The Association of State Wetland Managers Presents:

Improving Wetland Restoration Success
2014 — 2015 Webinar Series

Vernal Pool Restoration:
How to Restore the Landscape

Presenters:
Mick Micacchion, Midwest Biodiversity Institute;
Christina M. Schaefer, Schaefer Ecological Solutions; and
Aram J.K. Calhoun, The University of Maine

Moderators: Jeanne Christie & Marla Stelk

Supported by EPA Wetland Program Development Grant 83541601

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HAVING TROUBLE WITH THE SOFTWARE?

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Check your email from this morning:

1. You were sent a link to instructions for how to use the Go To Webinar software.
2. You were also sent a PDF of today's presentation. This means you can watch the PDF on your own while you listen to the audio portion of the presentation by dialing in on the phone number provided to you in your email.

AGENDA

- **Welcome and Introductions** (5 minutes)
- **Restoration Webinar Schedule & Future Recordings** (5 minutes)
- **Vernal Pool Restoration: How to Restore the Landscape** (75 minutes)
- **Question & Answer** (15)
- **Wrap up** (5 minutes)

WEBINAR MODERATORS

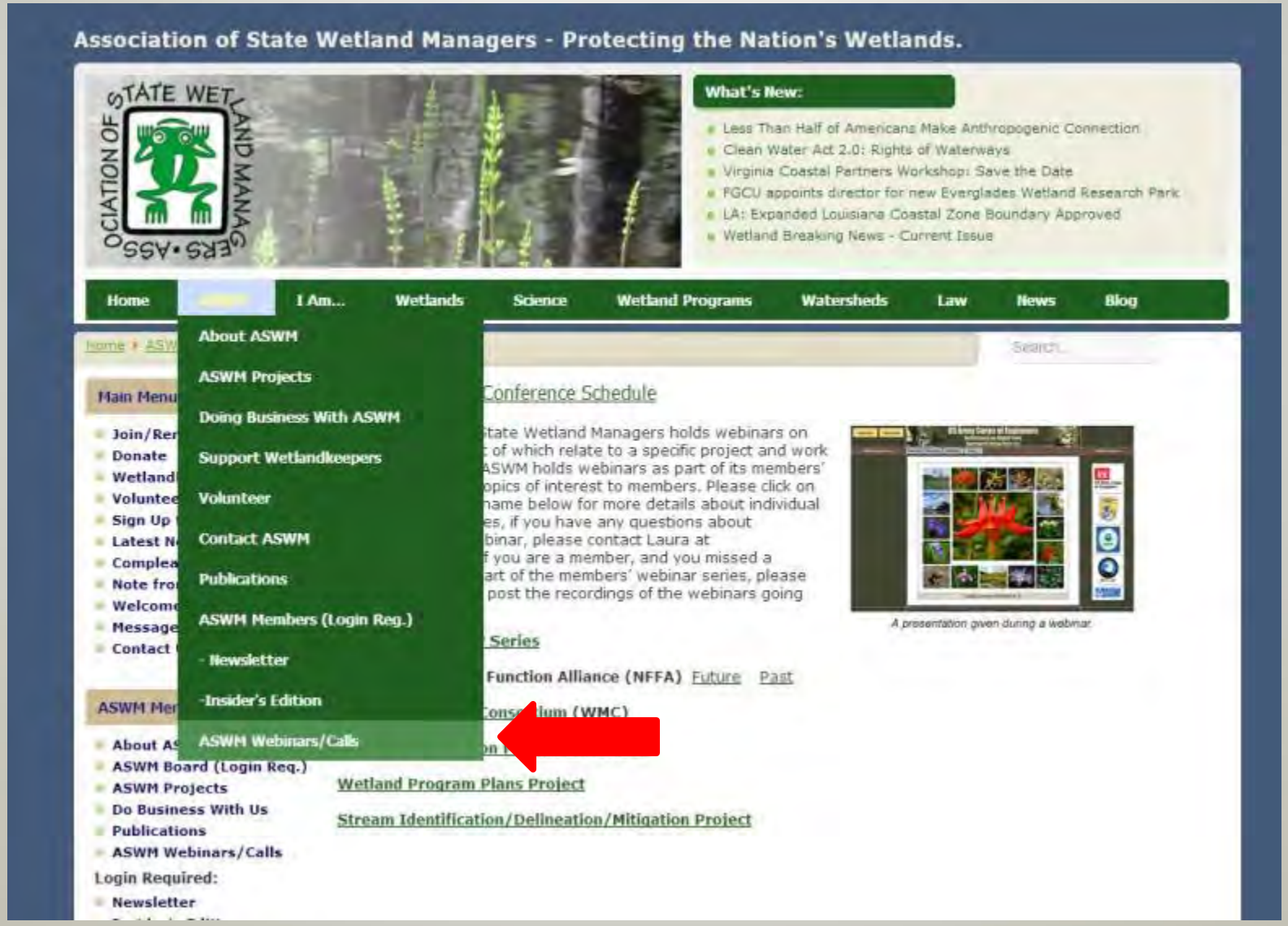
Jeanne Christie,
Executive Director

Marla Stelk,
Policy Analyst

WETLAND RESTORATION PROJECTS

- Convened interdisciplinary workgroup of 25 experts
- Developing monthly webinar series to run through September 2015
- Developing a white paper based on webinars and participant feedback
- To be continued through 2016 in an effort to pursue strategies that:
  - Maximize outcomes for watershed management
    - Ecosystem benefits
    - Climate change
  - Improve permit applications and review
  - Develop a national strategy for improving wetland restoration success

WEBINAR SCHEDULE & RECORDINGS



WEBINAR SCHEDULE & RECORDINGS

FUTURE SCHEDULE - 2015

- **Tuesday, May 19, 3:00pm eastern:**
  - **Prairie Pothole Restoration**

    Presented by:

    Sue Galatowitsch, University of Minnesota; and

    Carter Johnson, South Dakota State University
- **Tuesday, June 9, 3:00pm eastern:**
  - **Riverine/Riparian Wetland Restoration**

    Presented by:

    Richard Weber, NRCS Wetlands Team; and

    Larry Urban, Montana Dept. of Transportation

FOR FULL SCHEDULE, GO TO: http://aswm.org/aswm/6774-future-webinars-improving-wetland-restoration-success-project

PRESENTERS

Aram Calhoun
Professor of Wetland Ecology and
Director of the Ecology & Environmental Sciences Program
University of Maine

Mick Micacchion
Wetland Ecologist
Midwest Biodiversity Institute

Christina Schaefer
Landscape Ecologist
Schaefer Ecological Solutions

A “COOKBOOK” APPROACH TO WETLAND RESTORATION WON’T WORK

There are too many variables.

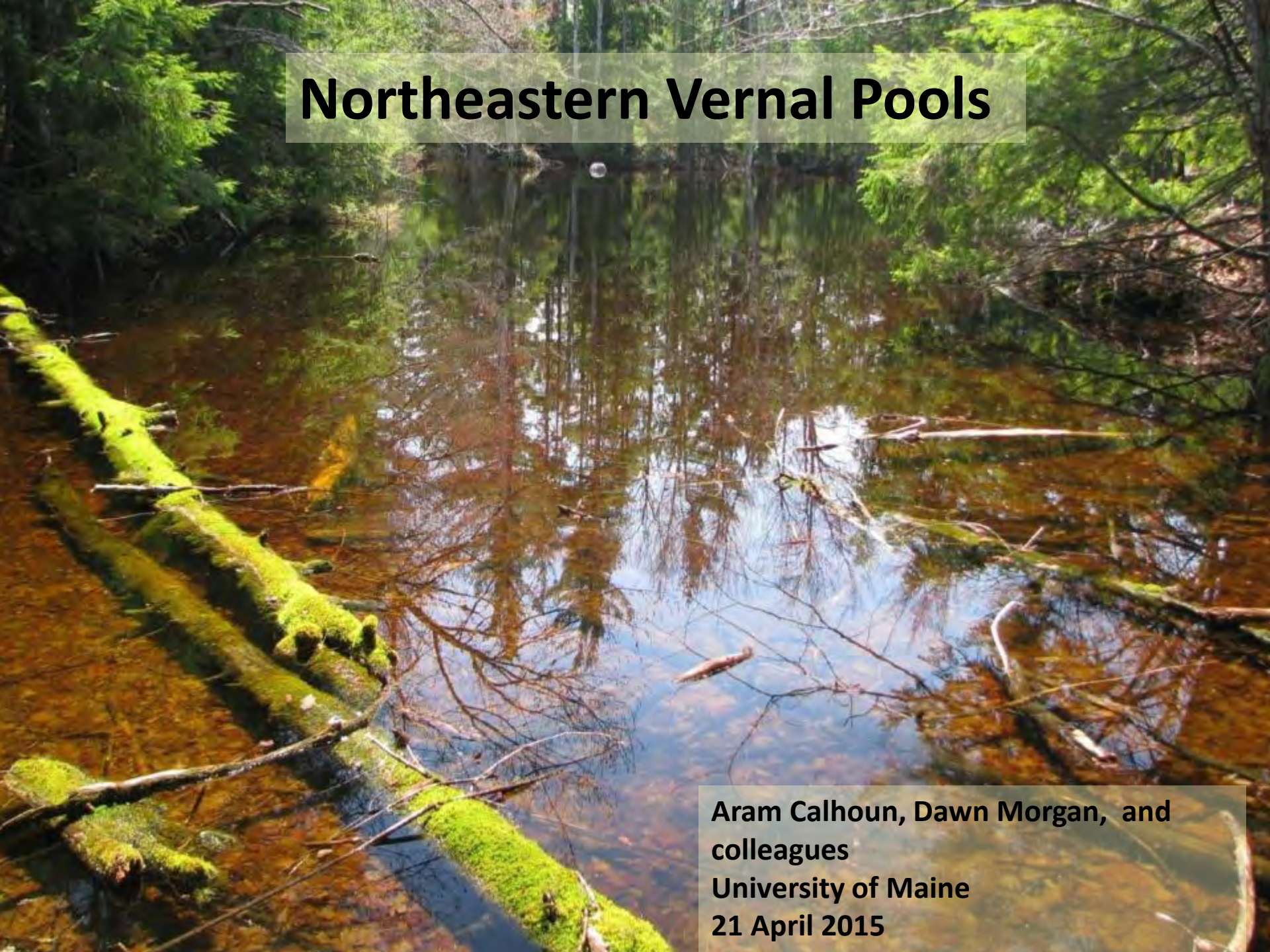
- *Ingredients are always different*
- *Reason for ‘cooking’ varies*
- *Recipe isn’t always correct*
- *Inexperienced cooks*
- *Cooking time varies*
- *Poor inspection when “cooking”*
- *Additional ingredients may be needed*
- *Is it really done?*

WE NEED TO UNDERSTAND THE PLANNING PROCESS AND VARIABLES FROM SITE TO SITE THAT MUST BE STUDIED, UNDERSTOOD AND ADDRESSED

EACH WETLAND RESTORATION PROJECT IS UNIQUE:

- *Consider both historic and current landscape setting*
- *Analyze how water moves into and out of the site*
- *Evaluate soils present and identify any onsite drainage*
- *Focus first on hydrology and soil first, last on plants*
- *Develop a plan that is achievable for the site*
- *Develop comprehensive cost estimates*
- *Ensure plan is followed*
- *Hire experienced and knowledgeable contractors*
- *Adapt plan as needed during construction*
- *Determine if monitoring criteria will measure progress*
- *Keep good records and share with others*

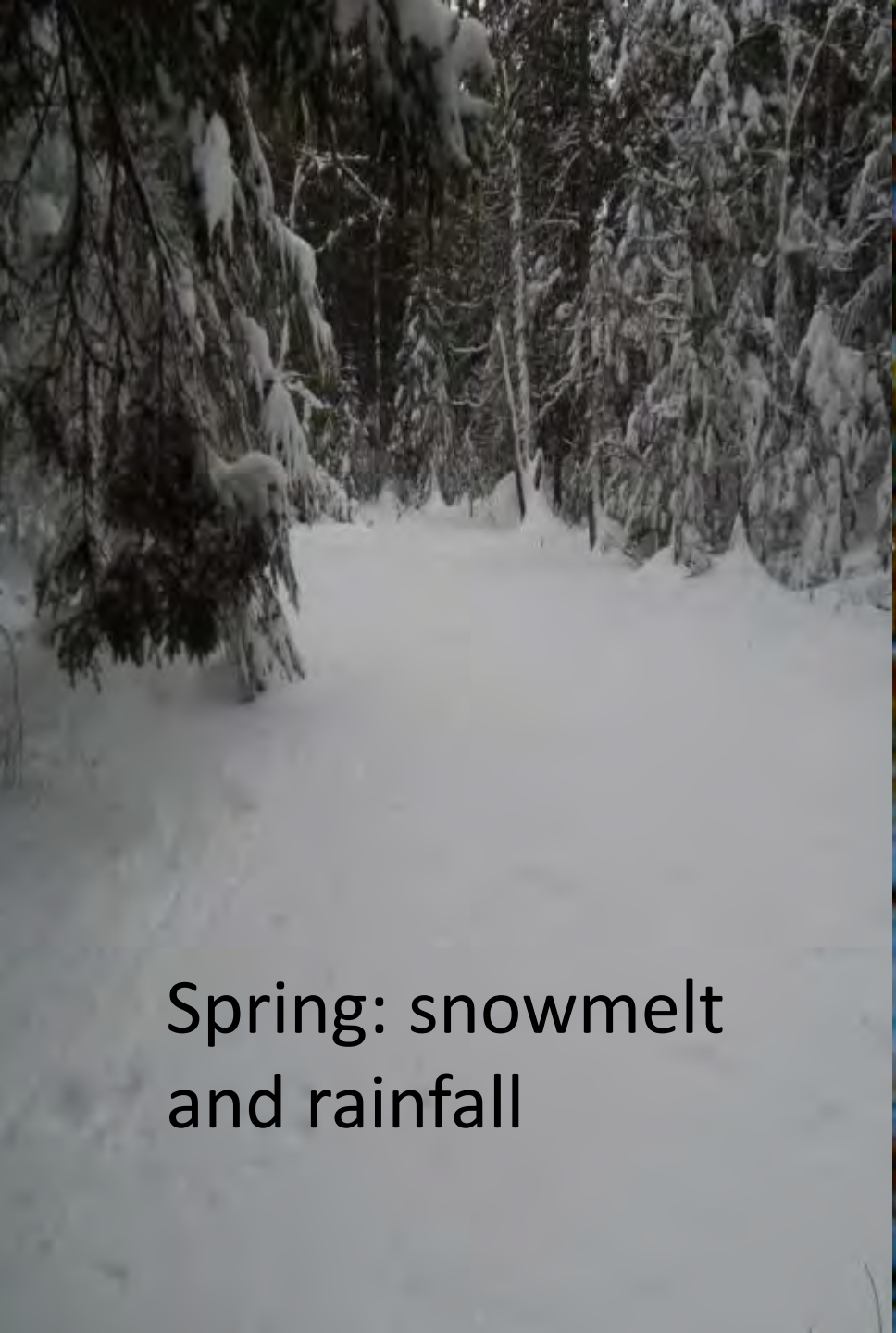
Northeastern Vernal Pools



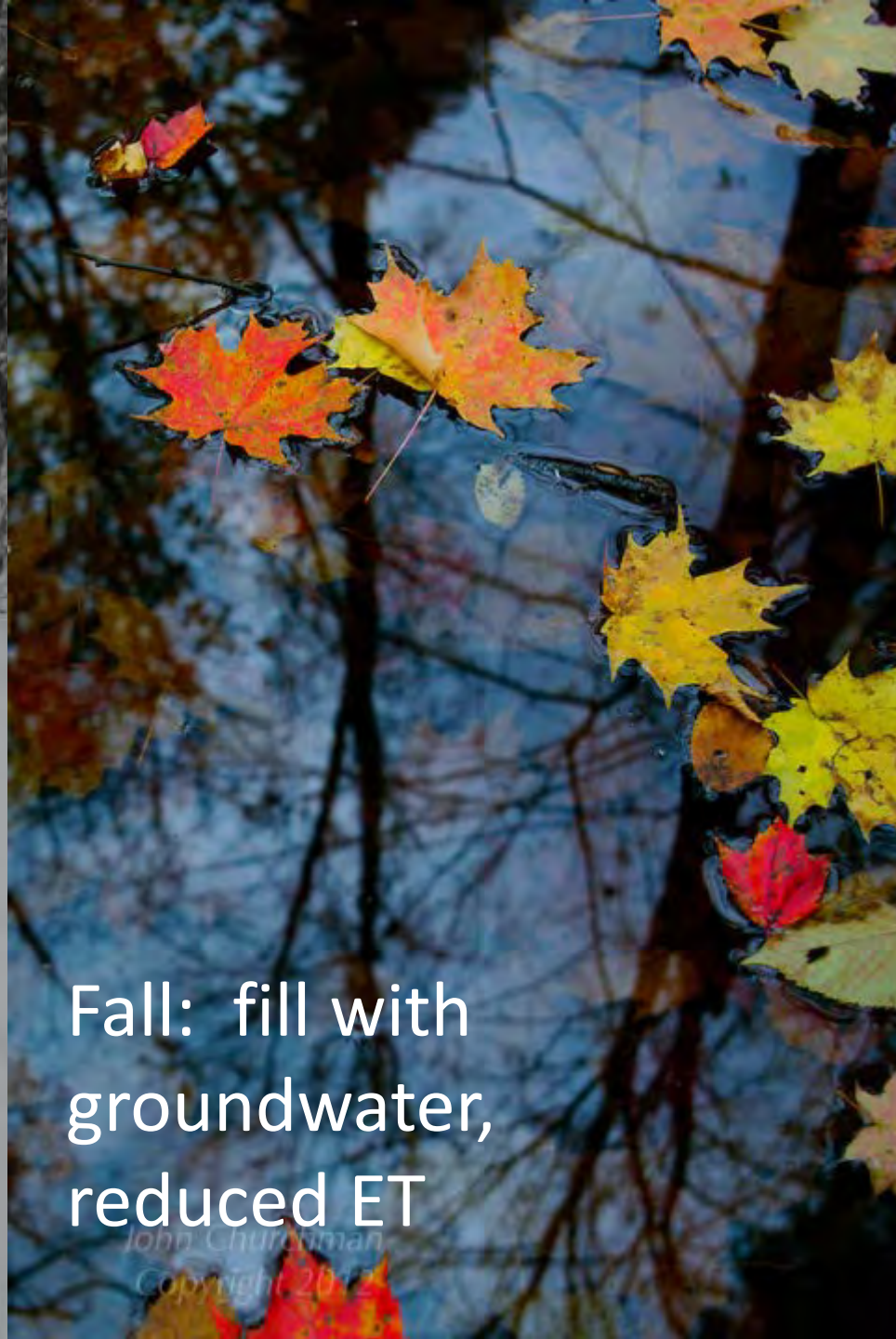
Aram Calhoun, Dawn Morgan, and colleagues
University of Maine
21 April 2015

Signature Pool Characteristics

- Small (<0.5 ha)
- Shallow depressions
- Temporary to Semi-Permanent
- Fishless
- Range of wetland types
- Support breeding indicator species



Spring: snowmelt and rainfall



Fall: fill with groundwater, reduced ET


Groundwater depression


Surface water depressions


Floodplain pool


Forested wetland


Shrub swamp


Emergent marsh


PUB or POW


©Warren Photographic


Challenges to restoration or creation

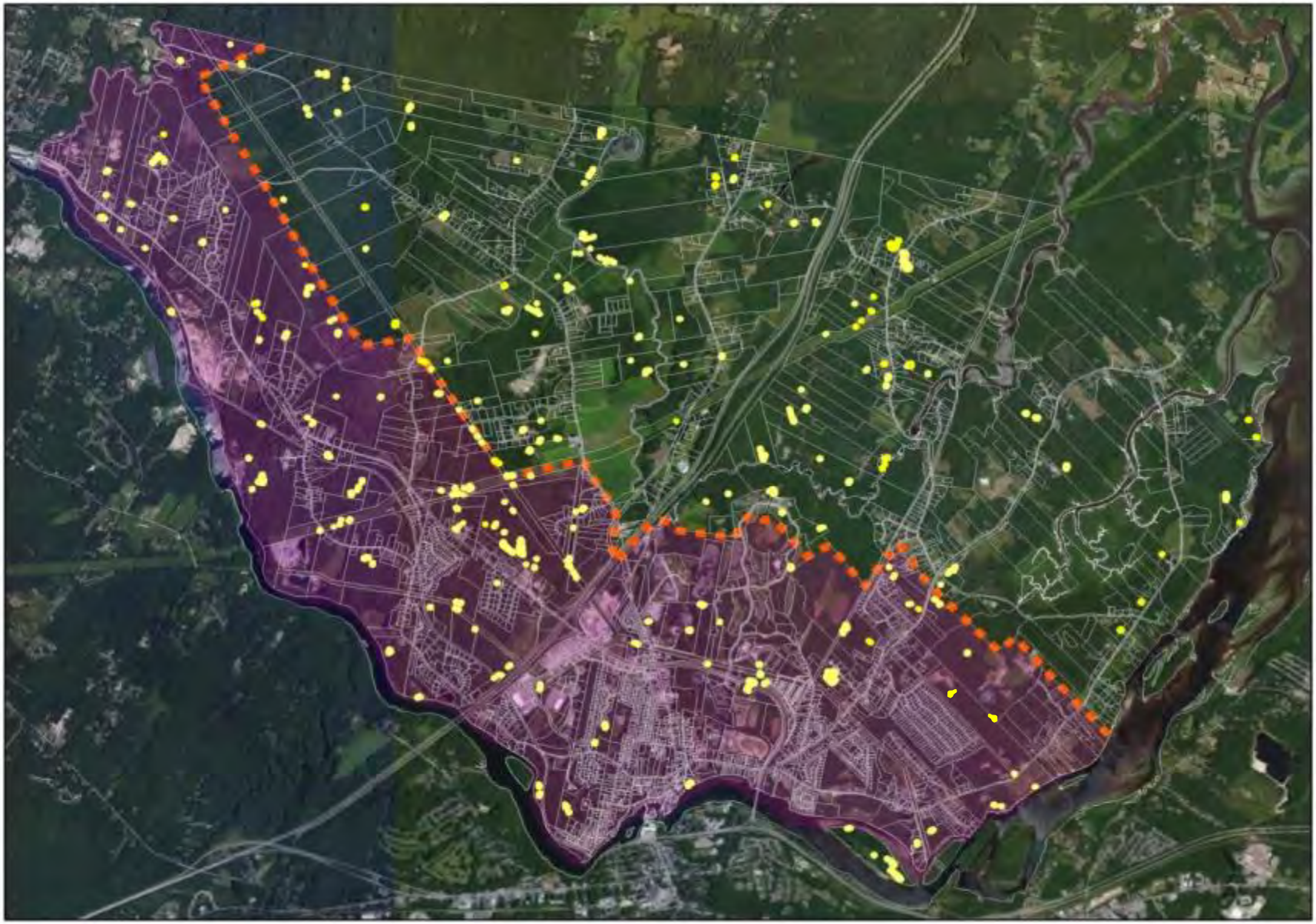
Wetlands
DOI 10.1007/s13157-014-0556-8

REVIEW ARTICLE

Creating Successful Vernal Pools: A Literature Review and Advice for Practitioners

A. J. K. Calhoun · J. Arrigoni · R. P. Brooks · M. L. Hunter · S. C. Richter

Natural pools are relatively abundant



Wood Frog
Max: 3018 feet
Median: 435 feet

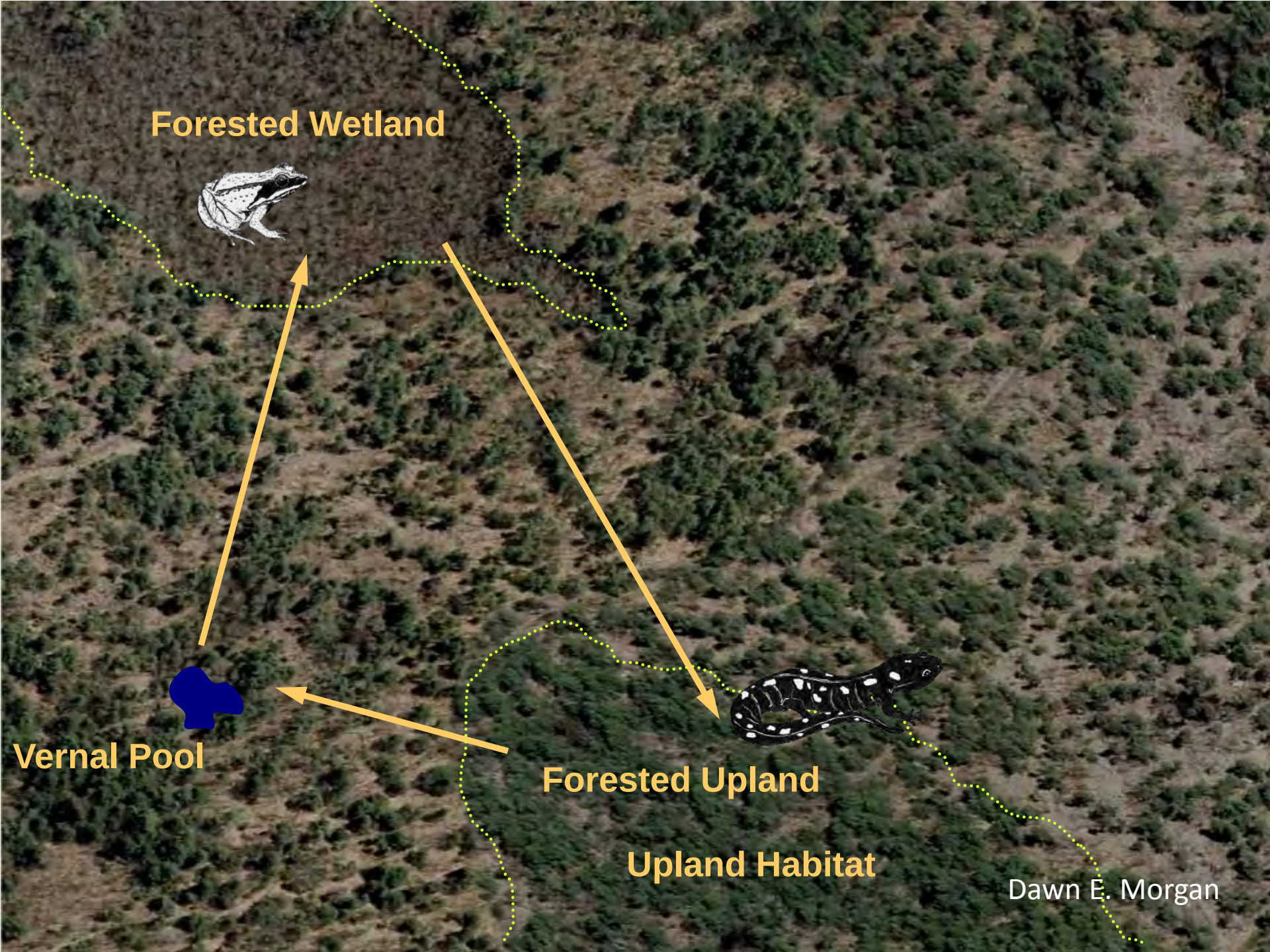
Jefferson Salamander
Max: 1550 feet

Blue-spotted Hybrid
Max: 922 feet
Median: 133 feet

Blue-spotted Salamander
Max: 715 feet
Median: 219 feet

Spotted Salamander
Max: 817 feet

Dawn E. Morgan


Forested Wetland
Vernal Pool
Forested Upland
Upland Habitat
Dawn E. Morgan

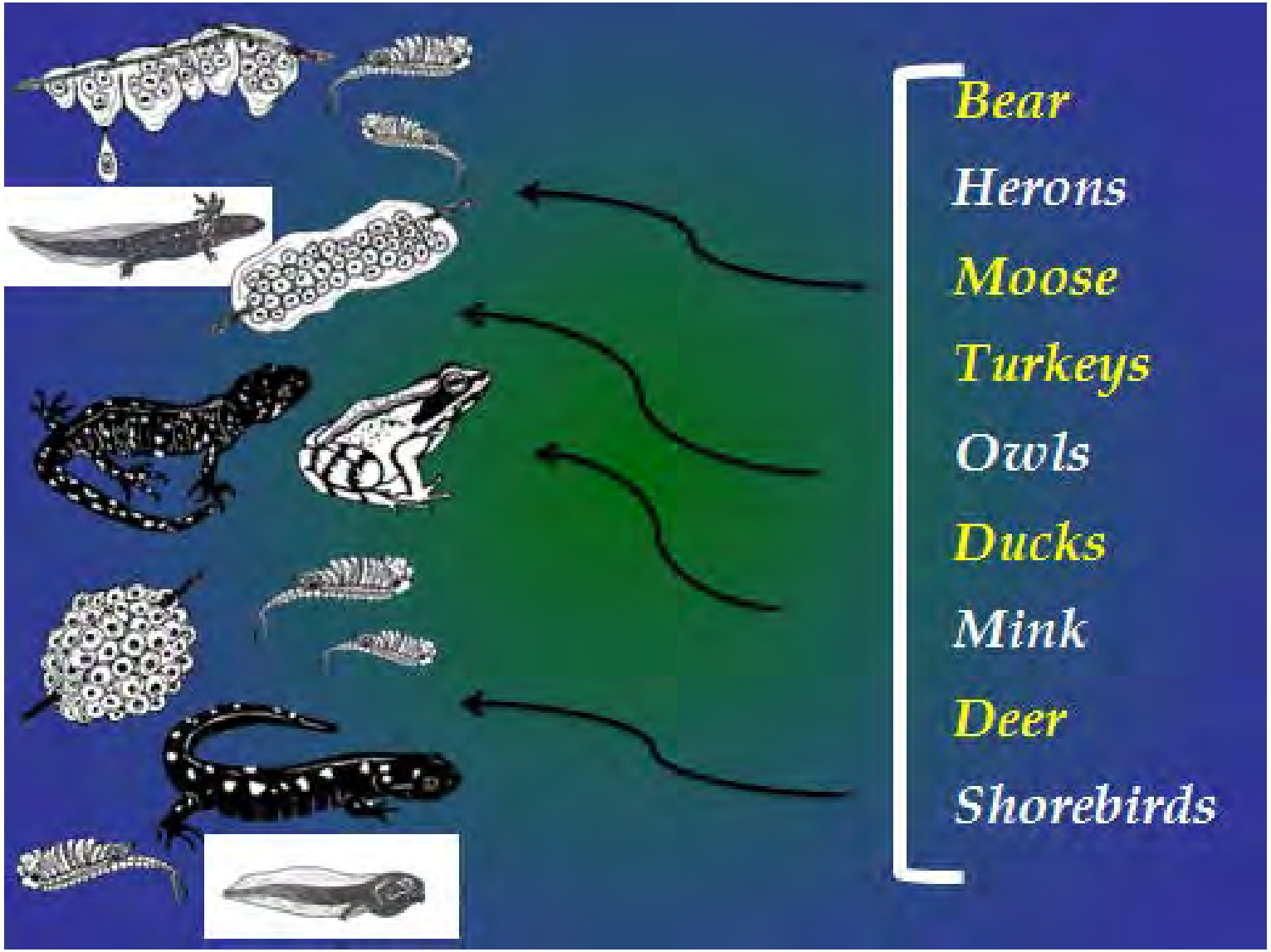
Post-breeding habitat: context dependent

Groff, Calhoun, and Loftin (in prep)

Natal philopatry


Hibernal fidelity?

Facultative species: many state-listed


Bear
Herons
Moose
Turkeys
Owls
Ducks
Mink
Deer
Shorebirds

Broad Recommendations

- ***Avoid*** natural pools
- ***Restore*** pools if cannot avoid natural pools
- Create pools as a ***LAST*** resort

Pool Specific: Hydroperiod

- Situate pool in similar HGM setting
- Maintain forested pool “envelope”
- Use native , uncompacted soils
- Provide gentle slopes

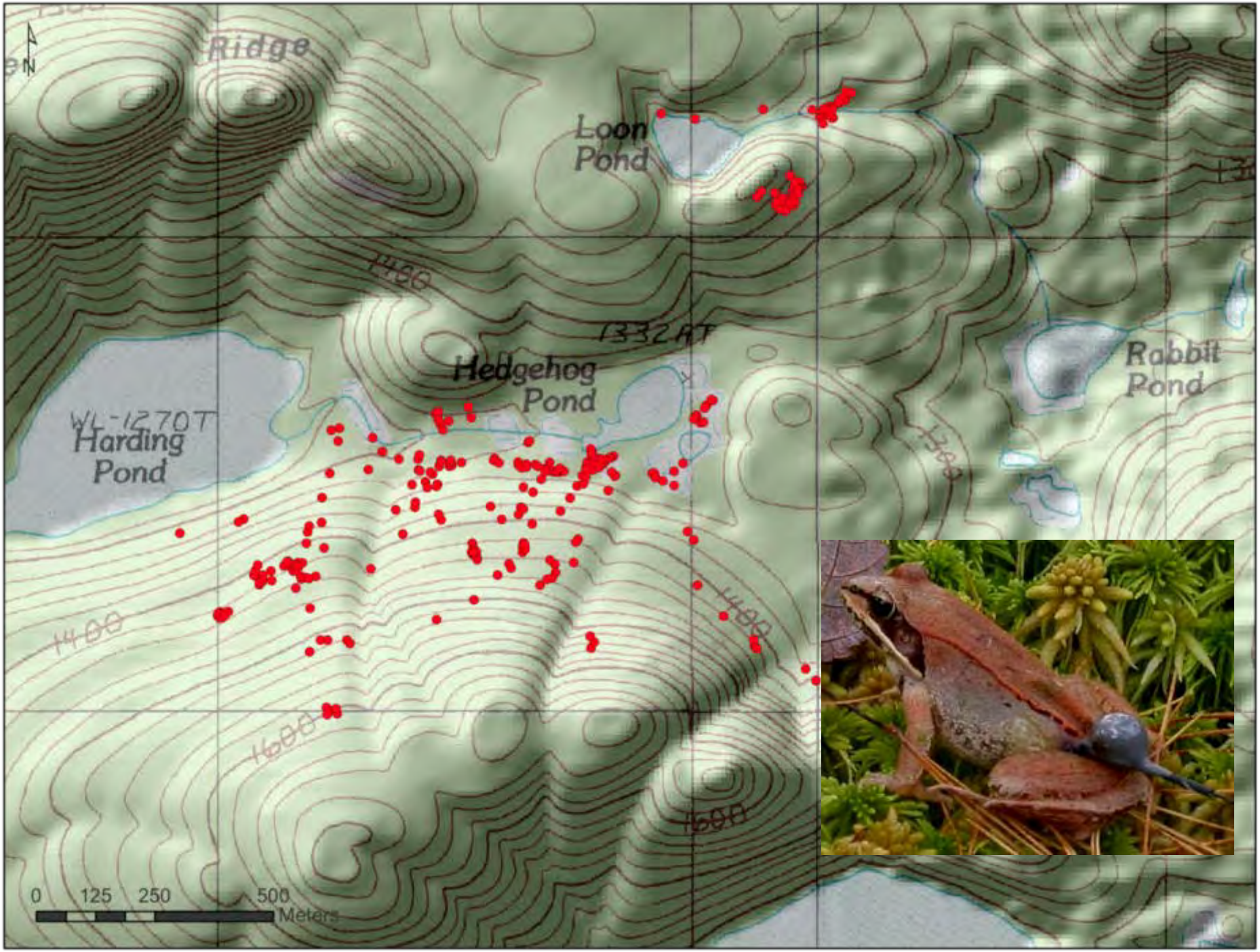

Failed hydroperiod/ high populations of predators

Failed hydroperiod, lack of canopy cover

Landscape Scale

- Context is everything: emulate natural pool type, density, and hydrogeomorphic settings
- Maintain ample post-breeding habitat
- Maintain connectivity among habitat elements


"Classic" Vernal Pool
Shrub Swamp Vernal Pool
Forested Wetland
Forested Wetland
Forested Wetland
Tarbox Rd
Butts Bridge Rd


Ridge
Loon Pond
1400
1332 MT
Hedgehog Pond
Rabbit Pond
WL-1270T
Harding Pond
1400
1400
1600
1600
0 125 250 500
Meters


250 feet

Adaptive Management

- Practitioner-scientist collaboration
- Clear success measures
- Long-term monitoring protocol
- Plans for remediation

Monitoring and Measures of Success

- Minimum ***5-year*** *monitoring* period

- ***Recruitment*** as metric, not reproductive effort

- ***Target species*** use as metric, not species richness

Calhoun Top Five Recommendations for conserving vernal pools in the Northeastern US

Recommendation	Justification	Literature
1. Create pools as a last resort	It is very difficult to replicate pool hydrology and a high percentage of attempts in our region fail	Denton RD, Richter SC (2013) Amphibian communities in natural and constructed ridge top wetlands with implications for wetland construction. J Wildl Manag 77:886–889 Korfel CA, Mitsch WJ, Hetherington TE, Mack JJ (2009) Hydrology, physiochemistry, and amphibians in natural and created vernal pool wetlands. Restor Ecol 18:843–854
2. If you must create pools, pay attention to context (HGM) and nature of native pools (density, vegetation, soil type)	Hydroperiod drives vernal pool function. Establish current hydrology and conceptual target hydrology by using an analog, historic or constructed reference condition. If this fails, goals for classic pool native flora and fauna fail.	Calhoun AJK, J Arrigoni, RP Brooks, ML Hunter, SC Richter. 2014. Creating Successful Vernal Pools: A literature review. Wetlands Gamble DL, Mitsch WJ (2009) Hydroperiods of created and natural vernal pools in central Ohio: a comparison of depth and duration of inundation. Wetl Ecol Manag 17:385–395
3. Pay attention to landscape setting and historical context	Vernal pool functions are tied to quality of adjacent forested habitat for support of amphibians , support of carbon dynamics, and role of pools in terrestrial ecology	Richter SC, Price SJ, Kross CS, Alexander JR, Dorcas ME (2013b) Upland habitat quality and historic landscape composition Influence genetic variation of a pond-breeding salamander. Diversity 5:724–733 Compton BW, McGarigal K, Cushman SA, Gamble LR (2007) A resistant-kernel model of connectivity for amphibians that breed in vernal pools. Conserv Biol 21:788–799
4 Create pools to provide breeding and post-breeding habitat for target species, not to enhance species richness	Many created pools support generalist amphibians but, either owing to hydroperiod or lack of forested post-breeding habitat, do not support persistence of target species	Petranka JW, Harp EM, Holbrook CT, Hamel JA (2007) Long-term persistence of amphibian populations in a restored wetland complex. Biol Conserv 138:371–380
5. a. Have clear long-term monitoring protocols, measures of success, and remediation plans if measures are not met and b. SHARE losses and successes with practitioners	One cannot create a vernal pool without clear goals (what are target species? what functions must be replace? Is the adjacent habitat suitable?). Monitoring must be at an ecologically relevant time scale: invasive plants or animals or facultative species may take over five years to become established. If more people publish the failures and share successes through resources used by practitioners, the science and art could advance more quickly.	Calhoun AJK, J Arrigoni, RP Brooks, ML Hunter, SC Richter. 2014. Creating Successful Vernal Pools: A literature review. Wetlands Vasconcelos D, Calhoun AJK (2006) Monitoring created seasonal pools for functional success: a six-year case study of amphibian responses, Sears Island, Maine, USA. Wetlands 26:992–1003 Lichko LE, Calhoun AJK (2003) An evaluation of vernal pool creation projects in New England: project documentation from 1991–2000. Environ Manage 32:141–151

Acknowledgments

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- Kris Hoffman
- Kevin J. Ryan
- Rob Baldwin

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Identifying Potential Vernal Pool Restoration Sites in Ohio

Mick Micacchion
Midwest Biodiversity Institute
Brian Gara
Ohio EPA Wetland Ecology Group

Red-spotted Newt (*Notophthalmus viridescens viridescens*)

Identifying High Quality Vernal Pool Restoration Sites Using GIS

- Development of Level I (desktop) analysis tool to estimate ecological integrity of areas surrounding wetlands.
- Field testing using Level II (rapid field and Level III (intensive field) wetland assessment tools to validate GIS model.
- Identification of "high quality" vernal pools.
- Creation of potential vernal pool restoration GIS layer.

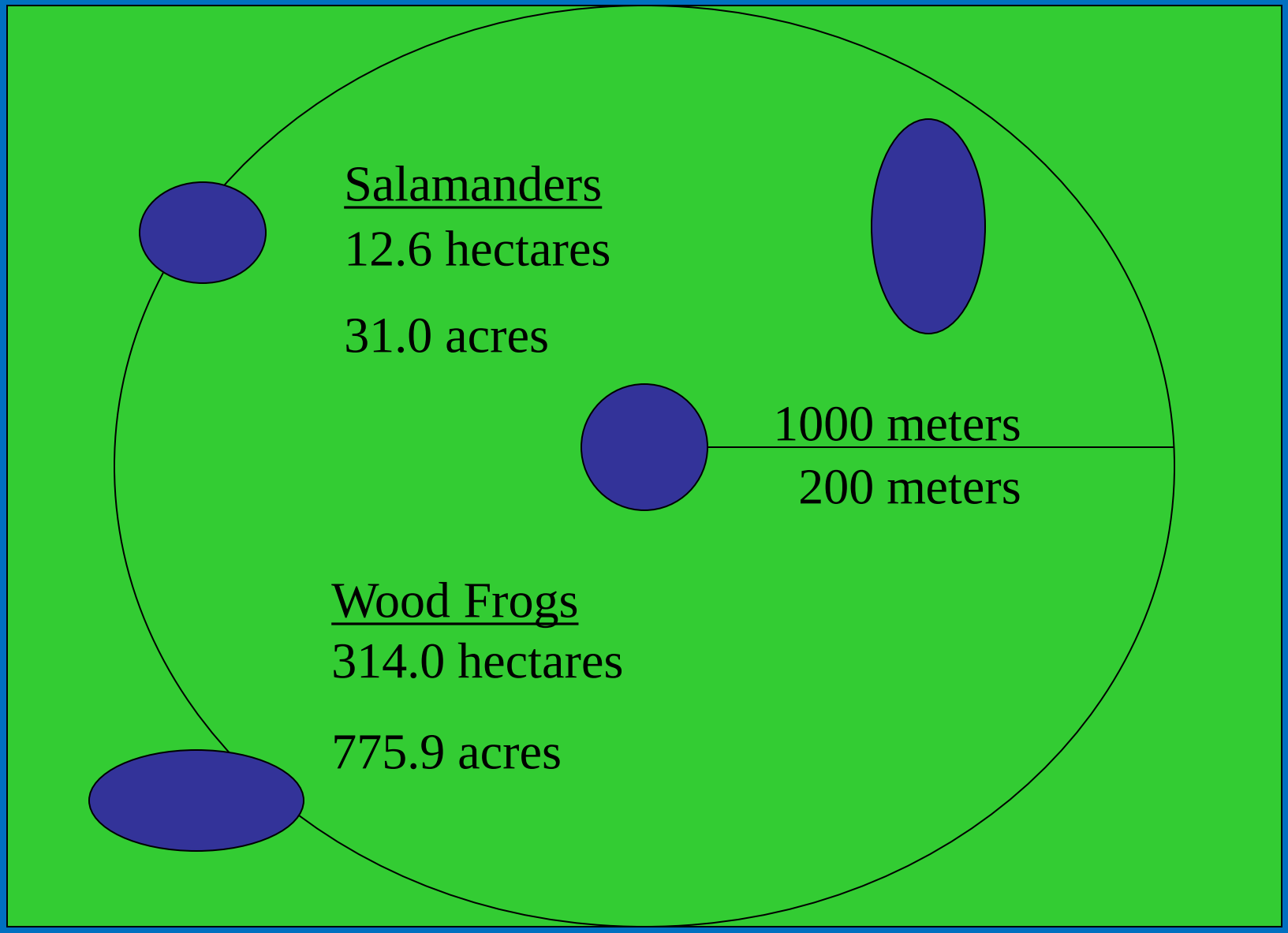
Vernal Pools

- Forest and shrub depressional wetlands in a largely forested landscape
- Isolated hydrology – primarily surface and ground water, generally have no seasonal or permanent connection to rivers, streams, or lakes
- Seasonal hydrology – ephemeral at least late winter (Feb/March) to early summer (June/July)
- Provide important amphibian breeding habitat

Ohio Vernal Pool Amphibian Habitat Summary

- Forest or shrub habitat
- Forest surrounding pools
- Other nearby pools
- Seasonal hydrology
- Surface water and/or groundwater hydrology, sometimes stream-fed
- Free of predatory fish– or low levels present
- Leaf litter and woody debris drive food chain
- Unfortunately, a habitat we are losing in Ohio
- Complex ecosystems, not easy to replicate

Amphibian Habitat Needs



Wetland Mitigation in Ohio

- The Ohio EPA 401 program regulates all impacts to wetlands in Ohio and requires compensatory mitigation for any unavoidable impacts to these resources.
- Frequently does not result in quantity or quality of wetland habitat necessary to meet section 401 or isolated wetland permit requirements.
- Very rarely targets vernal pool restoration, even though these resources have historically been heavily impacted across the state.

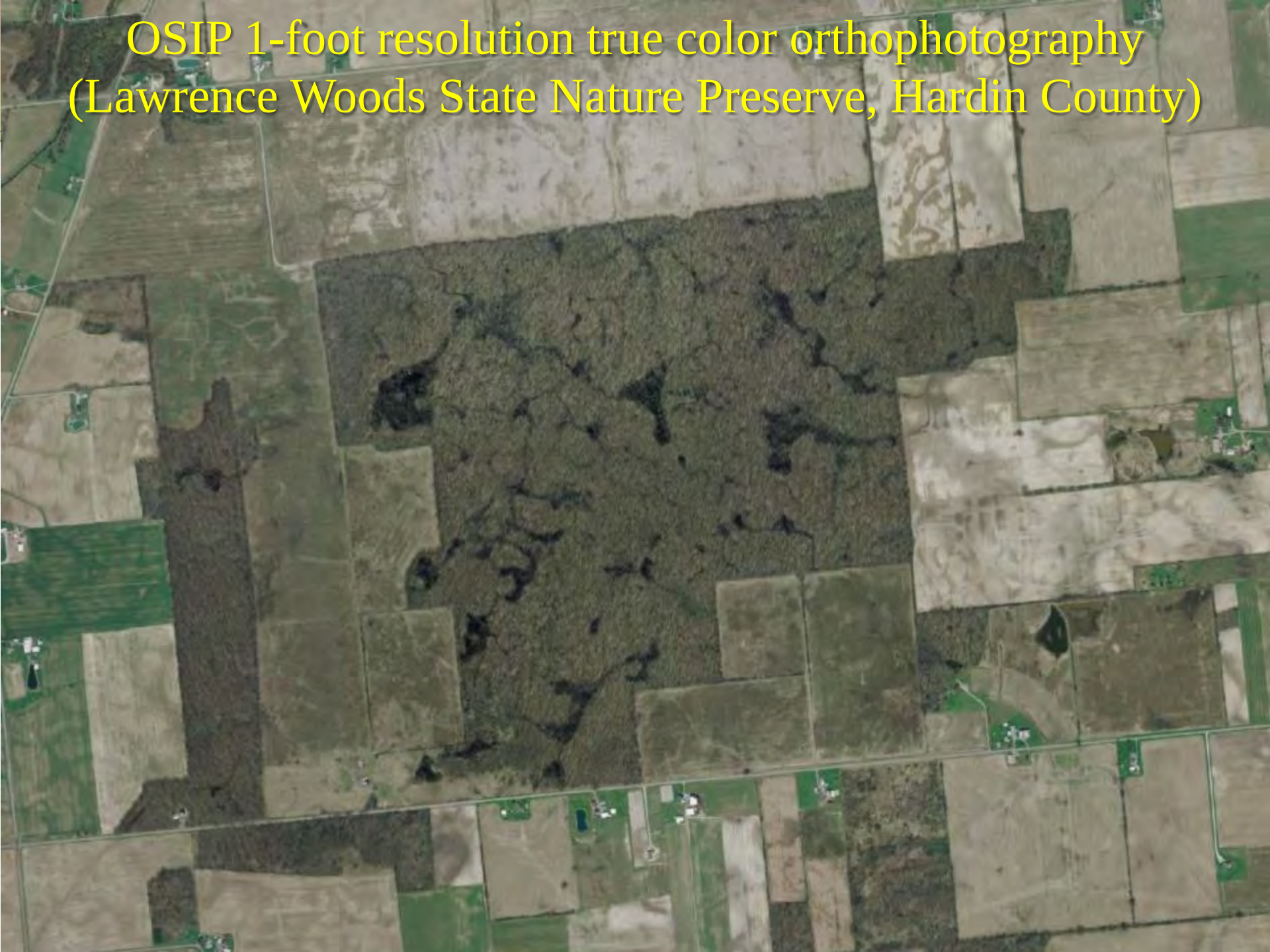

Spotted Salamander (*Ambystoma maculatum*)

Appropriate site selection for successful re-establishment of vernal pools

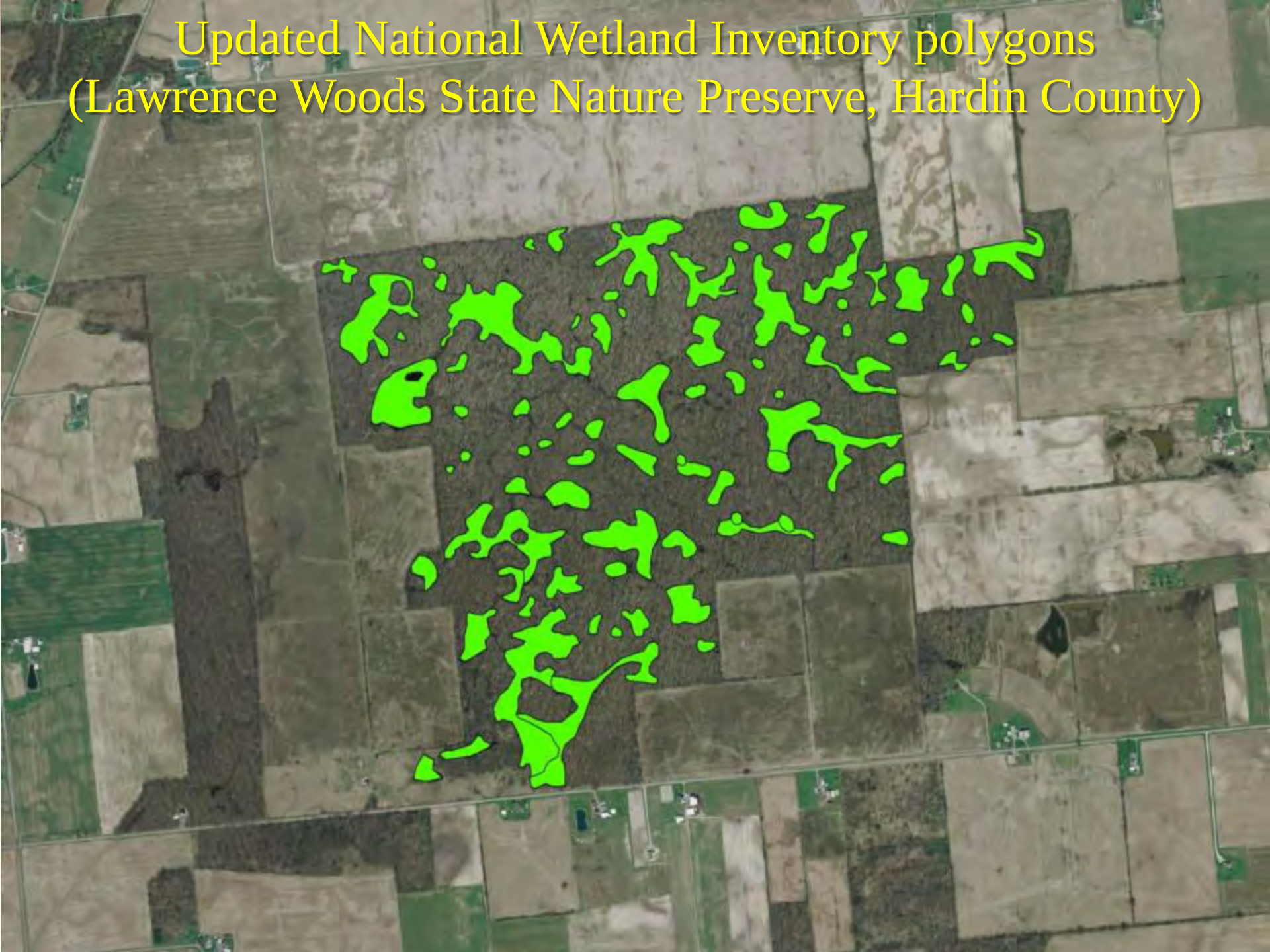
- Site needs to have large areas of predominantly hydric soil (>50% hydric inclusion).
- Adjacent to mature forest to provide habitat and to ensure appropriate revegetation of the site with plant species adapted to specific ecoregion.
- Most importantly, within reasonable migration distance of existing, high quality vernal pools with known pond-breeding (vernal pool species) amphibian populations!!!

How can we identify potential high quality vernal pools on a statewide basis?

- Use Geographic Information System (GIS) technology.
- Ohio is fortunate to have a wealth of the extremely detailed GIS data layers to make this analysis possible.


OSIP 1-foot resolution true color orthophotography
(Lawrence Woods State Nature Preserve, Hardin County)

Updated National Wetland Inventory polygons (Lawrence Woods State Nature Preserve, Hardin County)

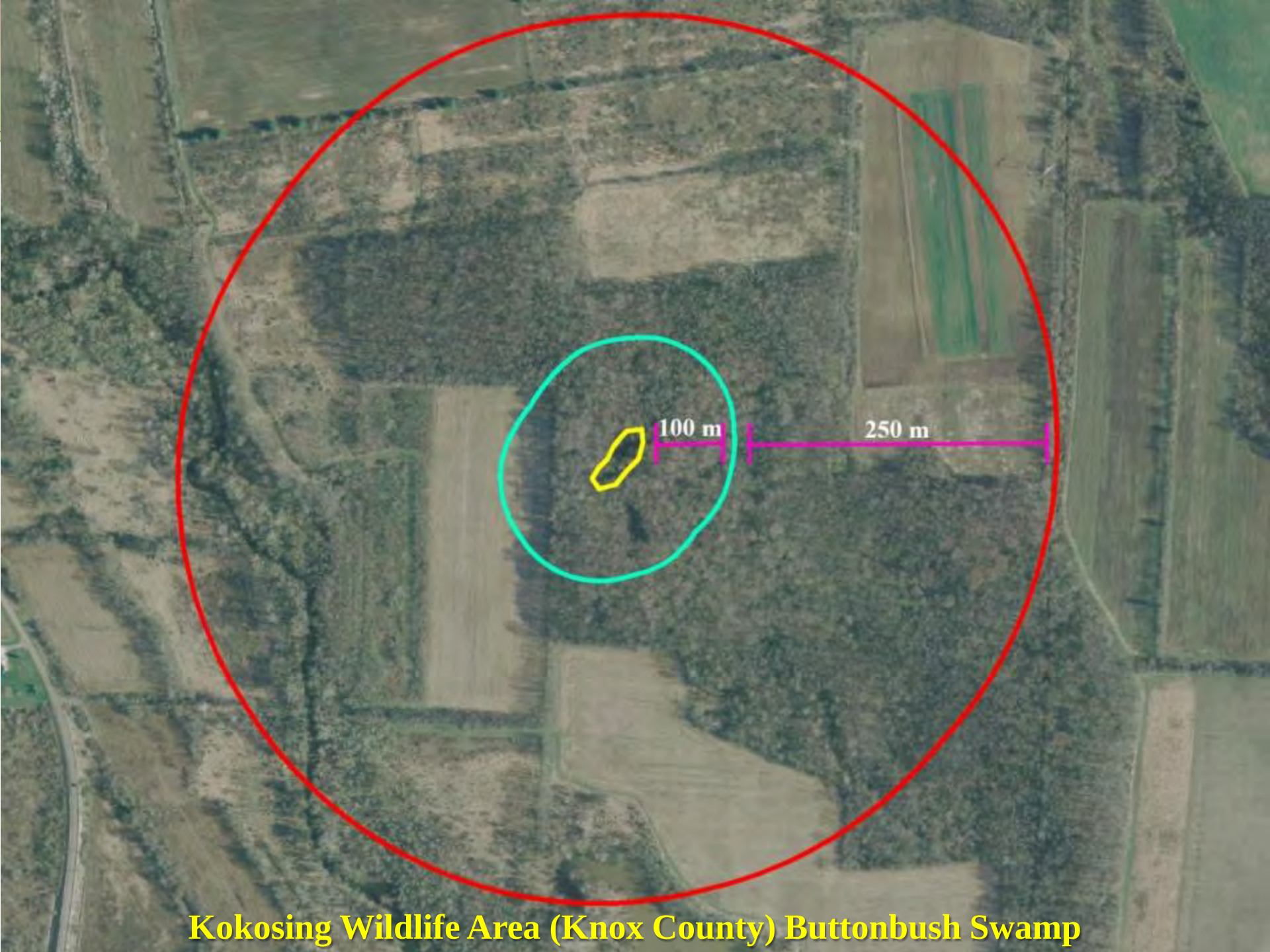


Level I Assessment of Updated NWI Polygons

- Each wetland was placed into one of six generalized categories based on the assigned Cowardin classification. The categories are: Emergent, Scrub-Shrub, Forested, Mudflat, Aquatic Bed, and Open Water.
- For the purposes of this analysis, only the categories most likely to actually meet wetland criteria were used.
- This still required a total of 134,736 wetlands be included in the analysis (22,103 scrub-shrub, 55,650 forested, and 56,983 emergent).


Kokosing Wildlife Area (Knox County) Buttonbush Swamp

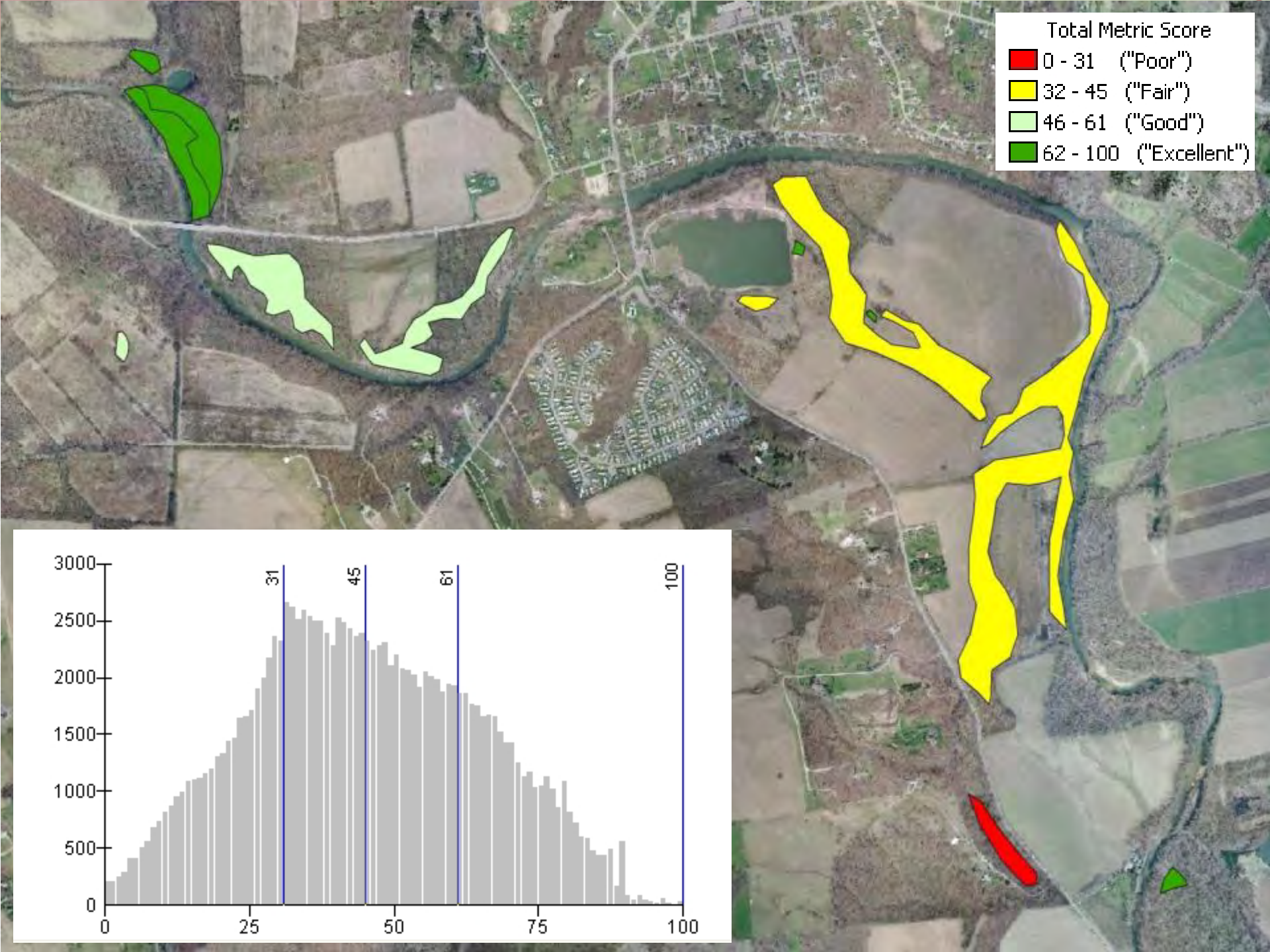
Kokosing Wildlife Area (Knox County) Buttonbush Swamp



Kokosing Wildlife Area (Knox County) Buttonbush Swamp

Level I Condition Assessment of Updated NWI Polygons: Metric Calculation

- 10 different environmental factors were calculated independently for each of the two buffer areas, including overall landscape disturbance levels, amount of impervious surface, and percent forest cover.
- Total range of values calculated for each of these 10 factors was divided into quartiles for each different wetland type (emergent, scrub-shrub, forested), and a metric score of 0, 3, 7, or 10 was then assigned.
- All metrics were then summed for the inner and outer buffer zones, resulting in a total score between 0 and 100 for each.
- Final score for the wetland = (inner zone score * 0.67) + (outer zone score * 0.33) .

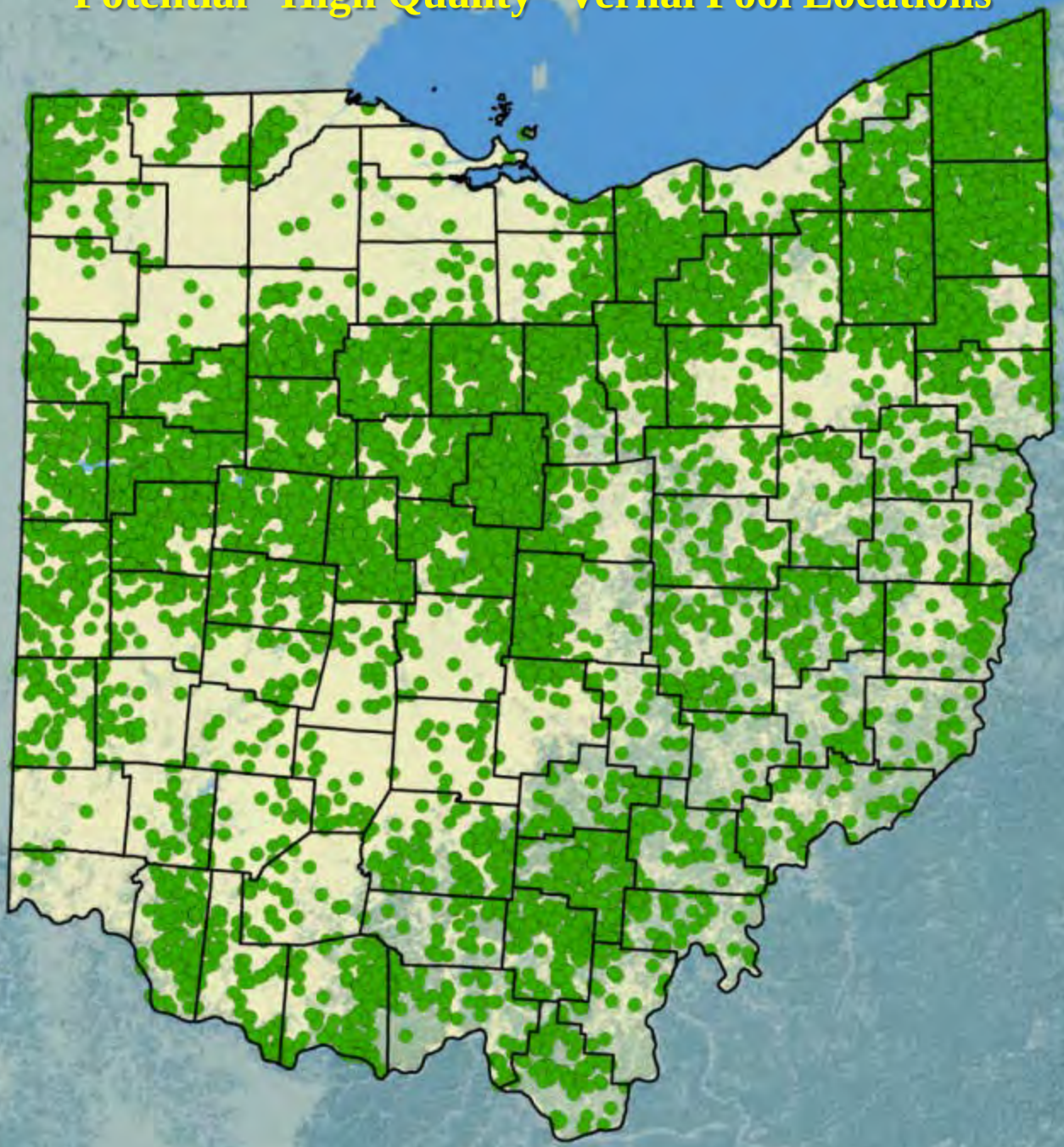

Total Metric Score
0 - 31 ("Poor")
32 - 45 ("Fair")
46 - 61 ("Good")
62 - 100 ("Excellent")
3000
2500
2000
1500
1000
500
0
31
45
61
100
0
25
50
75
100

Level I Assessment: Identification of Potential "High Quality" Vernal Pools

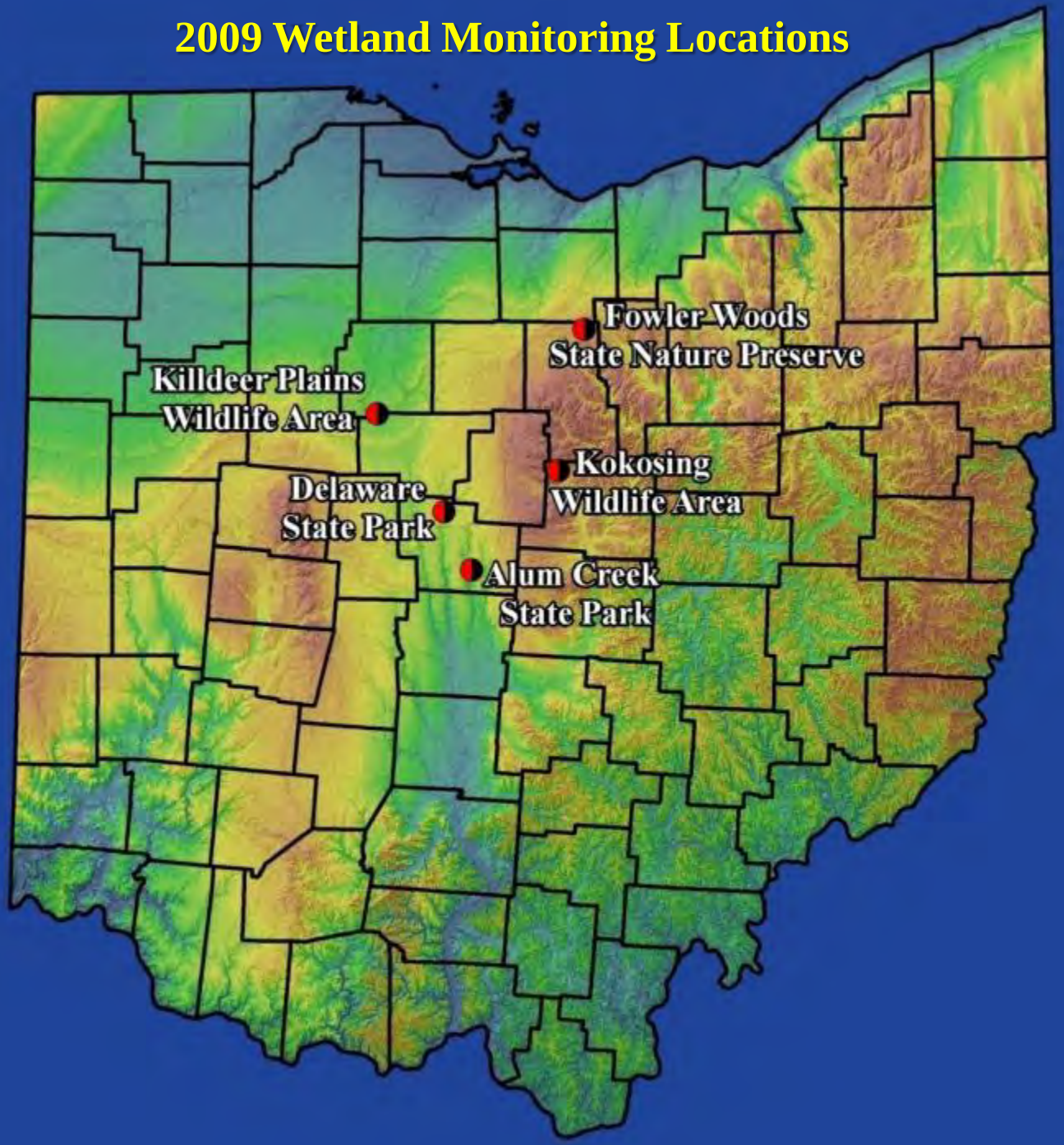
Select NWI wetlands meeting the following criteria:

1) level 1 quality = "good" or "excellent"
2) wetland type = forested or scrub-shrub
3) wetland size < 2 acres
4) existing forest within inner buffer zone > 50%
5) historic forest within inner buffer zone > 50%
6) not occurring on soils identified as alluvial by NRCS

Potential “High Quality” Vernal Pool Locations

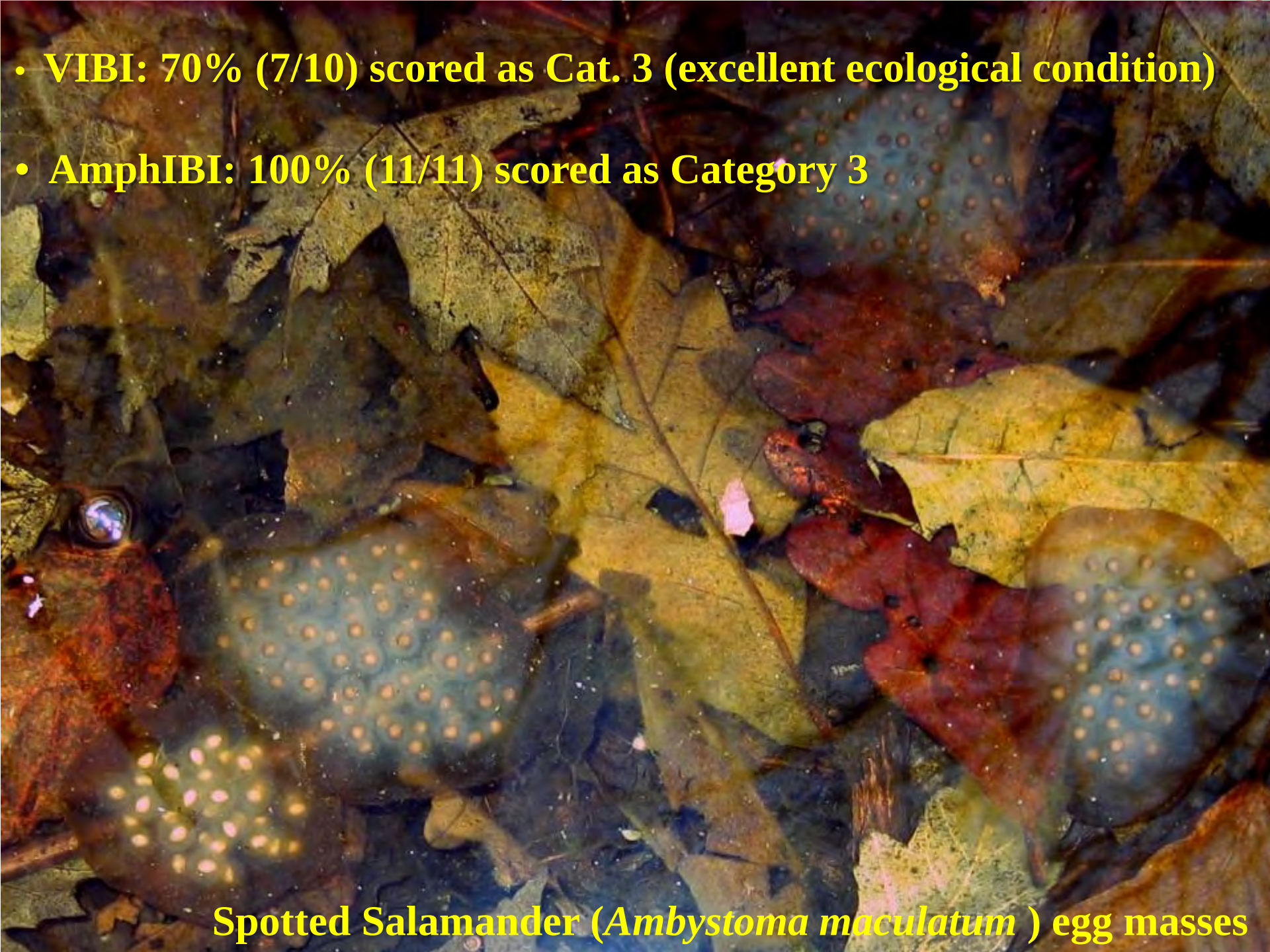


2009 Wetland Monitoring Locations



Wood Frog (*Lithobates sylvaticus*)


Alum Creek State Park, Africa Road Vernal Pool


• VIBI: 70% (7/10) scored as Cat. 3 (excellent ecological condition)
• AmphIBI: 100% (11/11) scored as Category 3
Spotted Salamander (*Ambystoma maculatum*) egg masses

Level I Condition Assessment: Identify Potential Vernal Pool Restoration Sites

- Based on the following criteria:

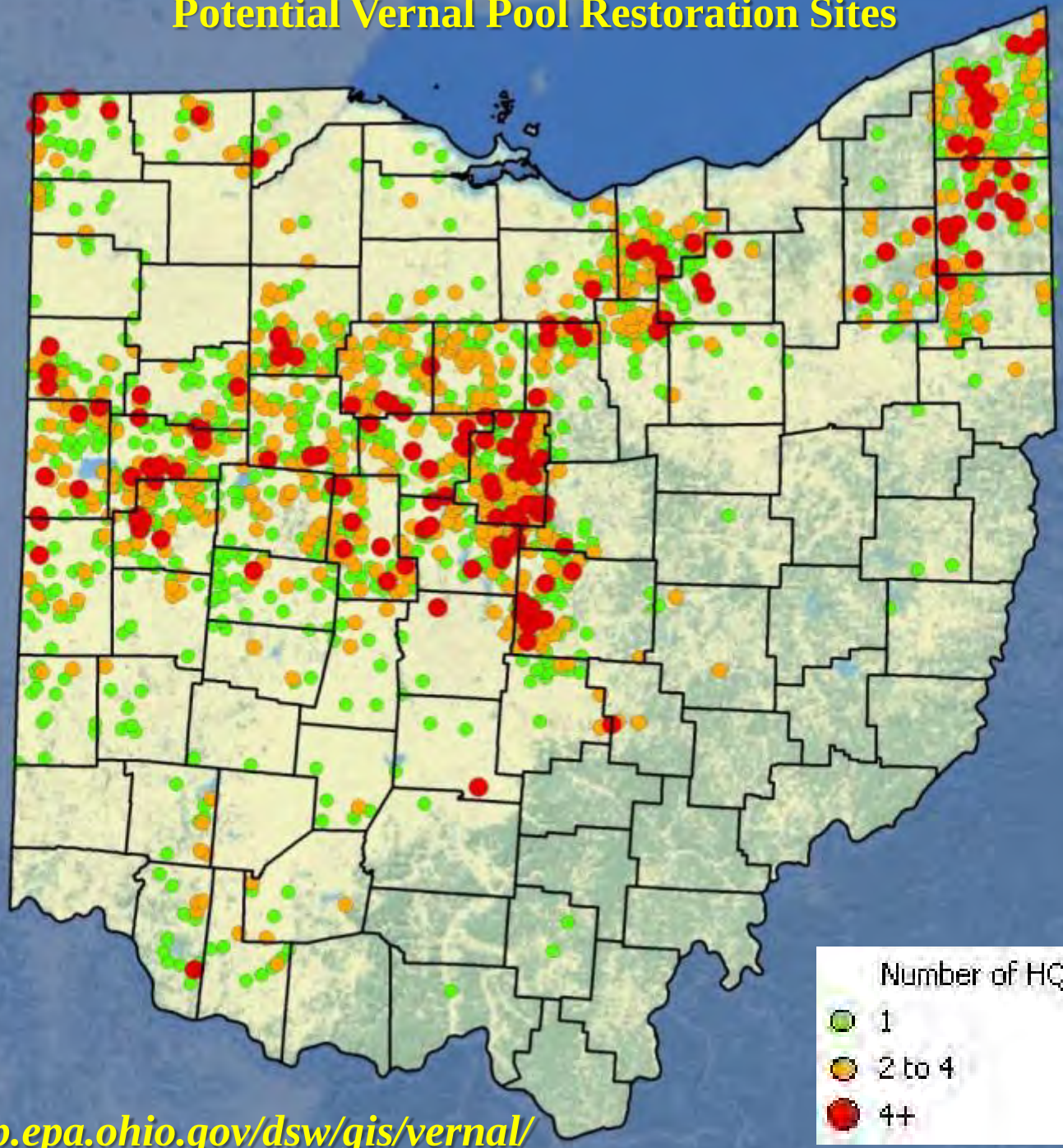
1) areas within 500 meters of “high quality” vernal pool

2) > 10% of buffer area was historically wetland

3) >10% of buffer area currently consists of agricultural land use (row crops or pasture)

Morris Woods State Nature Preserve (Licking County)

Potential Vernal Pool Restoration Sites



http://wwwapp.epa.ohio.gov/dsw/gis/vernal/

Mick Micacchion recommendations:

Cause of Failure	Recommendation	Selected Measures
A general assumption that all constructed wetlands will provide habitat for pond-breeding (vernal pool) amphibian species	Need to understand and incorporate essential habitat features into vernal pool restorations that will attract amphibians and other vernal pool organisms	Develop site plans that include all of the habitat features needed to support healthy populations of vernal pool amphibian species. Provide settings with appropriate surrounding landscape features, hydrology sources, hydroperiods, pool slopes and depths, and other features.
Vernal pool restorations located where they are isolated from other high performing vernal pools	Strategically locate vernal pool restoration projects	Place vernal pool restorations close to high quality vernal pools and within migration distances of existing populations of pond-breeding amphibian species. Situate on hydric soils and connect new pools to existing pools through reforestation.
No goals for wetland restoration projects that are specifically aimed at restoring biologically diverse vernal pools	Set goals and monitor the restored vernal pools to determine if they are being utilized by the targeted amphibian species and are otherwise of high quality	Use Amphibian IBI score or other quantifiable ecological performance standards as goals. Set goals of “GOOD” or better ecological condition to assure restored VPs compensate for losses, have high quality pond-breeding amphibian communities, high environmental resilience, & require minimal management.

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Jefferson Salamander (*Ambystoma jeffersonianum*)

The Challenges of Vernal Pool Restoration in Southern California

Christina M. Schaefer

April 21, 2015

Schaefer Ecological Solutions

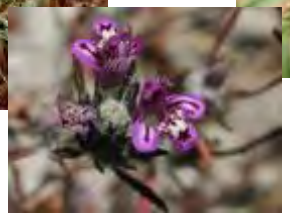
Regenerating Nature

Southern California vernal pools

- Southern and Northern California vernal pools are geomorphologically and biologically different
- Are characterized by a Mediterranean climate
  - Winter rains (from October through March)
  - Summer drought
- Are considered one of the rarest, most sensitive, and threatened ecosystems
  - In San Diego County, about 95% of vernal pools have been lost due to development and agriculture
  - High biodiversity and large number of narrow endemic and federally/state-listed species

Characteristics





- Narrow endemic and listed flora
  - San Diego button-celery (*Eryngium aristulatum* var. *parishii*)
  - Otay mesa mint (*Pogogyne abramsii*)
  - San Diego mesa mint (*Pogogyne nudiuscula*)
  - Spreading navarretia (*Navarretia fossalis*)
  - California orcutt grass (*Orcuttia californica*)
  - Little mousetail (*Myosorus minimus* ssp. *apus*)



- Listed or sensitive fauna
  - San Diego fairy shrimp (*Branchinecta sandiegonensis*)
  - Riverside fairy shrimp (*Streptocephalus woottoni*)
  - Spadefoot toad (*Spea hammondii*)


Characteristics

- On flat mesa tops (coastal marine terraces) or in valley grasslands
- Mima mound/basin landscape
- Often spatially isolated or grouped within a vernal pool complex (not connected to other water sources)
- Characterized by a clay unit, claypan, or hardpan subsurface that prevents water from percolating into the groundwater table
- Hydrologically contained (no inflows/outflows)
- Ephemeral; seasonally ponded, holding water for varying durations directly correlated to rainfall patterns and size of micro-watershed (hydroperiod)

Characteristics

- Upland vegetation communities are coastal sage scrub, chaparral, or grasslands
- Obligatory vernal pool indicator species
- Undulating topography (mima mounds)
- Mounds 1’-6’ tall
- Basins 4”-13” deep
- The mima mound : vernal pool basin ratio ranges between 4:1 – 12:1; often 7:1

Characteristics

- Biological attributes change with rainfall patters:
- Aquatic phase:
  - pool are indundated by precipitation;
  - aquatic life forms (e.g., fairy shrimp; spadefoot; floating plants) thrive

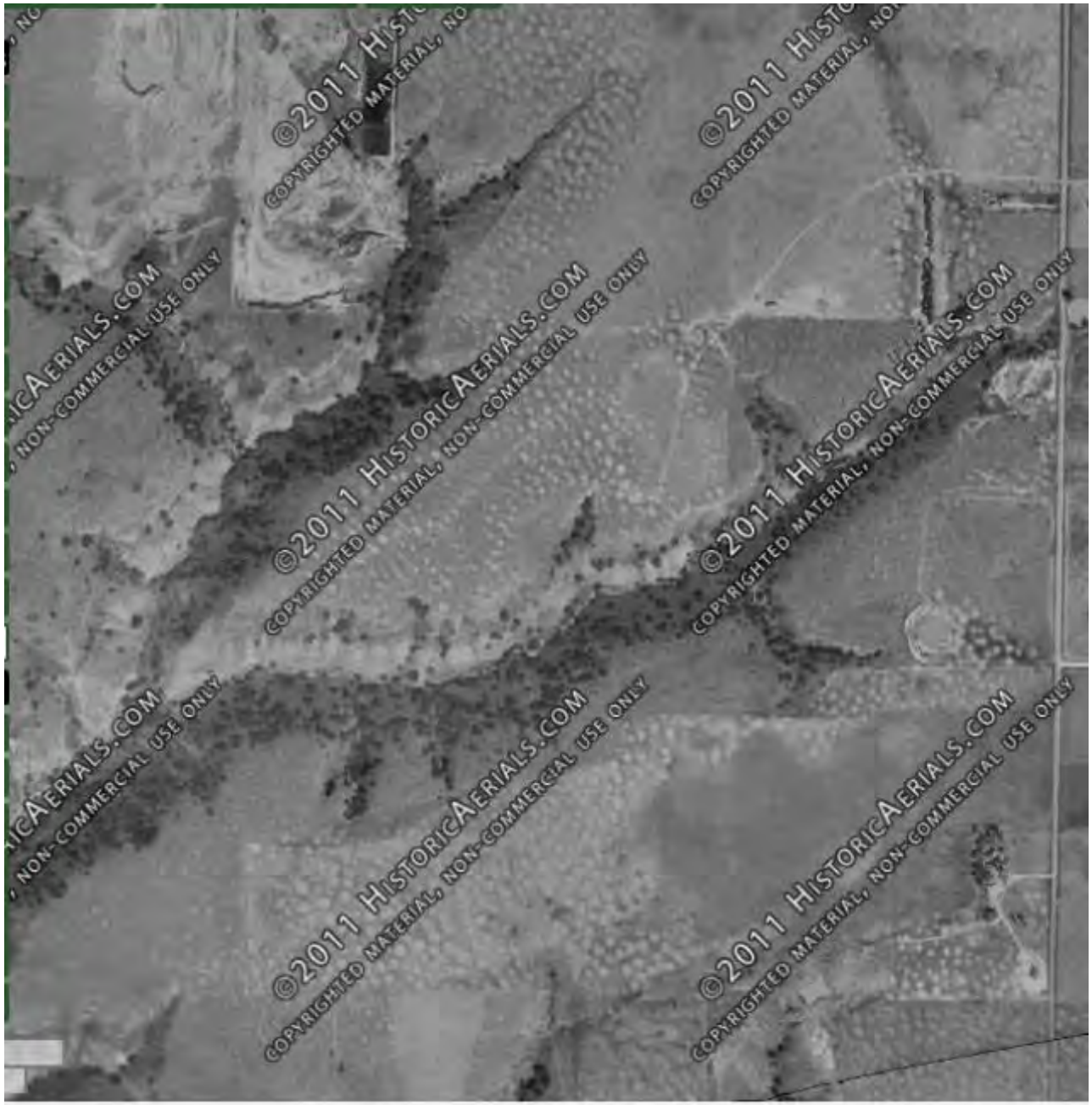
Characteristics

- Terrestrial phase:
  - pools are evaporating
  - terrestrial flora develops, often as concentric rings around the pool

Characteristics

- Dormant phase:
  - rainfalls cease and pools dry out
  - life forms diapause in dry soils as cysts/eggs and seeds until the next hydration period (often for several decades)

1953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1964


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1989


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2003


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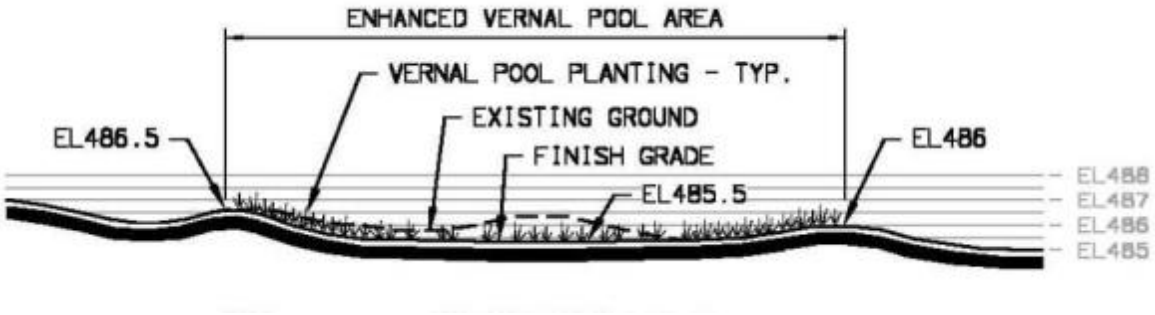
Vernal pool creation vs. restoration

- ‘Creation’ is used by the U.S. Army Corps of Engineers to assure that there is no net loss of wetlands in the U.S.; for every acre lost, at least one acre of wetland must be created where it did not exist previously.
- Vernal Pool restoration and vernal pool creation are used synonymously
- Creation cannot be undertaken if the fundamental habitat components are lacking, e.g., impervious soil
- Restoration of lost vernal pool functions can only occur provided the impermeable soil layer is intact

Vernal pool restoration principles

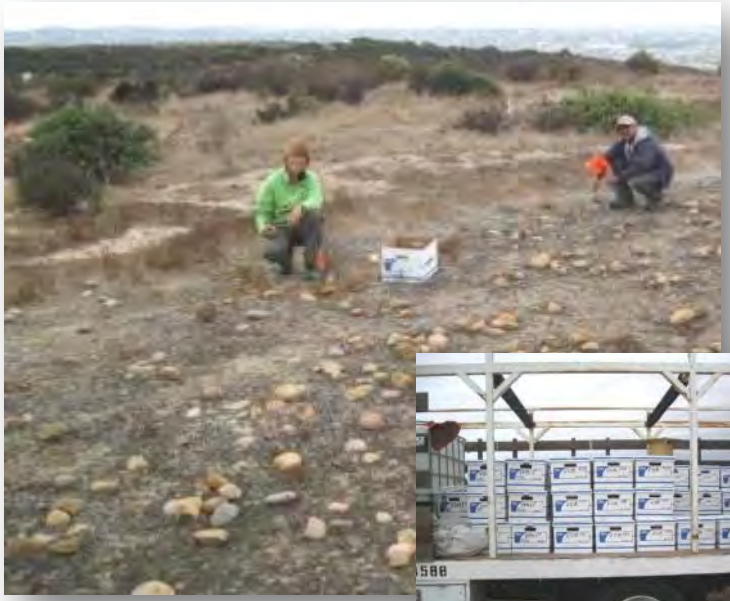
- Vernal pool restoration requires the following baseline conditions
  - Historical presence of vernal pools
  - Impermeable soils (e.g., claypan, hardpan)
  - Part of a vernal pool complex – not isolated
  - Suitable hydrology/watershed



Vernal pool restoration principles

- Adequate baseline condition assessment
  - Land Surveying of micro-topography (2”-6” contours)
    - Alternative to hydrology study: template watershed topo
  - Hydrological study (e.g., water balance model, continuous hydrological model)
    - Calibrated for minimum requirements for fairy shrimp
    - Modeled for 1-year, 24-hour event through 100-year event
    - Water holding capacity of 3” for 14 days
    - Identifying flow lines (peak events)
  - Soil studies
    - Ground-penetrating radar to identify hardpan
    - Soil testing (without permeating hardpan)
  - Floral and faunal surveys (mitigation targets, habitat components, inoculum sources)

Vernal pool restoration



Post-restoration monitoring

- Document restoration conditions/trend over time
- Document a ‘functional lift’ (improved vernal pool functions over time)
- Measure quantitative relationships to restoration goals and objectives (performance standards, success criteria)
- Monitor habitat components comprehensively: flora, fauna, hydrology, topography, edge effects, etc.
- Compare data collected at the restored vernal pools (treatment) to data collected in natural vernal pools (control or reference).

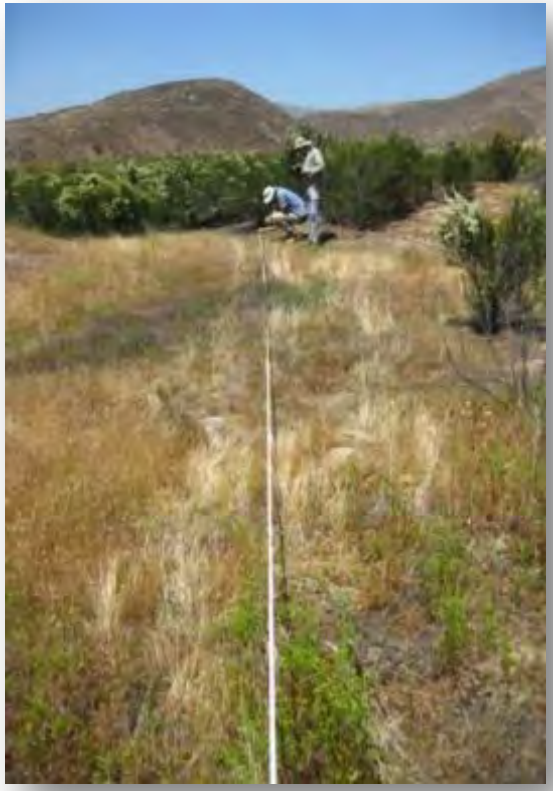
Monitoring elements

- Five-Year Post-Restoration Quantitative Monitoring
  - Metrics to measure restoration objectives/success criteria
  - Comprehensive Approach
    - Hydrology
    - Vegetation transects
    - Branchiopod sampling
    - CRAM (Vernal Pool Module)

- Long-Term Monitoring
  - Metrics to measure long term trend
    - HGM (Bauder et al. 2009)
    - Vegetation, hydrology, wet season fairy shrimp surveys: every 3-5 years
    - Dry season fairy shrimp sampling: every 10 years

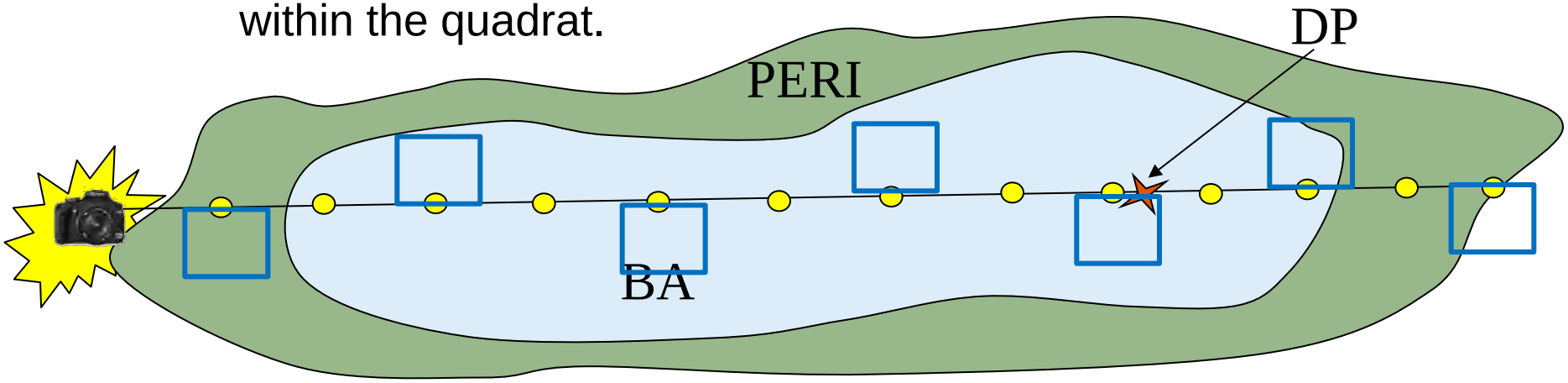
Vegetation

- Stratified sampling
  - Sentinel pools (same pool every year)
  - Random pools (different pool every year)
- Data collection for
  - Richness (the number of species in a given area)
  - Frequency (distribution)
  - Density (cover) of vernal pool indicators
  - Density (cover) of non-native species
  - Trend (change over time)



Vegetation

- Data collection method:
  - Point intercept data at each 1-meter interval using a thin metal rod;
  - Standing vegetation that is incident at the point where the rod is vertically placed will be recorded in a datasheet as the species epithet (flora and bare ground in separate columns);
  - Species occurrence will be measured by placing 0.25-meter quadrats at each 2-meter intercept and recording all species within the quadrat.



Branchiopods

- Wet season sampling
  - Document presence/absence
  - Seining and fairy shrimp ID
  - Sampling will begin 10 days after the first pools fill and continue approximately every 10 to 14 days thereafter until pools are dry
  - Identification of federally endangered San Diego and/or Riverside fairy shrimp
  - Identification of versatile fairy shrimp (interbreed w/San Diego fairy shrimp)
- Dry season sampling (year 4 only)
  - Determine population size, density and vigor
  - Dry soil sampling (diapausing propagule bank)
  - Sifting and ID eggs/cysts

Hydrology

- Rain gauge per site (or local weather station data)
- Frequent (daily) visits to record water levels off rulers installed in the deepest portion of the pool;
- Frequent visits to record water levels from Visitubes (clear PVC tubes with a ‘floater’ (cork) that marks water levels);
- Data recording from stack-mounted i-Buttons (electronic, button-sized temperature/humidity data loggers); and
- Pressure transducers (non-vented water level recorders).

Hydrology

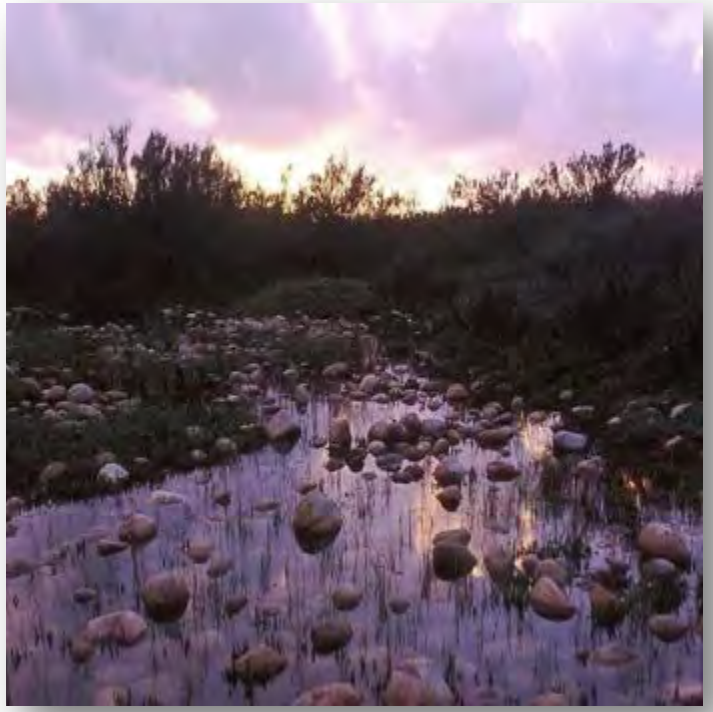
- Traditional:
  - Ruler in the deepest point
  - Monitor water level within 24 hours after each rainfall in every pool until dry (every 3-4 days)
- Experimental
  - Place i-button sensors along stake in deepest point of pool
  - Data recording from stack-mounted i-Buttons (electronic, button-sized temperature/humidity data loggers)
  - Collect data once per rainy season (download data from data recorder)

i-Buttons

- Temperature loggers (Thermochrons)
- Depending on model, work with a range of temperatures
- Water proof
- Record temperature above and below water
- Data recorder logs data
- Data processing software
- Differential between above and below water temperature indicates water level
- Efficient and inexpensive

Vernal Pool Functions

- California Rapid Assessment Method (CRAM) – Vernal Pool Module
  - Pre-restoration conditions
  - Post restoration conditions
- Identify Assessment Area (AA)
- CRAM parameters for scoring:
  - Landscape Context/Buffer
  - Hydrology
  - Structure
    - Physical Structure
    - Biotic Structure
  - List of Stressors



Treatment vs. Control (Reference)

- Treatment = manipulated sample (restoration site)
  - Not natural
  - Chaotic variables
- Control (reference site)
  - Natural or naturalized
  - Predictable variables (fixed variables)
- Initially, restoration site behaves very differently than control
- Over time, restoration site will be similar to control

Treatment vs. Control (Reference)

- Multiple controls needed to adjust for temporal effect
  - natural reference site
  - Successfully restored reference site
  - Possibly adjust success criteria
- Compare treatment and control data
  - Compare restored pool to the range of reference pool
  - Ultimately, pools should not be statistically different (p=0.05) between treatment and control
  - Compare restored and reference pools using confidence interval
  - If the CIs overlap, they are statistically equivalent and therefore the restored pools would be approximating the reference pools.

Programmatic reference site

- With increasing development pressures, vernal pool restoration to mitigate for development projects is becoming frequent
- In order to minimize impacts natural vernal pool complexes from multiple post-restoration monitoring surveys, identify programmatic reference site per landscape unit (watershed, complex, etc.)
- Collect reference data and make available by
  - Distributing to other entities directly; or
  - Uploading on database accessible to others (e.g., San Diego Monitoring and Management Program (SDMMP))

Programmatic reference site

- The vernal pool complex J-26 is one of the last remaining relatively intact complexes on Otay Mesa
- Was chosen from a series of complexes as programmatic reference site for all Otay Mesa vernal pool restoration projects.

Restoration signature

Restoration signature

2000 – pre-restoration

2004 – During construction

2006 – 2 years later

2012 – 8 years later

2014 – 10 years later

Dos and Don’ts

- Do use experienced planners
  - Restoration plan that is scientifically justified, implementable, and contains meaningful performance criteria
  - Plans and specifications reviewed by an experienced vernal pool restoration ecologist
- Do use experienced practitioners
  - Vernal pool grading requires specialized experience
  - Art vs. science: vernal pool basin and mima mound lay-out often shifts in the field relative to the construction drawings
  - Inoculum/seed collection and seed bulking by an experienced botanist/ecologist/nursery
  - Installation of habitat elements for pollinators and other vernal pool associated species
- Do use programmatic reference sites

Dos and Don’ts

- Don’t create pools where they didn’t exist before
- Don’t create pools where the soil layer has been compromised
- Don’t use Bentonite!!!
  - Bentonite has different physical qualities than extant clays
- Don’t ignore non-native species
  - Increased phytomass can impede watershed hydrology
  - Invasive species displace sensitive native species
- Don’t hesitate to experiment, but test your methods carefully
  - Managed grazing has been shown effective as vernal pool management tool

Schaefer Top Recommendations for restoring vernal pools in the Southern California

Causes of Failure	Recommendations	Selected Measures
1. Overall reduction in viable and functioning vernal pool ecosystems (San Diego County loss about 97%)	Conserve and preserve vernal pool complexes before allowing impacts that require mitigation/restoration	Vernal pool restoration science is too young to guarantee comprehensive improvement of ecosystem functions in perpetuity, specifically given climate change and the California drought. There are no comprehensive studies that show that vernal pool restoration is successful in the long term, but some studies show their failures. Provide for comprehensive regional guidelines (e.g., NCCP, HCP) and ordinances for vernal pool conservation.
2. Failure of vernal pool restoration due to inadequate baseline conditions	If you must create pools to mitigate unavoidable impacts, do so only where pools once (historically) existed. Collect adequate baseline data by experienced vernal pool restoration practitioners and biologists.	Vernal pools require functioning hydrology, and with it impermeable soils. It has been shown that artificially created impermeable soil layers do not work (bentonite has different physical characteristics than the extant clay layers and hard pans that characterize SoCal vernal pools). Develop hydrological models for vernal pool conditions. Collect baseline data within the vernal pool complex (or watershed), including botanical surveys, faunal surveys (incl. fairy shrimp sampling), and soil tests.
3. Vulnerability of restored vernal pools to edge effects, fragmentation, and other threats due to their position in the landscape	Avoid creating postage stamp vernal pools that lack sufficient/appropriate watershed, buffers, and landscape context	Vernal pool functions require an appropriate watershed to allow for reliable filling of pools. Vernal pool ecosystems are sensitive to edge effects, including trampling, invasive species introduction, pollution, predation, and lack of pollinator access.
4 Failures due to inadequate experience by restoration contractor	Only use experienced contractors with documented track record of successful vernal pool restoration. This is not necessarily the lowest bid.	Vernal pool restoration requires micro-topographic grading to create functioning vernal pool basins and mima mounds without penetrating the hard/clay pan. This requires years of specialized experience. Vernal pools are unique ecosystems and the contractor must have an understanding of the baseline physical and ecological conditions. There is a common misunderstanding that a low bid saves tax payer money; however, in the end, a low bid may actually be more expensive down the line due to changes orders, remediation costs, or project failure.
5. Failures of successfully installed vernal pool restoration due to lack of continued monitoring and management	5. Set up management funds. Avoid disturbance through monitoring; use programmatic reference sites and consistent monitoring protocols and metrics geared toward ecosystem function rather than singling out one organism over another, and protect restored pools through long-term management.	Meaningful monitoring is important to show ecosystem functions of the entire system, not just plants. Use statistically rigorous monitoring protocols, but avoid over-monitoring (killing with good intentions). Long-term monitoring is important to inform adaptive management and buffer from climate change effects. Vernal pools are susceptible to invasive species that accumulate phytomass, which prevent proper hydrological function and result in species extirpation. Calculate management funds/endowments using experienced personnel that understand what it takes. Consider managed grazing.

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