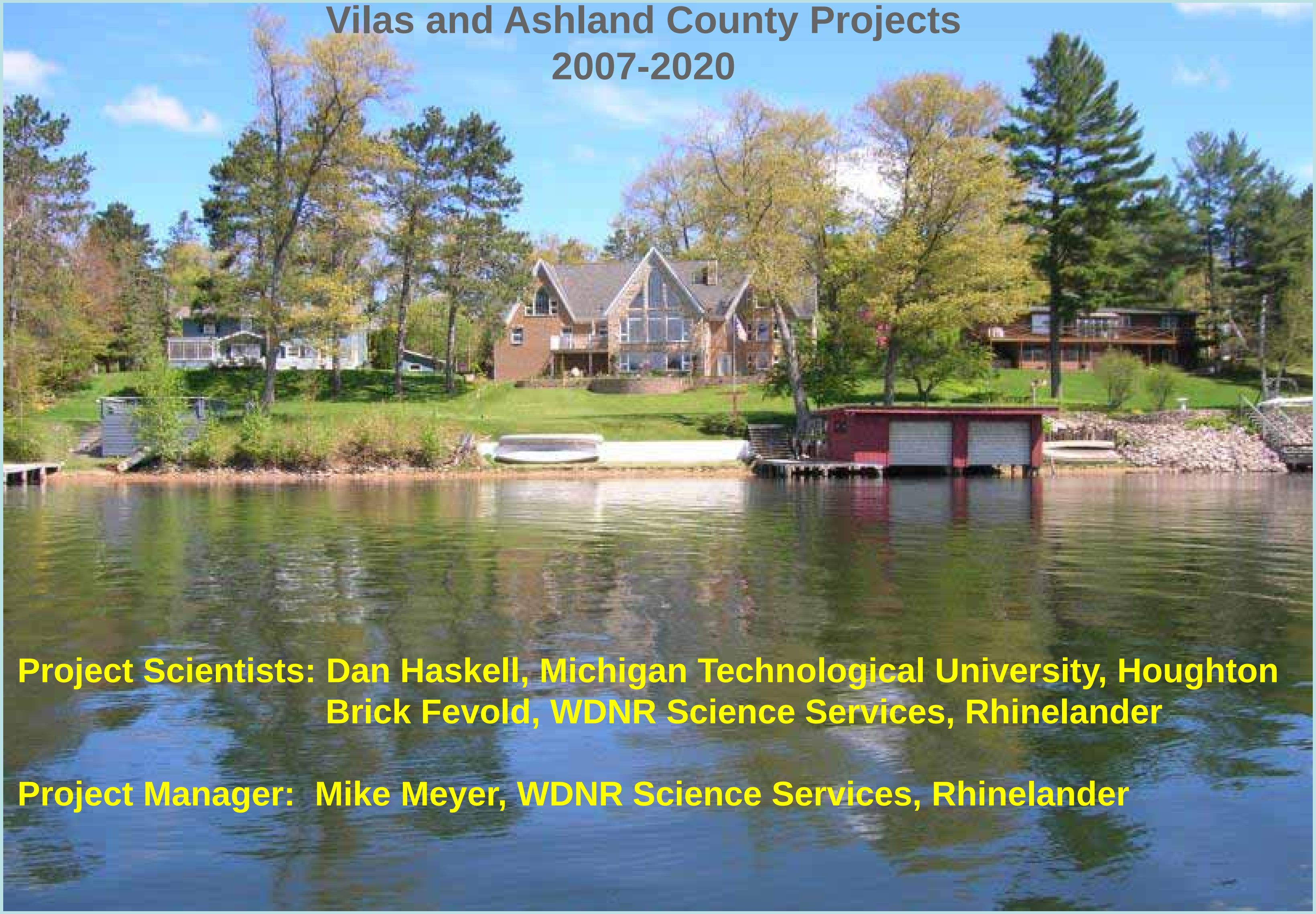
Quantifying the Ecological Benefits of Lakeshore Restoration in Wisconsin



Vilas and Ashland County Projects
2007-2020

Project Scientists: Dan Haskell, Michigan Technological University, Houghton
Brick Fevold, WDNR Science Services, Rhinelander

Project Manager: Mike Meyer, WDNR Science Services, Rhinelander

Photo by: D. Haskell

Research Findings (1990s)

Current Wisconsin Shoreland Management Rules (NR 115) do not protect critical fish and wildlife habitat –

Shoreline development densities (52 homes/mile) are too high!

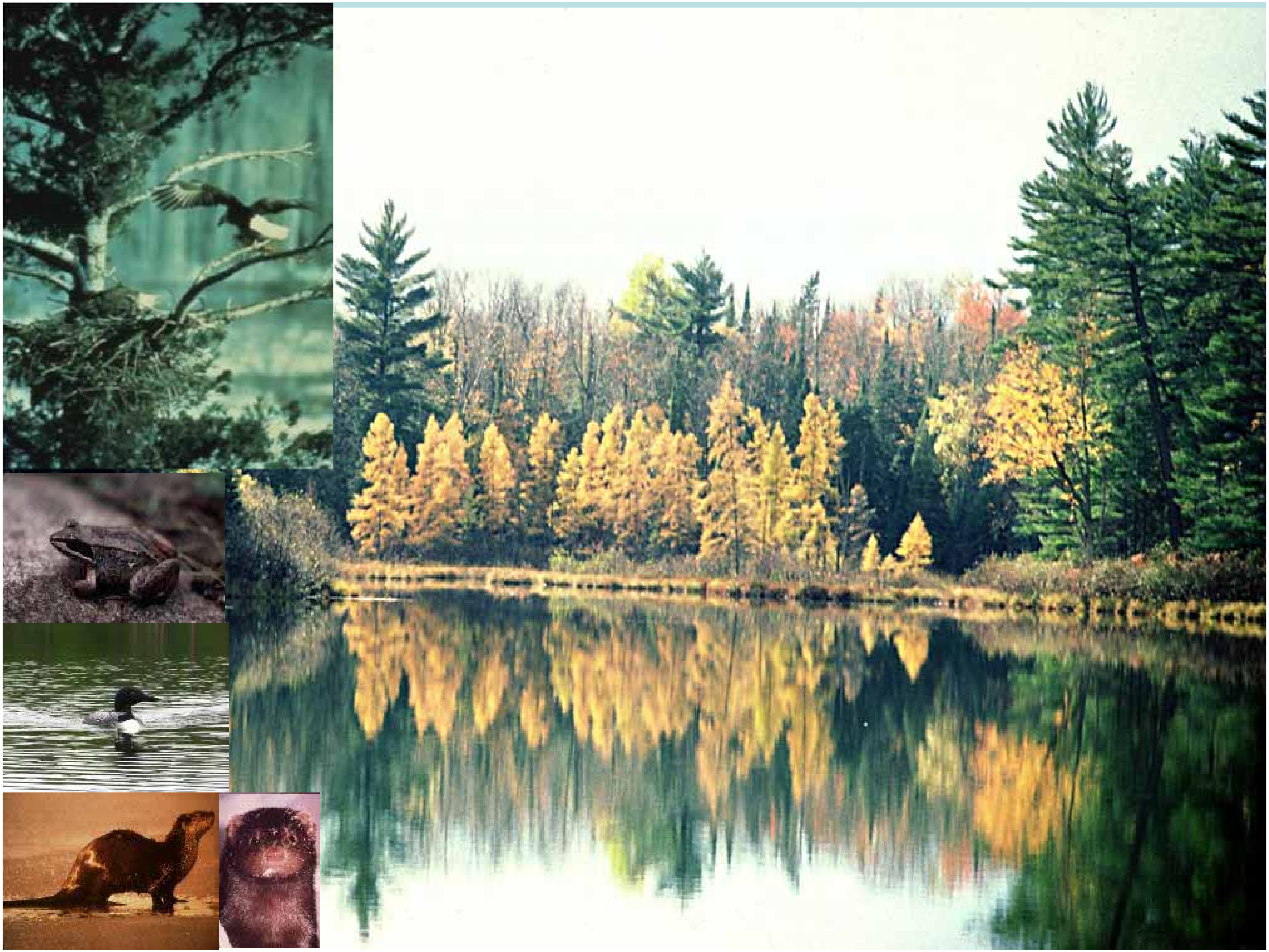


Photo by: D. Haskell

Shoreland plants trends

From: Elias, JE and Meyer, MW (2003) Wetlands 23: 800-816.

b) SHORELINE	Mean % Shoreline (2SE) Undeveloped	Developed
Trees**	38.8 (6.77)	29.5 (6.15)
Shrubs***	66.7 (6.98)	28.0 (6.62)

c) AQUATIC	Mean % Cover (2SE) Undeveloped	Developed
Floating**	15.7 (5.50)	5.8 (2.54)
Shrub	1.8 (2.34)	0.4 (0.50)
Narrow-leaved emergent	1.2 (1.17)	1.4 (1.14)
Broad-leaved emergent	0.9 (0.71)	1.6 (1.21)
Submergent	14.0 (5.85)	3.9 (2.21)
Isoetid	1.7 (1.16)	0.8 (0.81)
Unvegetated***	65.0 (7.48)	85.5 (3.73)

Table 1. Mean percent cover of vegetation and percent coniferous component and 2 standard errors (2SE) in structural layers in the upland (a), mean percent and 2 standard errors (2SE) of shoreline covered by overhanging trees and shrubs (b), and mean percent cover and 2 standard errors (2SE) of aquatic vegetation types (c) at undeveloped (reference) and developed sites, Vilas and Oneida Counties, Wisconsin, 1997. '**' and '***' indicate significance at $p < 0.01$ and $p < 0.001$, respectively, Mann-Whitney U tests.

a) UPLAND	Mean % Cover (2SE) (N = 84) Undeveloped	(N = 97) Developed
Canopy***	55.4 (5.30)	40.1 (4.94)
Subcanopy***	22.0 (3.93)	12.1 (2.60)
Understory***	34.5 (5.41)	17.4 (4.13)
Ground	66.4 (6.28)	63.0 (5.96)

Mean % Coniferous Component (2SE)

Table 2. Percent of undeveloped and developed sites showing relative amount of coarse woody debris in upland, shoreline, and shallow water transects, Vilas and Oneida Counties, Wisconsin, 1997. '***' indicates $p < 0.001$ for the chi-square test of independence.

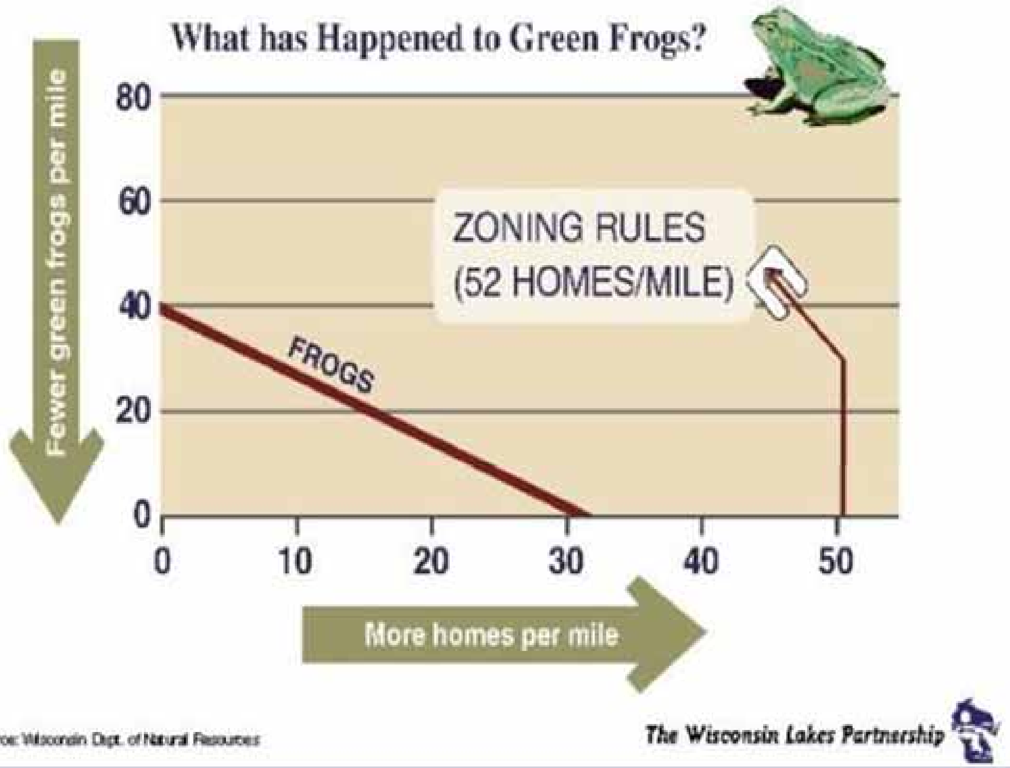
	% Transects With Coarse Woody Debris None	Sparse	Abundant
Upland***			
Undeveloped	1.2	24.1	74.7
Developed	60.0	29.5	10.5
Shoreline***			
Undeveloped	1.2	32.1	66.7
Developed	54.2	31.2	14.6
Shallow water***			
Undeveloped	7.6	26.6	65.8
Developed	58.3	24.0	17.7

From: Woodford, JE and Meyer, MW (20
Biological Conservation. 110(2):277-284.

Table 2
A comparison of lake attributes (physical characteristics), house and cottage density, green frog abundance, habitat fragmentation, and amphibian species richness among 12 developed and 12 undeveloped lakes in northern Wisconsin

	Developed lakes ($n = 12$)	Undeveloped lakes ($n = 12$)	Paired t-test ($t =$)	P-value
Lake area (ha)	46.7 (range = 11.2–160.0)	46.5 (range = 6.4–144.8)	0.09	NS
PH	6.8 (range = 5.3–7.8)	6.8 (range = 5.7–7.5)	0.21	NS
Alkalinity (ppm)	11.5 (range = 1.0–48.0)	13.1 (range = 1.0–57.0)	0.08	NS
Total shoreline perimeter sampled (km)	43.3	44.9	0.51	NS
House or cottage density (per 100 m of shoreline)	1.3 (0.48)	0.179(0.24)	8.56	<0.001
Green frog population (per 100 m of shoreline)	1.82 (1.66)	2.3 (2.06)	2.77	0.02
Suitable habitat (%)	0.66 (0.23)	0.82 (0.20)	2.83	<0.02
Green frog population (per 100 m of habitat)	1.49 (1.03)	2.60 (1.92)	2.24	<0.05
Habitat fragmentation D (ln$D$)	23.42 (1.77)	22.24 (2.66)	2.47	<0.05
Amphibian species richness	5.08 (1.44)	5.08 (1.16)	0.01	NS

NS = not significant.



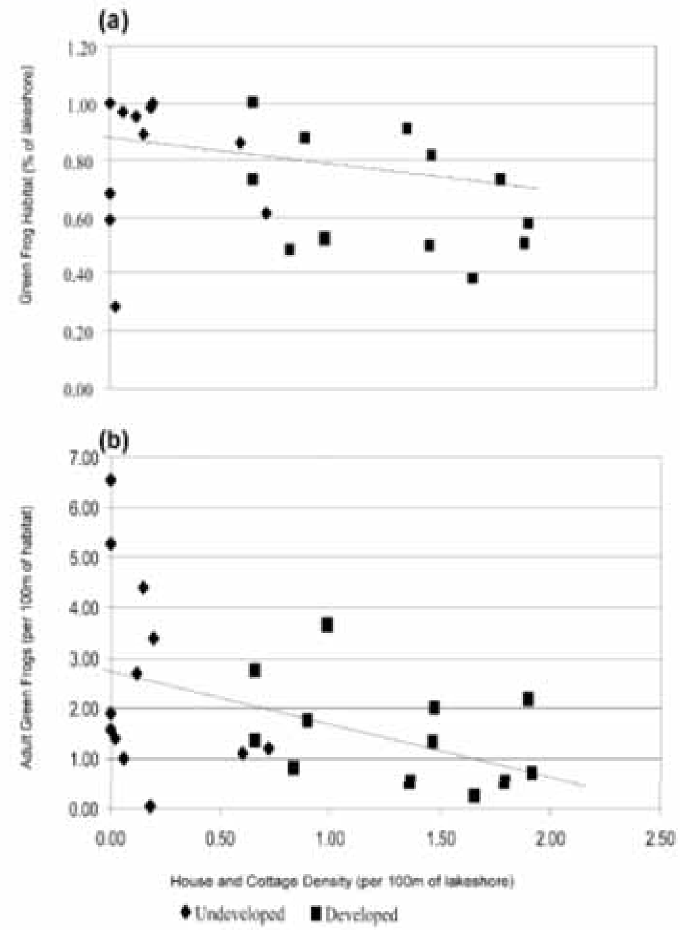


Fig. 3. "Best fit" models from linear regression for decreasing (a) green frog habitat ($y = -0.14x + 0.845$; $P < 0.05$) and (b) adult abundance ($y = -1.08x + 2.838$; $P < 0.05$) at developed and undeveloped lakes as shoreline house and cottage density increased.

Shoreland bird trends

From: Lindsay, AR et al. (2002) Biological Conservation 107: 1-11.

Several species showed significant associations with developed or undeveloped lakes. The American crow *Corvus brachyrhynchos*, American goldfinch *Carduelis tristis*, American robin *Turdus migratorius*, eastern phoebe *Sayornis phoebe*, great crested flycatcher *Myiarchus crinitis*, Baltimore oriole *Icterus galbula* and red-winged blackbird *Agelaius phoeniceus* were all associated with developed lakes ($P < 0.05$; G-test). The black-and-white warbler *Mniotilta varia*, black-throated blue warbler *Dendroica caerulescens*, common loon *Gavia immer*, golden-crowned kinglet *Regulus satrapa*, hermit thrush *Catharus guttatus*, ruffed grouse *Bonasa umbellus* and the warbling vireo *Vireo gilvus* were associated with undeveloped lakes ($P < 0.05$; G-test). Several

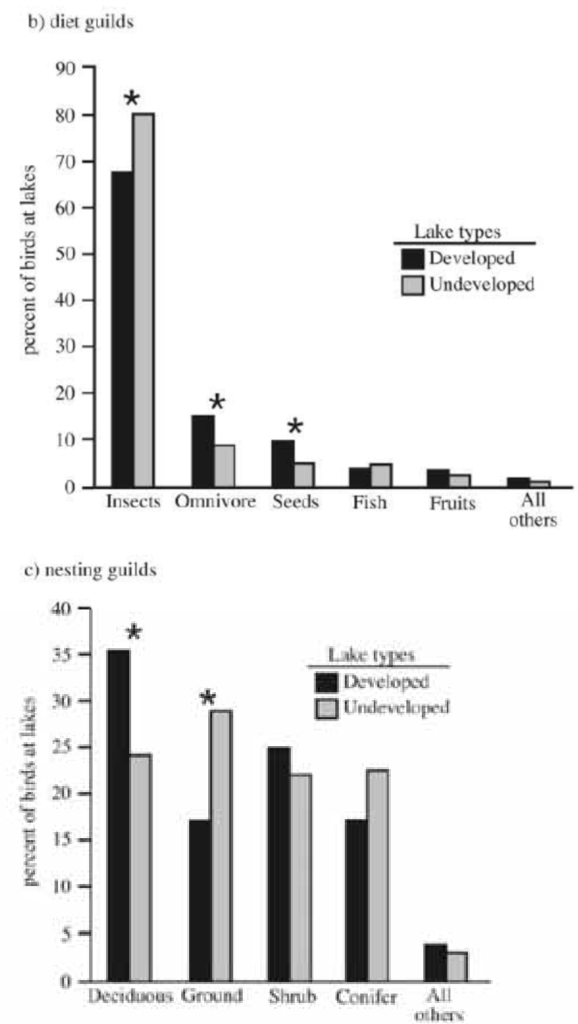
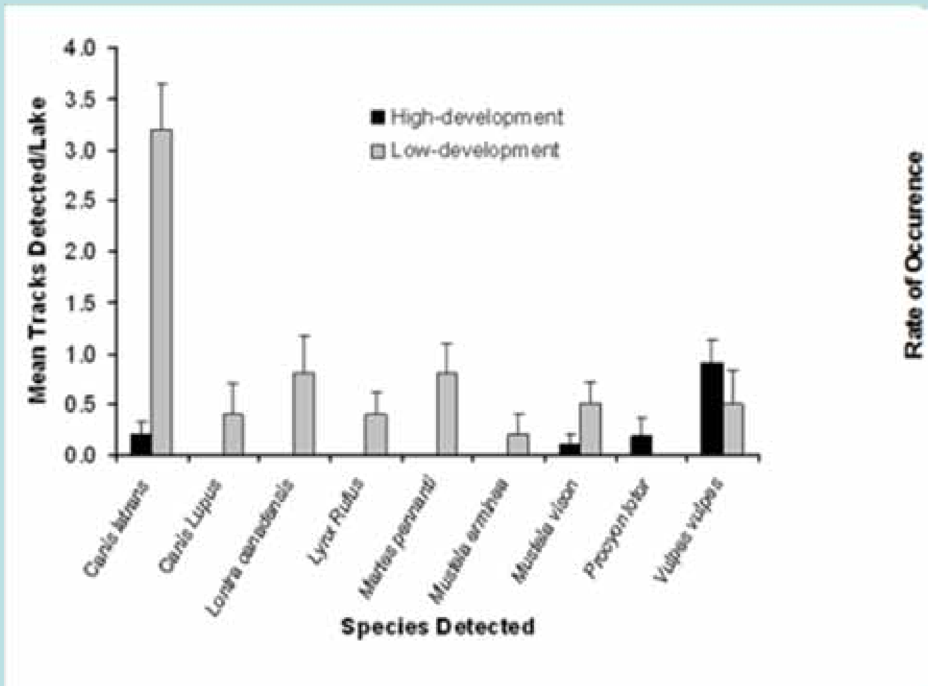


Fig. 2. Compositions of each of the three resource guild classes [(a) foraging guilds, (b) diet guilds, (c) nesting guilds] observed on developed and undeveloped lakes. Values given are the percentages of each guild within the resource guild class across all developed or undeveloped lakes. Light bars are values for undeveloped lakes, dark bars are for developed lakes.

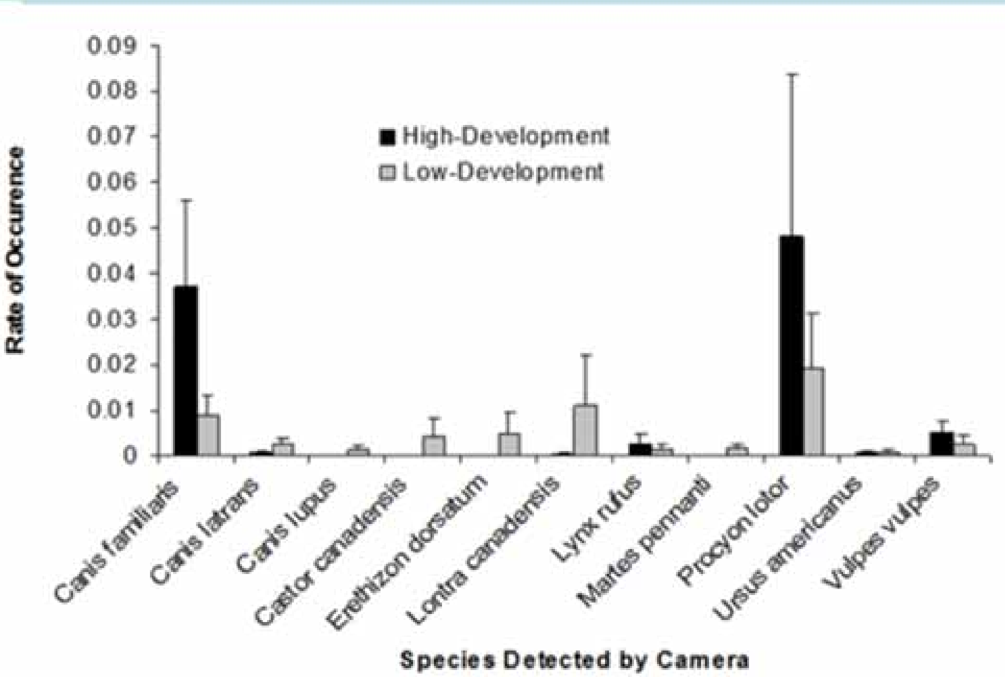
Relationship between Carnivore Distribution and Landscape Features in the Northern Highlands Ecological Landscape of Wisconsin.

From: Haskell et al. 2012. American Midland Naturalist.

Snow Tracks



Camera



Our results suggest that a higher diversity of carnivores (P = 0.006) were present on low-development lakes Coyotes (Canis latrans) were detected most frequently (n = 34) especially on low-development lakes. Fishers (Martes pennanti), wolves (Canis lupus), bobcats (Lynx rufus), and northern river otters (Lontra canadensis) were exclusively detected on low-development lakes by snow track surveys. Raccoons (Procyon lotor) and red fox (Vulpus vulpus) detection was greater on higher-development lakes than low-development lakes.

White-tailed deer much more abundant on developed lakes
Supplemental feeding by property owners, no hunting

Because feed sites attract deer into tight densities, natural nearby browse is often depleted.

What is Shoreland Restoration?

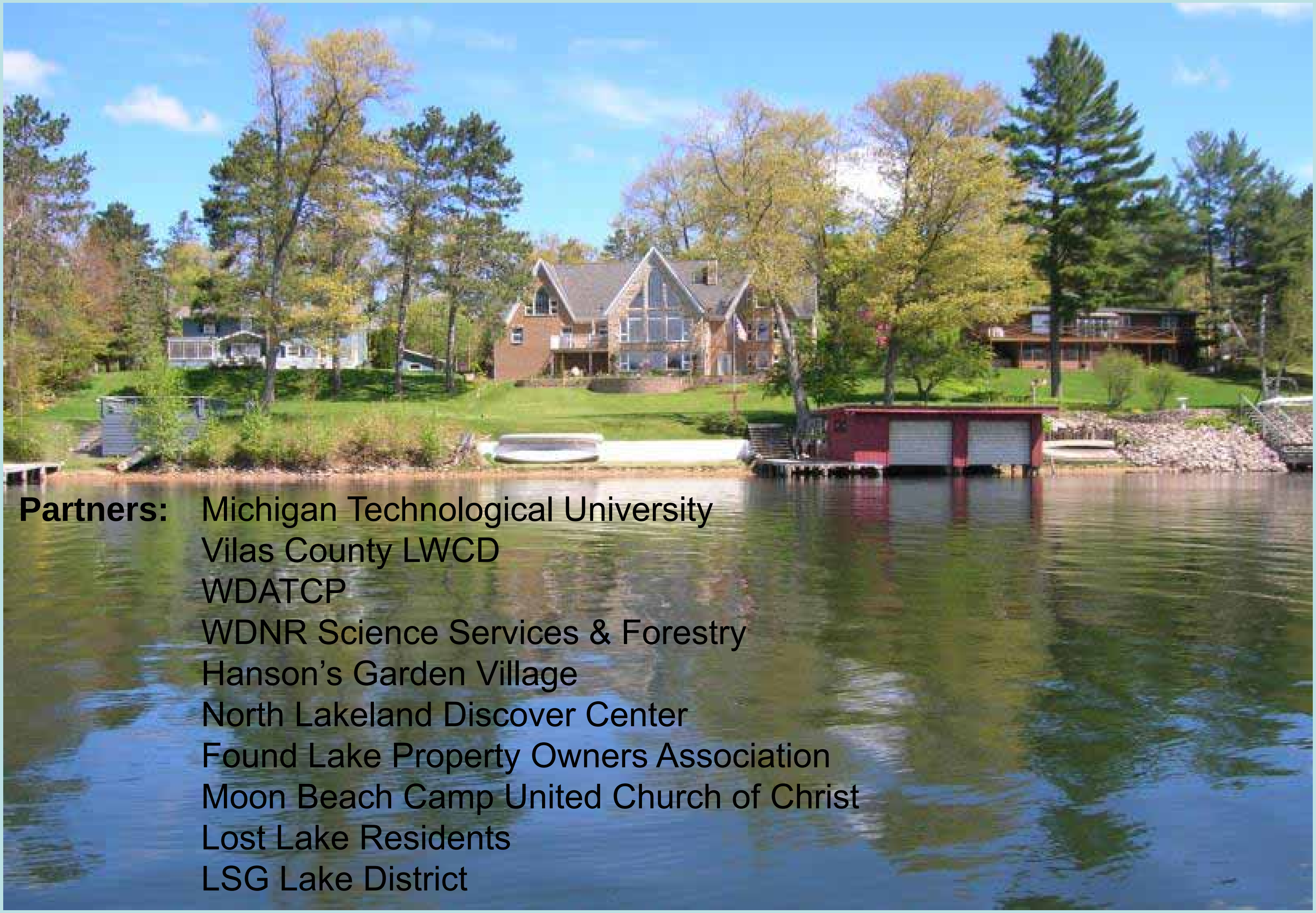
Shoreland Restoration is a lake management practice that uses native trees, shrubs, and groundcover, along with natural and biodegradable materials (biologs, delta-lock bags, sediment logs, soil lifts, woody material), to reduce lakeshore erosion and improve aquatic and wildlife habitat quality.

Measures of Success

Shoreland Restoration will be considered a successful management practice if it:

- Increases native plant abundance and diversity
- Improves wildlife habitat quality
- Increases wildlife abundance and diversity
- Reduces surface water and nutrient run-off

Measurements of Lakeshore Habitat Restoration in Vilas County: Preliminary Findings 2007-2012



Partners: Michigan Technological University
Vilas County LWCD
WDATCP
WDNR Science Services & Forestry
Hanson’s Garden Village
North Lakeland Discover Center
Found Lake Property Owners Association
Moon Beach Camp United Church of Christ
Lost Lake Residents
LSG Lake District

Photo by: D. Haskell

Five Paired Lakes Sampled in 2007-2012

High-Development:
- ***Found***
- Moon
- Lost
- LSG
- Crystal

Low-Development:
- Escanaba
- Jag
- White Sand
- Star
- Starrett

Lakes were paired by:
- Surface size
- Water Chemistry
- Lake Type (drainage, seepage, spring)
- Substrate

1999 Storm: Found Lake


Photo by: D. Kloepfer

Removal of DWM

Results from Strom Event & Human Activity

- Open canopy layer and understory vegetation die off
- Erosion proceeded to occur
- Residents failed at veg. re-establishment
- Enrolled in restoration project

Photos by Dan Haskell

Photo by Dan Haskell

Woody Material Test Plots

Photos by Dan Haskell

Benefits of Downed Woody Material (DWM)

- DWM important component to ecosystems.
- Influence soil and sediment flow.
- Energy flow & nutrient cycling.
- Provides nursery sites for plants.
- Provides organic matter to soil.
- Creates microclimates.
- Influences interactions between terrestrial & aquatic systems.
- Critical habitat for variety of wildlife.
- Fungi use as nutrient source.

(Harmon *et al.* 1986)

Plants in Test Plots

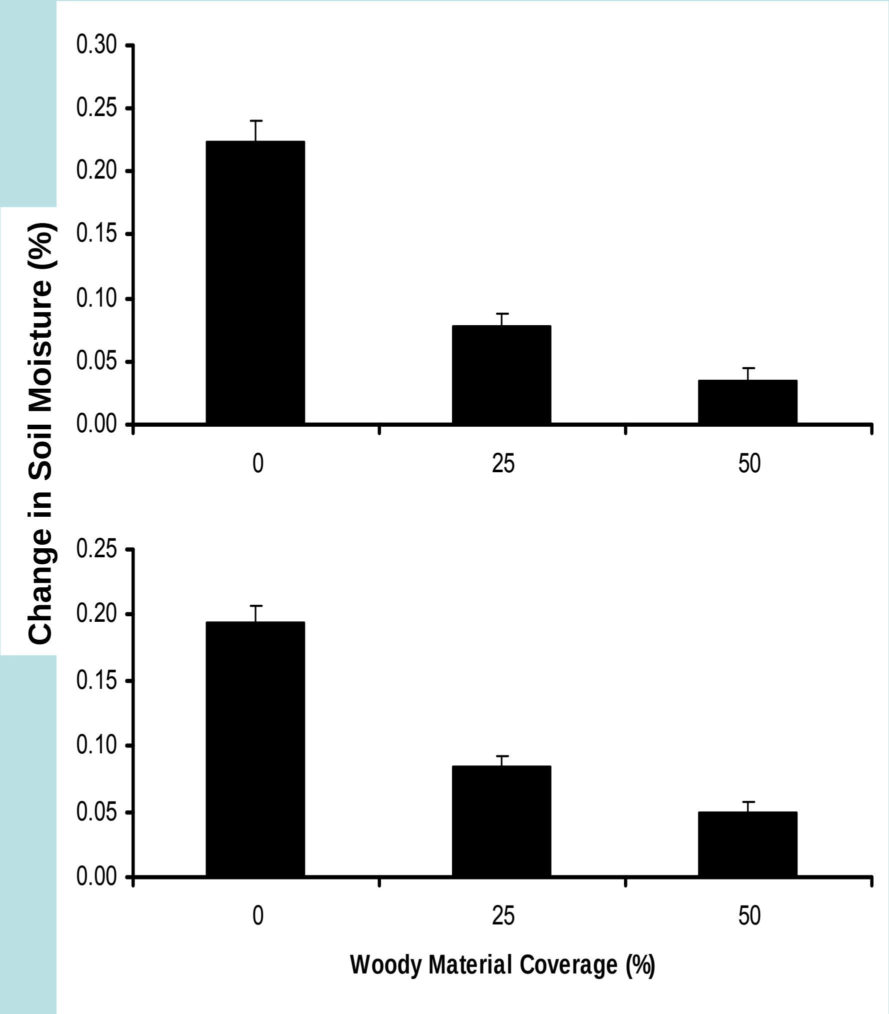
- **Three Shrubs: *(n = 90)***
  - One Snowberry (*Symphoricarpos albus)*
  - Two Sweet Fern (*Comptonia peregrine*)
- **25 forbs & grass: (*n =750)***
  - Little-blue stem (*Schizachyrium scoparium*)
  - Barren's strawberry (*Waldstenia fragaroides*),
  - Pearly everlasting (*Anaphalis margaritacea*)
  - Bergamot (*Monarda fistulosa*)
  - Big-leaf aster (*Aster marcophyllus*)

Photo by Dan Haskell

2008 Soil Moisture Results

- **July:** *n* = 25/treatment
- 0% DWM plots had higher % change in moisture.
- (P = **<0.001**)

- **August:** *n* = 34/treatment
- 0% DWM plots had higher % change in moisture.
- (P = **<0.001**)

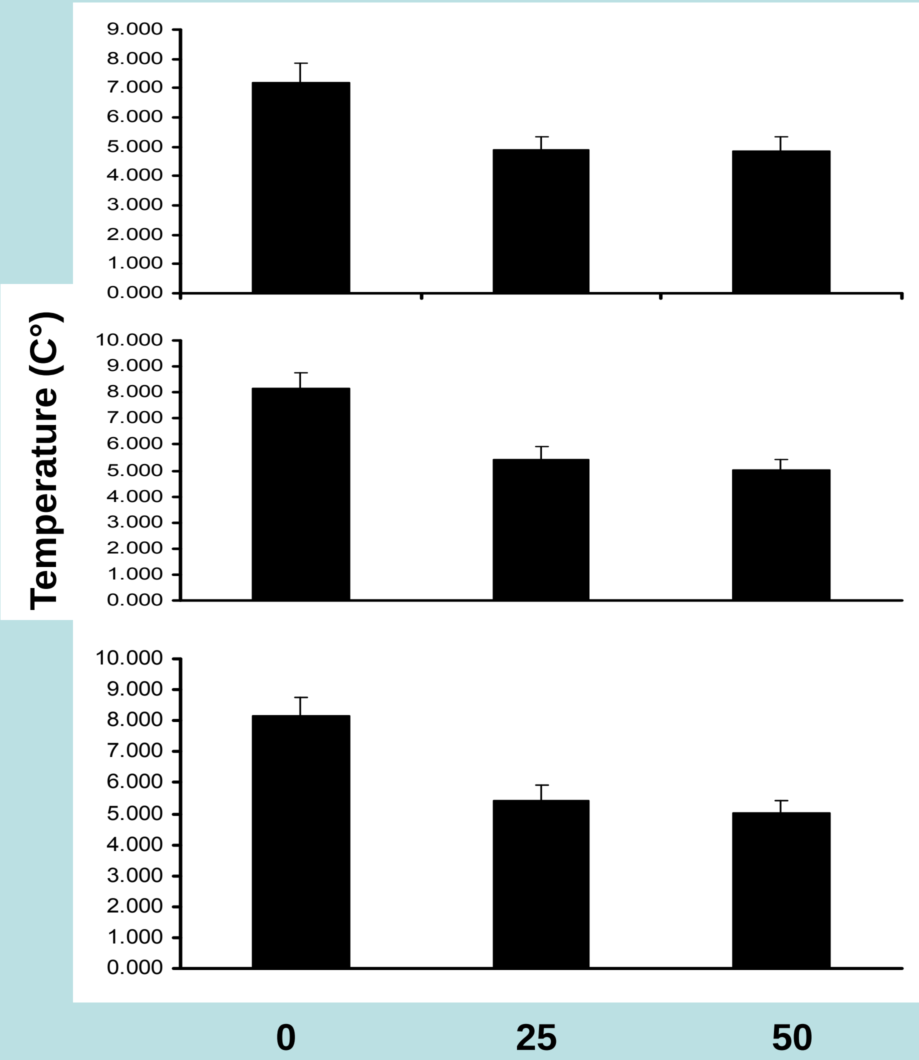


Difference Between High & Low Soil Temp

- **June:** 0% DWM plots had a greater difference in temp. (*P* = **0.005**)

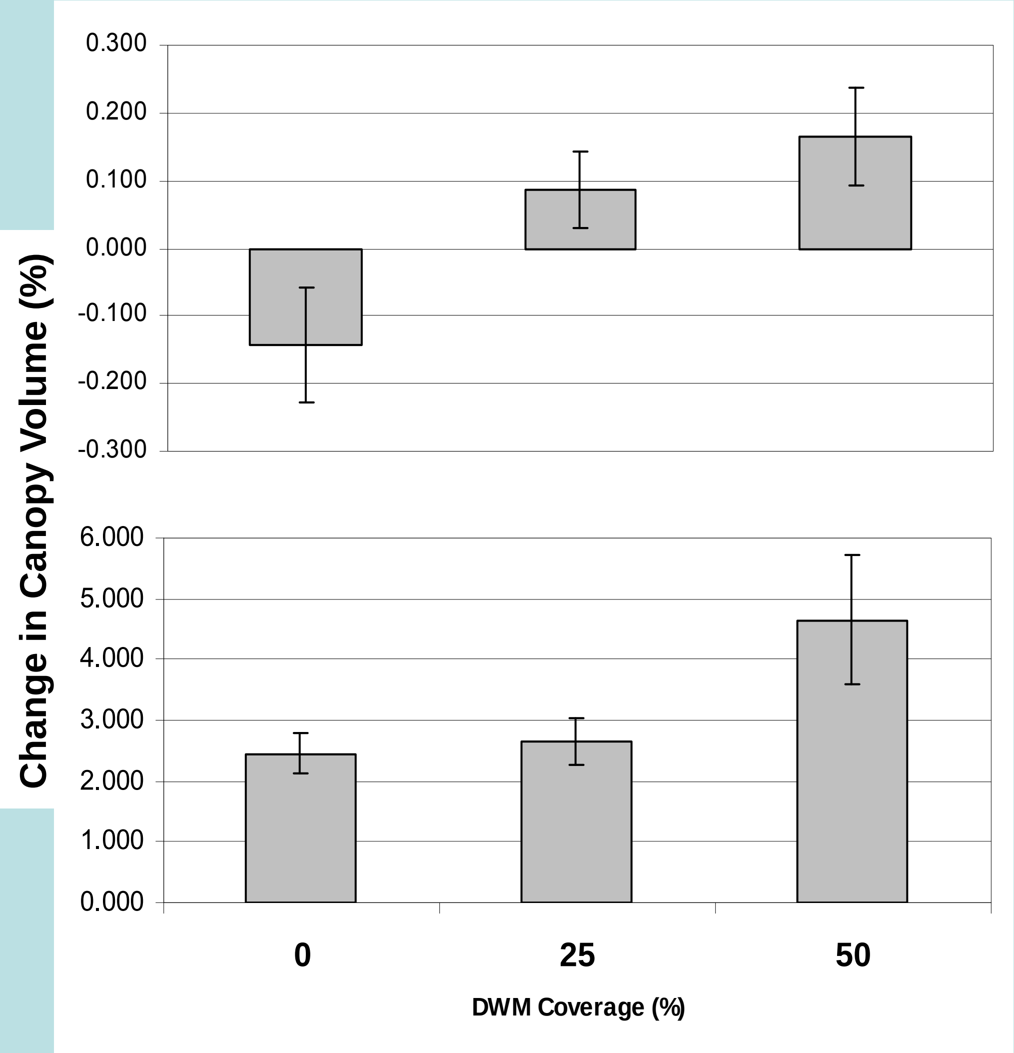
- **July:** 0% DWM plots had a greater difference in temp. (*P* = **<0.001**)

- **August:** 0% DWM plots had a greater difference in temp. (*P* = **<0.001**)



Shrub Change in Canopy Volume (%)

- **Snowberry:** negative growth in 0% DWM (*P* = **0.015**)
- **Sweet Fern:** no significant difference (*P* = 0.264)



Discussion

- DWM lessened daily variation in soil temp and moisture.
- DWM improved growth of snowberry shrubs & barren strawberry.
- No difference in plant survival among plots.
- **WOOD IS GOOD.**

Gravel Culture vs. Potted Shrubs & Trees

Gravel Culture Shrubs & Trees

Potted Shrubs & Trees

Gravel Culture Shrub & Trees

- This technique is relatively new and provides bare root plant stock to restoration projects throughout the planting season.
- Cost approximately half to ¾ of the price of traditional container plants.

Gravel Culture Results

- Six species of shrubs
- 100 % first year survival
- No significant difference in growth between all GC and CT shrubs (*P* = 0.682)
- A paired *t* – test between GC and CT revealed a significant difference for two shrub species, common ninebark (*Physocarpus opulifolius*) (*P* = 0.044) and snowberry (*Symphoricarpos Albus) (P* = 0.039)
- Common ninebark CT had a four times higher percent change in canopy volume (Mean = 2.457 ± 0.678) compared to GC shrubs (mean = 0.604 ± 0.345).
- Snowberry GC grew three times more (mean = 0.278 ± 0.0953) than the CT shrubs (mean = 0.097 ± 0.084).

Bioengineering Techniques

Erosion Control

- Biologs
- EnvorLok Bags™
- Coconut Erosion Mat
- Sediment Logs
- Tree Drops
- Water Retention Ponds (Rain Gardens)

Before & After

Installation of Bio-Logs

Photos by: D. Haskell

Bio-logs One Year Later

Before EnviroLok™ Bags

Photo by D. Haskell

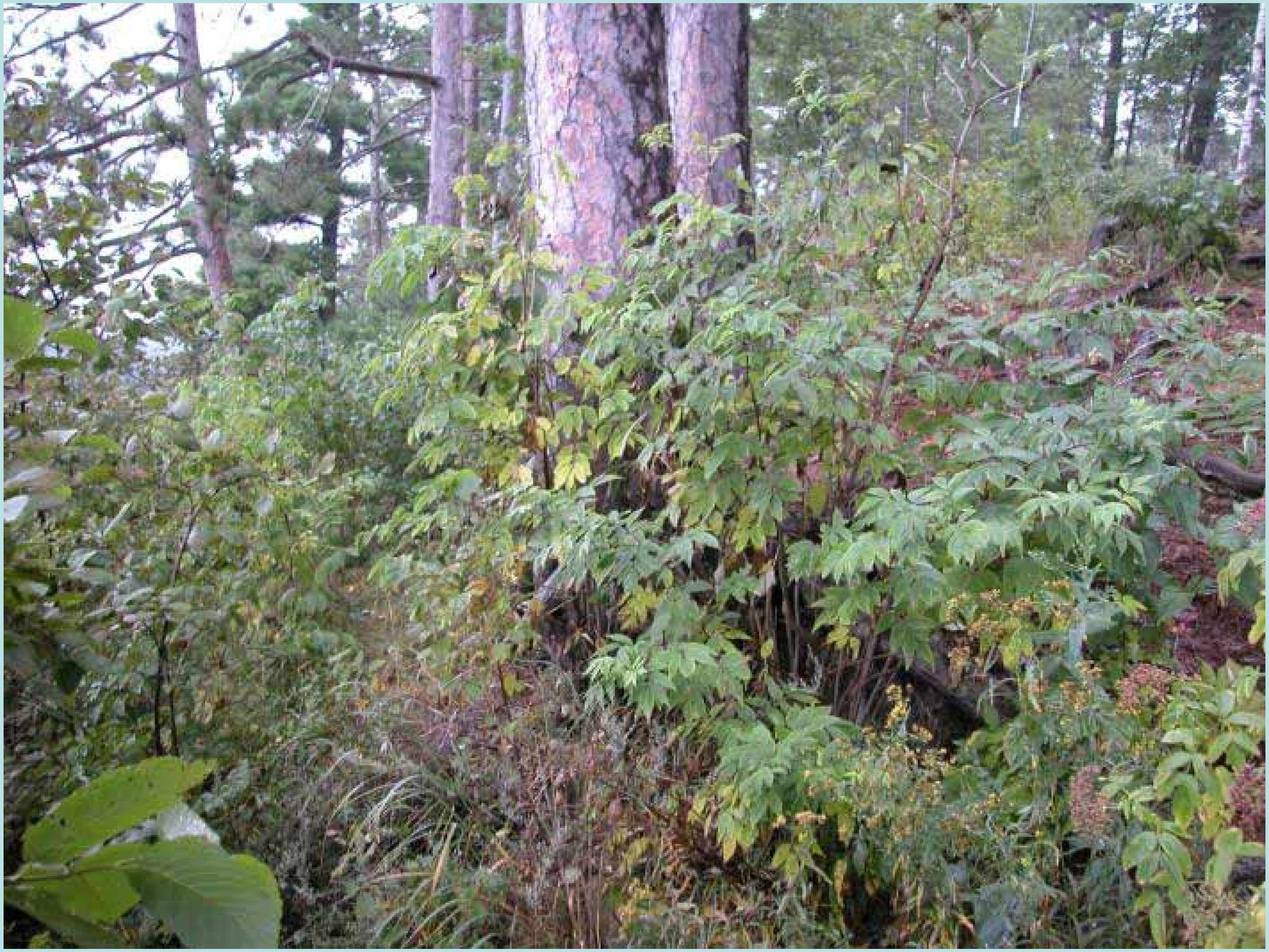
After EnviroLok™ Bags

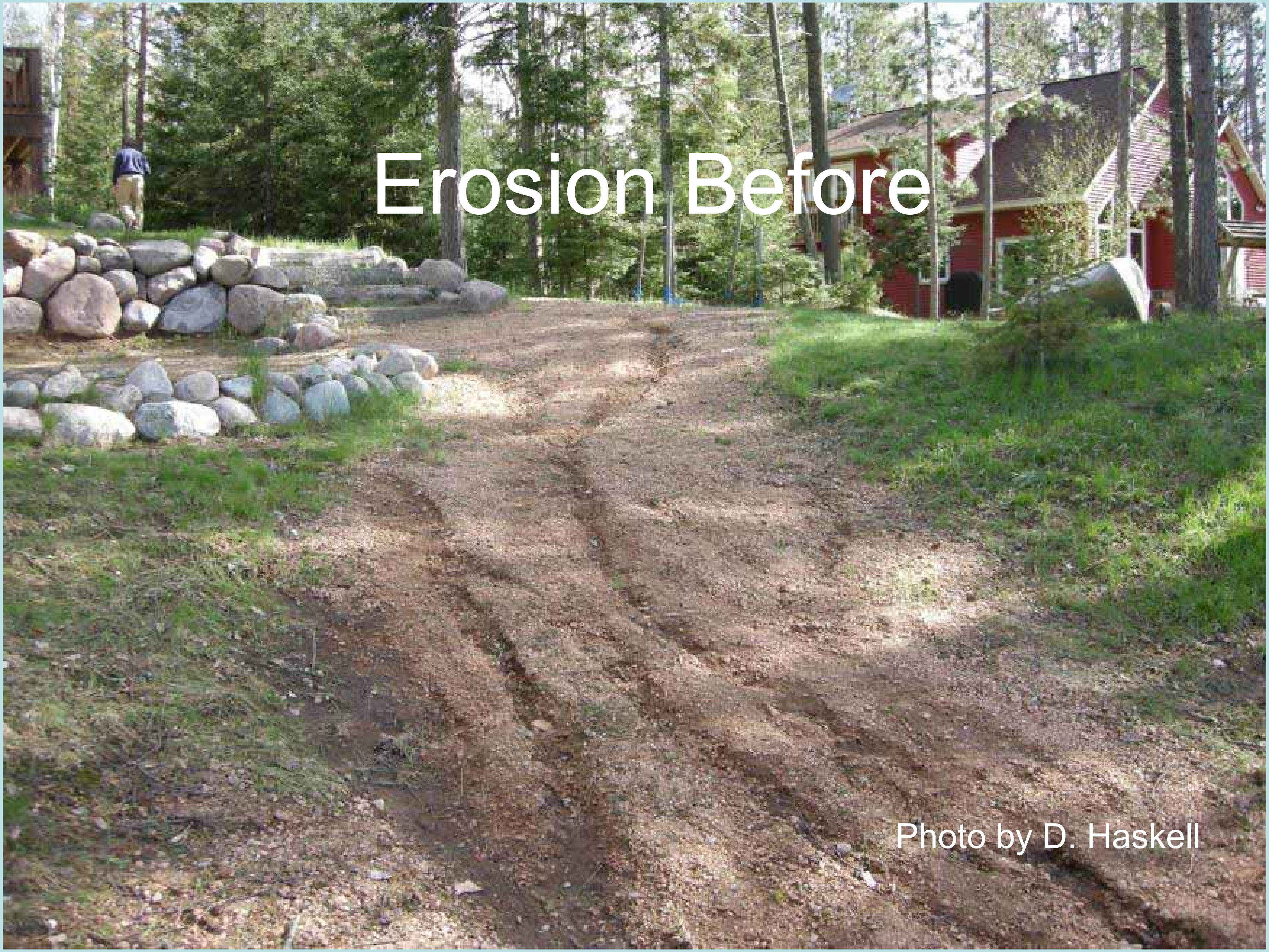
Photo by D. Haskell

EnviroLok™ Bags

Figure 1. Photos A & B: before EnviroLok™ bags were installed. Photos C & D: after EnviroLok™ were installed on Moon Beach during the spring and summer of 2009.

EnviroLok™ Bags 2011




Erosion Before
Photo by D. Haskell


Erosion After

Results From Restoration Efforts

- 26 private properties on Found, Moon, Lost, LSG Lakes
- ≈17,000 m^2
- ≈40,000 ground cover plants (100 spp.)
- ≈8,000 shrubs (30 spp.)
- ≈800 trees(20 spp.)
- ≈15,000 m of fence (deer exclosure)

Photo by Dan Haskell

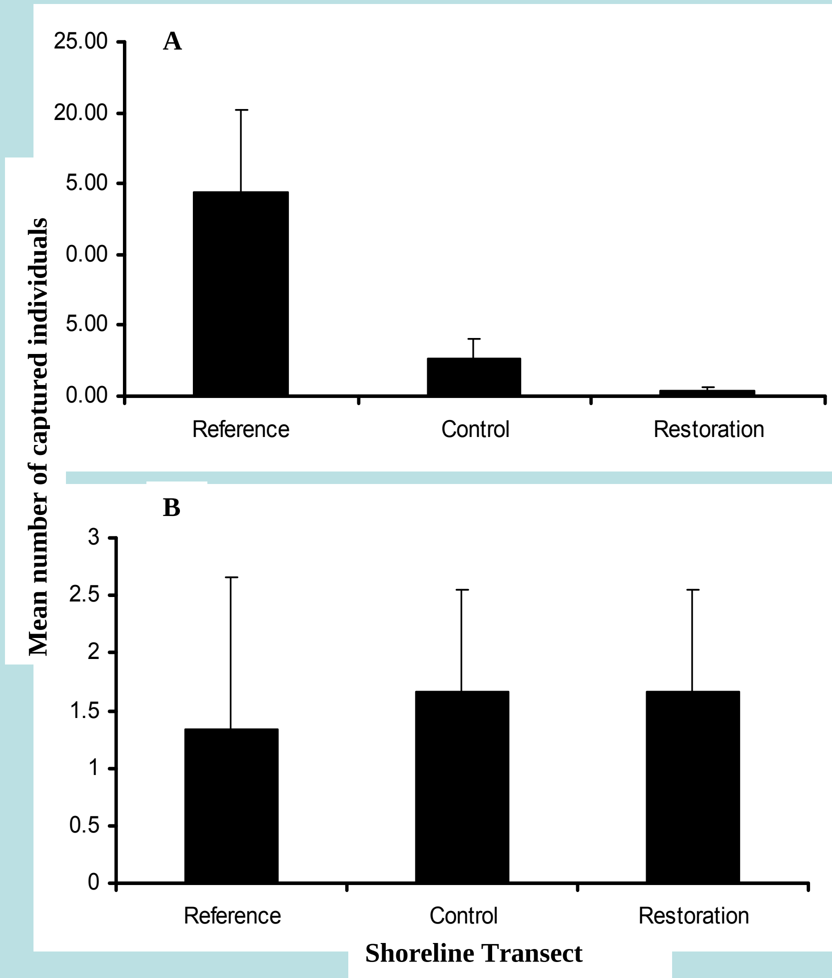
Wildlife monitoring: Small Mammals

Photo by D. Haskell

Peromyscus Spp.

- Deer mice abundance was negatively correlated with human development in central Ontario, Canada (Racey & Euler 1982)
- Historically, white-footed mouse were found in the southern three quarters of the state with a preference for deciduous forests (Jackson 1961)
- Currently, it may be moving slowly northward with the habitat alterations, climate change, and/or forest management practices
- White-footed mouse are associated with habitat fragmentation in the eastern United States and are hypothesized to be important ecological drivers of human TBID risks

Results *Peromyscus Spp.*



Deer Mouse
(*Peromyscus maniculatus)*

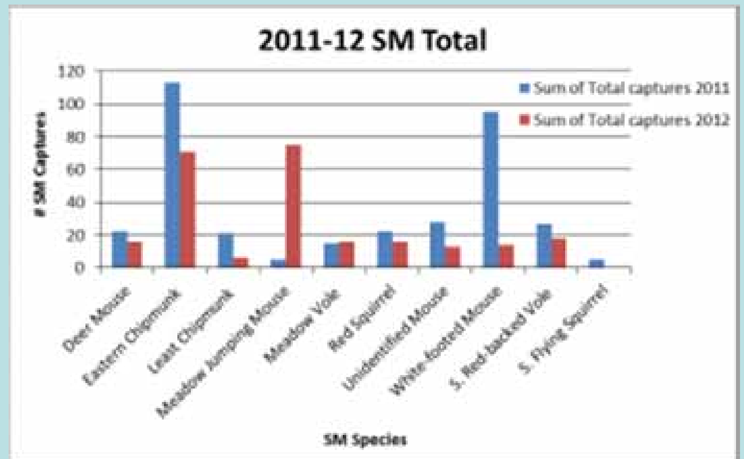
White-footed Mouse
(*Peromyscus leucopus)*

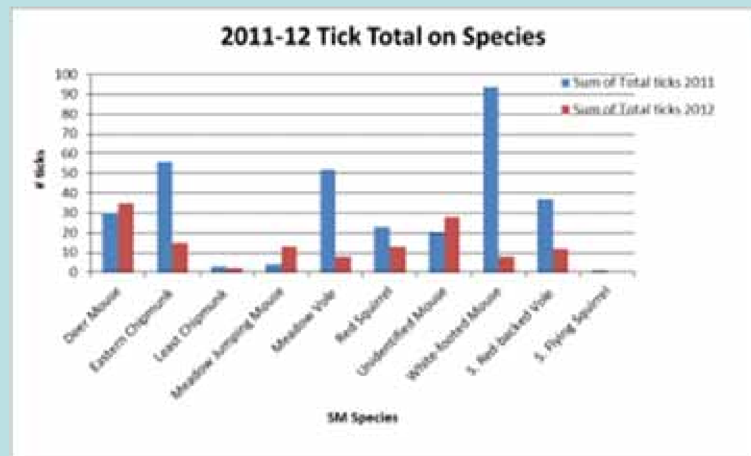
Means and standard errors of deer mouse (*Peromyscus maniculatus)* (A) and white-footed mice (*Peromyscus leucopus*) (B) captured on three matched lakes in Vilas County, Wisconsin in 2008.

Ticks and Lyme Disease

Results of SM 2011-12

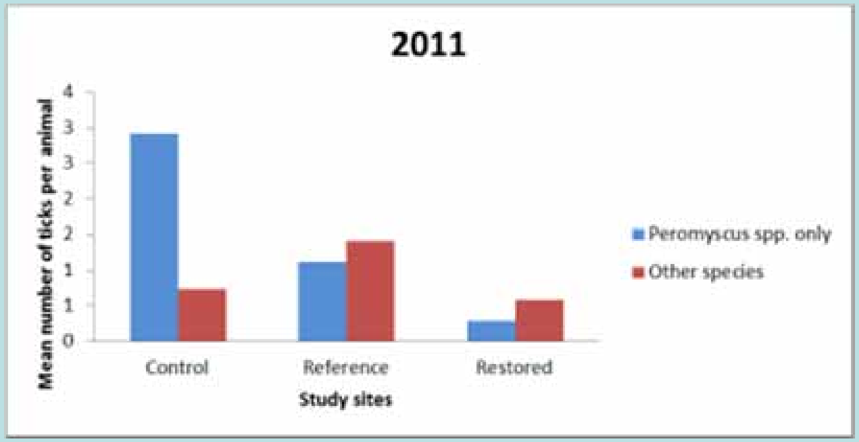
- 2011Total SM Capture 353
- 2012 Total SM Capture 245
- 2011 Total Ticks Collected 320
- 2012 Total Ticks Collected 134

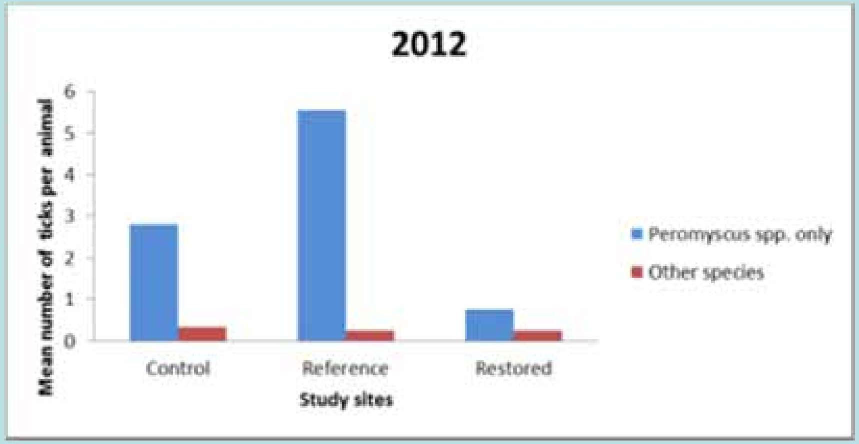




Mean Number of Ticks/SM 2011-12

- SM captured on restored may have lower risk TBID compared to the control sites and overall were infested with lower abundances of ticks
- These observations suggest there may be higher risks of TBIDs at high-developed lakes
- Lakeshore restoration may somehow mitigate these risks
- Efforts are underway to investigate these possibilities further





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MTU Graduates & Under Graduates Students
The Residents of Found, Lost, Moon, LSG Lakes
UW-Trout & Kemp Research Stations
Trout Lake WDNR Forestry Headquarters
Marshfield Clinic Research Foundation

Great Lakes RESTORATION

WISCONSIN DEPT. OF NATURAL RESOURCES

Brick M. Fevold

WDNR, NR Research Scientist & Project Leader

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Dan Haskell

MTU, Applied Scientist & Collaborator

USEPA & USFS Great Lakes Restoration Initiative Program

Ashland Chequamegon Bay Shoreland Restoration Project

Evaluating the Ecological Benefits of Shoreland Restoration Along an Urban Waterfront

Ashland WISCONSIN

NORTHLAND COLLEGE

UW Extension

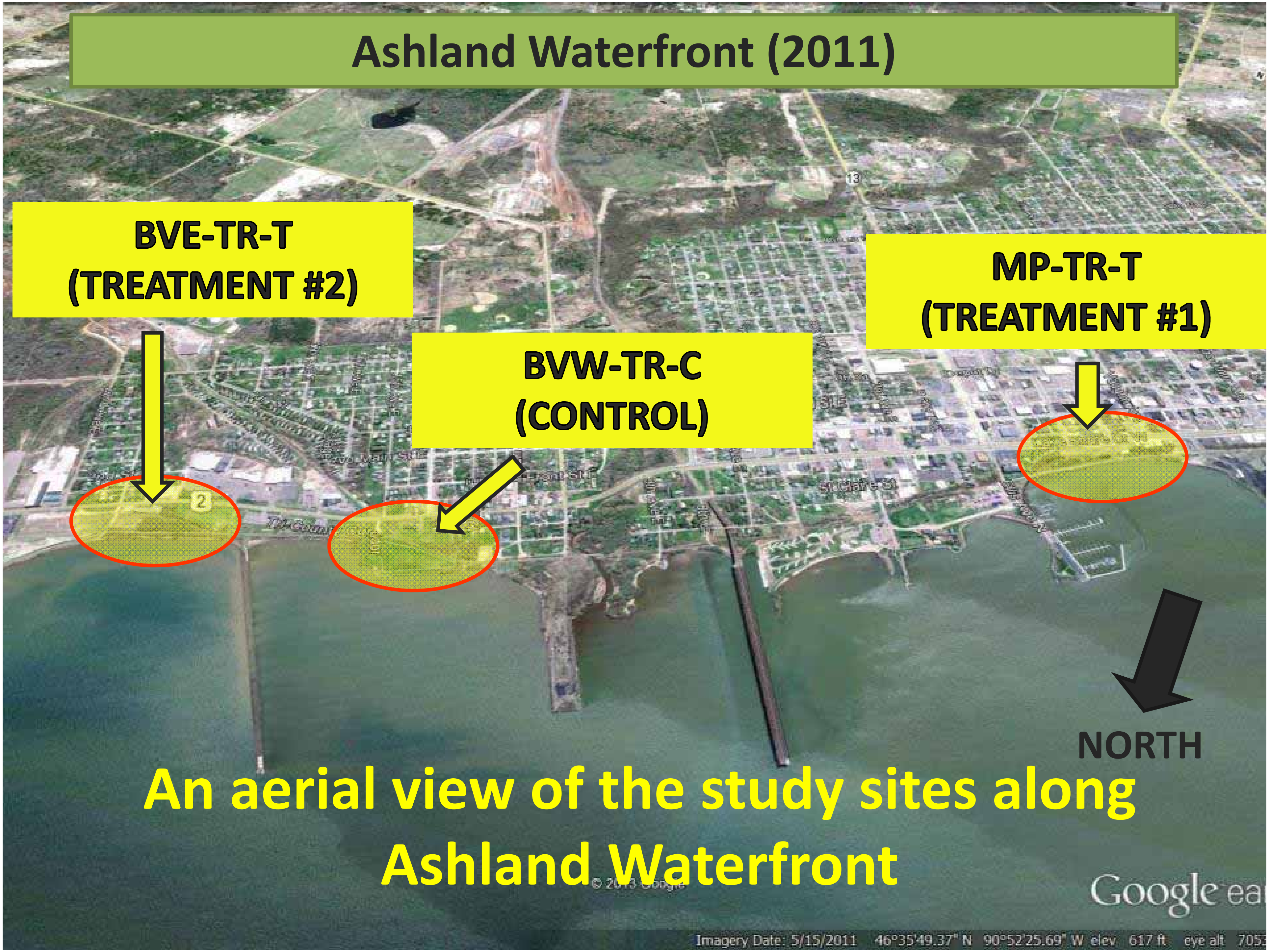
Michigan Tech

Measuring Restoration Success

Significant increase over time in:
(<u>relative to control</u>)

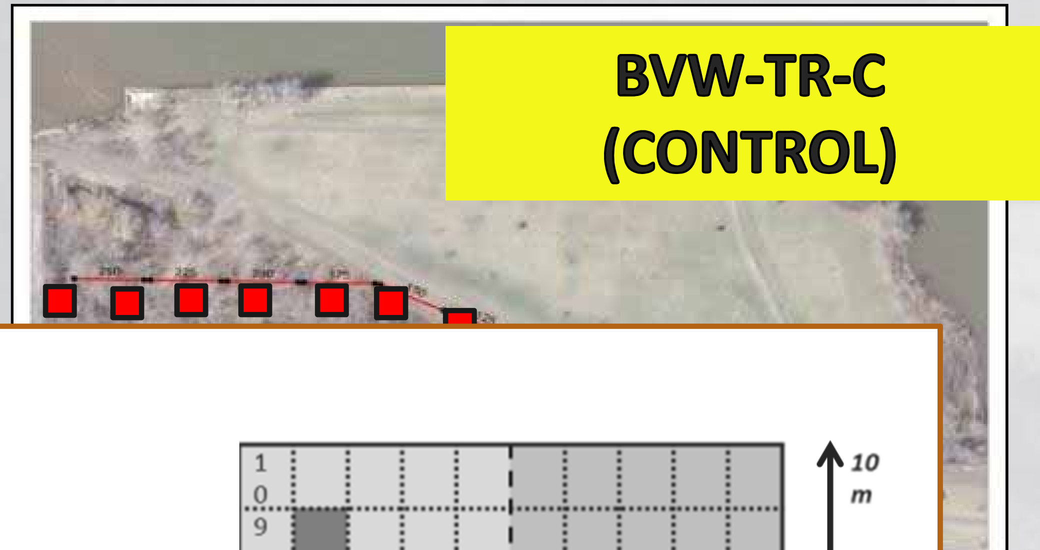
1. Proportion of native conifer and hardwood tree, sapling, and shrub species typical* of northern forest.
   - Increased woody structure
   - Diversified age-classes
   - Decreased canopy openness
2. Proportion of native bird and small mammal species more typical* of mixed conifer/hardwood urban woodland.
   - In response to changes in bullet 1.
3. Reduction in surface water runoff volume and nutrient loading.
   - Lower runoff concentrations in:
     - » Phosphorus
     - » Nitrogen
     - » Total Suspended Solids

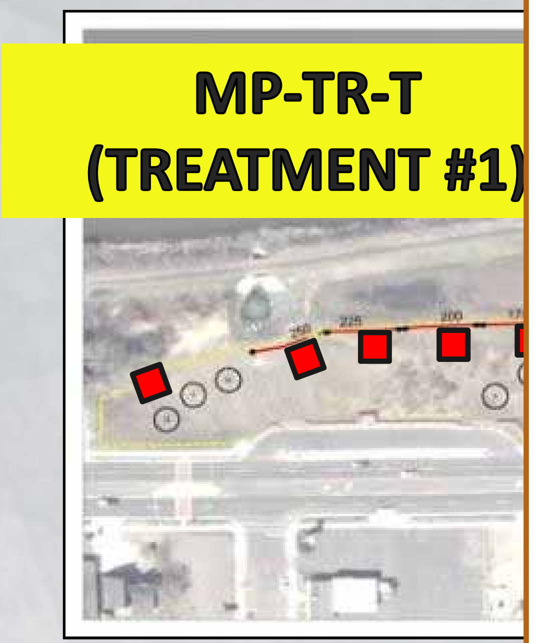
* Reflecting species planted/selected for

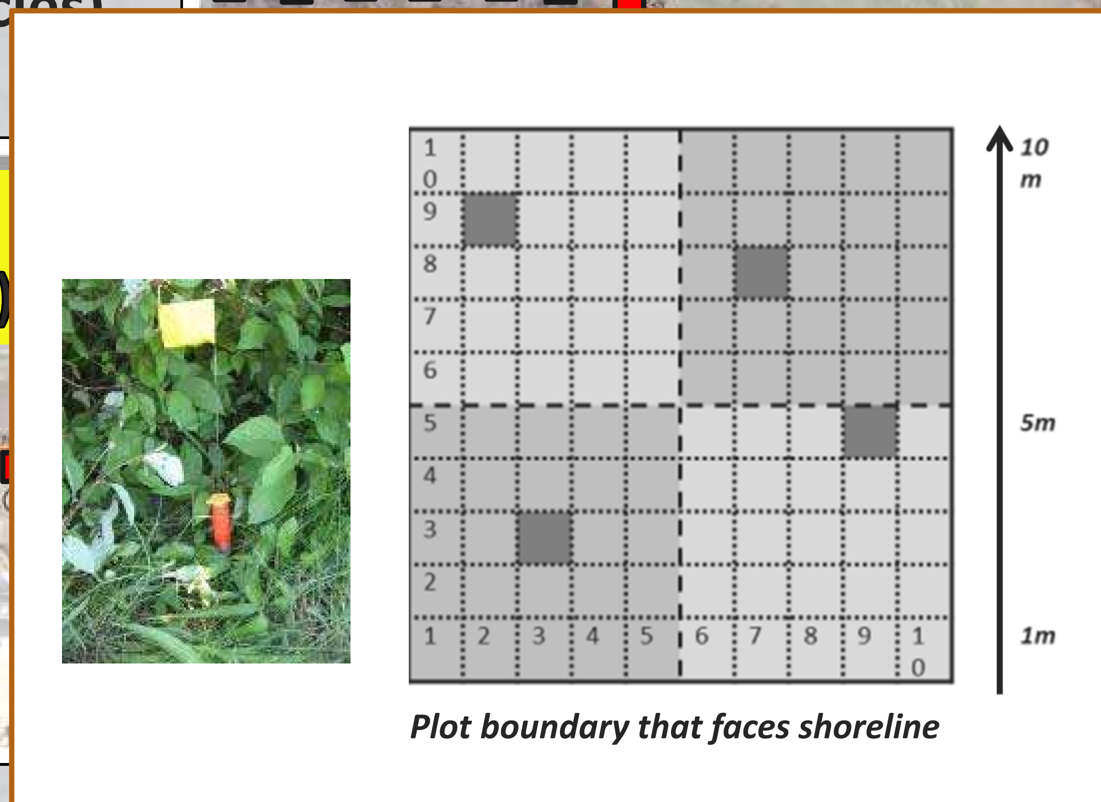

Ashland Waterfront (2011)
BVE-TR-T
(TREATMENT #2)
BVW-TR-C
(CONTROL)
MP-TR-T
(TREATMENT #1)
NORTH
An aerial view of the study sites along
Ashland Waterfront
Imagery Date: 5/15/2011 46°35'49.37" N 90°52'25.69" W elev 617 ft eye alt 7053

Ashland Restoration and Control Sites

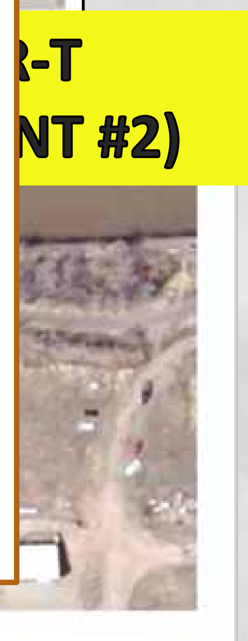
Site-level (Transects)
And
Plot-level (circles)

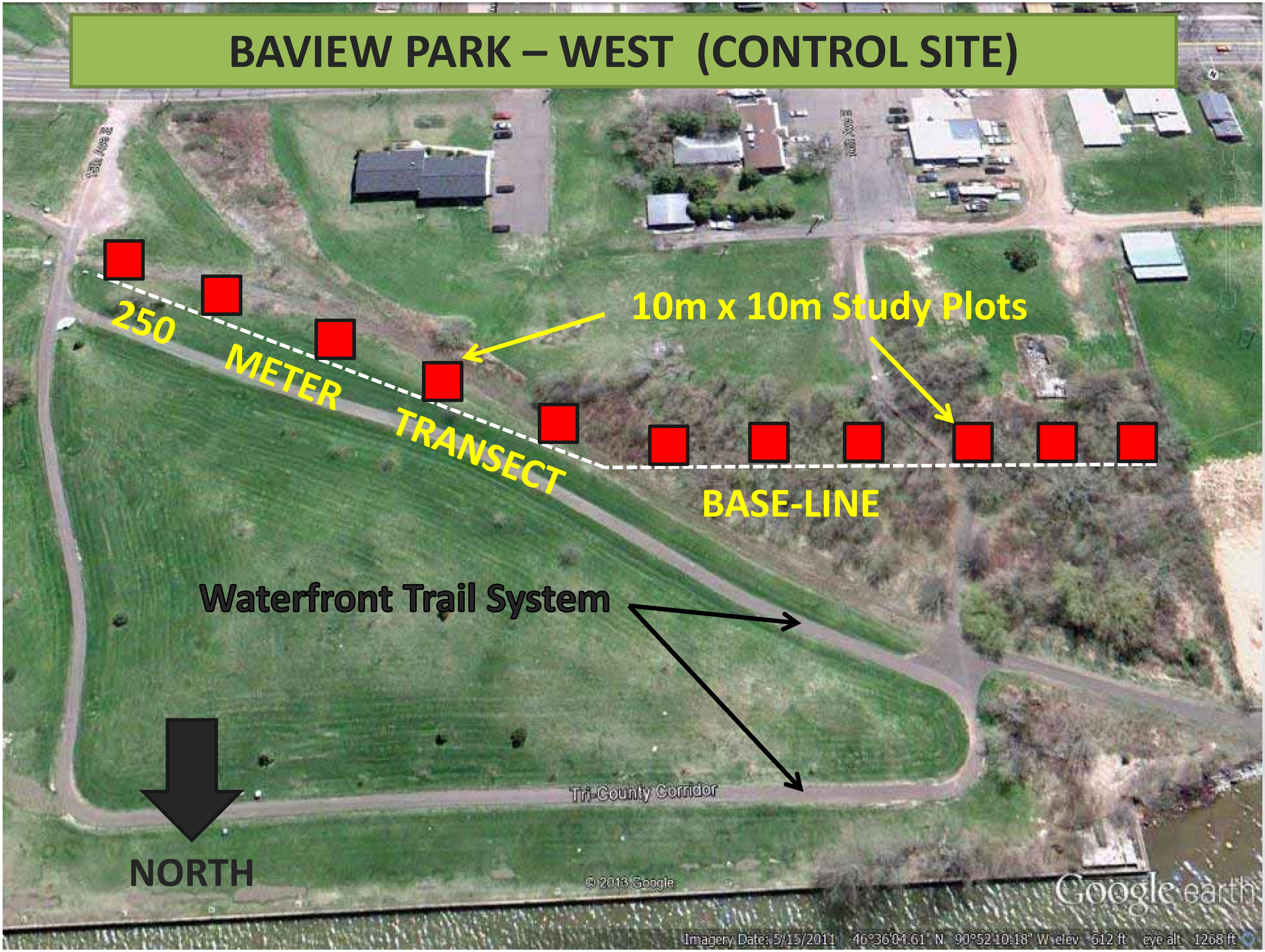




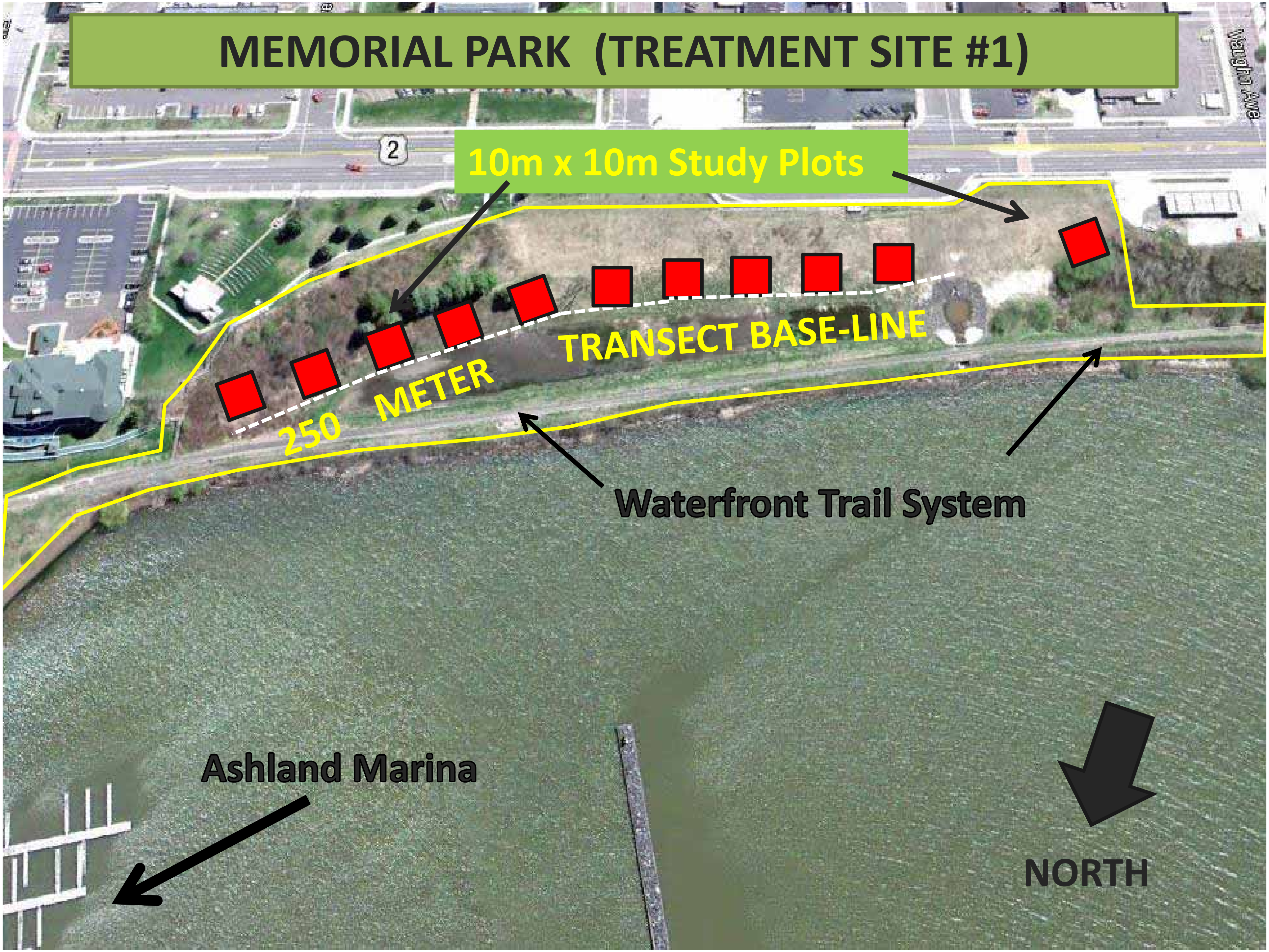


Plot boundary that faces shoreline

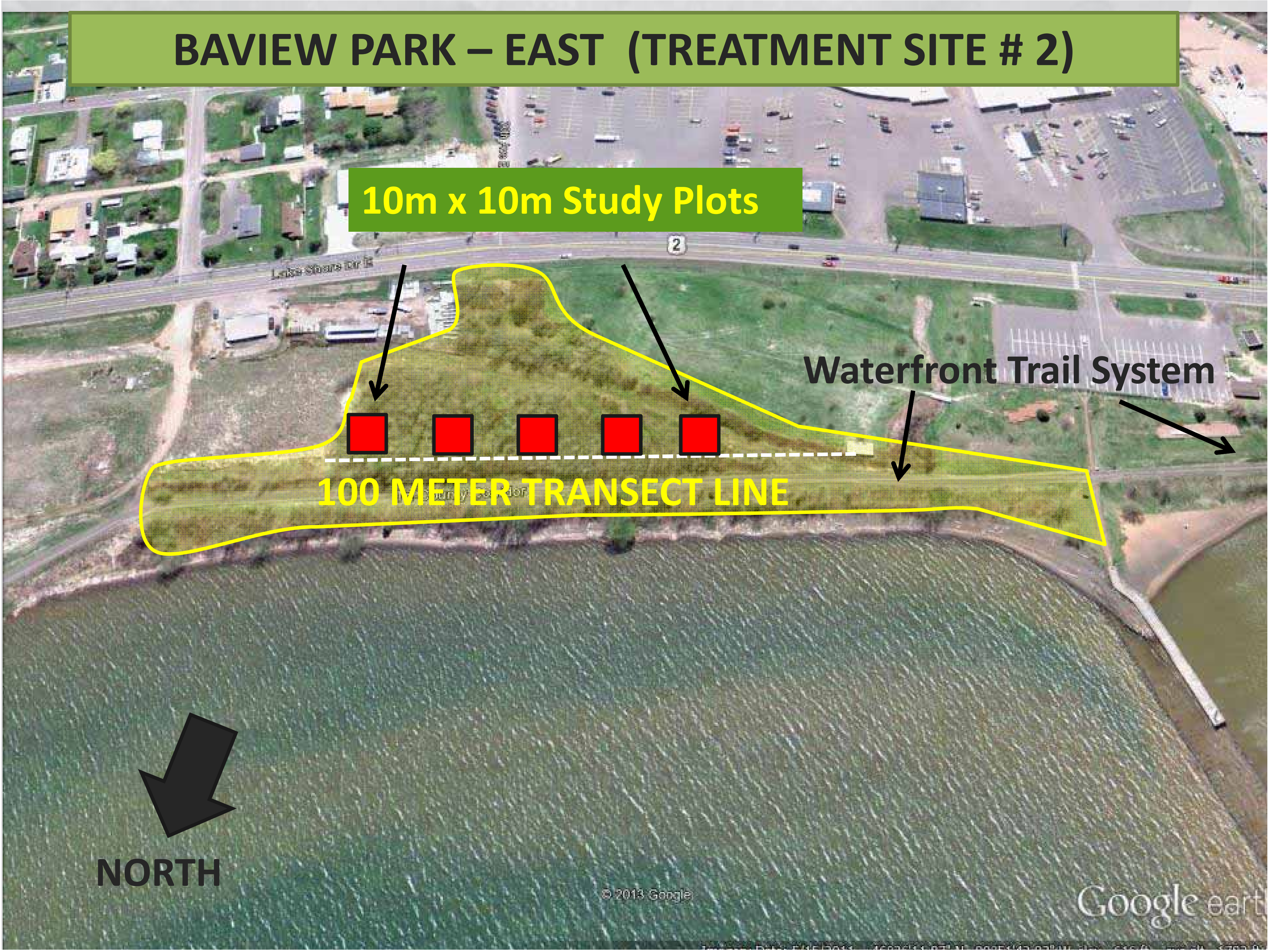




BAVIEW PARK – WEST (CONTROL SITE)
10m x 10m Study Plots
250 METER TRANSECT
BASE-LINE
Waterfront Trail System
Tri-County Corridor
NORTH
© 2013 Google
Google earth
Imagery Date: 5/15/2011 46°36'04.61" N 90°52'10.18" W elev 612 ft eye alt 1268 ft



MEMORIAL PARK (TREATMENT SITE #1)
10m x 10m Study Plots
250 METER TRANSECT BASE-LINE
Waterfront Trail System
Ashland Marina
NORTH


BAVIEW PARK – EAST (TREATMENT SITE # 2)
10m x 10m Study Plots
Lake Shore Dr E
2
Waterfront Trail System
100 METER TRANSECT LINE
NORTH
© 2013 Google

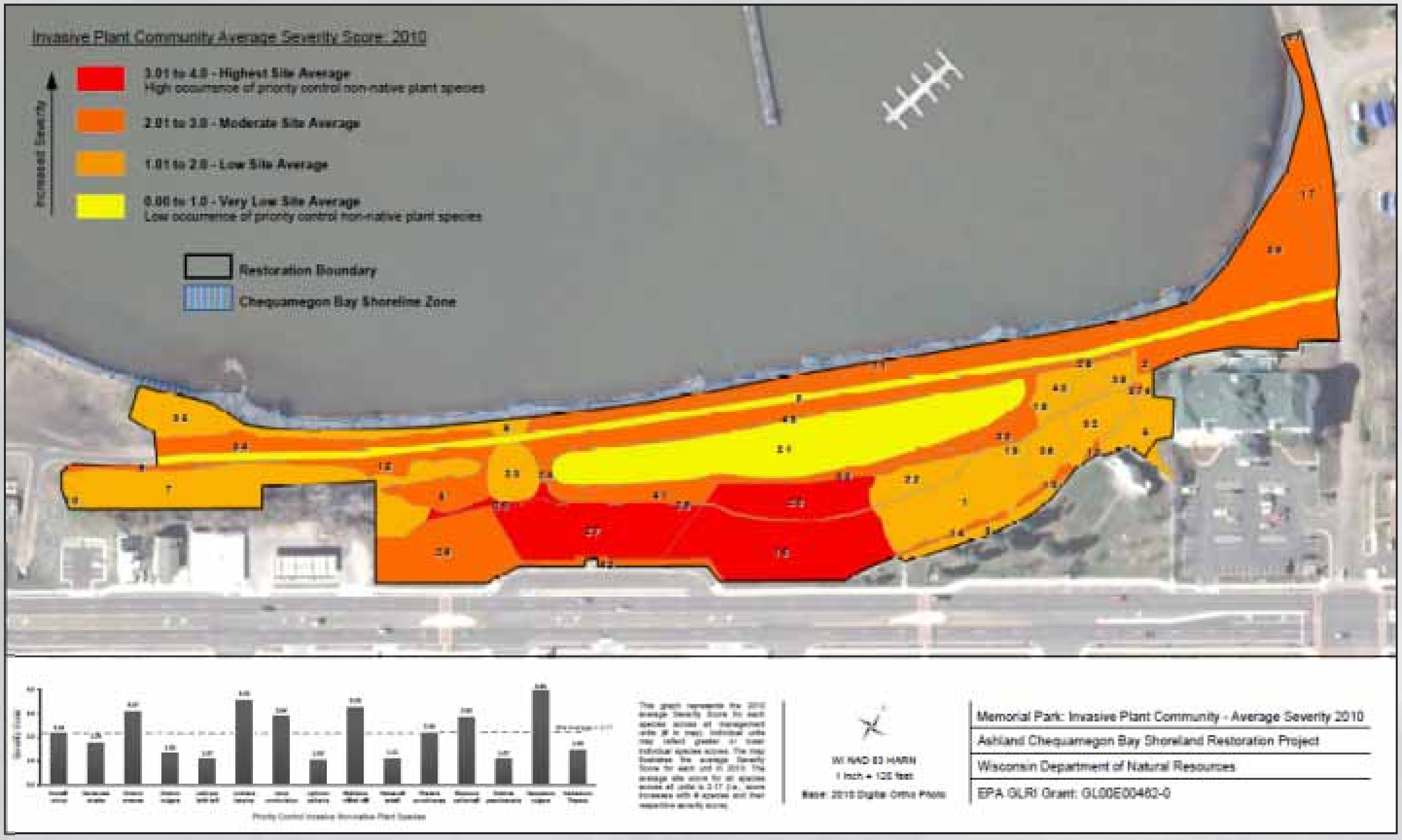
Wildlife Habitat – Invasive Plant Control

Invasive Plant Species

Common Name	Scientific Name	High Priority Species
Bird's foot trefoil	Lotus corniculatus (LOCO6)	♦
Black locust	Robinia pseudoacacia (ROPS)	♦
Bull thistle	Cirsium vulgare (CIVU)	
Burdock	Arctium minus (ARMI2)	
Canada thistle	Cirsium arvense (CIAR4)	♦
Common buckthorn	Rhamnus cathartica (RHCA3)	♦
Common mullein	Verbascum Thapsus (VETH)	
Common tansy	Tanacetum vulgare (TAVU)	♦
Perennial Pea	Lathryus latifolius (LALA4)	
Purple loosestrife	Lythrum salicaria (LYSA2)	
Reed canarygrass	Phalaris arundinacea (PHAR3)	♦
Spotted knapweed	Centaurea stoebe (CESTM)	♦
Tartarian honeysuckle	Lonicera tatarica (LOTA)	♦
White and Yellow sweet clover	Melilotus officinalis (MEOF)	♦
Wild Parsnip	Pastinaca sativa (PASA2)	

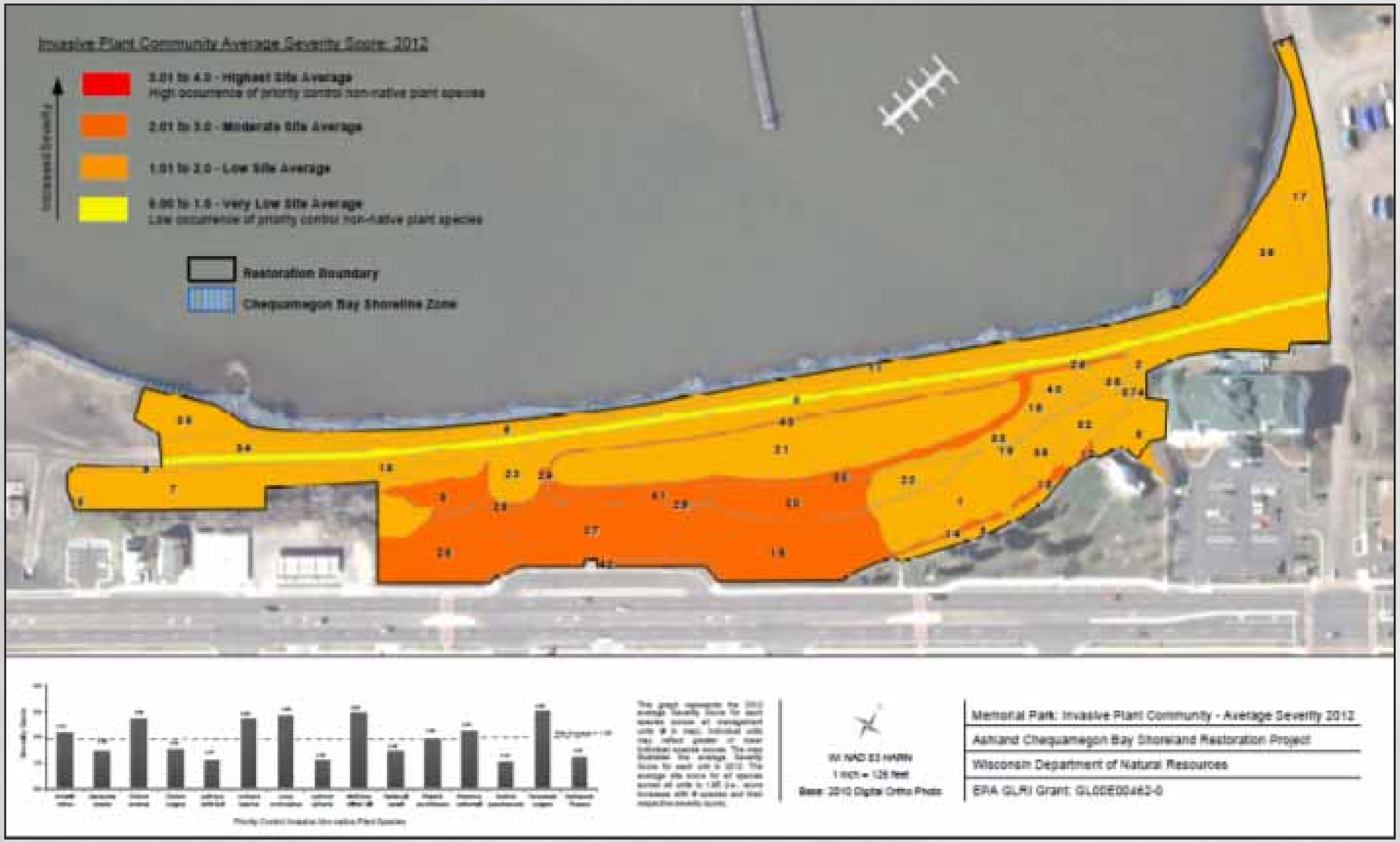
Wildlife Habitat – Invasive Plant Control

Invasive Plant Community Severity - 2010



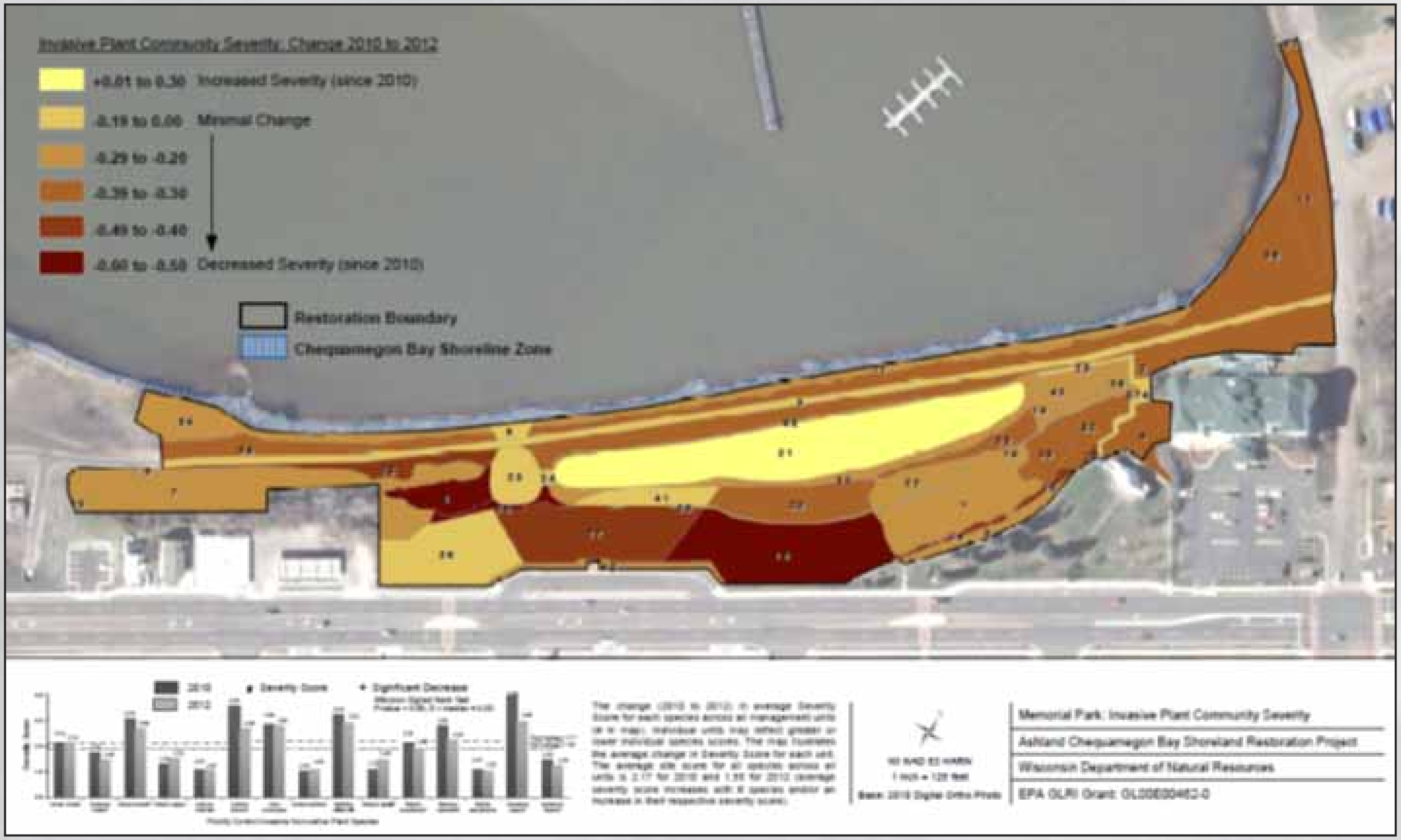
Wildlife Habitat – Invasive Plant Control

Invasive Plant Community Severity - 2012



Wildlife Habitat – Invasive Plant Control

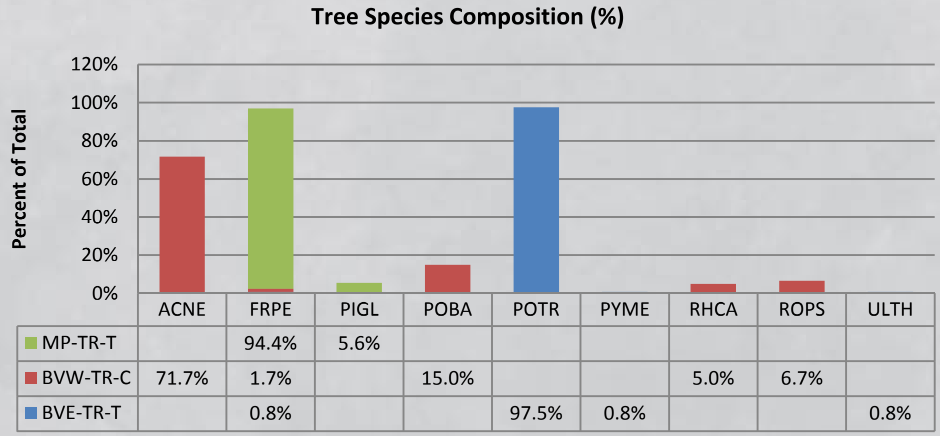
Invasive Plant Community Severity – <u>Change</u> 2010 to 2012



"By – Chance" Observations

Wildlife Habitat - Trees

(2012)



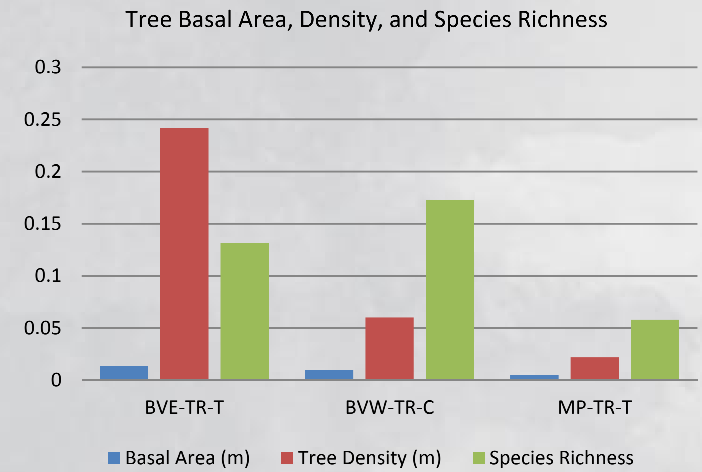


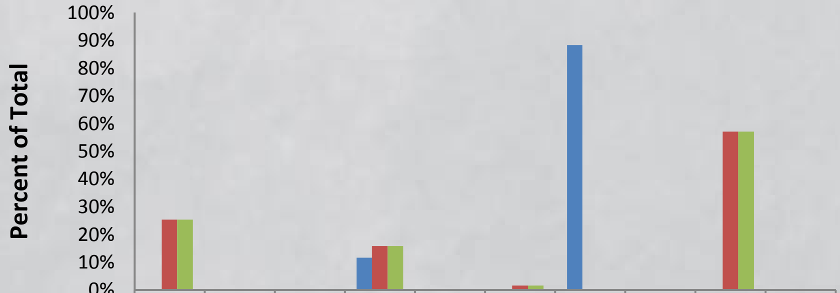
Table 6. Tree Species Crown Type (Canopy Position) and Total Count by Treatment.

Scientific Name	Common Name	Crown Class	BVE-TR-T	BVW-TR-C	MP-TR-T
Acer negundo (ACNE)	Boxelder	C, D, I, S		43	
Fraxinus pennsylvanica (FRPE)	Green Ash	C, D, I	1	1	17
Picea glauca (PIGL)	White Spruce	D			1
Populus balsamifera (POBA)	Balsam Poplar	D, C, S		9	
Populus tremuloides (POTR)	Quaking Aspen	C, D, I, S	118		
Pyrus melanocarpa (PYME)	Black Chokeberry	S	1		
Rhamnus cathartica (RHCA)	Common Buckthorn	I, S		3	
Robinia pseudoacacia (ROPS)	Black Locust	C, D		4	
Ulmus thomasii (ULTH)	Rock Elm	I	1		
Tree Total per Line-Transect			121	60	18
Crown Class: D-Dominant, C-Codominant, I-Intermediate, S-Suppressed; represents observed crown class positions across all sites.					

(2012)

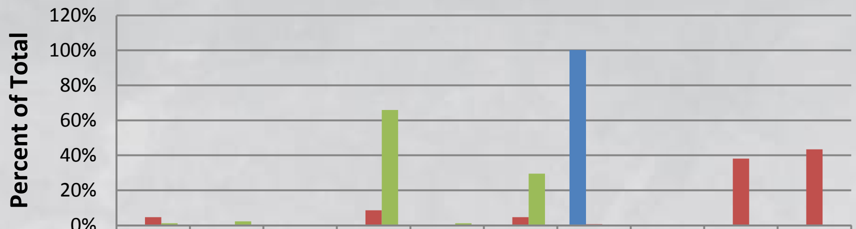
Wildlife Habitat - Saplings

Sapling Species Composition (%) - Height 0.3m - 1.4m



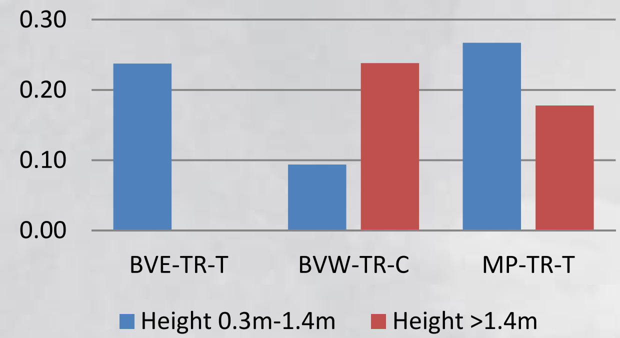
	ACNE	ACRU	ACSA	FRPE	PIGL	POBA	POTR	PRSE	SACI	SAXX
BVE-TR-T				11.6%			88.4%			
BVW-TR-C	25.4%			15.9%		1.6%			57.1%	
MP-TR-T	25.4%			15.9%		1.6%			57.1%	

Sapling Species Composition (%) - Height > 1.4m

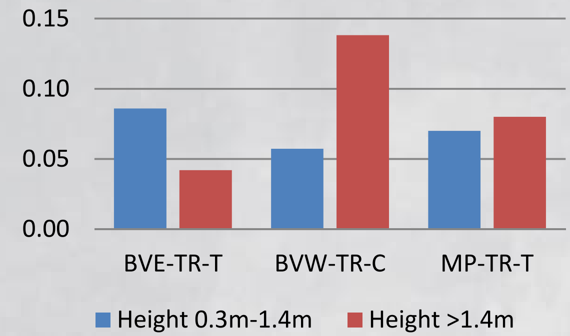


	ACNE	ACRU	ACSA	FRPE	PIGL	POBA	POTR	PRSE	SACI	SAXX
BVE-TR							100.0%			
BVW-TR	4.6%			8.6%		4.6%	0.7%		38.2%	43.4%
MP-TR	1.1%	2.3%		65.9%	1.1%	29.5%				

Sapling Species Diversity (SW Index)



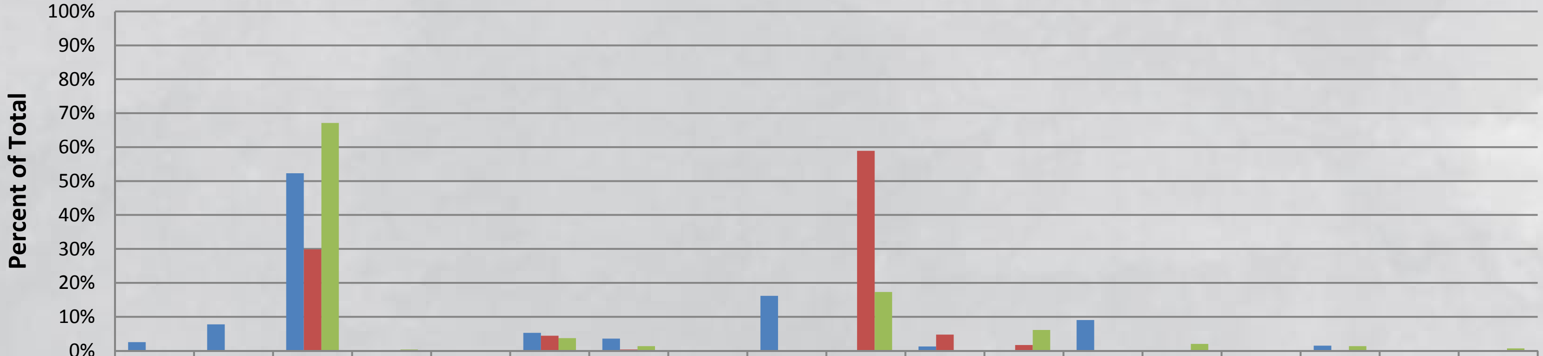
Sapling Density (m²)



Wildlife Habitat - Shrubs

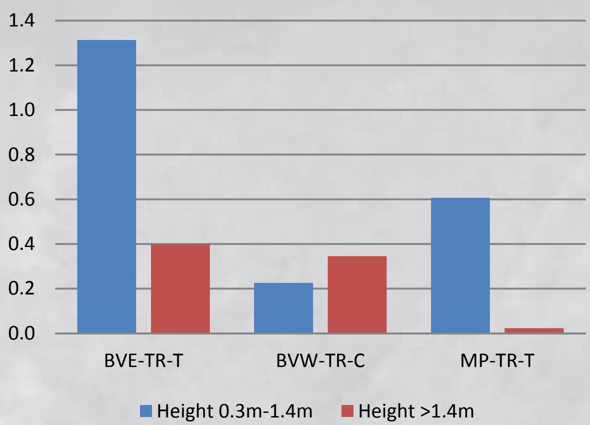
(2012)

Shrub Species Composition (%) - Height 0.30m - 1.4m

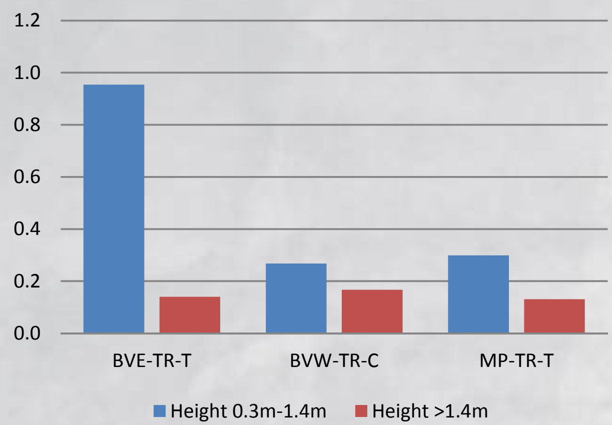


	AMAL	AMAR	COST	COAM	ILVE	LOTA	PHOP	PRVI	PYME	RHCA	RHFR	RIXX	ROXX	SACA	SAPU	SYAL	VILE	VITR
BVE-TR	2.5%	7.8%	52.3%		0.2%	5.3%	3.6%	0.2%	16.2%	0.2%	1.3%		9.0%			1.5%		
BVW-TR			29.9%			4.4%	0.3%			58.9%	4.8%	1.7%						
MP-TR			67.1%	0.3%		3.7%	1.4%			17.3%		6.1%		2.0%		1.4%		0.7%

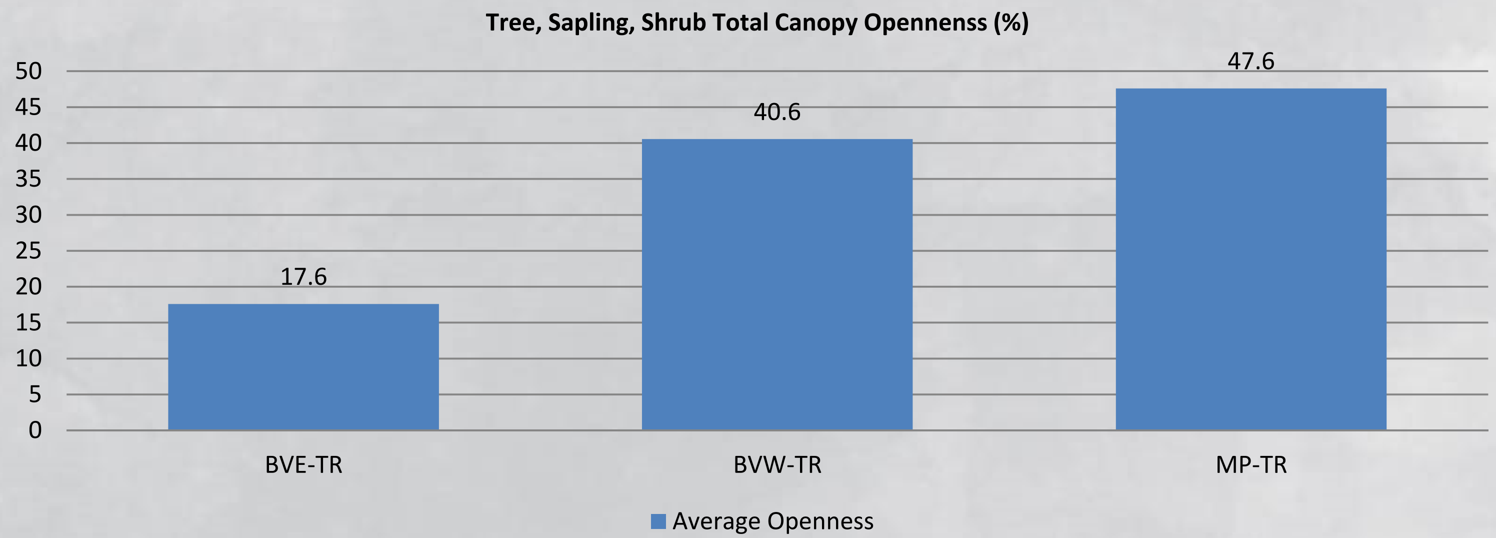
Shrub Species Richness (SW Index)



Shrub Stem Density (m^2)

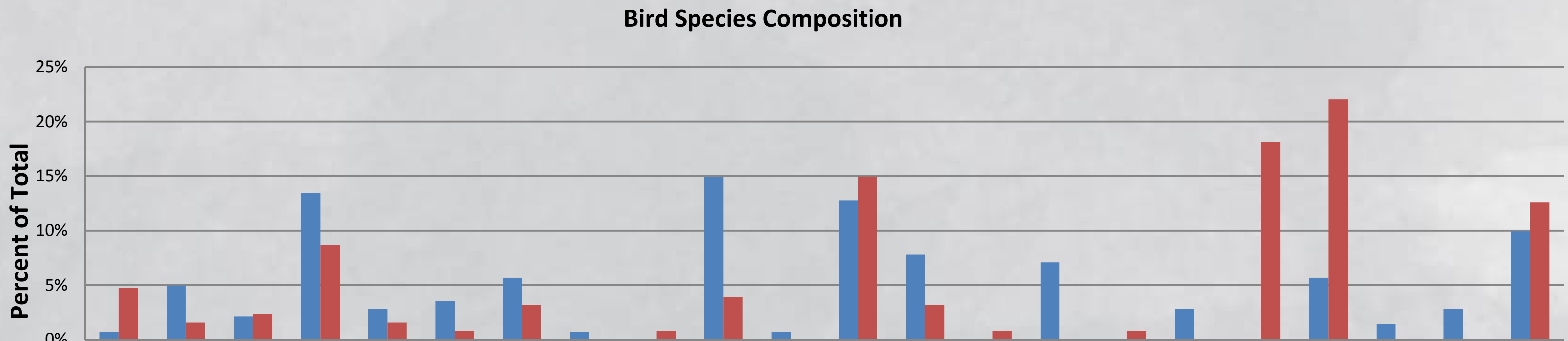


Wildlife Habitat - Canopy Openness (2012)



Wildlife Use – Birds

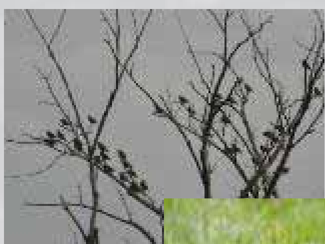
(2012)

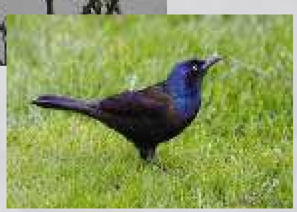


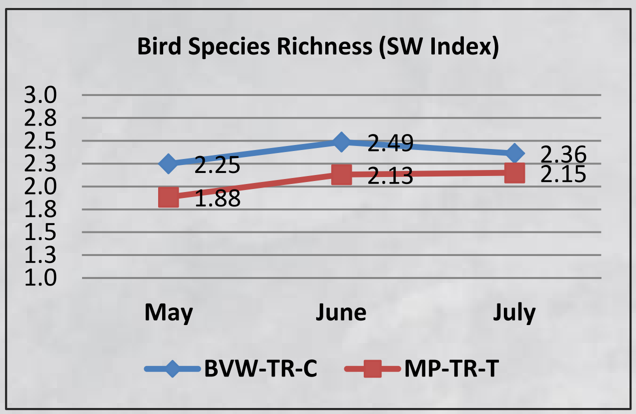
	AMCR	AMGO	AMRE	AMRO	BCCH	BHCO	CEDW	CSWA	CHSW	COGR	DOWO	EUST	GRCA	KILL	MODO	NOFL	REVI	RWBL	SOSP	TRES	WAVI	YEWA
BVW-TR-C	0.7%	5.0%	2.1%	13.5%	2.8%	3.5%	5.7%	0.7%		14.9%	0.7%	12.8%	7.8%	0.0%	7.1%		2.8%		5.7%	1.4%	2.8%	9.9%
MP-TR-T	4.7%	1.6%	2.4%	8.7%	1.6%	0.8%	3.1%		0.8%	3.9%		15.0%	3.1%	0.8%		0.8%		18.1%	22.0%			12.6%

Treatment Site	*N*	*S*	*H'*	*E*	*VarH'*	*CN*	*df*	*t-statistic*	*p*
BVW-TR-C	71	16	2.49	0.898	0.008				
MP-TR-T	64	12	2.13	0.857	0.013				
Community (site) Comparison						0.54	124	2.48	< 0.02

N: total birds counted; S: total species; H': Shannon-Weiner Index; E: S-W Evenness Index; VarH': variance of S-W Index estimate; C_N: Sorenson quantitative similarity index; t-test evaluating H_o:$H'_{BVW-TR-C} = H'_{MP-TR-T}$.

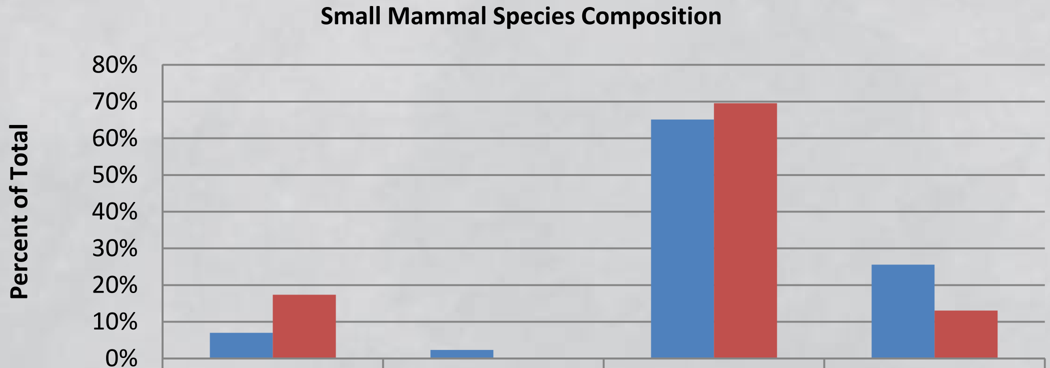




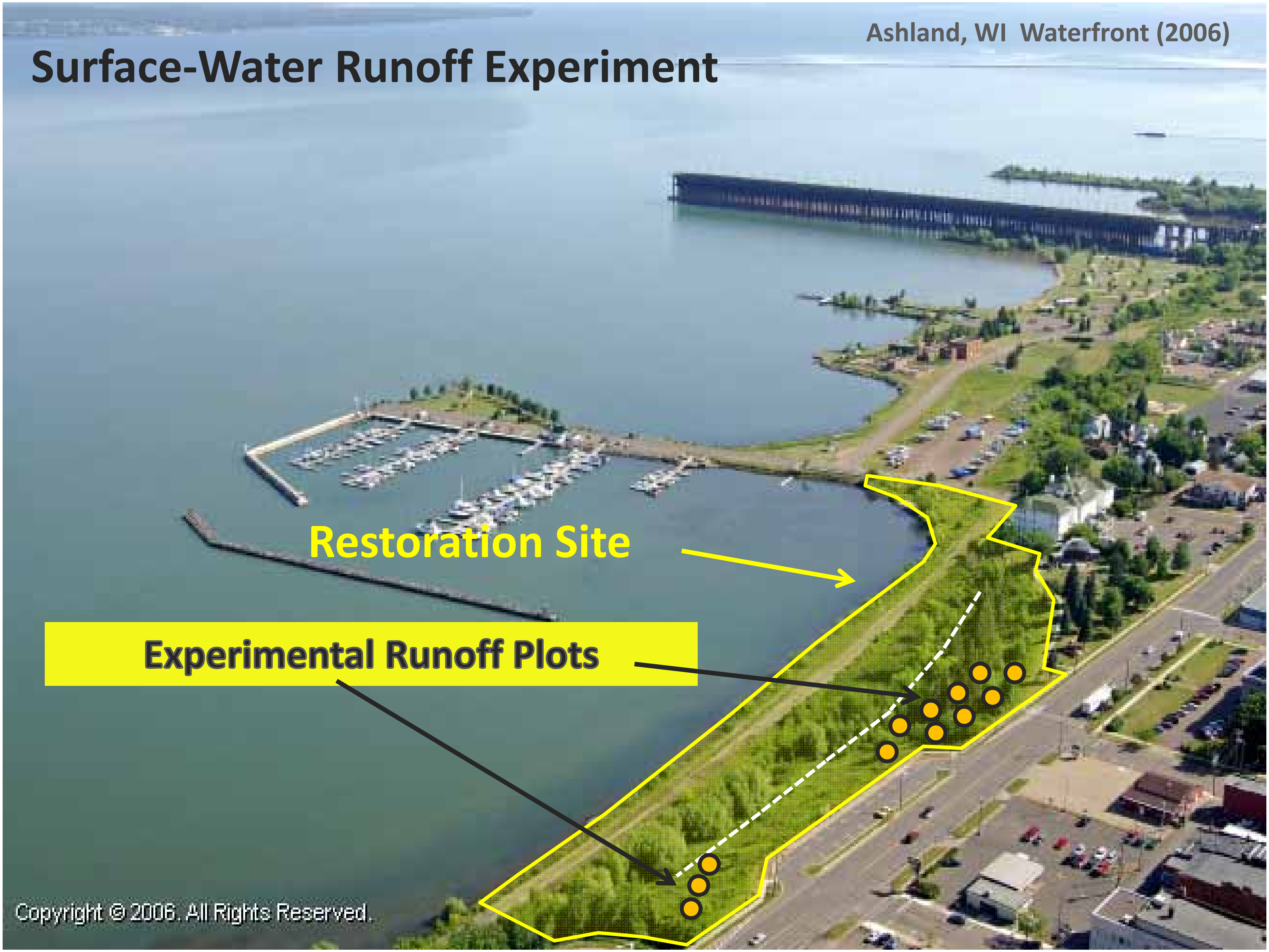


Wildlife Use – Small Mammal

(2012)



	Microtus pennsylvanicus	Mus musculus	Peromyscus	Tamias striatus
BVW-TR-C	7.0%	2.3%	65.1%	25.6%
MP-TR-T	17.4%		69.6%	13.0%


Surface-Water Runoff Experiment
Ashland, WI Waterfront (2006)
Restoration Site
Experimental Runoff Plots
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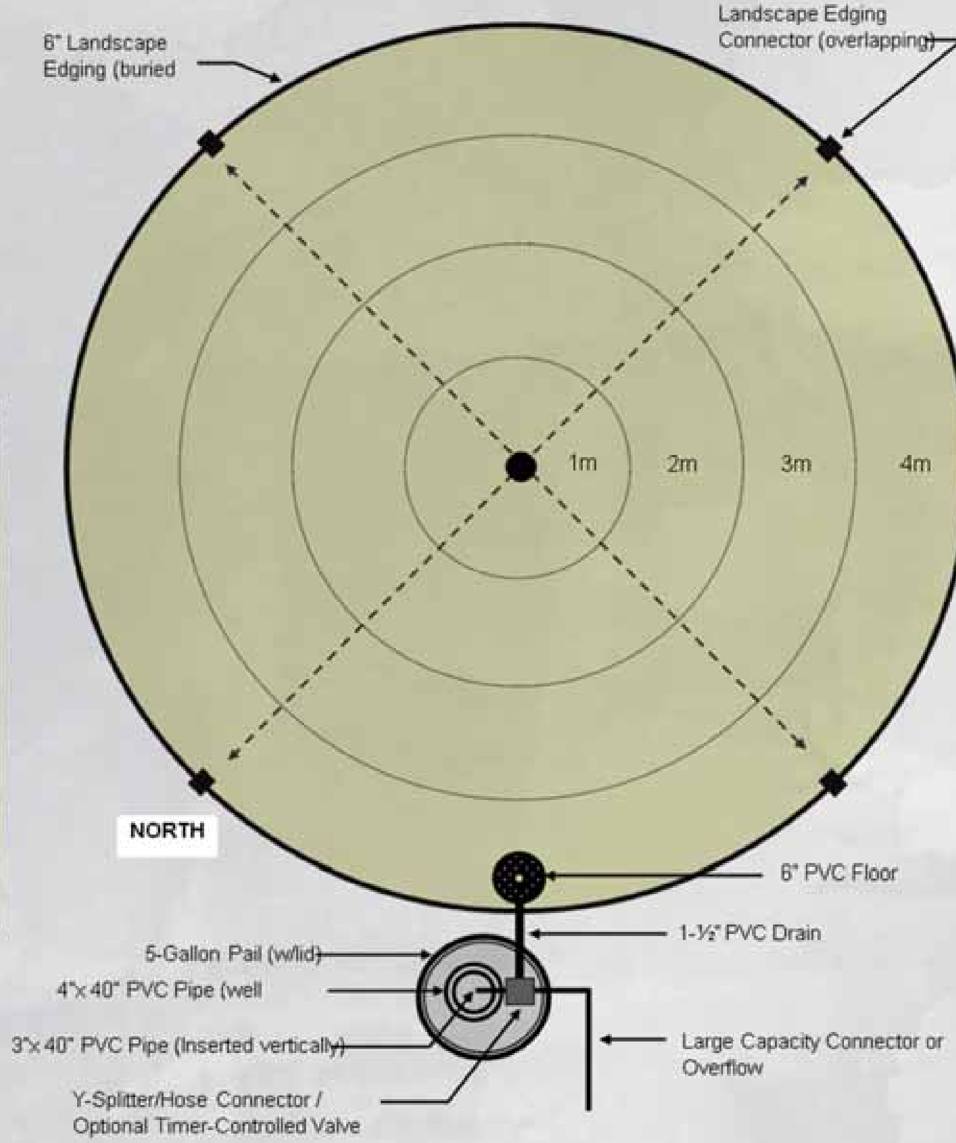
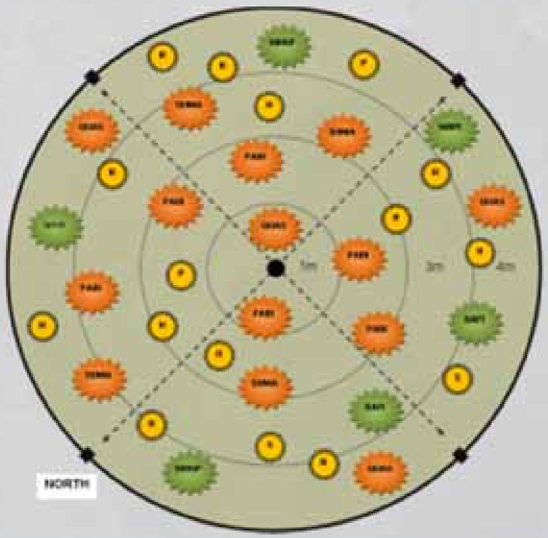
Surface-Water Runoff

Plot-level: (12 circular plots)

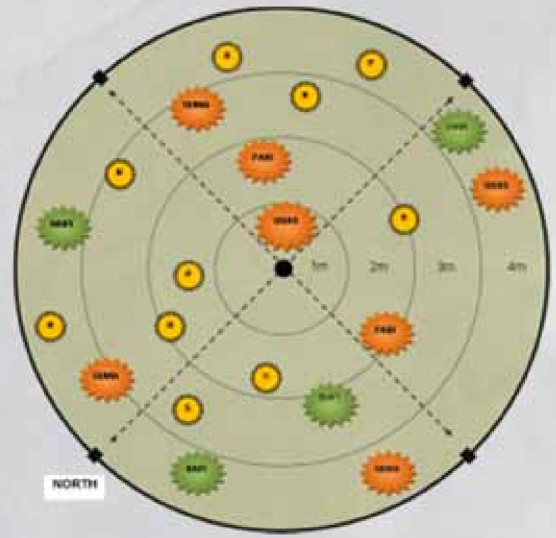
- Surface water runoff/WQ
- Soil carbon sequestration
- Terrestrial arthropods



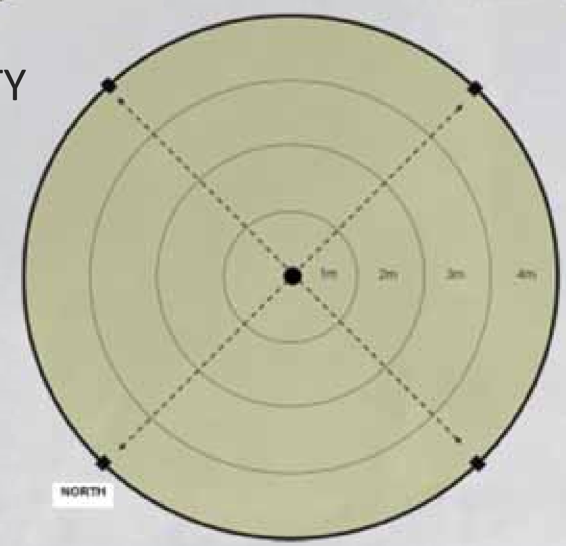
EXAMPLE EXPERIMENTAL BLOCK W/3 TREATMENTS



HIGH DENSITY



LOW DENSITY



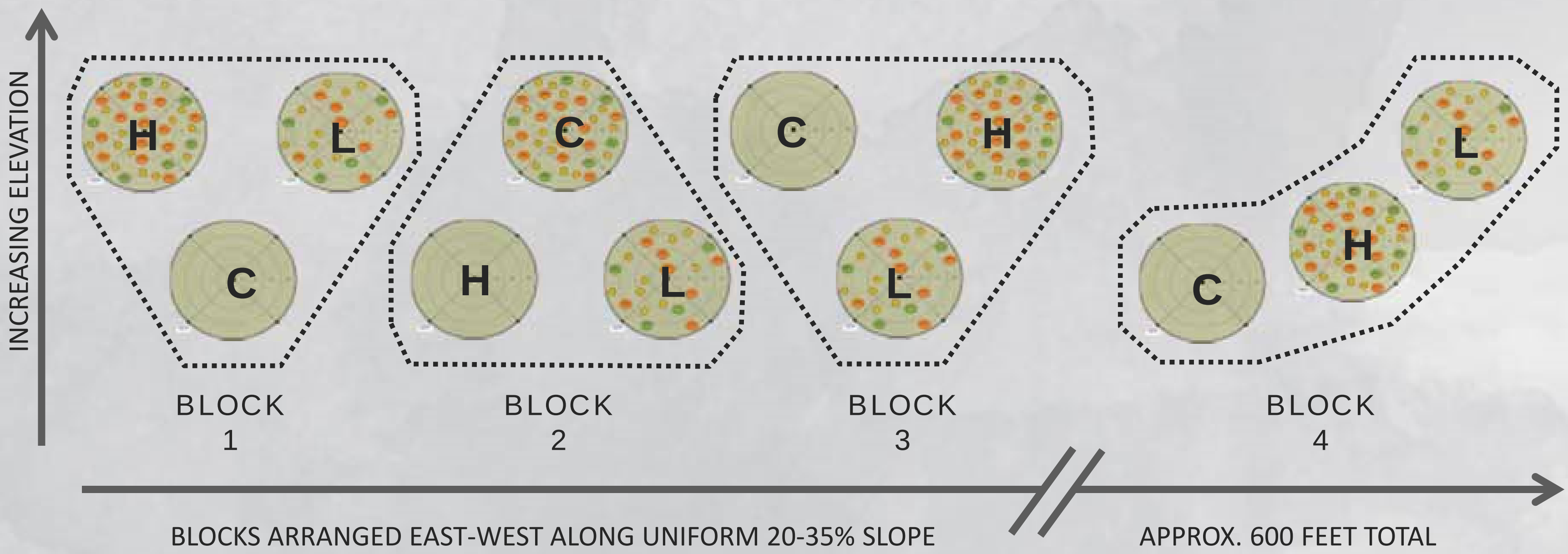
CONTROL

Conifer Tree

Deciduous Tree

Deciduous Shrub

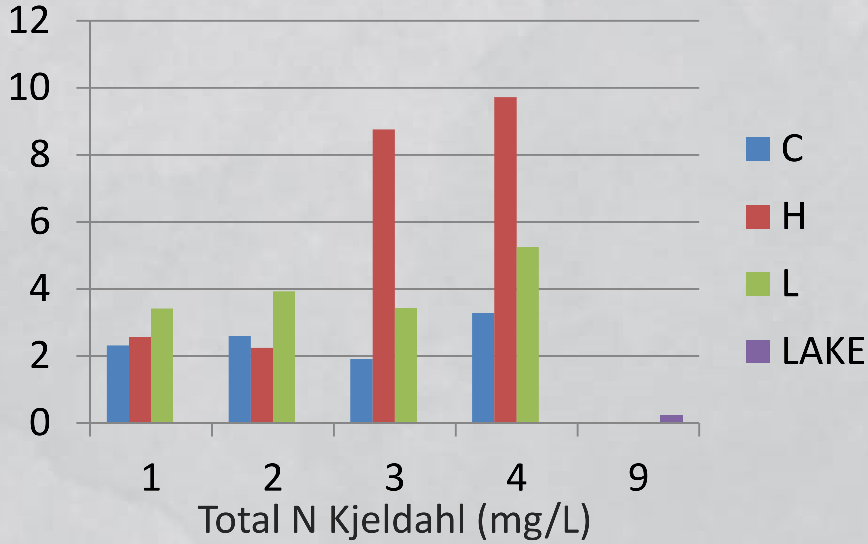
RANDOMIZED COMPLETE BLOCK DESIGN (RCBD)

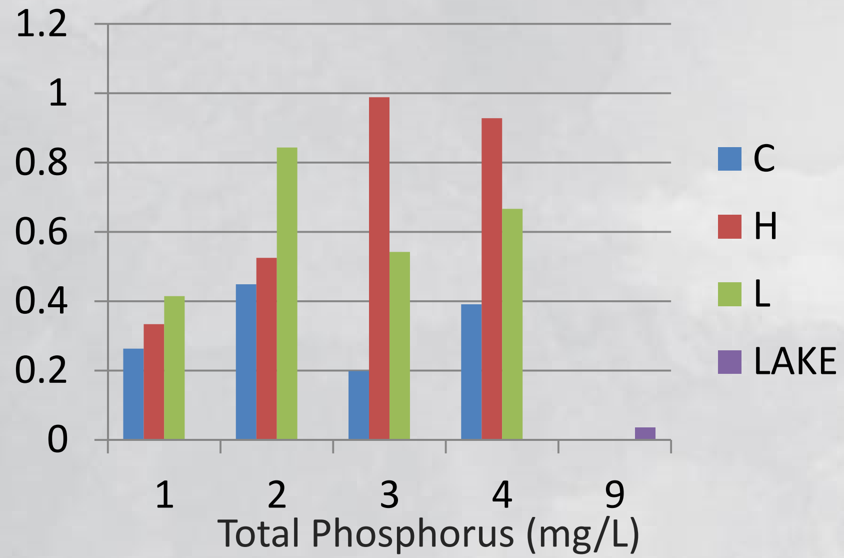


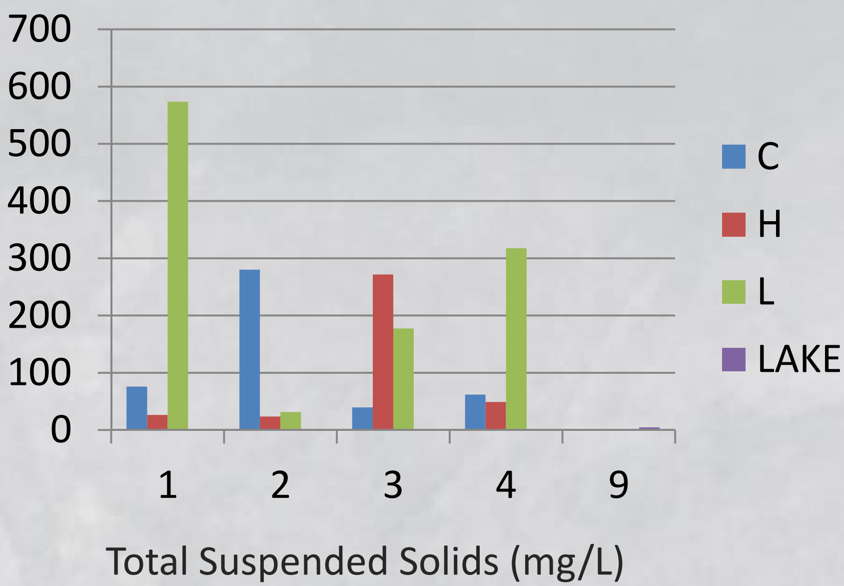
Schematic diagram of experimental plot layout at Memorial Park

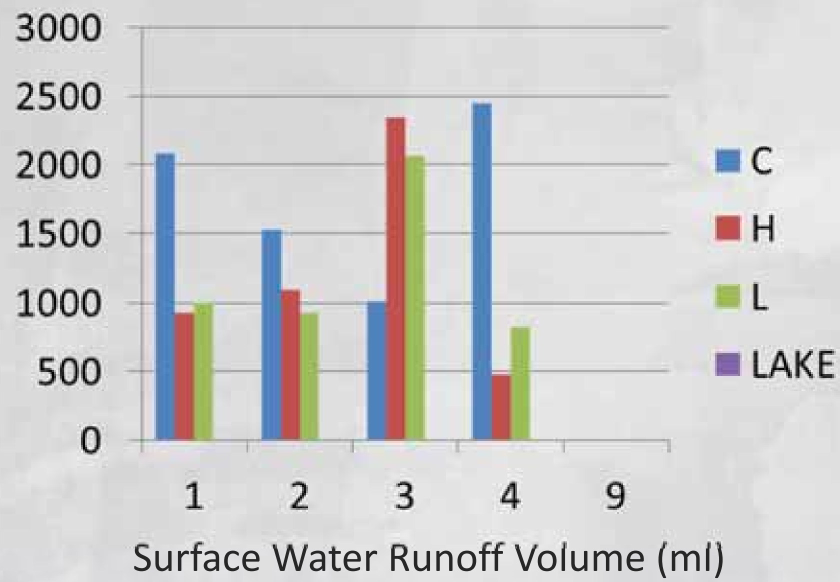
Surface-Water Runoff

Water Quality (2012)

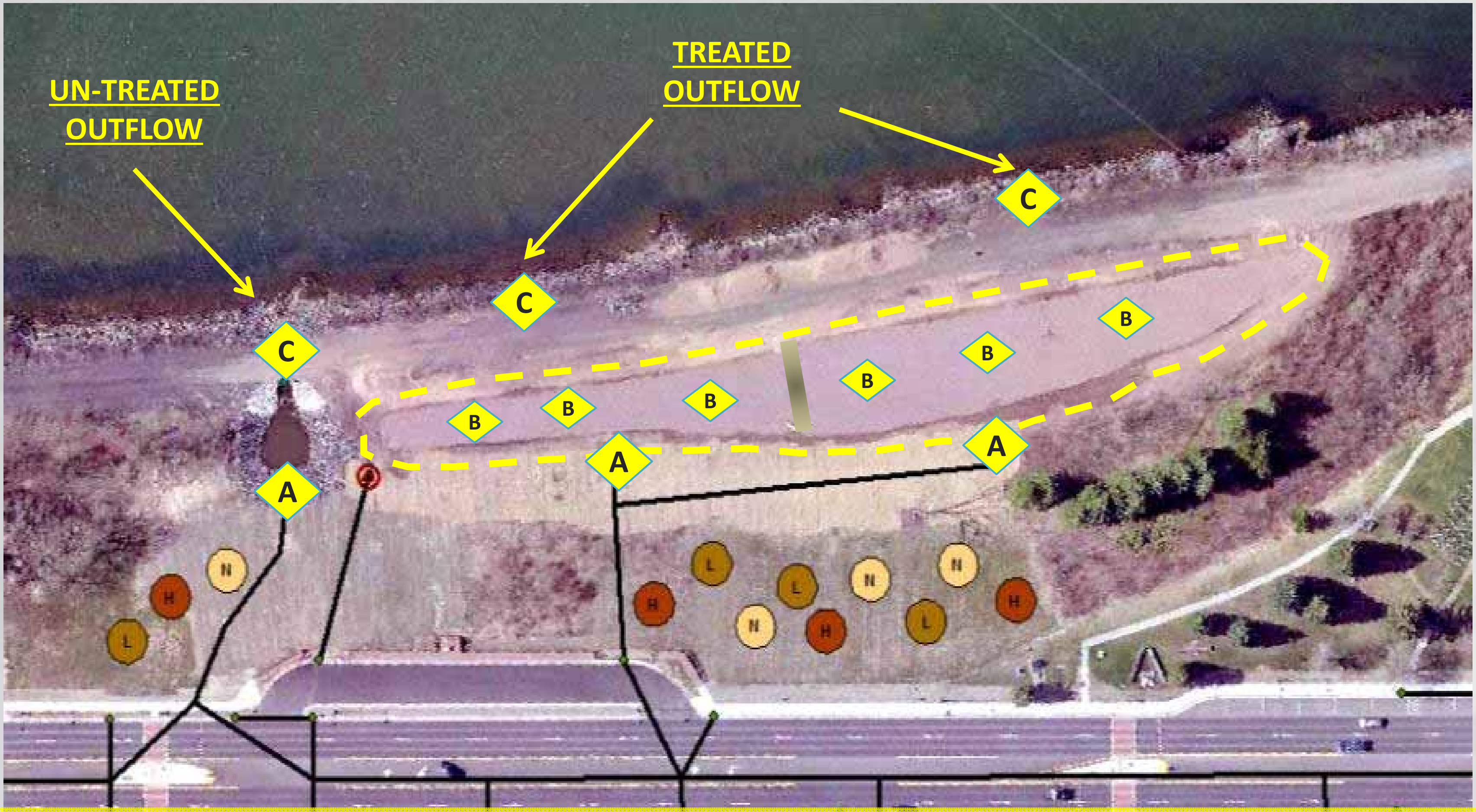








New Component - Bio-Retention Basin



Composite WQ Sample Collection

A & C - 3 grab samples each (1 minute apart) **B - 1 grab sample each**

Storm Water Flow & Non-point Source Inputs


BIO-RETENTION
WETLAND
2-YRS POST
INSTALLATION


BIO-RETENTION WETLAND
(3-YRS POST INSTALLATION)


BIO-RETENTION WETLAND
2-YRS POST INSTALLATION
(DRY PERIOD)


BIO-RETENTION WETLAND
OUTFLOW
SAMPLE SITE

THANK YOU!

BRICK.FEVOLD@WISCONSIN.GOV

MICHAEL.MEYER@WISCONSIN.GOV

Great Lakes Restoration Initiative Program

The
Ashland Chequamegon Bay Shoreland Restoration Project

2010 - 2022