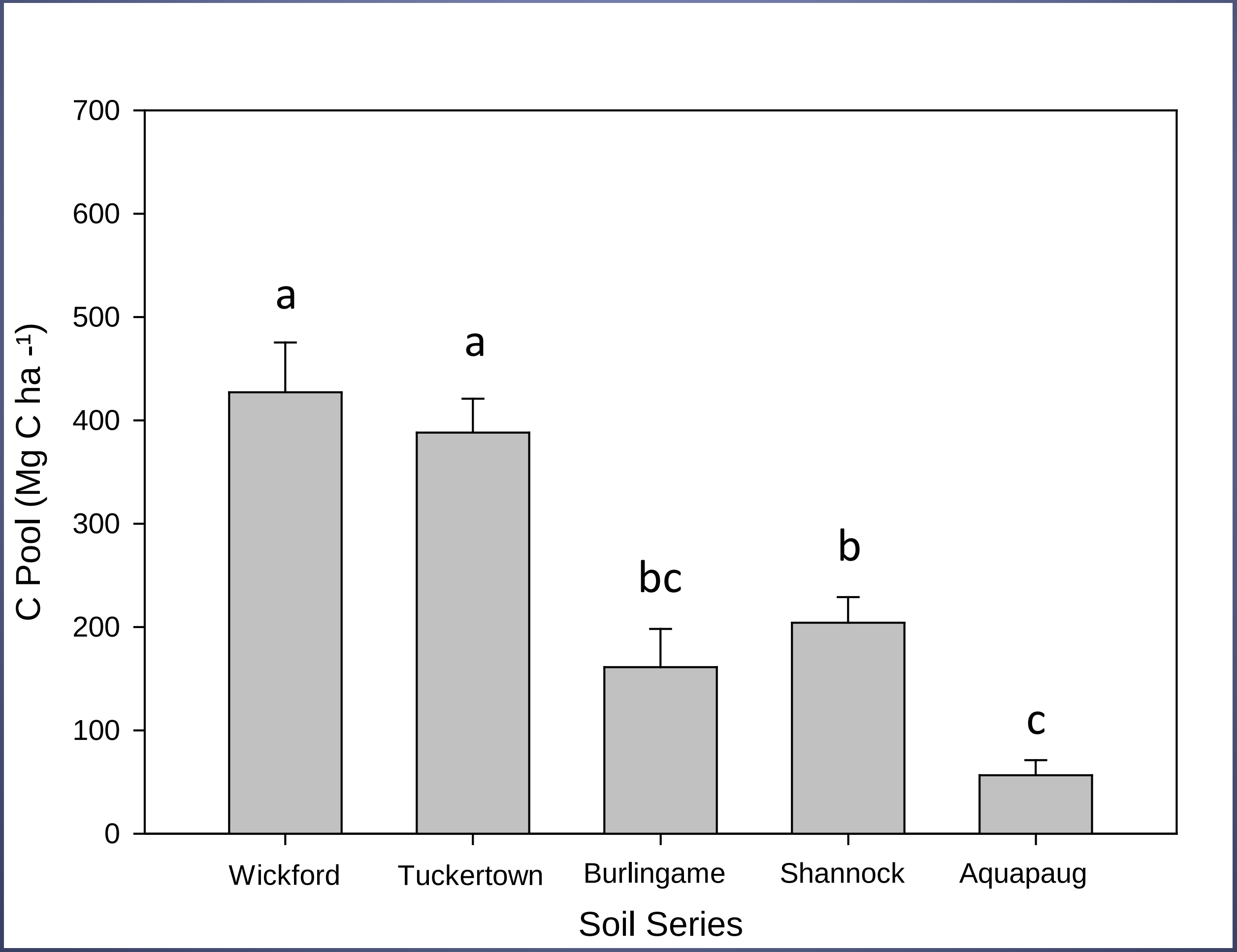
SOC contents







Freshwater subaqueous SOC pool comparisons



Weighted average SOC pool comparisons

Pond	Soil Series	Area (ha)	% of pond area	Weighted Cpool Average (Mg C ha^{-1})
Watchaug	Shannock	89	39	79
	Burlingame	56	24	39
	Tuckertown	37	16	62
	Wickford	15	6	27
	Aquapaug	33	15	8
	Sum:	**231**	**100**	**216**
Wordens	Aquapaug	251	57	32
	Burlingame	39	9	14
	Shannock	142	32	65
	Wickford	11	3	11
	Sum:	**444**	**100**	**122**
Tucker	Tuckertown	26	66	256
	Shannock	1	3	6
	Wickford	2	5	20
	Burlingame	10	27	43
	Sum:	**39**	**100**	**324**
Belleville	Wickford	29	61	259
	Tuckertown	12	26	100
	Shannock	5	11	23
	Aquapaug	1	2	1
	Sum:	**48**	**100**	**384**
S&S	Wickford	35	47	201
	Burlingame	34	45	73
	Aquapaug	6	8	4
	Sum:	**75**	**100**	**278**
Bowdish	Tuckertown	70	68	263
	Burlingame	22	21	34
	Aquapaug	11	11	6
	Sum:	**103**	**100**	**303**

Weighted average SOC pool comparisons

Pond	Soil Series	Area (ha)	% of pond area	Weighted Cpool Average (Mg C ha^{-1})
Watchaug	Shannock	89	39	79
	Burlingame	56	24	39
	Tuckertown	37	16	62
	Wickford	15	6	27
	Aquapaug	33	15	8
	Sum:	**231**	**100**	**216**
Wordens	Aquapaug	251	57	32
	Sum:	**48**	**100**	**384**
S&S	Wickford	35	47	201
	Burlingame	34	45	73
	Aquapaug	6	8	4
	Sum:	**75**	**100**	**278**
Bowdish	Tuckertown	70	68	263
	Burlingame	22	21	34
	Aquapaug	11	11	6
	Sum:	**103**	**100**	**303**

1	**Belleville**	**384**
2	**Tucker**	**324**
3	**Bowdish**	**303**
4	**S&S**	**278**
5	**Watchaug**	**216**
6	**Worden**	**122**

Freshwater subaqueous and subaerial SOC pool comparisons

Soil Type	Soil Classification	n	Mean SOC ($Mg\ ha^{-1}$)	CV (%)	Reference
Excessively Drained Uplands	Typic Udipsamments	20	110	15	Davis, 2004
Well Drained Uplands	Typic Udipsamments	29	136	28	Davis, 2004
Poorly Drained Palustrine Wetlands	Aeric Endoaquepts	20	187	31	Davis, 2004
Very Poorly Drained Palustrine Wetlands	Typic Haplosaprists	30	586	20	Davis, 2004
Poorly and Very Poorly Drained Riparian Wetlands	Aeric Endoaquepts	29	246	39	Ricker, 2010
Estuarine Subaqueous	Fluventic Psammowassents	9	47	43	Pruett, 2010
Estuarine Subaqueous	Sulfic Psammowassents	5	57	82	Pruett, 2010
Estuarine Subaqueous	Typic Fluviwassents	5	109	50	Pruett, 2010
Estuarine Subaqueous	Haplic Sulfiwassents	10	123	43	Pruett, 2010
Estuarine Subaqueous	Typic Sulfiwassents	5	141	42	Pruett, 2010
Estuarine Subaqueous	Fluvenitc Sulfiwassents	5	196	28	Pruett, 2010
Estuarine Subaqueous	Thapto-Histic Sulfiwassents	3	494	35	Pruett, 2010
Freshwater Subaqueous	**Sapric (Terric) Frasiwassists**	**8**	**427**	**33**	**This Study**
Freshwater Subaqueous	**Sapric Frasiwassists**	**16**	**388**	**33**	**This Study**
Freshwater Subaqueous	**Aeric Frasiwassents**	**7**	**161**	**63**	**This Study**
Freshwater Subaqueous	**Typic Humaquepts**	**10**	**204**	**38**	**This Study**
Freshwater Subaqueous	**Psammentic Frasiwassents**	**5**	**56**	**58**	**This Study**

Freshwater subaqueous and subaerial SOC pool comparisons

Soil Type	Soil Classification	n	Mean SOC (Mg ha^{-1})	CV (%)	Reference
Excessively Drained Uplands	Typic Udipsamments	20	110	15	Davis, 2004
Well Drained Uplands	Typic Udipsamments	29	136	28	Davis, 2004
Freshwater Subaqueous	**Aeric Frasiwassents**	**7**	**161**	**63**	**This Study**
Freshwater Subaqueous	**Typic Humaquepts**	**10**	**204**	**38**	**This Study**
Freshwater Subaqueous	**Psammentic Frasiwassents**	**5**	**56**	**58**	**This Study**

Davis, 2004	*Pruett, 2010*	*This Study*
110 (excessively drained)	**57** (Suflfic Psammowassents)	**56** (Psammentic Frasiwassents)
136 (well drained)	**109** (Typic Fluviwassents)	**161** (Aeric Frasiwassents)
187 (poorly drained)	**141** (Typic Sulfiwassents)	**204** (Typic Humaquepts)
586 (very poorly drained)	**196** (Fluventic Sulfiwassents)	**388** (Sapric Frasiwassists)
	494 (Thapto-histic Sulfiwassents)	**427** (Sapric(Terric)Frasiwassists)

Freshwater SOC sequestration

Waterbody	*Sampling ID*	*Depth to background levels of Pb and As*	*C Pool (Mg ha⁻¹)*	*Sequestration Rate (Mg C ha⁻¹ yr⁻¹)*
Belleville Pond	2011RI009018	15	81	0.89
Belleville Pond	2011RI009021	25	137	1.50
Belleville Pond	2011RI009022	20	87	0.95
S&S Reservoir	2011RI007003	30	86	0.95
S&S Reservoir	2011RI007005	20	99	1.08
S&S Reservoir	2011RI007007	25	131	1.44
Tucker Pond	2011RI009041	17.5	31	0.34
Tucker Pond	2011RI009044	12	90	0.99
Tucker Pond	2011RI009045	22.5	105	1.15
Worden Pond	2011RI009003	7.5	16	0.18
Worden Pond	2011RI009013	20	166	1.83
Worden Pond	2011RI009014	2.5	1.6	0.02
Watchaug Pond	2011RI009026	2.5	1.7	0.02
Watchaug Pond	2011RI009029	2.5	0.4	0.00
Watchaug Pond	2011RI009032	5	0.8	0.01

Freshwater SOC sequestration

Waterbody	***Sampling ID***	***Depth to background levels of Pb and As***	***C Pool ($Mg\ ha^{-1}$)***	***Sequestration Rate ($Mg\ C\ ha^{-1}\ yr^{-1}$)***
Belleville Pond	2011RI009018	15	81	0.89
Belleville Pond	2011RI009021	25	137	1.50
Belleville Pond	2011RI009022	20	87	0.95
S&S [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
S&S [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
S&S [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Tuc[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Tuc[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Tuc[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Worden Pond	2011RI009003	7.5	16	0.18
Worden Pond	2011RI009013	20	166	1.83
Worden Pond	2011RI009014	2.5	1.6	0.02
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Watchaug Pond	2011RI009029	2.5	0.4	0.00
Watchaug Pond	2011RI009032	5	0.8	0.01

$Mg\ C\ ha^{-1}\ yr^{-1}$

Dean and Gorham, 1998	**Mulholland, 1982**	**This Study**
0.05 - 0.72	0.03 - 1.28 (usually < 0.40)	0.00 – 1.83

Key Results and Conclusions

• Soil organic carbon content varied both with depth and among soil types.

• SOC pools were greatest for the Wassists (>350 Mg C ha^{-1} yr^{-1}) and least for the Psammentic Frasiwassents (< 60 Mg C ha^{-1}). Understanding the distribution of soil types in SOC accounting across the landscape is important.

• Average SOC sequestration rates ranged from 0.50 Mg C ha^{-1} yr^{-1} (natural) to 1.14 Mg C ha^{-1} yr^{-1} (created).

•A significant amount of SOC is being sequestered in both natural and created freshwater bodies throughout southern New England, although more work should be done.

Chapter 4 – Aquatic invasive plants, total extractable phosphorus, and freshwater subaqueous soil relationships

Objectives:

- To quantify extractable P concentrations in the freshwater subaqueous soil environment in order to better understand relationships with aquatic invasive plant species.

- Examine the effectiveness of subaqueous soil surveys to serve as an ecosystem based tool to understand the distribution of aquatic invasive plants in shallow southern New England lakes

Methods

1) Detailed vegetation mapping

2) Soil sampling (random)

3) Sequential phosphorus extraction (pore-water, $NaHCO_3$, and NaOH extractable P)

4) Statistical analysis using logistic regression

P sequential extraction

Extraction (ug g^{-1})	N	Mean	Median	25% percentile	75% percentile	SE
Porewater Extractable P Concentration	100	3.05	1.40	0.78	5.18	0.30
$NaHCO_3$ Extractable P Concentration	100	44.38	26.54	9.96	59.86	5.34
NaOH Extractable P Concentration	100	42.54	10.05	1.98	57.82	6.23
Total Extractable P	100	89.97	45.12	18.66	130.07	9.82

P sequential extraction – substrate type

Substrate Type	Depth (cm)	Porewater Extractable P Average (ug g^{-1})	NaHCO3 Extractable P Average (ug g^{-1})	NaOH Extractable P Average (ug g^{-1})	Total Extractable Phosphorus Average
Mucky mineral	0-5	1.44	14.61	16.21	32.26
	5-10	1.43	22.52	14.71	38.66
Organic	0-5	5.16	92.11	66.49	163.76
	5-10	5.84	64.01	91.96	161.81
Mineral	0-5	0.68	15.07	8.41	24.16
	5-10	0.69	12.94	9.26	22.89

Total extractable P and soil series relationships

Soil Series	Depth (cm)	Porewater Extractable P Average (ug g^{-1})	NaHCO3 Extractable P Average (ug g^{-1})	NaOH Extractable P Average (ug g^{-1})	Total Extractable P Average
Shannock	0-5	2.82	52.14	22.71	77.67
	5-10	2.37	27.91	19.98	50.26
Aquapaug	0-5	0.69	15.27	17.57	33.52
	5-10	0.75	12.33	16.17	29.25
Wickford	0-5	6.52	112.84	48.42	167.77
	5-10	6.82	53.00	128.59	188.41
Tuckertown	0-5	4.33	55.43	122.00	181.76
	5-10	5.80	65.09	79.60	150.48
Burlingame	0-5	1.75	36.03	11.44	49.23
	5-10	1.94	39.55	17.80	59.28

Vegetation mapping

Symbol	Species
Jm	Bayonet rush (*Juncus militaris*)
B	Bladderwort (*Utricularia*)
R	Burreed (*Sparganium* sp.)
Jc	Canadian rush (*Juncus canadensis*)
Ct	Cattail (*Typha* sp.)
F	Fanwort (*Cabomba caroliniana*)
Fh	Floating heart (*Nymphoides cordata*)
H	Hornwort/coontail (*Ceratophyllum*)
Hy	Pennywort (*Hydroctyle umbellata*)
Ph	Phragmites (*Phragmites australis*)
P	Pickerelweed (*Pontedaria cordata*)
T	Pipewort (*Eriocaulon aquaticum*)
D	Pondweed (*Potamogeton* sp.)
I	Purple loosetrife (*Lythrum salicaria*)
R	Redhead grass (*Potamogeton richardsonii*)
G	Sedges (*Cyperaceae* sp.)
Nl	Swamp loosetrife (*Decodon verticillatus*)
Vm	Variable milfoil (*Myriophyllum heterophyllum*)
Vp	Variable pondweed (*Potamogeton gramineus*)
A	Water naiad *(Najas* sp.)
S	Water shield (*Brasnia schreberi*)
M	Water-milfoils (*Myriophyllum* sp.)
W	White water lily (*Nymphaea odorata*)
C	Wild celery (*Vallisneria*)
Y	Yellow water lily (*Nuphar variegatum*)
Pe	Yellow-floating heart (*Nymphoides peltata*)


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J, P, N
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Scattered
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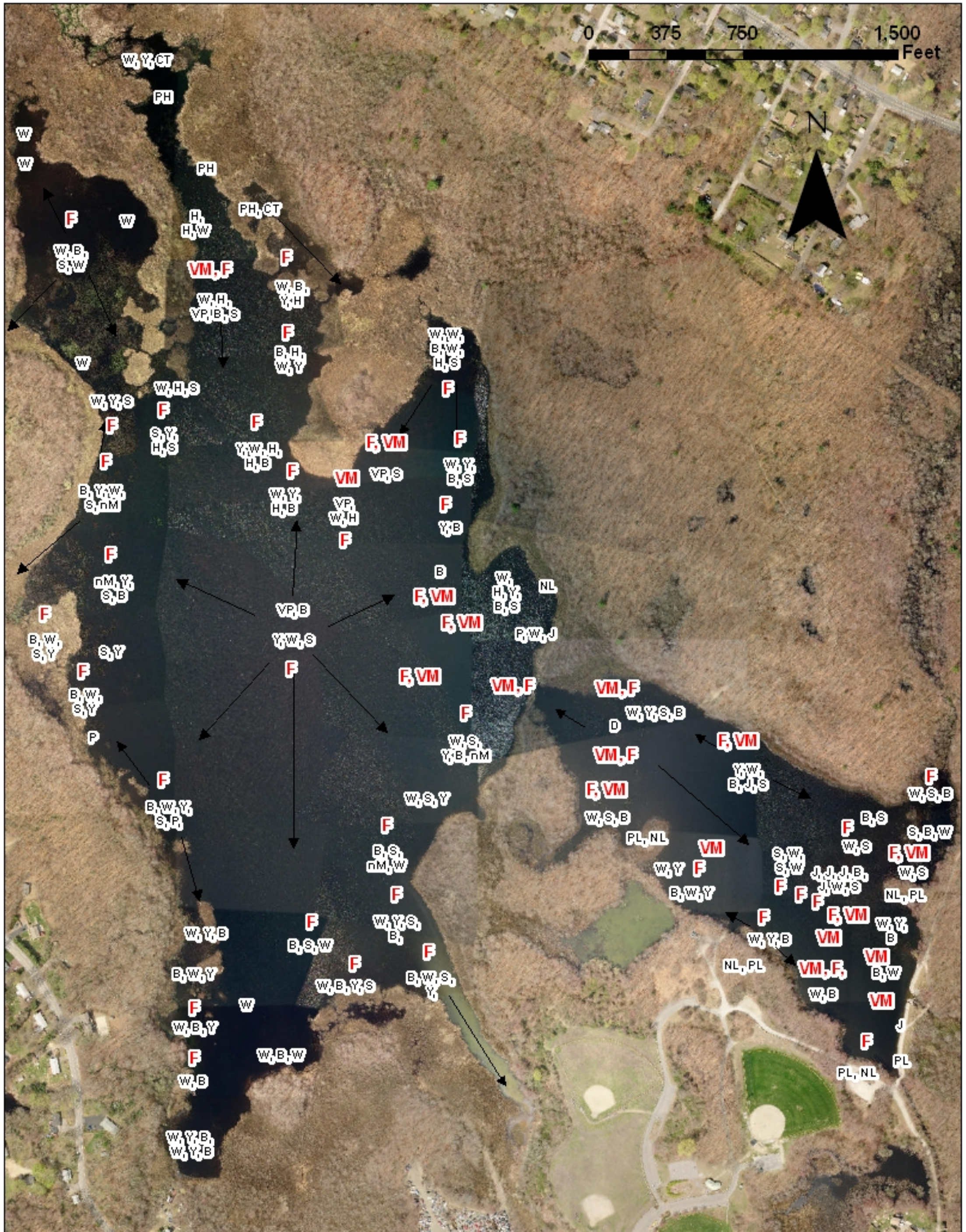

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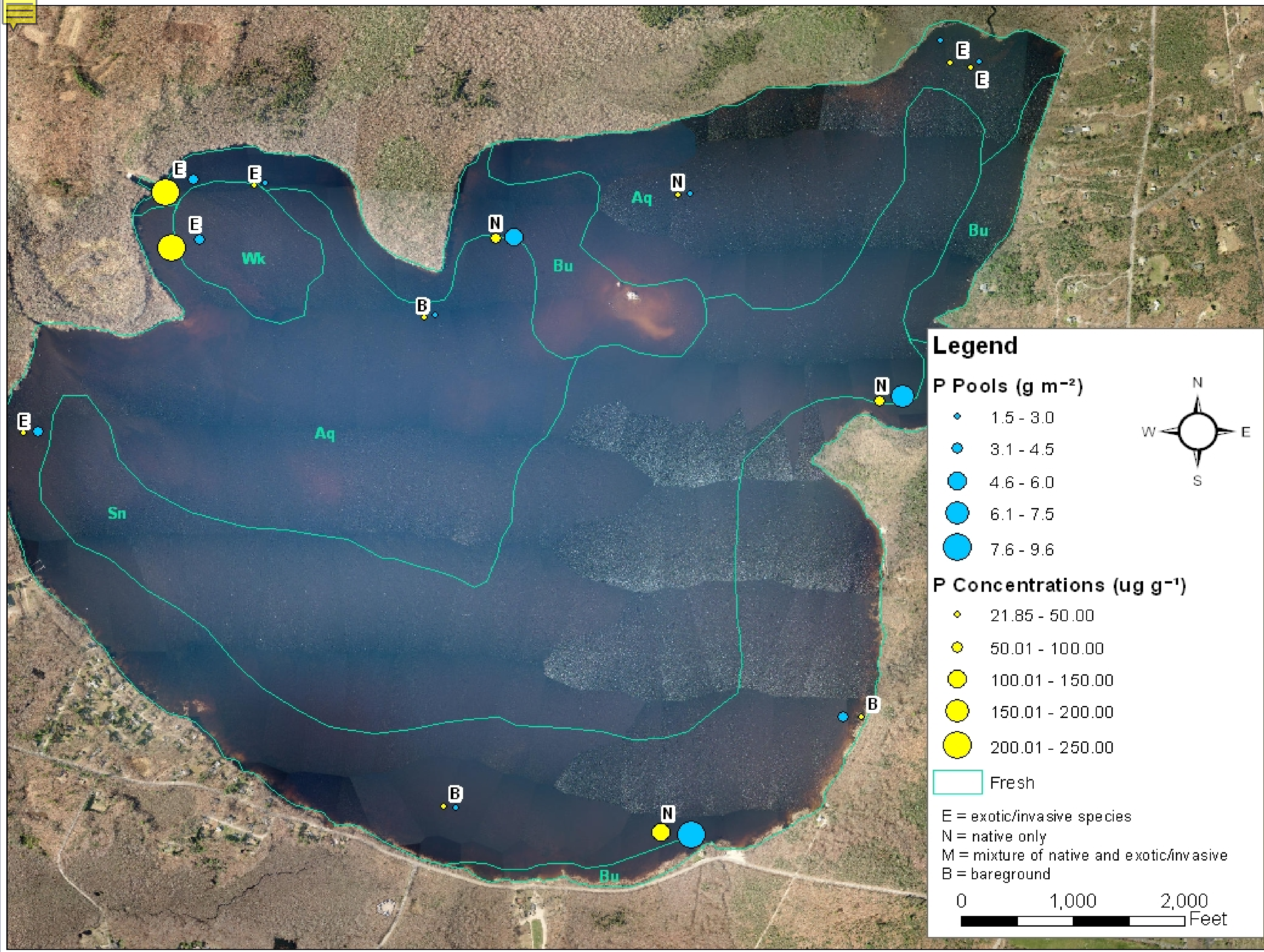


E
N
B
Wk
Aq
Bu
Sn
Legend
P Pools (g m⁻²)
1.5 - 3.0
3.1 - 4.5
4.6 - 6.0
6.1 - 7.5
7.6 - 9.6
P Concentrations (ug g⁻¹)
21.85 - 50.00
50.01 - 100.00
100.01 - 150.00
150.01 - 200.00
200.01 - 250.00
Fresh
E = exotic/invasive species
N = native only
M = mixture of native and exotic/invasive
B = bareground
N
W
E
S
0
1,000
2,000
Feet

Total extractable P and invasive species occurrence

	P-value by Extraction Method			
Variable Tested	**Porewater**	**$NaHCO_3$**	**NaOH**	**Total P**
P (0-5 cm) vs. occurrence of N	0.9708	0.3233	0.9903	0.5430
P (5-10 cm) vs. occurrence of N	0.5021	0.9894	0.9045	0.9198
P (0-5 cm) vs. occurrence of B	0.0750	0.2944	0.1054	0.1074
P (5-10 cm) vs. occurrence of B	0.0624	0.0484	0.1245	0.0673
P (0-5 cm) vs. occurrence of E	0.1095	0.9862	0.8626	0.9529
P (5-10 cm) vs. occurrence of E	0.0734	0.2726	0.0999	0.0899
P (0-5 cm) vs. occurrence of M	0.9937	0.9699	0.0355	0.1918
P (5-10 cm) vs. occurrence of M	0.2027	0.5123	0.8905	0.6642
P (0-5 cm) vs. occurrence of E and M	0.1029	0.9941	0.1733	0.3995
P (5-10 cm) vs. occurrence of E and M	0.0119	0.1286	0.0822	0.0485

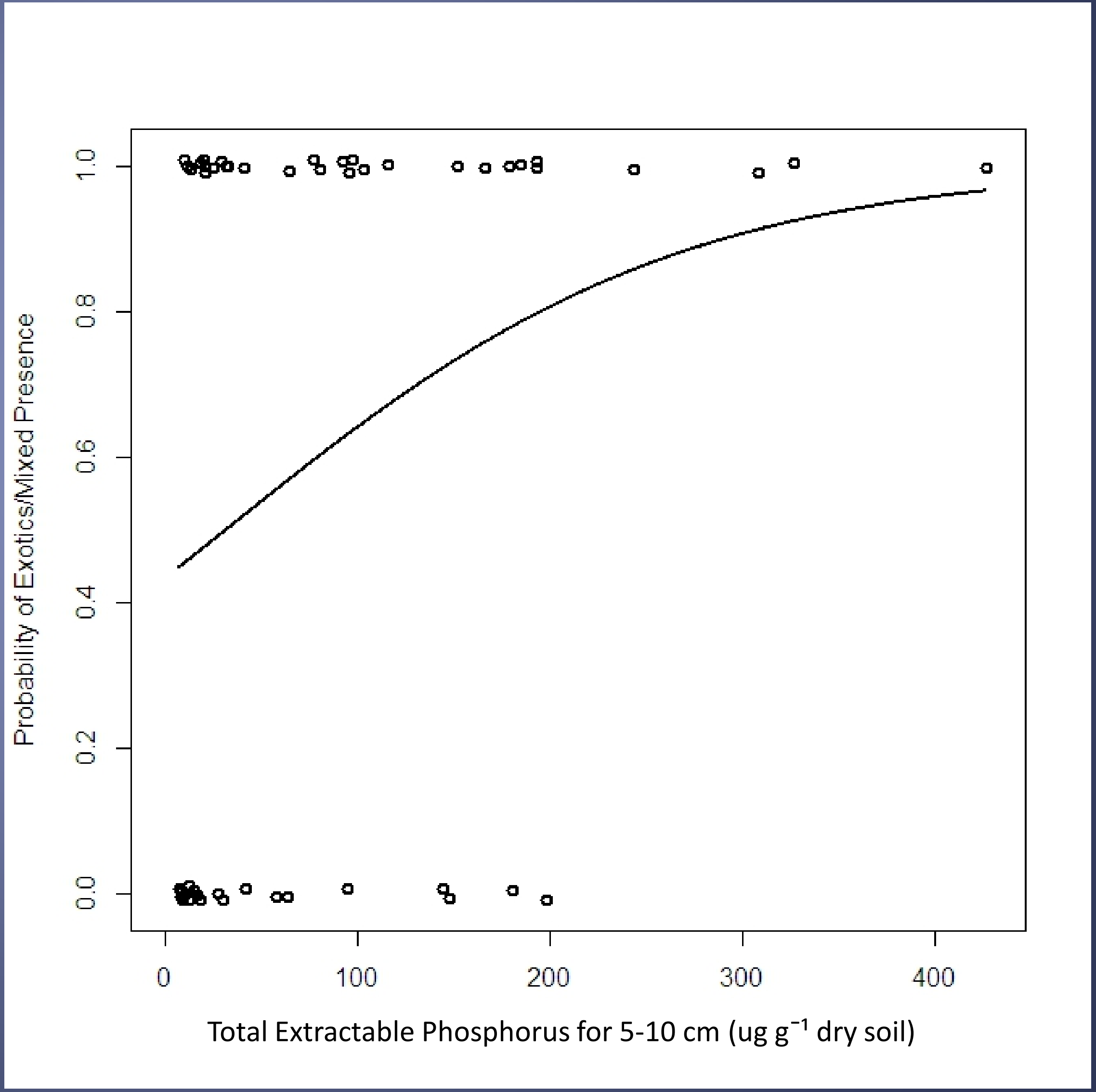
N = Native vegetation only (n = 11)
B = Unvegetated (n = 9)
E = Invasives only (Fanwort or Variable milfoil) (n = 24)
M = Mixture of both native and invasive plant species (n = 6)
E and M = A combination of the "E" and "M" categories above (Invasives only, along with a mixture of both native and invasive plant species (n = 30)

Logistic regression probability plot

- The output c-value = 0.714

- This signifies a fairly strong relationship

- ‘c’ can range from 0.5 to 1, where 0.5 corresponds to the model randomly predicting the response, and a value of 1.0 corresponds to the model perfectly discerning the response



Key Results and Conclusions

- Invasive plants were observed in all three impounded lakes, with variable milfoil (*Myriophyllum heterophyllum)* and *fanwort (Cabomba caroliniana)* the most common invasives. Two of the natural ponds were entirely free of all invasive plants.

- Total extractable P concentrations were found to vary significantly among soil types.

- Total extractable P concentrations were much greater in water bodies dominated by organic soils.

- Concentrations >200 $\mu g\ g^{-1}$ total extractable phosphorus showed a higher probability for an occurrence of aquatic invasive plants.

- Future research should test if 200 $\mu g\ g^{-1}$ is an important concentration for other invasive plants and subaqueous soil types.

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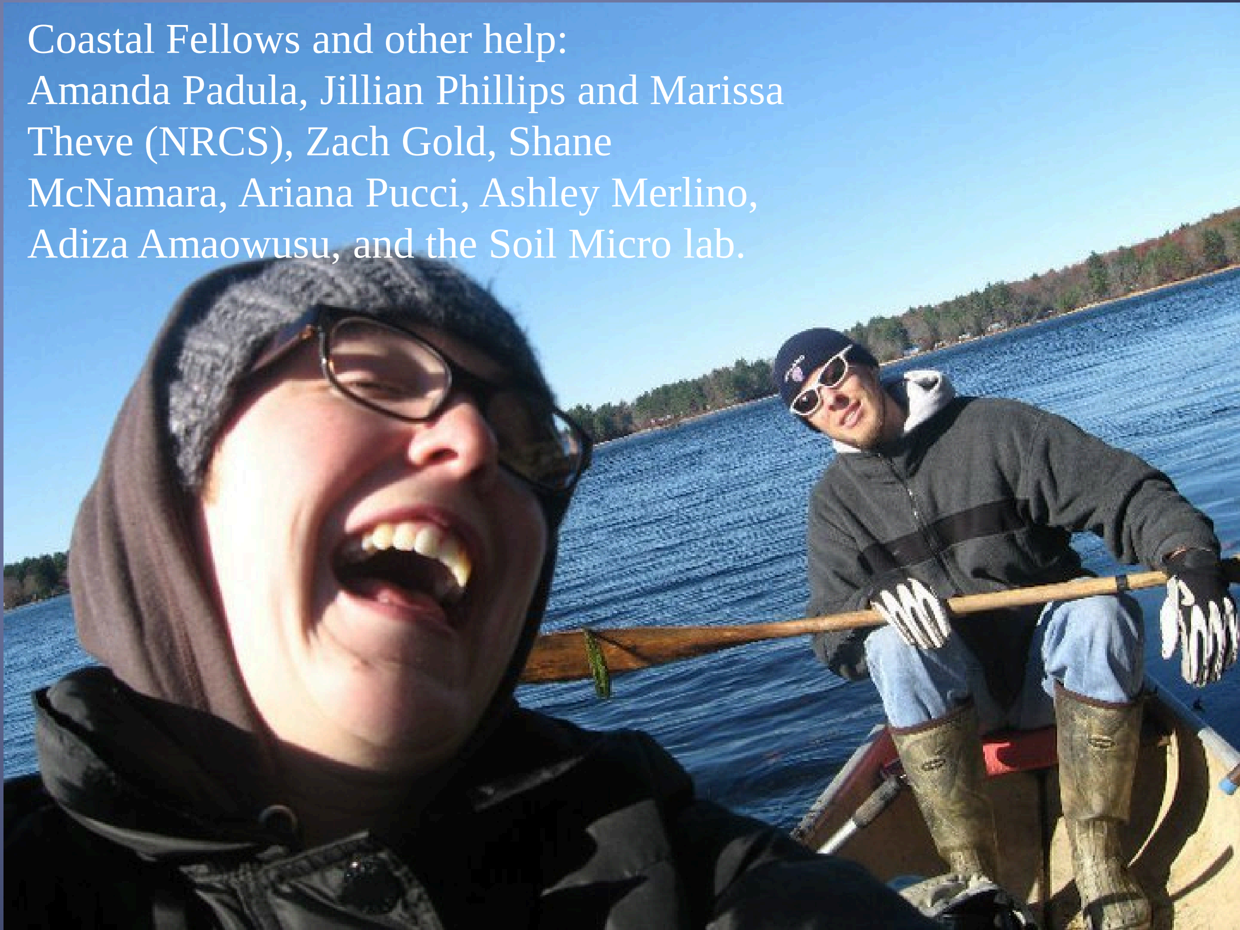


GUESS
WHO'S
OLDER
THAN
DIRT
daydream cakes

Happy Birthday Mark!!!


Questions?