Sampling Design for Early Detection of Aquatic Invasive Plants in Coastal Waters of the Great Lakes

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The Nature Conservancy

MSU Extension

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

- ***Phase 1 - "Aquatic plant survey methods development and site assessment,"*** GLRI F16AS00090 USFWS
- ***Phase 2 - "Invasive Aquatic Plant Surveillance in New York Great Lakes Ports"*** GLRI F20AP00244 USFWS

- ***Project goals:***
  - Develop an aquatic plant surveillance strategy capable of effectively sampling high risk sites
  - Apply and refine the surveillance protocol at priority sites

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Research Article

Towards a framework for invasive aquatic plant survey design in Great Lakes coastal areas

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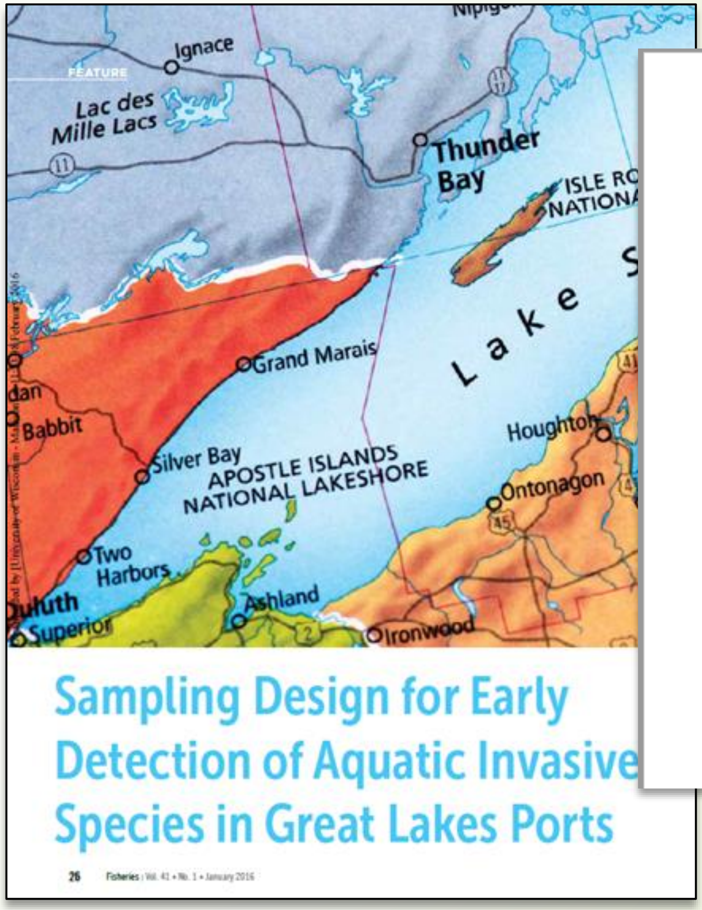
Abstract

At least 65 aquatic plant species have been identified as part of a surveillance list of non-native species that pose a threat to biodiversity and ecosystem services in the Laurentian Great Lakes. Early detection of these potentially invasive aquatic plants (IAP) could minimize impacts of novel incursions and facilitate successful eradication. We developed, implemented, and then adaptively refined a probabilistic boat-based sampling design that aimed to maximize the likelihood of detecting novel IAP incursions in large (400+ hectares) Great Lakes coastal areas. Surveys were conducted from 2017 to 2019 at five Great Lakes locations – St Joseph River (MI), Saginaw River (MI), Milwaukee (WI), Cleveland (OH), and the Detroit River (MI). Aquatic plant communities were characterized across the five sites, with a total of 61 aquatic plant species detected. One-fifth of the species detected in our surveys were non-native to the Great Lakes basin. Sample-based species rarefaction curves, constructed from detection data from all surveys combined at each location, show that the estimated sample effort required for high confidence (> 95%) detection of all aquatic plants at a site, including potentially invasive species, varies (< 100 sample units for Detroit River; > 300 sample units for Milwaukee, roughly equivalent to 6 to 18 days sampling effort, respectively). At least 70% of the estimated species pool was detected at each site during initial 3-day surveys. Leveraging information on detection patterns from initial surveys, including depth and species richness strata, improved survey efficiency and completeness at some sites, with detection of at least 80% of the estimated species pool during subsequent surveys. Based on a forest-based classification and regression method, a combination of just five variables explained 70% or more of the variation in observed richness at all sites (depth, fetch, percent littoral, distance to boat ramps and distance to marinas). We discuss how the model outcomes can be used to inform survey design for other Great Lakes coastal areas. The survey design we describe provides a useful template that could be adaptively improved for early detection of IAP in the Great Lakes.

Key words: surveillance, monitoring, early detection, rarefaction, aquatic macrophytes

Design principles and scope

- ***Survey design***
  - Quantitative and probabilistic (to evaluate sampling efficiency & completeness)
  - Stratified (to inform adaptive sampling)
- ***Constraints/Scope***
  - Open water habitat for detection of submerged, emergent, and floating species
  - Up to 3 days per site (500-2500 acres)



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Research article

Exploiting habitat and gear patterns for efficient detection of rare and non-native benthos and fish in Great Lakes coastal ecosystems

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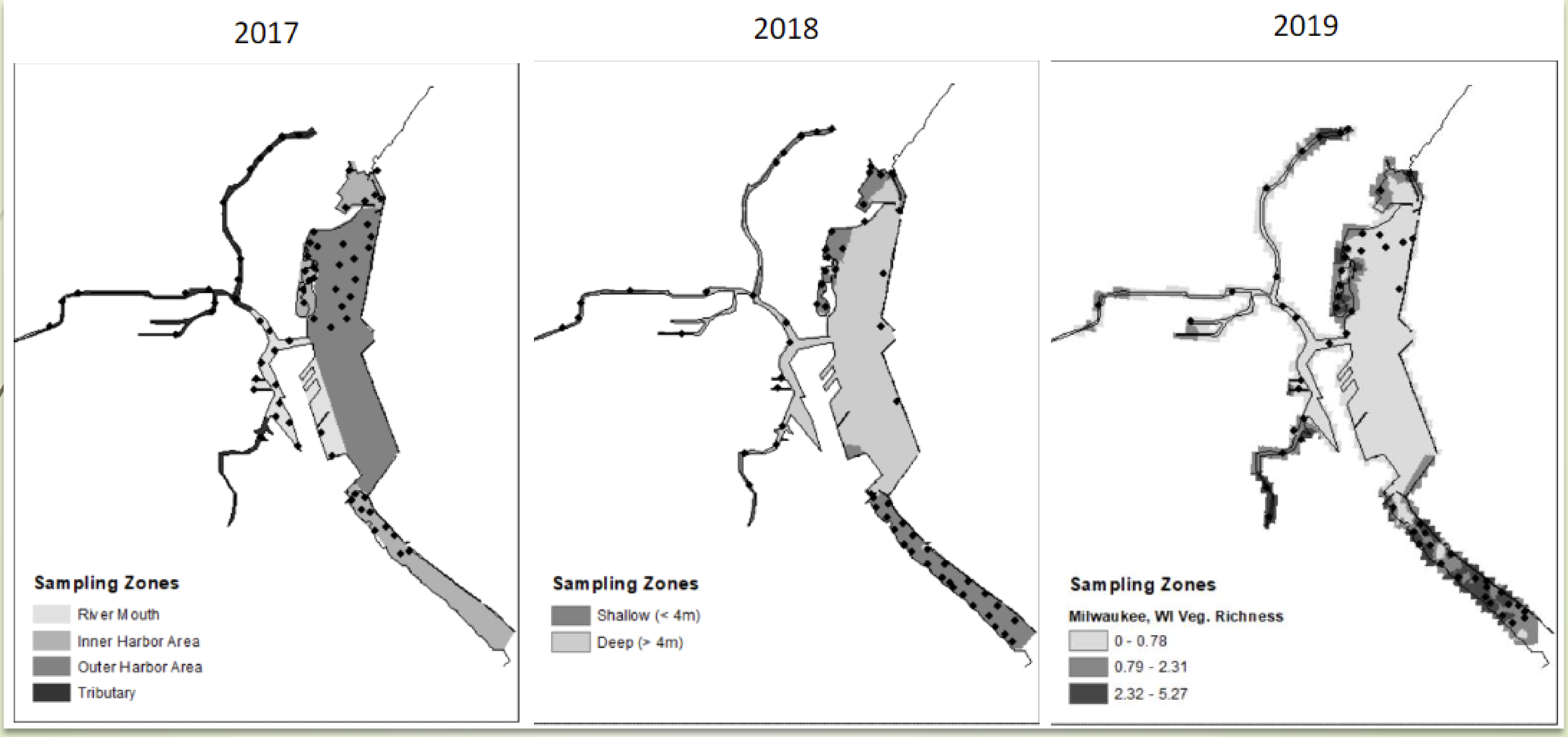
Abstract

Despite the continued arrival and impacts of non-native aquatic species in the Great Lakes, there is as yet no comprehensive early-detection monitoring program for them. As a step towards implementing such a program, we evaluated strategies for efficient non-native species monitoring based on the ability to detect a diverse set of benthos and fish species currently present in a heavily invaded, spatially complex Great Lakes subsystem. Taxa accumulation analyses confirmed that reliable detection of rare species requires substantial sampling effort but also that there is potential for exploiting patchiness in distributions to increase efficiency. While non-native species monitoring warrants generally comprehensive spatial coverage, it may be possible to identify areas where such taxa are broadly most prevalent (e.g., the lower reaches of our study system) as a way to focus effort. On a finer scale, richness of non-native taxa may vary substantially among stations in close proximity – which in this system was driven by habitat variability rather than distance from potential introduction points. Microhabitats that differ in physical attributes are also likely to differ in species composition and richness. Randomization analyses indicated that some monitoring effort should be directed towards all distinct habitats but that detection rates are maximized by biasing effort towards those habitats or gear yielding the most total, non-native, or rare taxa. For benthic invertebrates, shallow structurally complex (vegetated) habitats yielded the most taxa but shallow open and deep habitats also contributed unique taxa. For fish, fyke-net stations (shallowest habitats) yielded the most taxa, but electrofishing (intermediate-depth) and trawling (deepest) also contributed unique taxa. Our approach to identifying relevant sampling strata and exploiting difference among them to increase the efficiency of early-detection monitoring is applicable to a broad variety of systems.

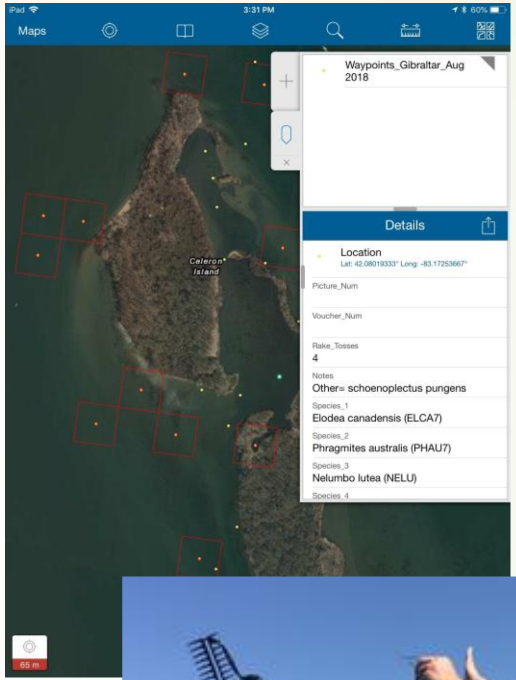
Key words: non-native species, early detection, sampling strategies, optimization, St. Louis River/Duluth-Superior Harbor

Survey design overview



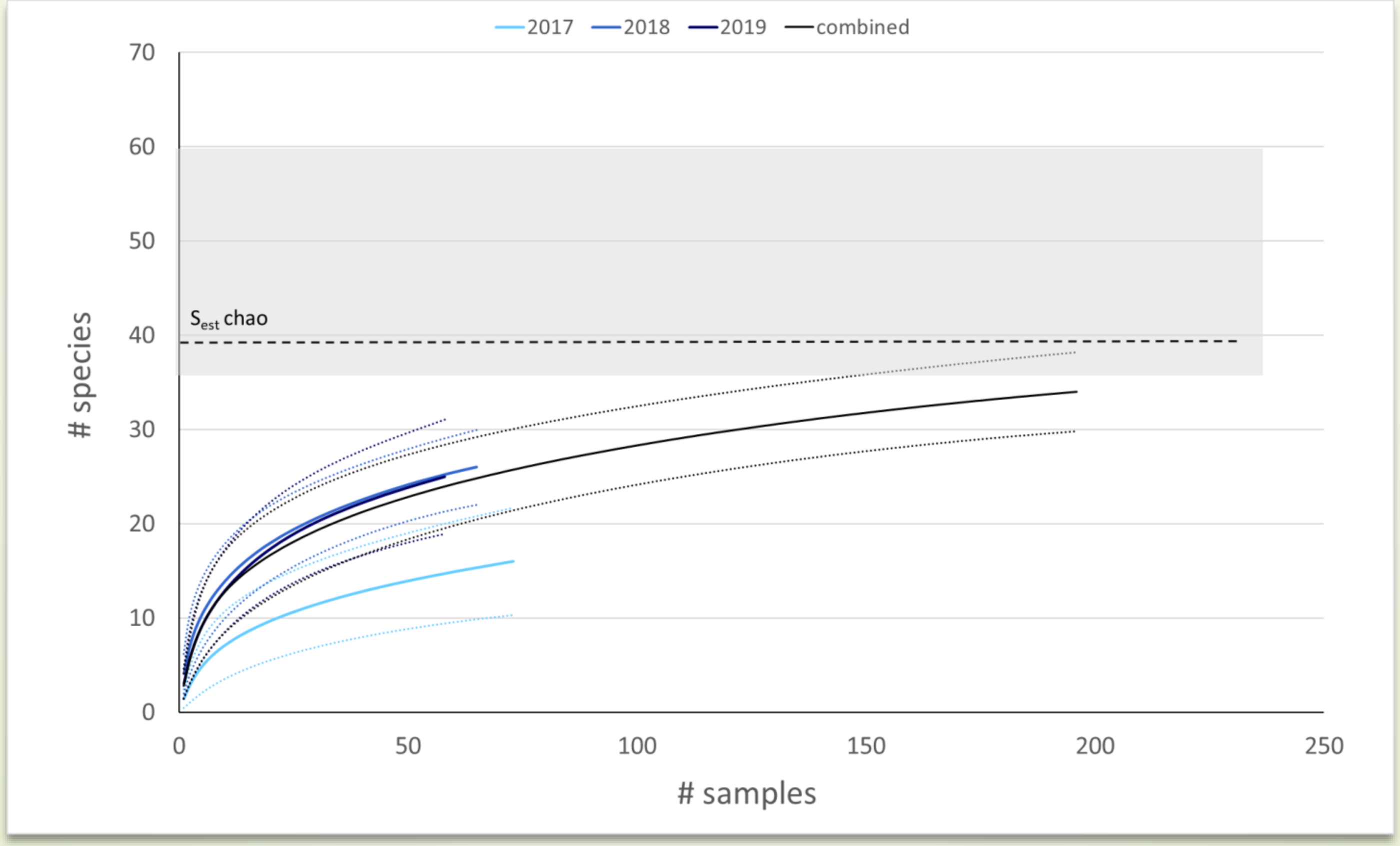
Methods

- ***FIELD***
  - *boat based*
  - *rake tosses and visual meander*
- ***ANALYTICAL***
  - *Sample-based rarefaction (to estimate species richness and survey completeness)*



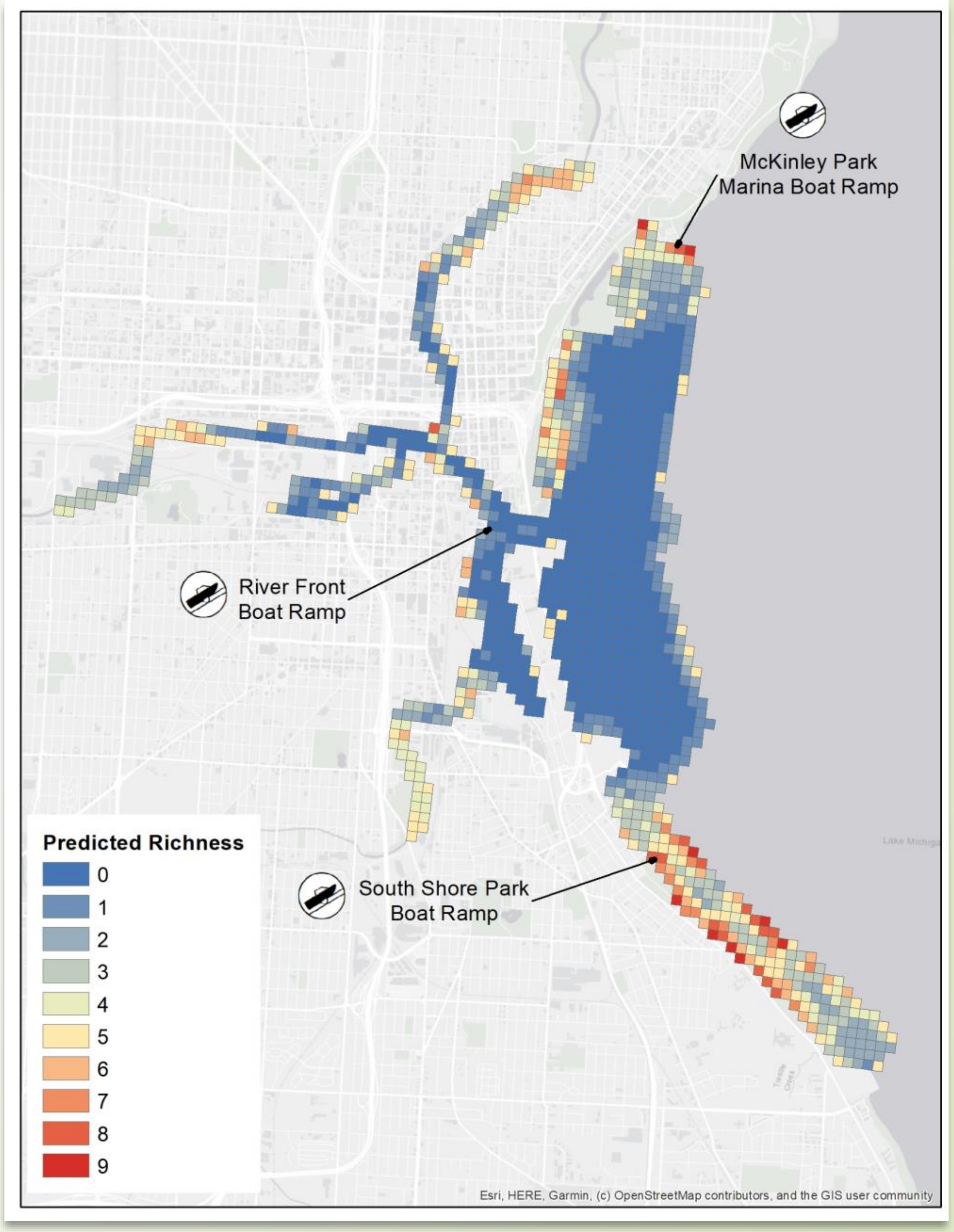
Results

- Targeting shallow or spp rich sites increases survey efficiency
- 75-95% of the estimated spp pool detected with single survey
- Detecting entire spp pool requires substantial effort



Strengths

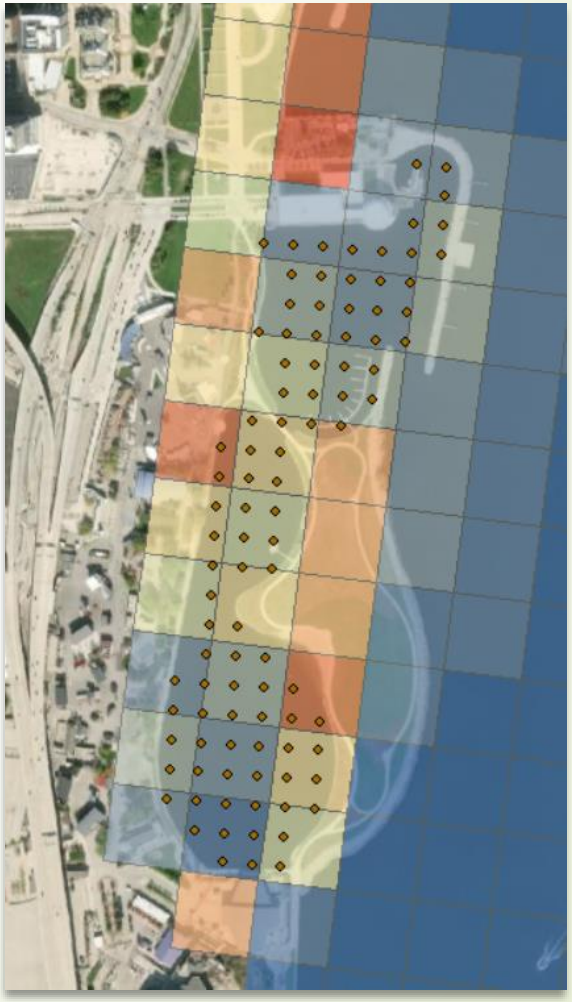
- Targets a range of “hotspots”; Richness is often (but not always) highest at points of entry



Strengths

- Targets a range of "hotspots"; Richness is often (but not always) highest at points of entry
- Efficient detection compared to more systematic sampling

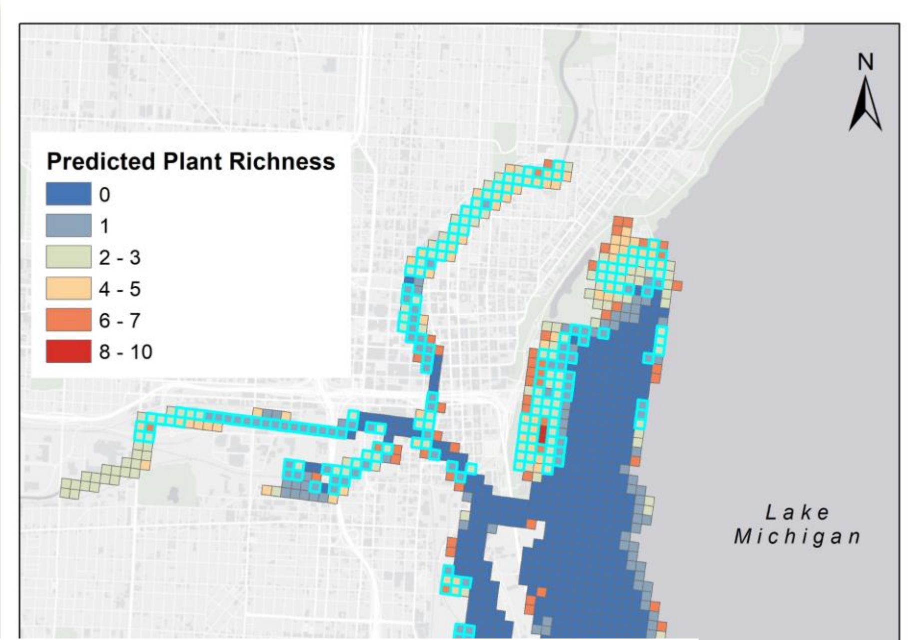
59 | 1 (0)

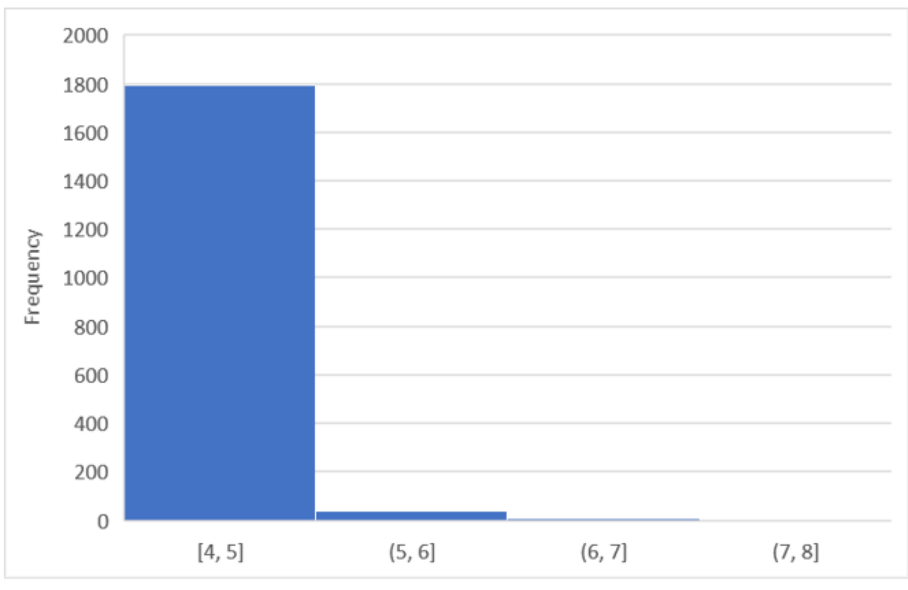


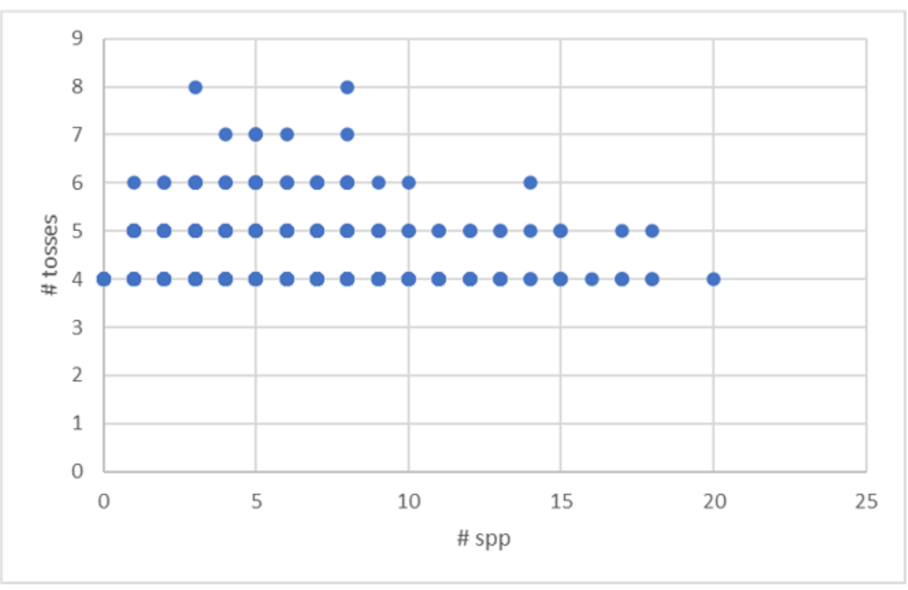
16 (64) | 8 (3)

Strengths

- Targets a range of "hotspots"; Richness is often (but not always) highest at points of entry
- Efficient detection compared to more systematic sampling
- Covers ground

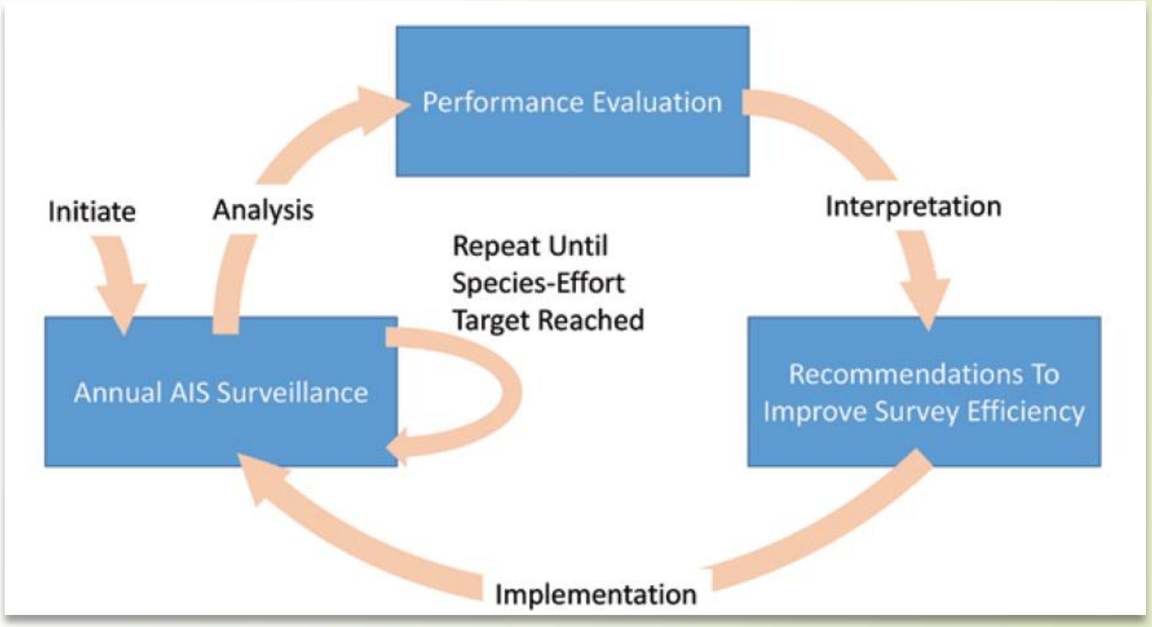






Strengths

- Targets a range of "hotspots"; Richness is often (but not always) highest at points of entry
- Efficient detection compared to more systematic sampling
- Covers ground
- Facilitates adaptive optimization

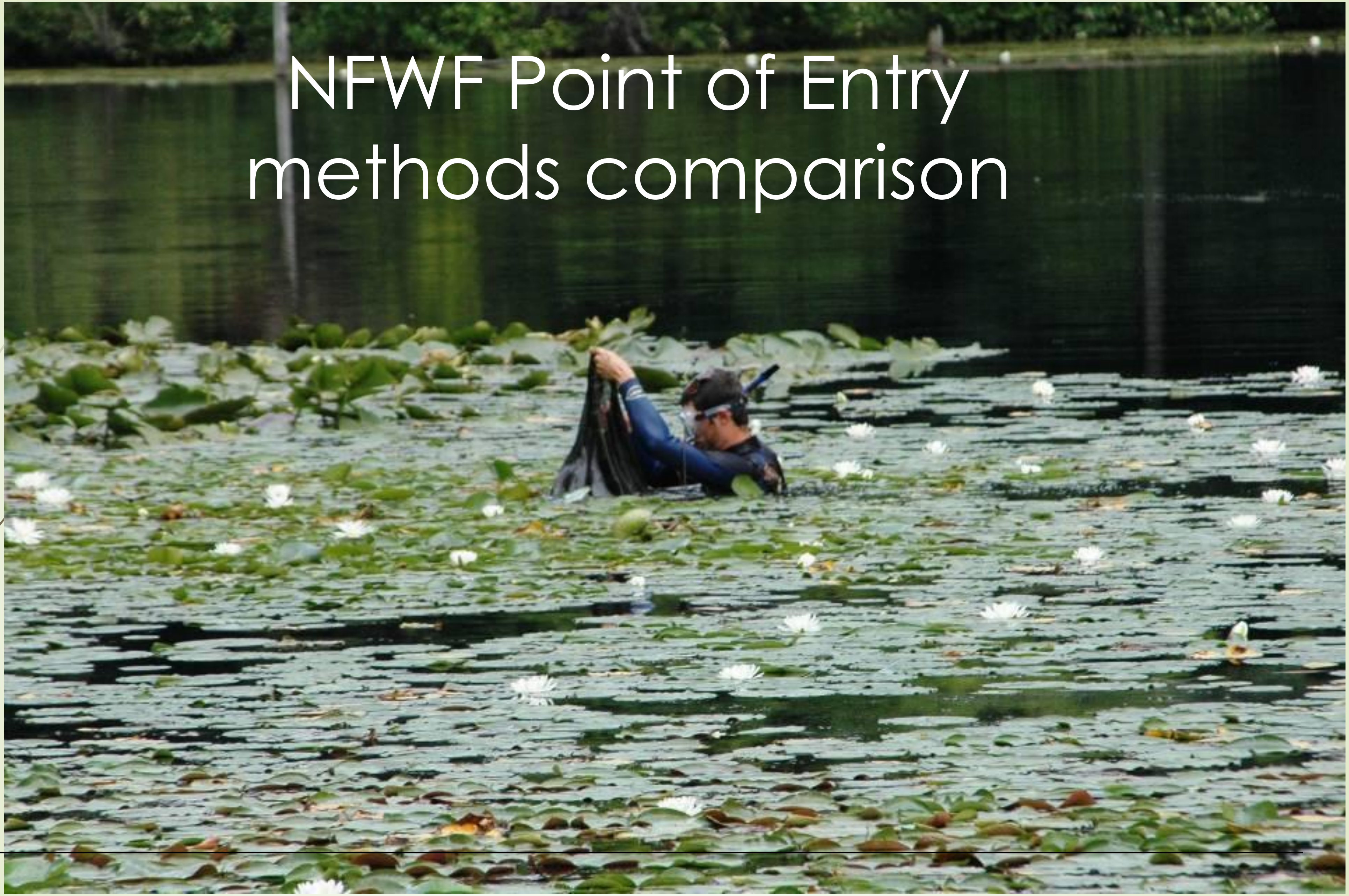


Limitations/Uncertainties

- Implementation requires taxonomic expertise
- Survey design requires some GIS proficiency; less so with the depth-based design; as yet unclear if richness-based design is worth the additional modeling effort
- How much is enough (from AIS detection perspective)? Detection of the rarest spp likely requires repeated visits/additional effort, although…
- The model assumes "rare" species are a good proxy for IAP…is that a good assumption? If not, then rarefaction may be underestimating detection sensitivity.
- Protocol could be adapted to incorporate abundance measures but random design wouldn't necessarily facilitate "status & trends" measures
- Capable of detecting all growth forms, but…

	Count	Proportion
Total spp	40	1.00
Submerged	25	0.63
Free floating	7	0.18
Emergent	6	0.15
Rooted floating	2	0.05
Native	30	0.75
Non-native	10	0.25

NFWF Point of Entry methods comparison



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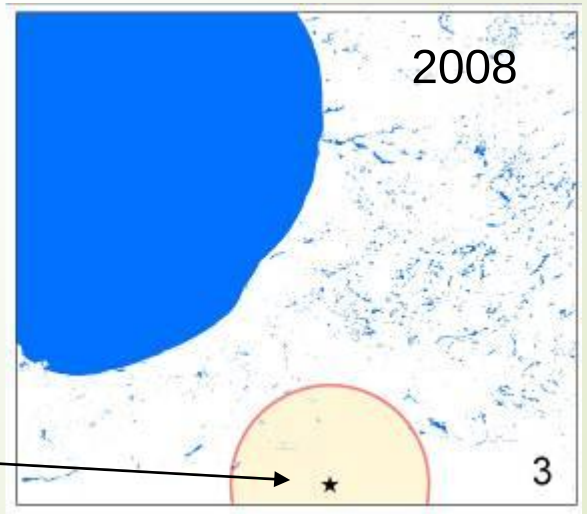
Project objectives

- Test & refine aquatic invasive plant surveillance methods
- Complete *Hydrilla* delimitation surveys to compliment Indiana response efforts
- Inventory other aquatic invasive plants
- Record presence of dresssenid mussels and mystery snails.

Lake Manitou
Delimitation undertaken out to 30 miles radius
But source, pathway, and spread uncertain?

Hydrilla detected



Surveillance & delimitation survey needs

Surveillance

- ideally need to detect new invasions in early phases of establishment (when most vulnerable) – *requires a high detection probability*

Delimitation survey - if new invasion detected:

- full management response can only be determined once full extent of range is established – *requires a high detection probability*

In selecting a survey method

- Trade off between covering ground & a complete species census
- Wanted to maximize number of lakes surveyed & minimize detection error
- Cost effective (needed to be affordable, limited budgets, no boats)




Aquatic plant surveillance methods

Illinois 2007 protocol

- Six rake tosses per site from boat landings

Indiana *Hydrilla* delimitation protocol

- 25 rake tosses from boat around boat landing

Indiana Tier II whole lake surveys

- Grid up lake & sample each intersect point with a single rake toss (Indiana = 50 tosses)

NFWF Shore-based rake survey

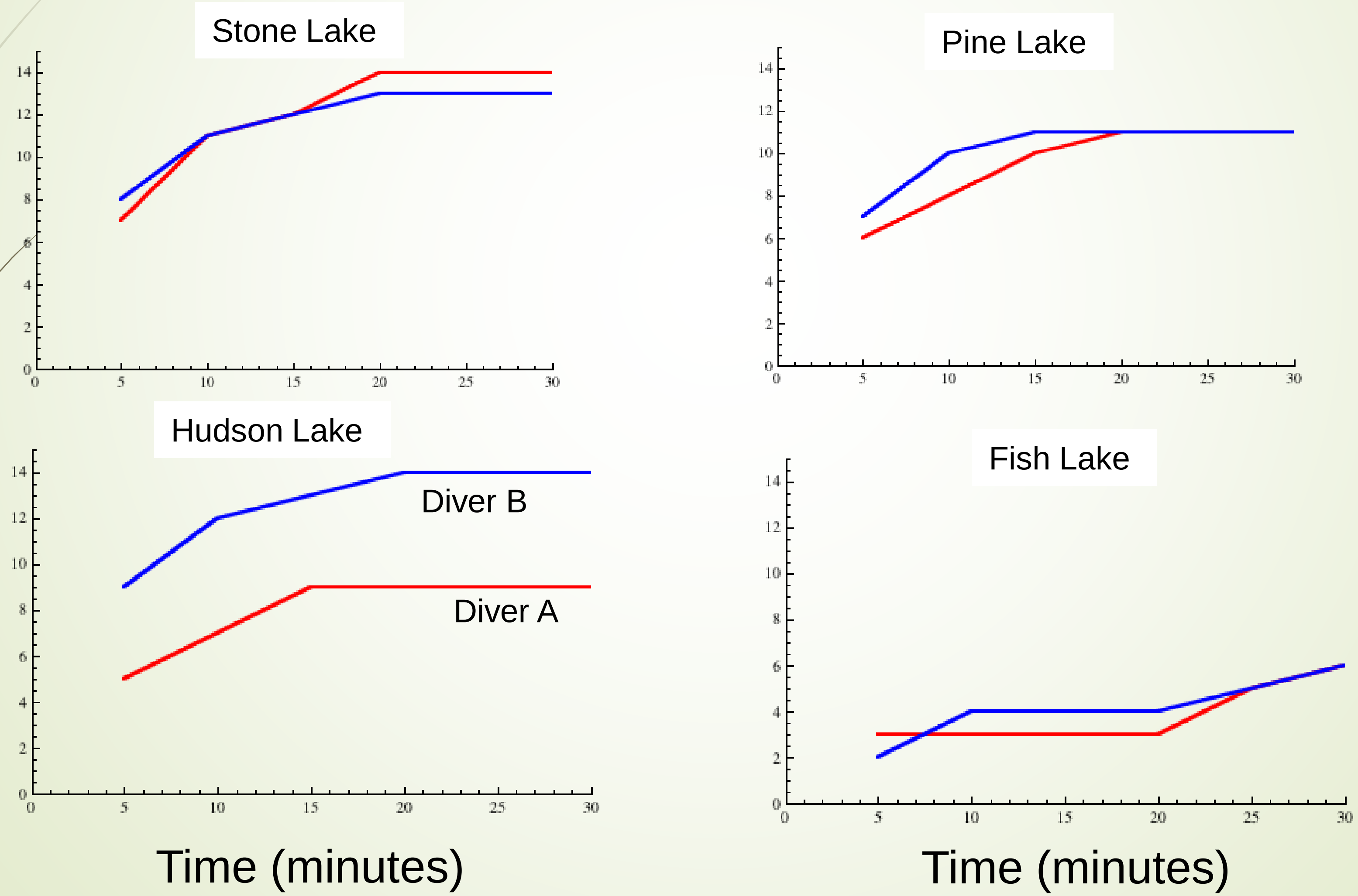
- Repeated rake tosses at up to 6 x 5m intervals from landing – toss rake at each point until no new species detected.

Snorkel survey

- 30 minute snorkel survey

Developing snorkel method (species accumulation curves)

- collect all species observed
- examine discovery rates to select optimal sampling time



Concluded 30 minutes snorkel time was optimal

NFWF survey protocol

- Snorkeler – 30 minutes searching area around the boat landing – collecting all plant species observed as well as introduced mollusks (Dreissenids and Mystery Snails)
- Kayaker role - safety, collects emergent plants, directs diver to potentially different plant communities, collect physico-chemical data.
- 4 x 2 person teams, each 2 person team self contained.

(kayak and all gear fit inside Van)

- Plant collections kept cool, returned to lab and identified by expert

Testing snorkeling efficacy vs Illinois rake toss

Questions:

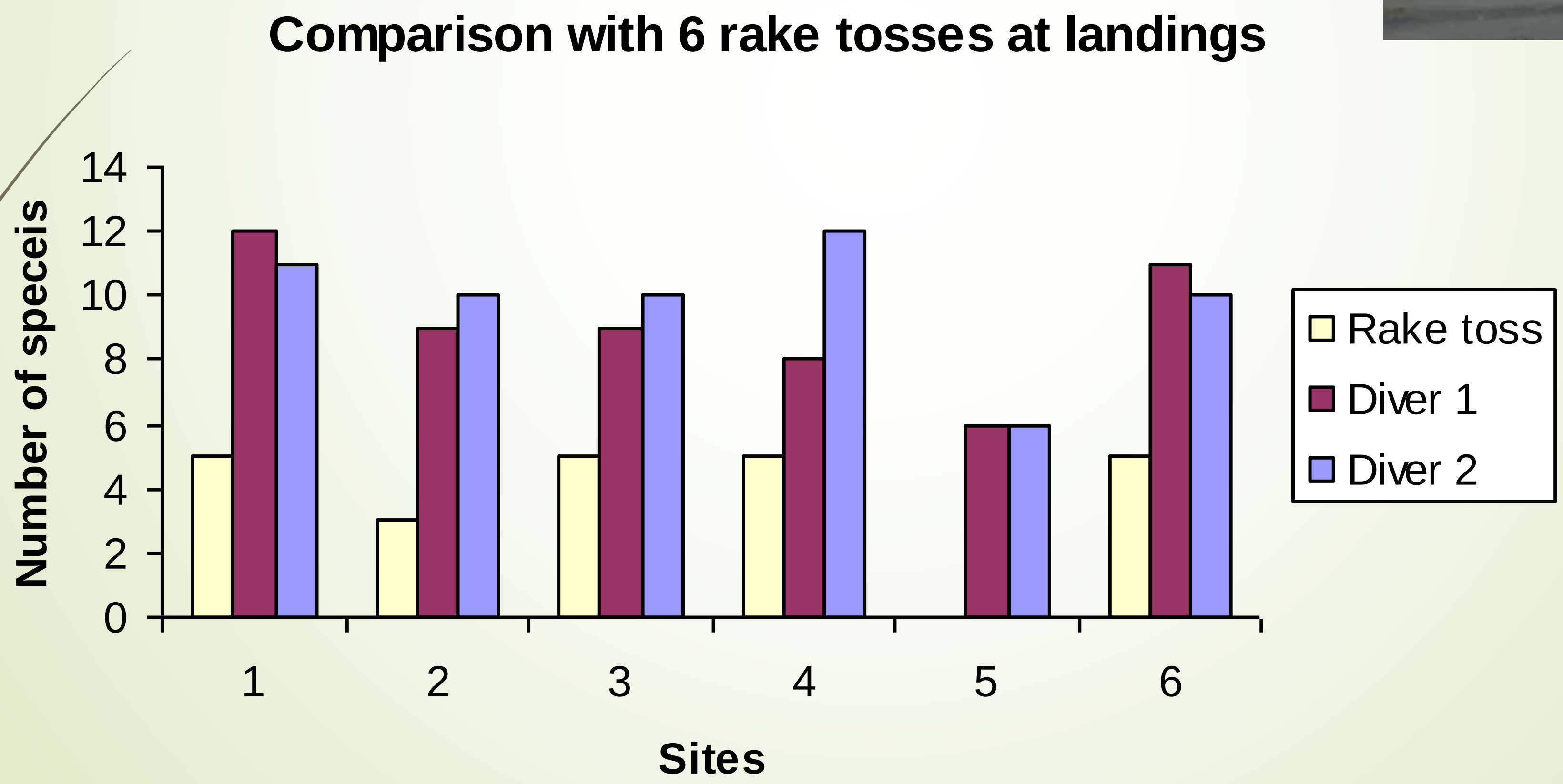
- Can snorkeling be used as a rapid survey method
- Are detection rates comparable to rake methods

- Illinois: 6 rake tosses around boat landing
- 30 minute snorkel around boat landing (1 diver)



Comparison of snorkel counts versus Illinois rake survey protocol (n=6)

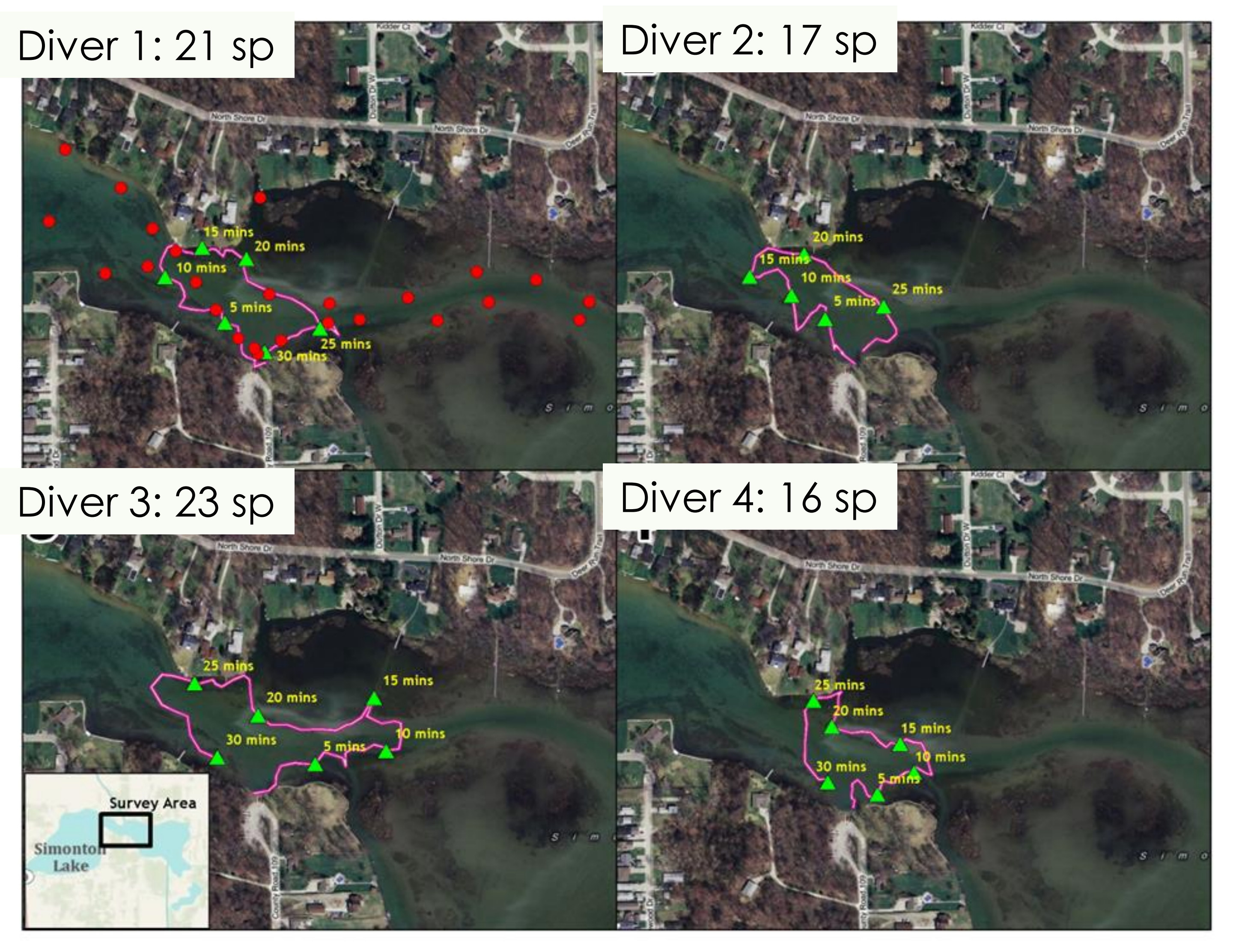
- surveyed six lakes in September 2008



Snorkel survey vs Indiana 25 rake toss

Rake survey = 12 sp
Total species (all methods) = 28

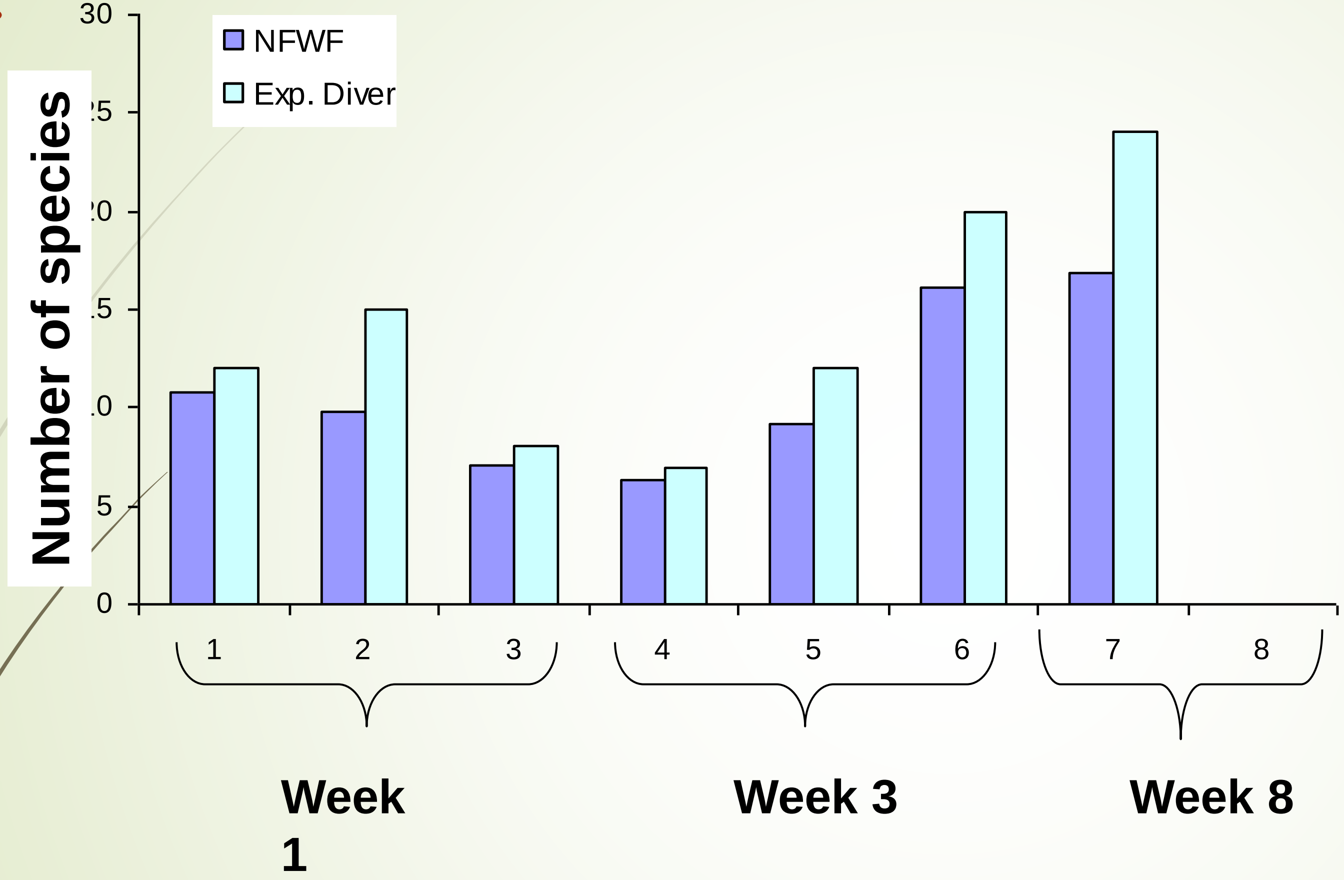
Snorkel average = 19 sp



Comparison across all methods

Lake	Total sp. discovered	No. Sp. by all Snorkelers	No. Sp. by IN Rake Toss (N=25 toss)	No. Sp. Shore based rake toss	No. Sp. by all Rake Toss
Webster	25	22 (88.0%)	6 (24.0%)	10 (40%) 11 toss	17 (68.0%)
Clear	21	20 (95.2%)	13 (61.9%)	15 (71%) 25 toss	18 (85.7%)
Simonton	28	26 (92.9%)	12 (42.9%)	10 (31%) 13 toss	14 (50.0%)
Syracuse	32	27 (84.4%)	18 (56.3%)	13 (41%) 14 Toss	25 (78.1%)
Wawasee	31	28 (90.3%)	17 (54.8%)	16 (52%) 19 toss	24 (77.4%)
Average (SE) (across 9 lakes)	25.4 (1.7)	24.1 (1.5)	11.3 (1.5)	11.2 13 toss	16.9 (1.7)

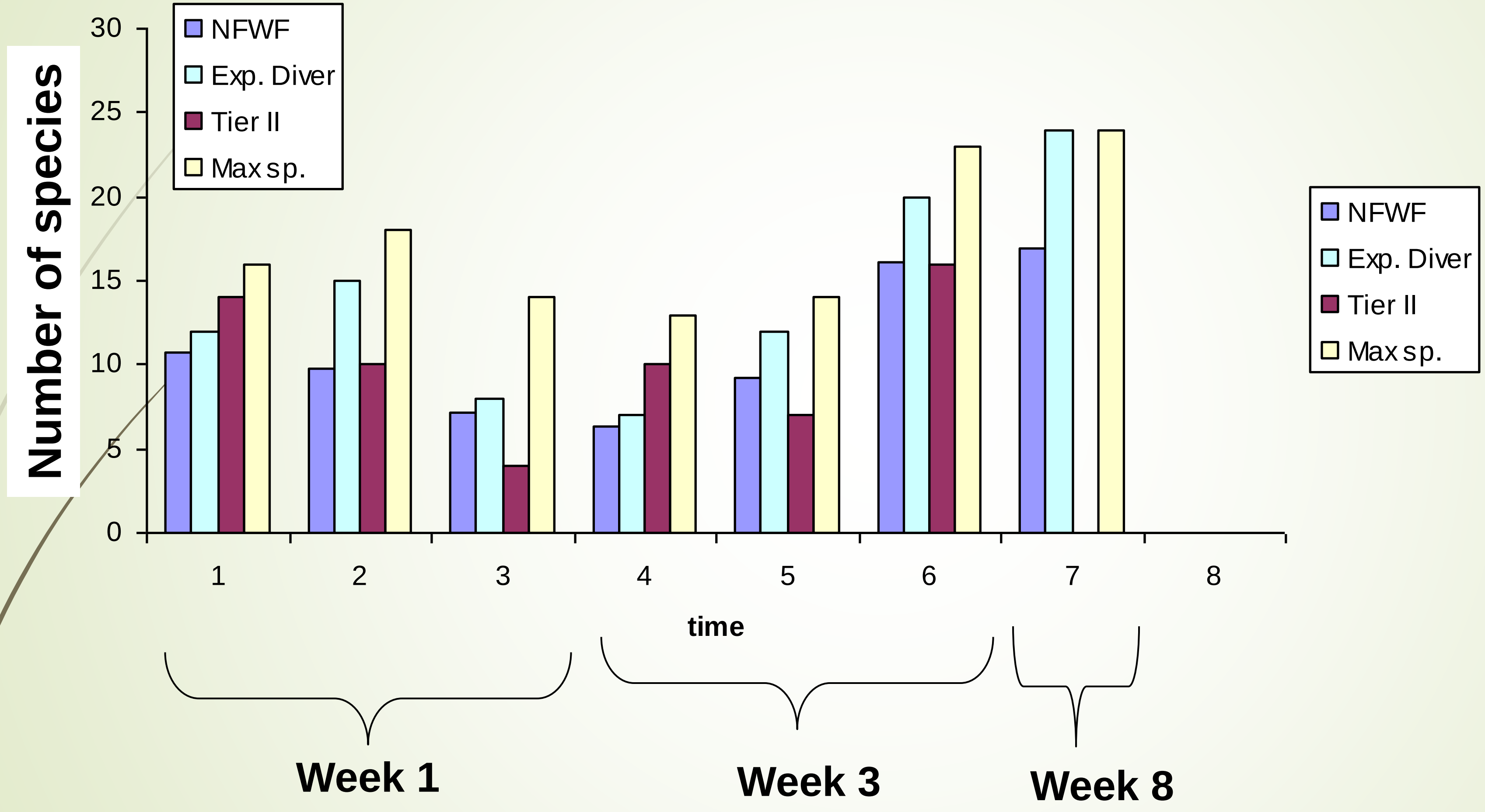
Diver experience matters



- Lakes listed in order sampled by NFWF crews
- NFWF = average of 8 divers

- **Difference tended to be rare native species and rarely AIS**
- *Training and QA important*

Divers vs Tier II vs total recorded species (all methods).



- Max species = all species encountered by all divers
- Even experienced diver only observed between 55% - 87% of max species pool
- *Most instances performed as well as IN Tier II survey (50 rake tosses across a whole lake*)

Strengths

Pro:

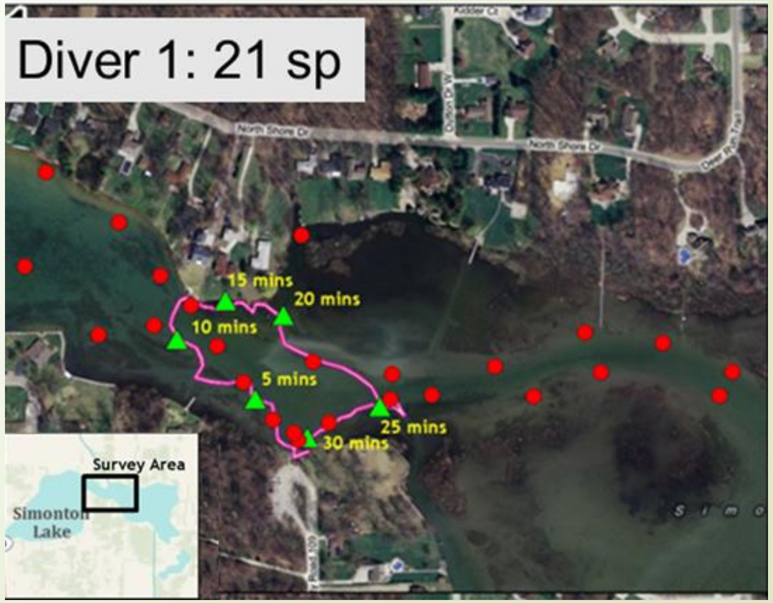
- 30 minute snorkel time appears sufficient to collect most common species
- 30 minute snorkel method more effective than standard POE rake toss methods, both in terms of species richness and collection of rare species especially if using experience divers
- Significant inter diver variability – difference usually due to rare species (and not AIS)
- Possible to cover multiple sites in a day
- Snorkeling boat ramps appears to provide a cost effective rapid survey methods that is suitable for surveillance & AIS delimitation surveys

(>800 sites, and over 500 lakes surveyed across 3 states in 2 years)




Weaknesses

- Cons:
- spatially coverage limited (> than ramp rake tosses – less than boat rake toss)
- Assumes boat ramps area of greatest risk (i.e. trailered boats most important pathway of invasion)
- Assumes rare natives are good surrogate for AIS – result possibly overestimate detection sensitivity
- Inter diver detection variability - experience matters
- Requires clean, clear water, and safe conditions



Acknowledgements

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- Collaborators/partners in IDNR, MDEQ, MDNR, ODNR
- The summer field crews

Questions

Inter-diver variability (% species detected)

Lake (total number of unique species by all divers)	Week	Diver									
		1*	2	3	4	5	6	7	8#	9	10
Loon (23)	1	20 (87%)	14 (61%)	12 (52%)	16 (70%)	10 (43%)	10 (43%)	14 (61%)	15 (65%)	11 (48%)	10 (43%)
Ceder (20)	1	11 (55%)	9 (45%)	10 (50%)	11 (55%)	10 (50%)	9 (45%)	10 (50%)	13 (65%)	9 (45%)	7 (35%)
Loon II (21)	3	12 (57%)	9 (43%)	9 (43%)	6 (29%)	9 (43%)	12 (57%)	6 (29%)	12 (57%)	6 (29%)	6 (29%)
Big (19)	3	15 (79%)	10 (53%)	12 (63%)	11 (58%)	14 (74%)	8 (42%)	9 (47%)	12 (63%)	10 (53%)	11 (58%)
Crooked (31)	3	25 (81%)	20 (65%)	21 (68%)	22 (71%)	20 (65%)	14 (45%)	18 (58%)	24 (77%)	16 (52%)	19 (61%)
Wawasee (30)	8	24 (80%)	19 (63%)	23 (77%)	21 (70%)	22 (73%)	22 (73%)	22 (73%)	25 (83%)	21 (70%)	23 (77%)

NFWF survey costs

- Yr 1 Hired 9 summer students for 8 weeks
- 4 X 2 person teams
- All plants collected were bagged & labeled - identified back in lab. (*for Mi & IN*).
- Same experienced person ID all plants
- Weekly running cost ~ $1200 -$1600 / crew
  - Wages ($800)
  - Van hire ($200)
  - Fuel ($200)
  - Accommodation
  - Consumables

  (*based in SBN*)