Mapping, monitoring, and managing seasonal ponds in forested landscapes

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Seasonal Ponds are Unique Wetlands

Seasonal ponds are tightly linked with surrounding uplands

- *Ecology:* Movement of amphibians between upland and wetland habitats; connections between ponds
- *Hydrology:* Snowmelt and rain are important hydrologic inputs; water budget of landscape
- *Biogeochemistry:* Biogeochemical hotspots (carbon, mercury)

Systematic Review

- **Objectives:** (1) define their fundamental physical and biological characteristics, (2) identify where they occur, and (3) address their sensitivity to landscape and global changes
- **Focus:** Practical forest management concerns in landscapes with seasonal ponds
- **Team:** Scientists, forest managers, and resource professionals from Federal, State, and Tribal governments, and nonprofit and private sectors




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Systematic Review Methods

- Searched Web of Science and TreeSearch databases for papers with:
  - Synonyms for seasonal ponds (vernal, ephemeral, depressional, woodland, temporary, autumnal)
  - Cowardin et al., 1979 wetland water regime modifiers (temporarily flooded, saturated, seasonally flooded)
- Judged relevance of each paper using scientific definition for seasonal pond
- Classified accepted papers according to geographic location, type of study, primary ecosystem factor (*e.g.,* flora, biogeochemistry, distribution)
- **Focus area:** western Great Lakes states (*i.e.,* Minnesota, Wisconsin, Michigan), included studies in northeastern United States
- Final bibliographic database included 180 papers
  - 12 papers specifically addressing impacts of forest harvesting on seasonal ponds

How are seasonal ponds mapped?

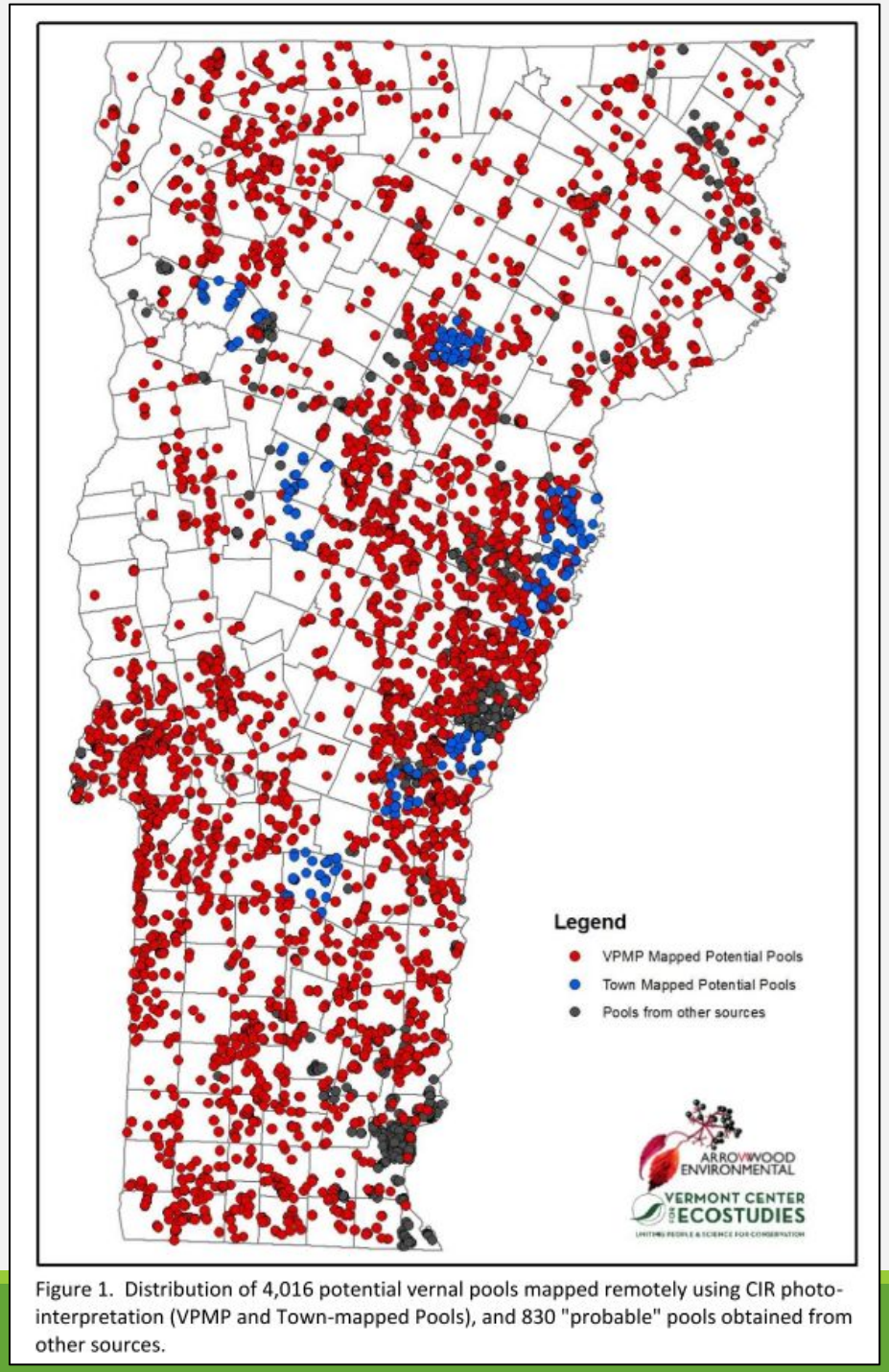

Figure 1. Distribution of 4,016 potential vernal pools mapped remotely using CIR photo-interpretation (VPMP and Town-mapped Pools), and 830 "probable" pools obtained from other sources.

Faccio et al., 2013

Aerial Imagery

Detection of seasonal ponds through photointerpretation of leaf-off aerial black and white or color infrared (CIR) photos

- 46-96% of seasonal ponds mapped depending on criteria used
- Minimum reliable mapping size: 250 m^2

State	Photo Scale	Photointerpretation Accuracy		Pond Size (m^2, mean or median)	Citation
		Wetland characteristics	Organism presence		
Maine	1:12,000; 1:4,800	N/A	46-74%	157-443	Calhoun et al. 2003; Baldwin and deMaynadier 2009
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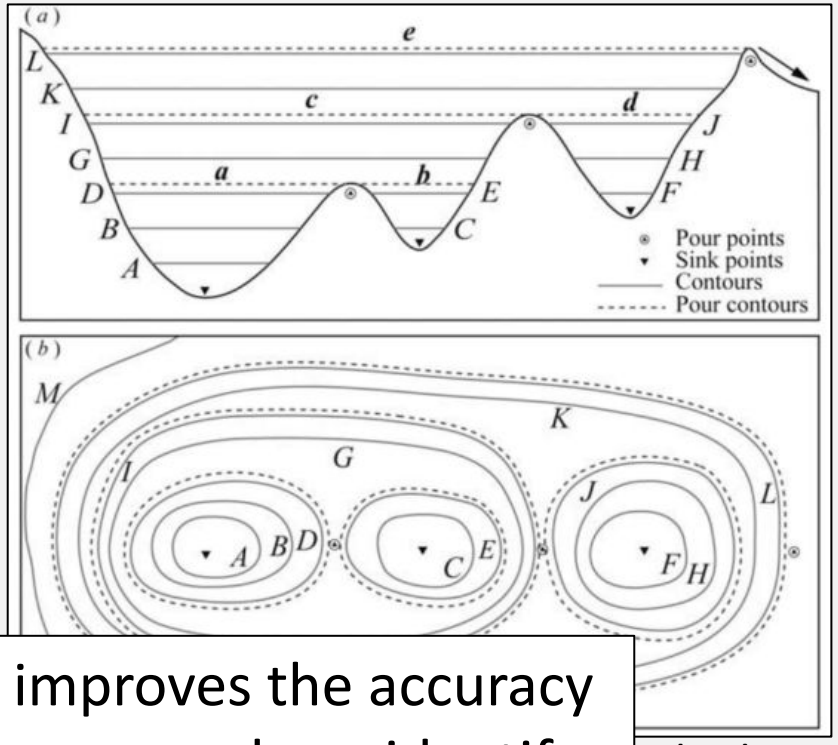
Take away: Photo scale, landscape setting, and canopy over influence the number of ponds identified.
Natural factors such as conifer cover appear to influence the accuracy of pond delineation more than methodological factors such as photo scale.

Topographic Tools

- DEMs, isolated depression maps, topographic indices (TWIs)
- Benefits of geospatial approaches
  - High resolution LiDAR is widely available
  - Layers can be obtained or derived for large areas
  - Geospatial tools can be automated and implemented consistently and repeatably



ethods.

Take away: Using topographic tools with aerial imagery improves the accuracy of seasonal pond maps, especially under heavy canopy cover, and can identify smaller ponds.
Field validation, including multiple visits, is essential to developing a successful seasonal pond inventory, regardless of mapping method used.

Seasonal Pond Density at Landscape Scales

Seasonal pond densities are highest in the till parent materials and lower in outwash plains and lacustrine landforms

State	Dominant Landform or Parent Material	Pond Density	Citation
North central Minnesota	Ground, end moraines	1 pond/10 ha	Palik et al. 2003
	Outwash plains	1 pond/20 ha	
	Lacustrine plains	1 pond/33 ha	
Adirondack region of New York	Shallow till	1 pond/20 ha	Karraker et al. 2008
Connecticut River Valley, Massachusetts	Shallow till; Outwash and lacustrine plains	1 pond/91 ha	Stone 1992; Brooks et al. 1998
Eastern Upper Michigan	Outwash and lacustrine plains	1 pond/400-588 ha	Resh et al. 2013; Previant and Nagel 2016

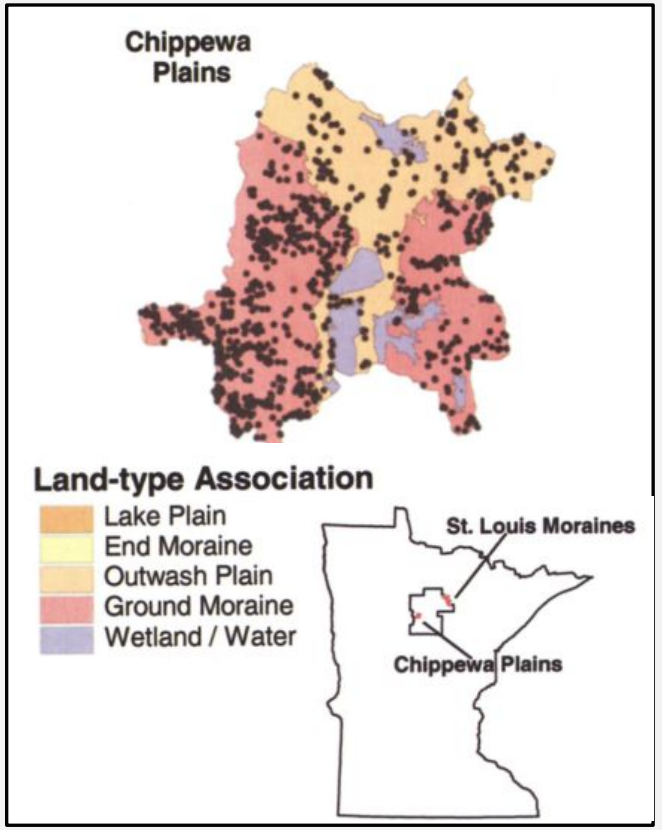


Fig. 2, Palik et al. 2003

How does forest management affect seasonal ponds?

What does forest management look like?

- Forest management includes diverse objectives, activities, and interconnections
- Management: who is the steward of the land?
- Forest management is usually done through the lens of forest type, rather than the physical factors that define a place
  - This creates the potential for problems in landscapes with seasonal ponds

Image: USDA-Forest Service (https://www.fs.usda.gov/research/news/highlights/estimating-greenhouse-gas-emissions-and-removals-managed-forest-land-Alaska)

But what does forest management *really* look like?

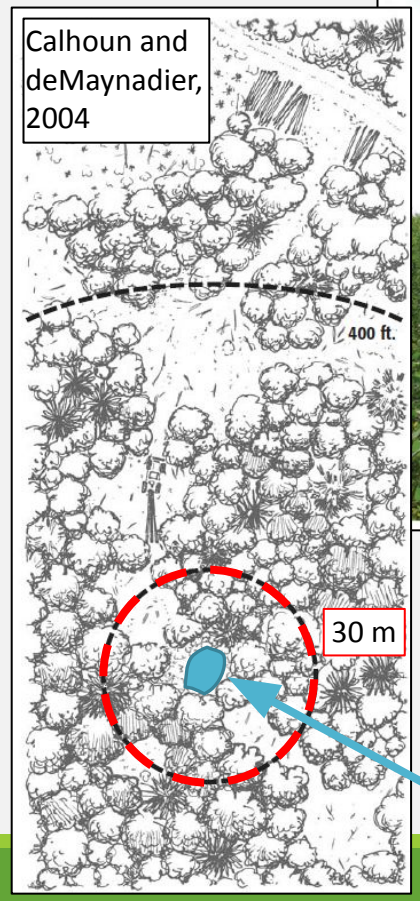
Forest Type	What is removed?	Treatment scale	How often?	Other practices?
Aspen-birch	75-100% of basal area	Patch cuts of 1-5 acres up to clearcuts of 10-40 acres	40-60 year rotation	Scarification
Northern hardwoods	5-50% of basal area	Individual tree or group selection, thinning or shelterwood cuts of 10-40 acres	Re-entry intervals of 10-20 years for selection or thinning, 20-40 years for thinning or shelterwood	Browse inhibition, seedling replanting or direct-seeding, invasive or competition control
Mixed conifers	25-75% of basal area	Group selection, precommercial thinning, shelterwood, 10-40 acres	20-80 years	Residue or prescribed burning, seedling replanting

The Problem With Ponds

- Seasonal ponds can be abundant, rare, or nonexistent in any forest type
- They may not be recognizable during planning, layout, or operations
- What to do? Map them as well as possible, mitigate impacts through adjustments to when, how, or where harvesting is done.

Forest Management Guidelines

- Management guidelines recommend minimizing impacts to seasonal ponds
  - Rutting, soil disturbance, excessive slash
  - Avoid roads and skidder trails through wetlands
- Use buffers or filter strips around ponds
  - MN, WI, MA: minimum width of 15 m
  - ME, VT: minimum width of 30 m
  - Harvesting can occur within buffers
- Identify ponds during spring, harvest during winter



Buffer of trees around seasonal pond

Forest Harvesting Experiments

Location	Experimental Design	Forest Type	Citation	Ecosystem Focus
North central Minnesota	Uncut control, uncut 15 m buffer, partial cut 15 m buffer, clearcut	Aspen-northern hardwoods	Palik and Kastendick, 2010; Kolka et al. 2011; Hanson et al. 2010; Hanowski et al. 2006	Vegetation, Hydrology, Invertebrates, Birds
North central Minnesota	Clearcut	Wet-mesic hardwood-conifer	Hanson et al. 2009	Invertebrates
Northeast Maine	Uncut control, 30 m buffer, 100 m buffer	Mixed hemlock-hardwood	Freidenfelds et al. 2011; Powell et al. 2017; Veysey et al. 2009	Amphibians
Northeast Maine	Uncut control, partial cut, clearcut w/ and w/o CDW	Mixed coniferous and deciduous	Patrick et al. 2006	Amphibians
Connecticut	Uncut control, clearcut	Mixed hardwoods	Skelly et al. 2014	Amphibians

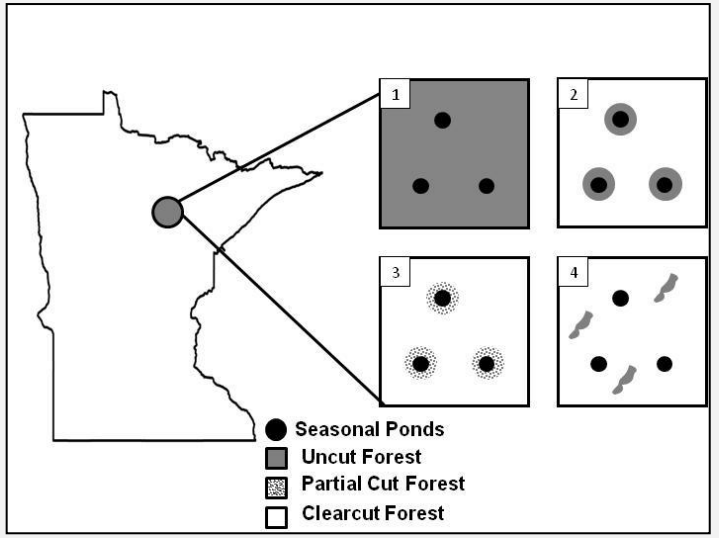


Fig. 1 from Kolka et al., 2011

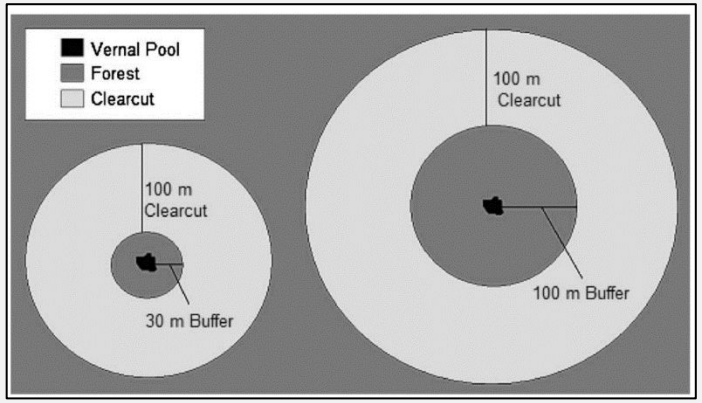
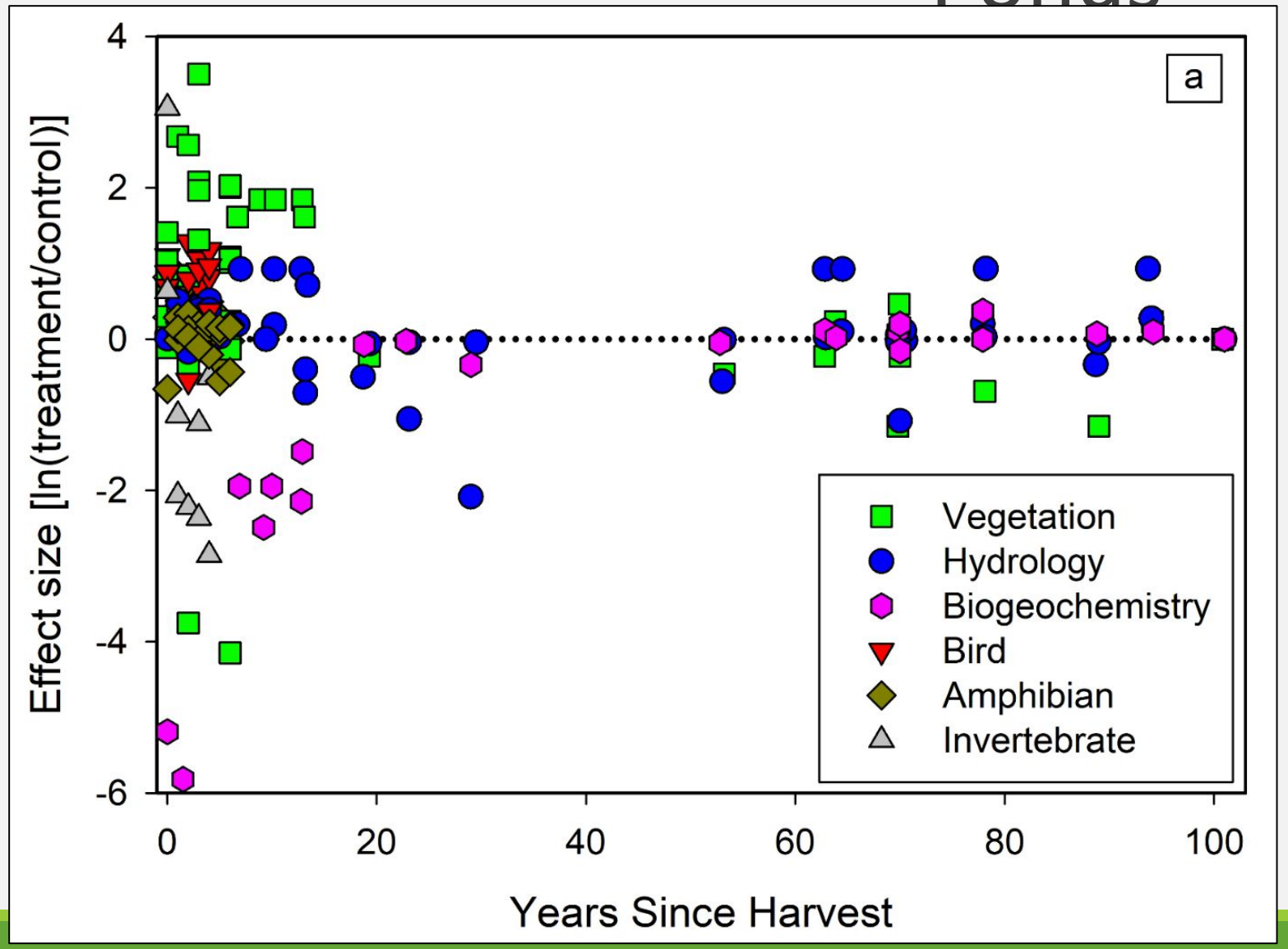


Fig. 1 from Freidenfelds et al., 2011

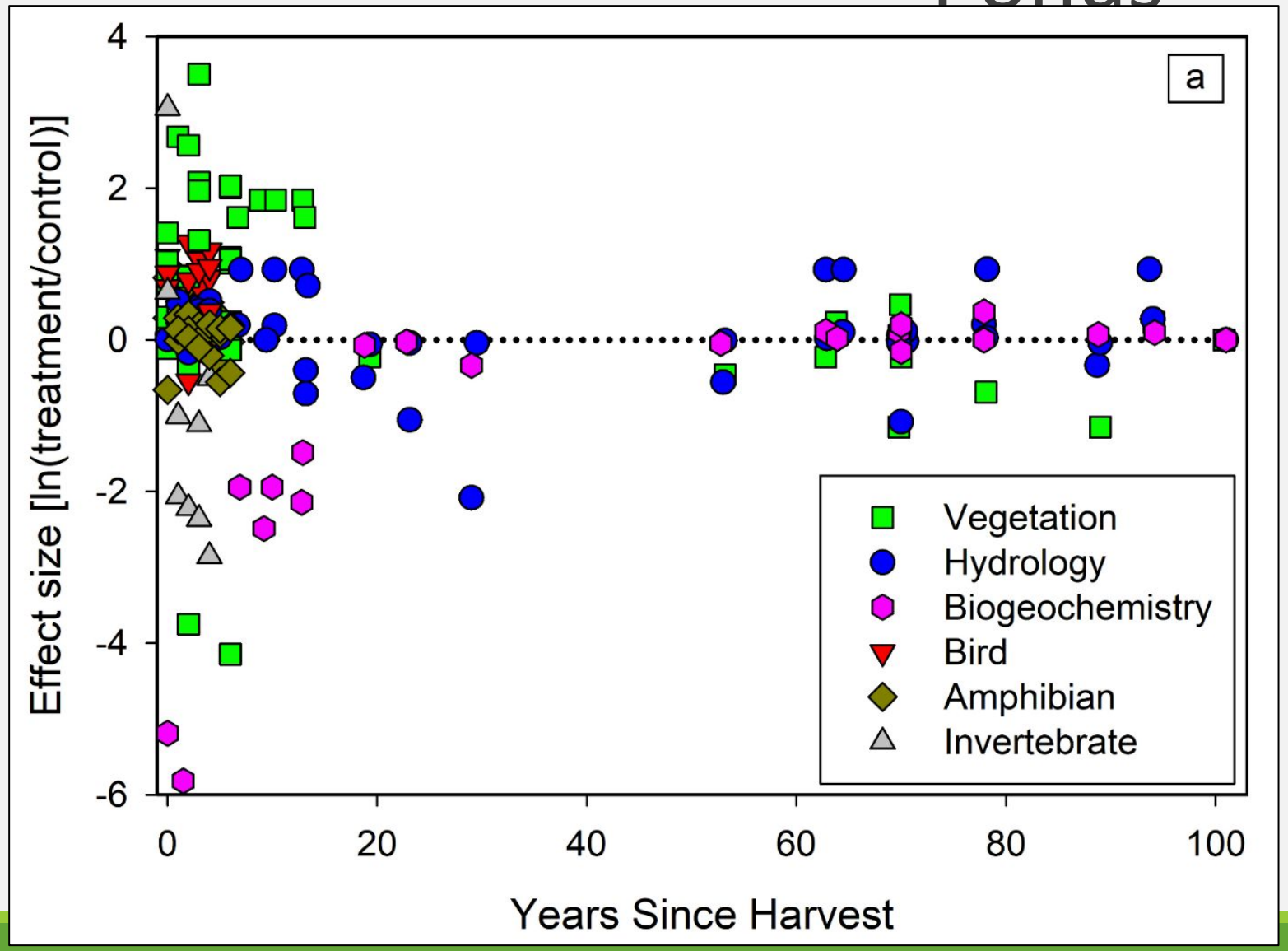
Forest Management Effects on Seasonal Ponds



Vegetation: Canopy openness and sedge and grass cover increased with harvesting and minimal buffers

Hydrology: Any level of adjacent upland harvesting can change stand-level water balance enough to increase water levels and hydroperiods in seasonal ponds

Forest Management Effects on Seasonal Ponds



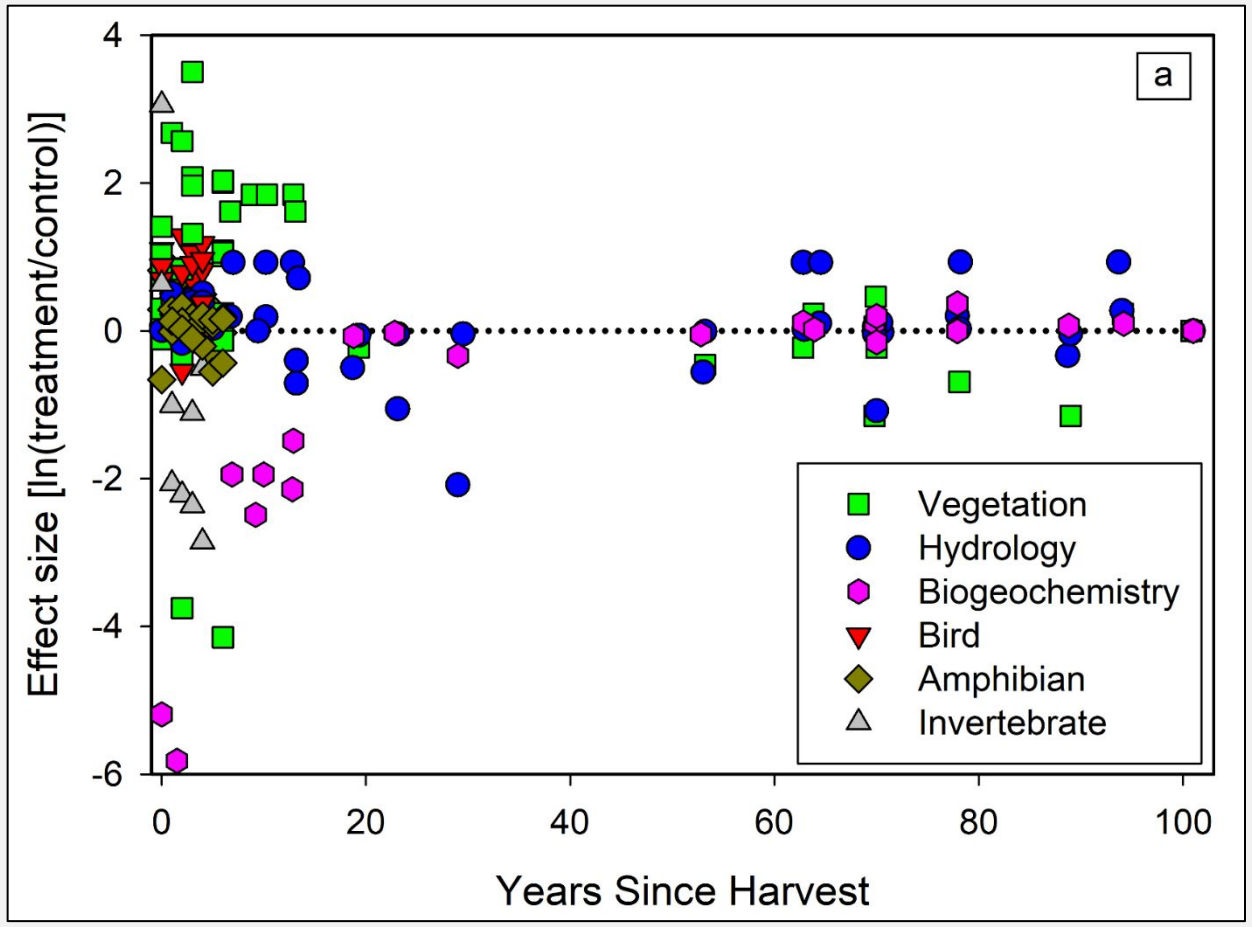
Invertebrates: Community changes took 3-4 years to emerge and were often a result of hydroperiod change

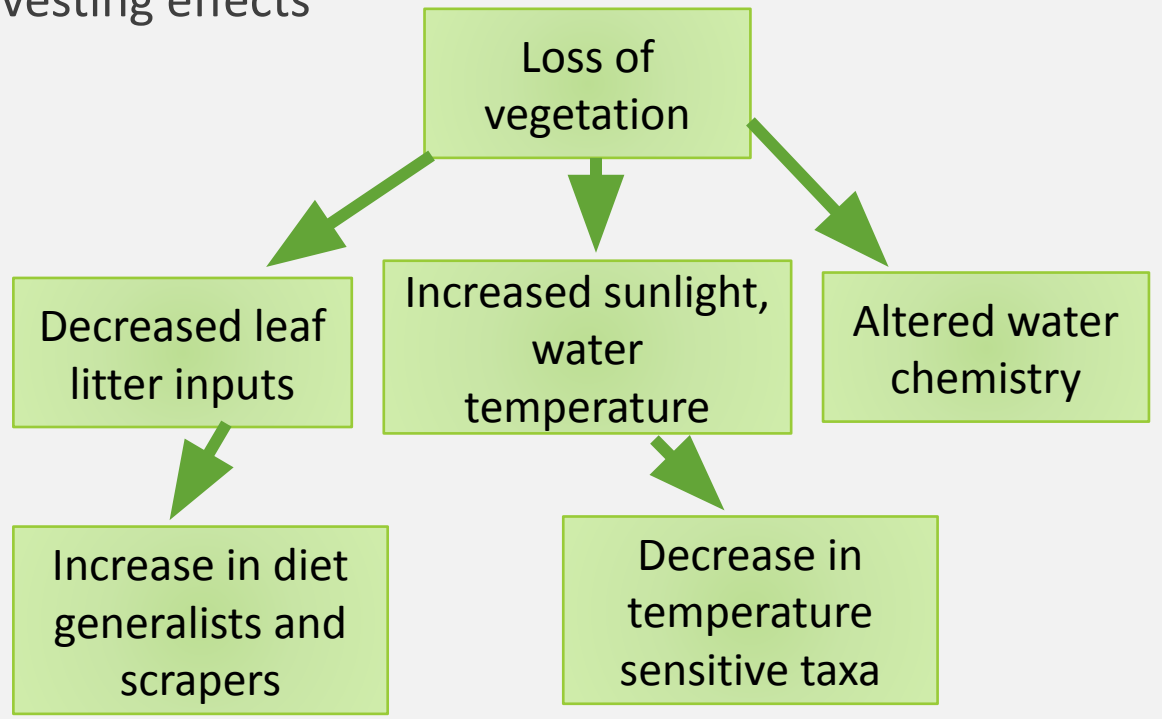
Amphibians: Reproduction and growth were less sensitive to larger buffers

- Larger buffers provide more protected upland habitat, but some frogs and salamanders still migrate through clearcut areas to reach undisturbed upland forest

Forest Harvesting Effects on Seasonal Ponds

- Buffer width and canopy cover influence the magnitude of harvesting effects
  - In general, wider and more intact buffers mitigate harvesting effects



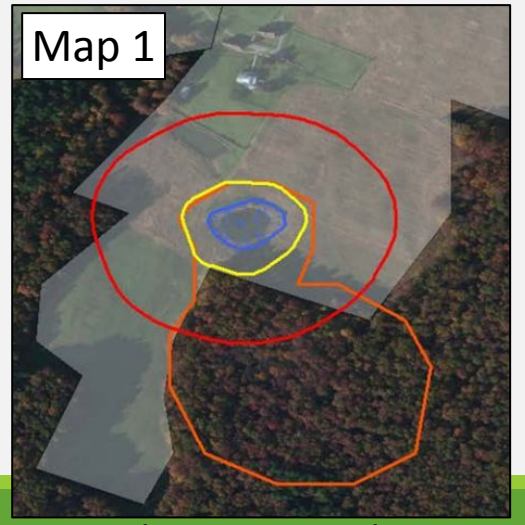


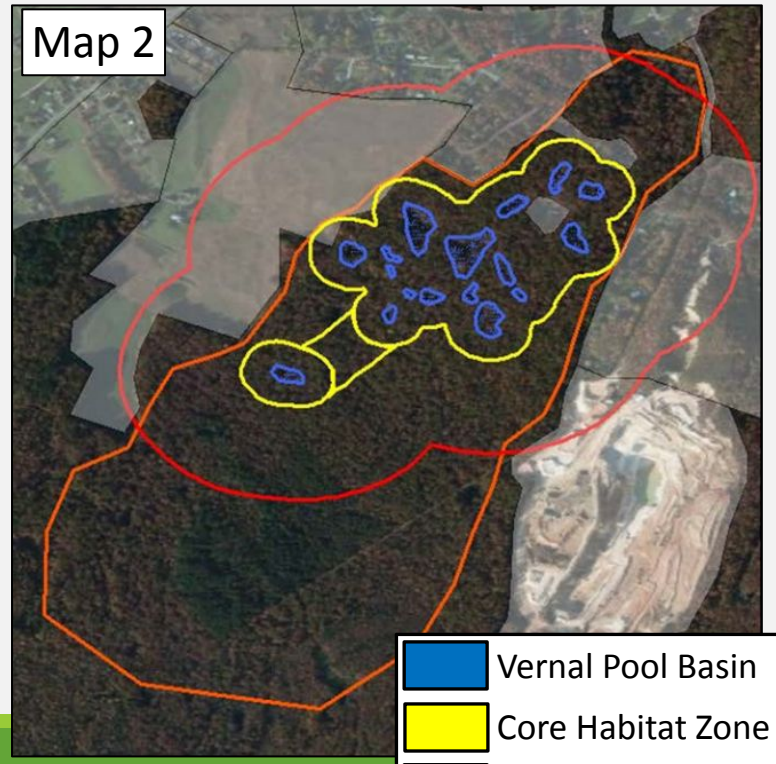
Seasonal pond recovery trajectory: Initial changes within 2-4 years of harvesting. Could take 10-20 years for canopy cover and related ecosystem factors to recover following upland harvest

Seasonal Pond Management Strategies

- Operational challenges:
  - Fully forested buffers are important and do mitigate impacts of adjacent harvesting
  - Large enough buffers to capture all upland habitat could be > 200 m
  - Smaller harvested areas likely have fewer negative impacts than larger clearcut openings
- How to implement buffers in stands with high seasonal pond densities?
  - Protect high quality upland and wetland habitat (Map 1)
  - Protect clusters of seasonal ponds (Map 2)

Need for seasonal pond maps at landscape-state scales to allow for landscape level management plans





Pennsylvania Natural Heritage Program, 2015

Pond protection as a co-benefit

- Pond protection may be most readily achieved as a management co-benefit
  - Aligns with objectives including climate adaptation, soil protection, carbon storage…

Forest Type	Pond-focused Action	Co-benefit / Intent
Aspen-birch	In clearcuts, exclude harvest in areas upslope of ponds that contribute to their hydrology	Keep more carbon on the landscape (financial incentives for carbon storage)
Northern hardwoods	In thinning, expand buffers around individual embedded ponds	Expanded buffers mean larger carbon reserves onsite
Mixed conifer	Configure shelterwood retentions to maintain shading of ponds	Maintain cooler, moister microclimatic refugia for pond organisms and climate-sensitive trees

Documenting how actions are intended to create co-benefits can make pond protection more feasible.

Buffer of trees around seasonal pond

Thank you!

I am excited about collaborating with researchers, managers, and organizations on seasonal pond conservation efforts.

Please reach out with ideas and opportunities!


Blue spotted salamander *(Ambystoma laterale)*

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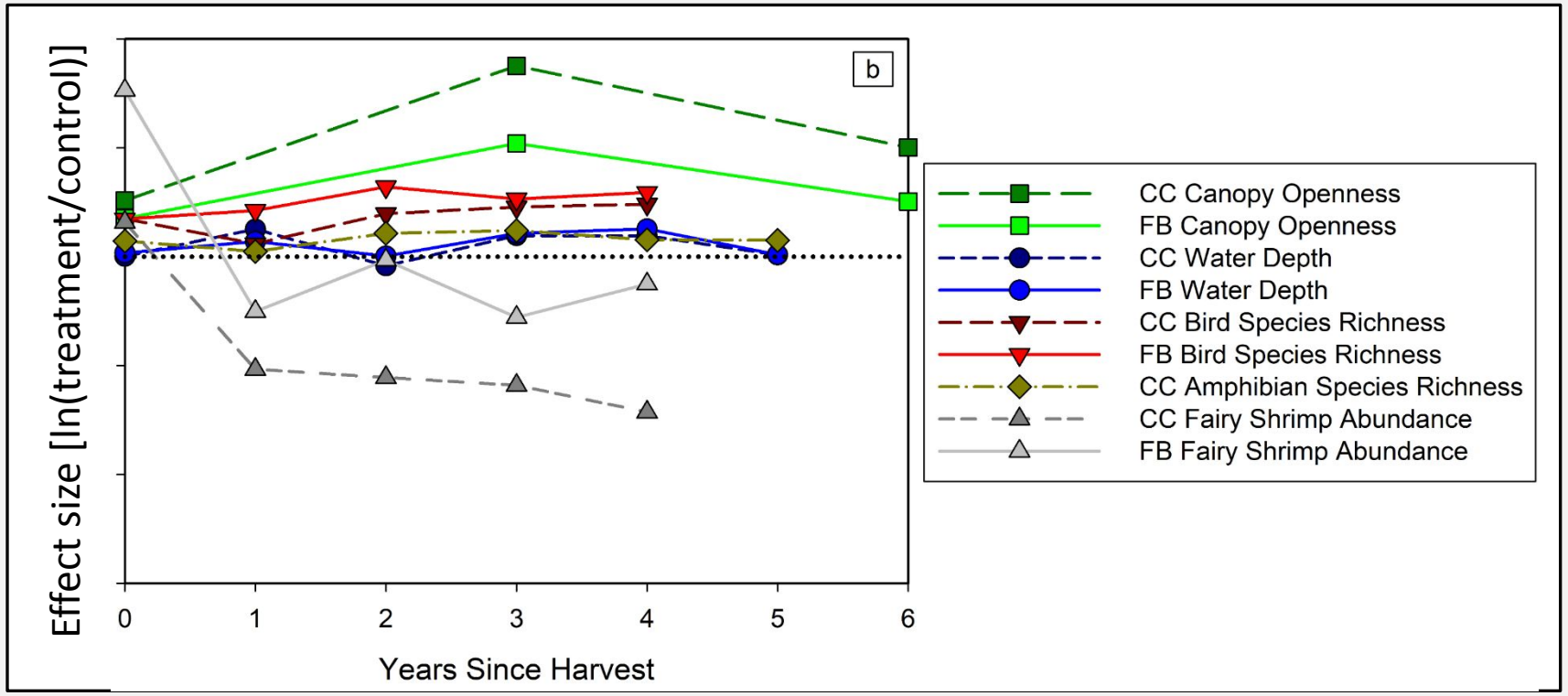
Seasonal Ponds are Unique Wetlands

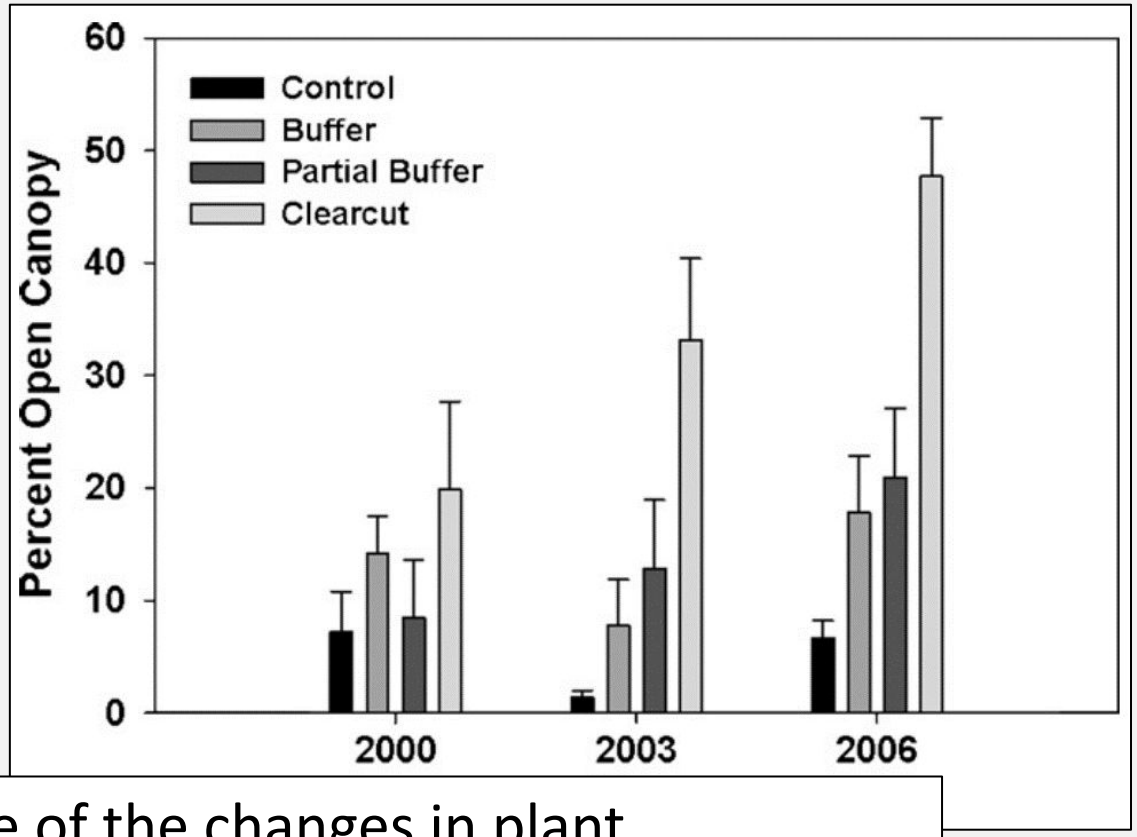
Immediate Responses to Forest Harvesting

- Vegetation and some invertebrates (*i.e.,* fairy shrimp) are most sensitive to harvesting
- Hydrologic response to harvesting is the smallest, could be compounded with natural variability or climate change events



Vegetation Responses

- Increased canopy openness for all treatment seasonal ponds
- Increase in sedge and grass cover
  - Largest increase in clearcut > partial buffer > full buffer treatments
- Increase in willow (*Salix* sp.), alder (*Alnus incana*), trembling aspen (*Populus tremuloides*) especially in clearcut and partial buffer
- Windthrow of mature trees in full and partially cut buffers after harvesting



Take away: Forested buffers mitigated some of the changes in plant community composition, although partial buffer treatments were less effective than full buffer treatments.

Hydrologic Responses

- First year following harvest, water levels were deepest in the clearcut treatment
- Water levels in all buffer treatments were higher than the control until 5th year post-treatment
- Forest type likely influences hydrologic recovery type
  - Fast growing aspen shortened hydrologic recovery in MN (Kolka et al. 2011)
- Warmer water temperatures in ponds with harvesting to the edge (+1.1°C; Skelly et al. 2014)

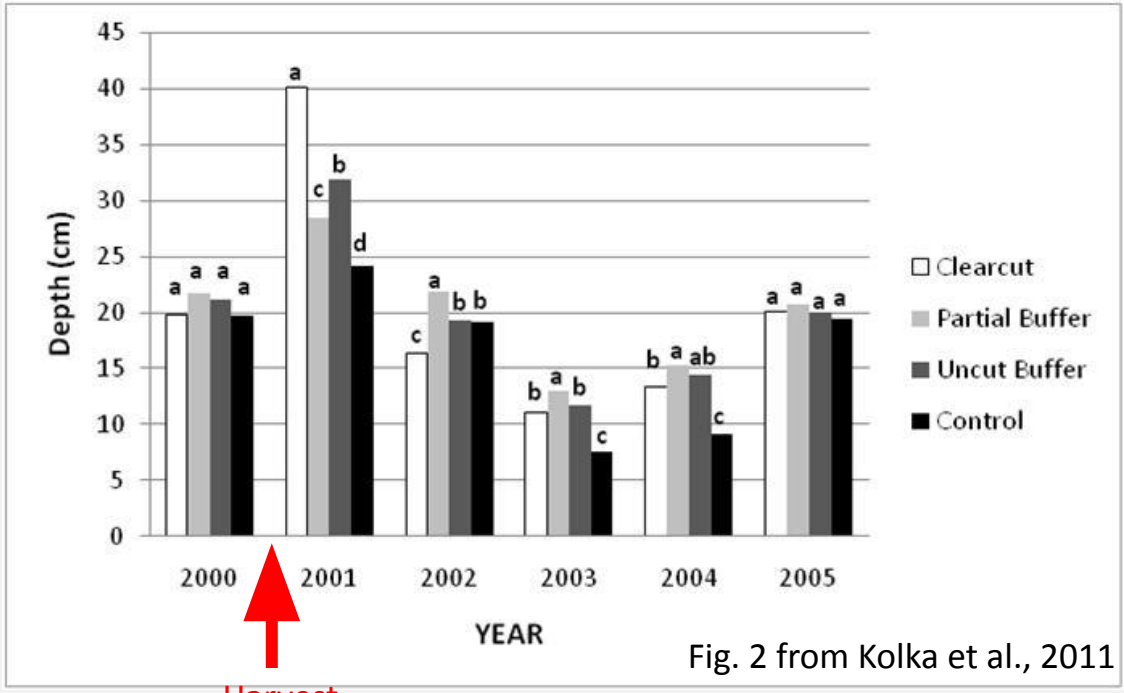


Fig. 2 from Kolka et al., 2011

Take away: Any level of adjacent upland harvesting can change stand-level water balance enough to increase water levels and hydroperiods in seasonal ponds.

Invertebrate Responses

- Invertebrate communities are resilient to variation in many environmental variables, but are most sensitive to changes in hydroperiod
- Harvest-induced changes to canopy cover and hydroperiod have influenced invertebrate community composition (Hanson et al., 2009, 2010)
  - Fairy shrimp (*Eubranchipus* spp.) more abundant in control seasonal ponds
  - Predatory Coleoptera, Diptera, Odonata, Hemiptera taxa more abundant in clearcut ponds
  - Modest increase in taxon richness with longer hydroperiods
- Community differences appeared 3-4 years following treatment
  - Greatest differences between clearcut and control ponds

Take away: Invertebrate community changes are mitigated to some extent by buffers around seasonal ponds, with less community change in ponds with uncut buffers compared to partially cut buffers.

Amphibian Responses

- Movement:
  - <20% of wood frogs remained within the 30 m buffers vs. 50% of frogs and 48% of salamanders within the 100 m buffers (Freidenfelds et al., 2011; Vesey et al., 2009)
  - Migration distances for both frogs and salamanders exceeded 100 m buffer
    - 22-64% of amphibians migrated out of buffer through clearcut area to surrounding upland forest
- Reproduction:
  - Reproductive output was most sensitive at 30 m buffer ponds, especially for salamanders
  - Productivity at all ponds strongly mediated by hydroperiod (Powell and Babbitt, 2017)
- Hab
  - A
  - C

Take away: Amphibian reproduction and growth were less sensitive to larger buffers. Larger buffers provide more protected upland habitat, but some frogs and salamanders still migrate through clearcut areas to reach undisturbed upland forest.

Canopy intolerant species:

Gray treefrog *(Hyla versicolor)*

Spring peeper *(Pseudacris crucifer)*

Red-backed salamander *(Plethodon cinereus)*

American bullfrog *(Lithobates catesbeianus)*

Seasonal Pond Definitions

SCIENTIFIC

- Wetland characteristics (water at or near surface, hydric soils, wetland vegetation)
- Small, isolated wetlands with seasonally varying hydrology, which can provide valuable fishless habitat

JURISDICTIONAL

- Federal protection of “isolated” wetlands subject to political whims
- State definitions can be based on wetland hydrology, soils, vegetation

  OR

- wildlife habitat provided for specific “indicator” organisms (*e.g.,* wood frogs, ambystomatid salamanders, fairy shrimp)