01 - Ditch

02 - Tire Pile

03 - Artificial Container - Other

04 - Crypt - Root/Natural

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06 - Blow Down

07 - Field Depression

08 - Marsh

09 - Pond - Natural

10 - Pond - Stormwater Retention

11 - Puddle - Curbside

12 - Puddle - Other

13 - Runoff Channel

14 - Septic

15 - Swale

16 - Swamp

17 - Tire Rut

18 - Treehole

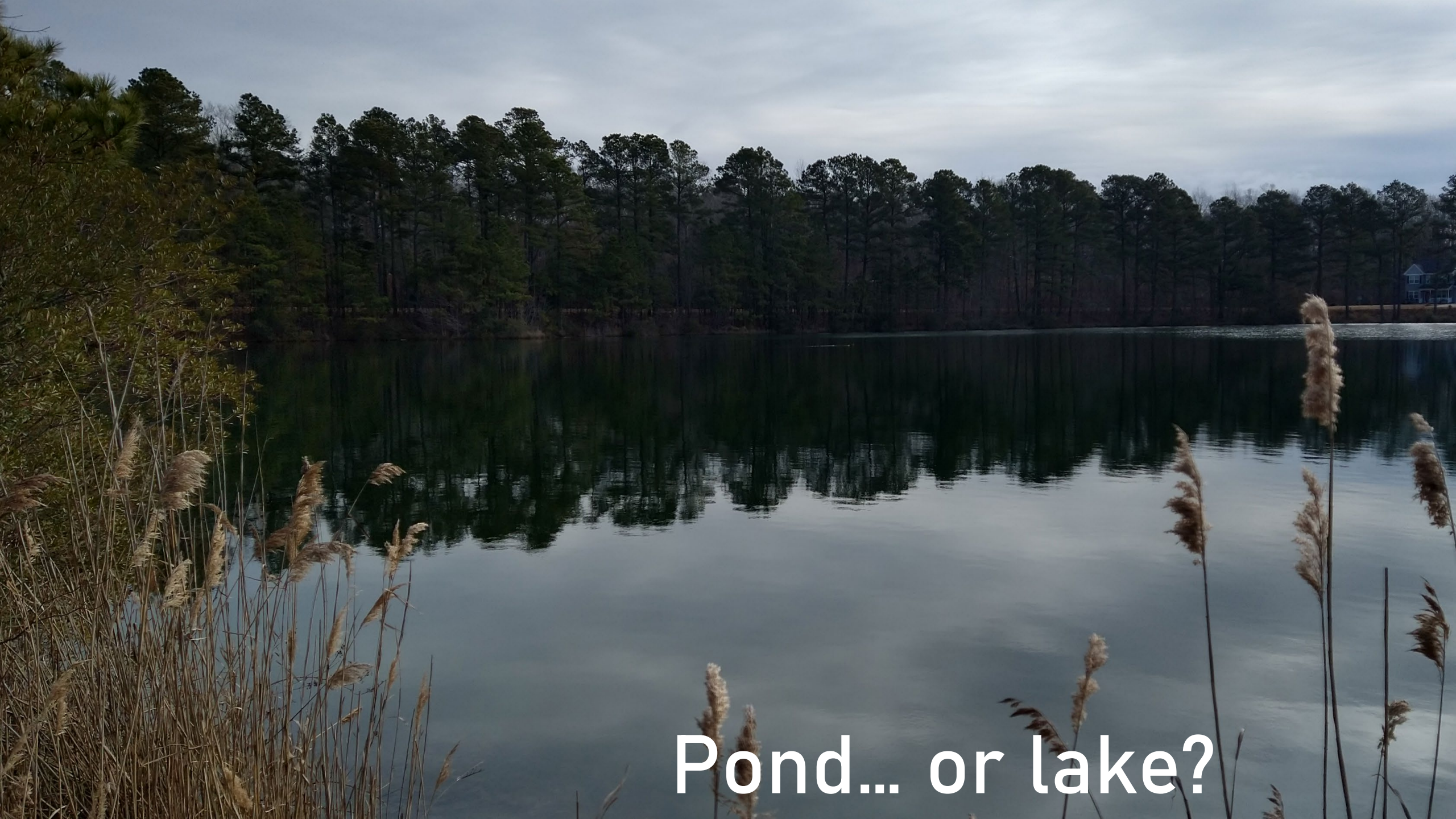
19 - Woodland Pool

20 - Outfall

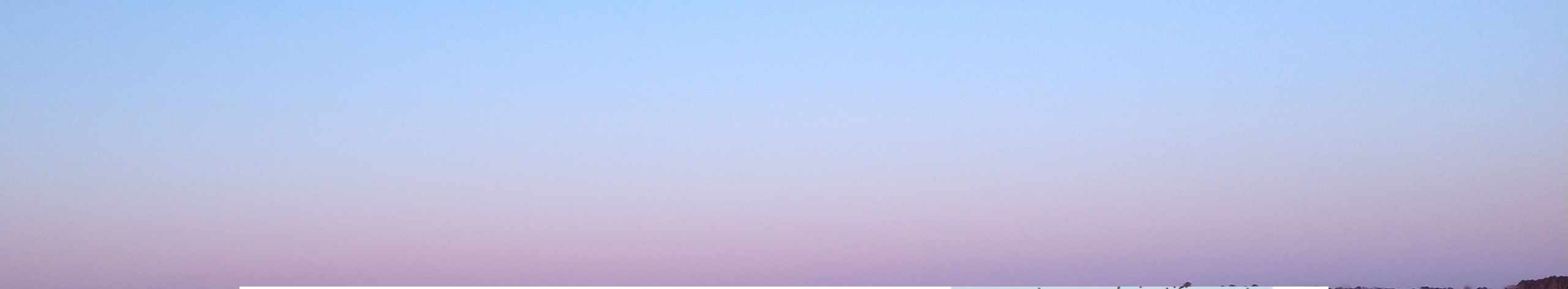
What

is a

Pond?


Pond… or lake?


Pond… or wetland?



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A functional definition to distinguish ponds from lakes and wetlands

David C. Richardson[1,19]✉, Meredith A. Holgerson[2,19], Matthew J. Farragher[3], Kathryn K. Hoffman[4], Katelyn B. S. King[5], María B. Alfonso[6], Mikkel R. Andersen[7], Kendra Spence Cheruveil[8], Kristen A. Coleman[9], Mary Jade Farruggia[10], Rocio Luz Fernandez[11], Kelly L. Hondula[12], Gregorio A. López Moreira Mazacotte[13], Katherine Paul[1], Benjamin L. Peierls[14], Joseph S. Rabaey[15], Steven Sadro[10], María Laura Sánchez[16], Robyn L. Smyth[17] & Jon N. Sweetman[18]

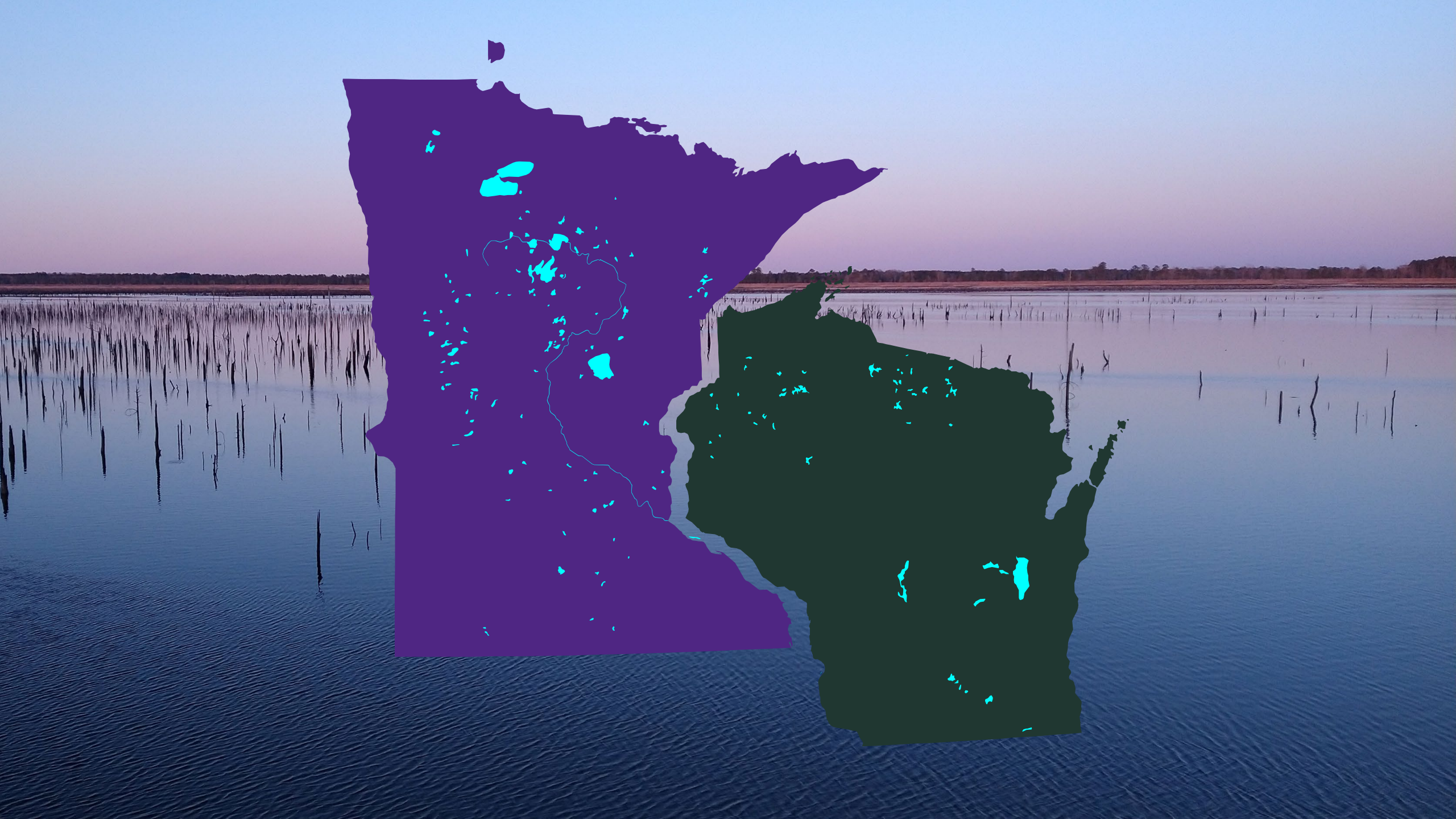
Ponds are often identified by their small size and shallow depths, but the lack of a universal evidence-based definition hampers science and weakens legal protection. Here, we compile existing pond definitions, compare ecosystem metrics (e.g., metabolism, nutrient concentrations, and gas fluxes)

Current scientific definitions of ponds. We compiled existing scientific definitions of ponds by conducting a backwards and forwards search of papers referenced in or subsequently referencing three seminal pond papers[8,17,18] (see "Methods"). We ultimately compiled 54 pond definitions from scientific literature (data available[19]). The variables most often included in definitions were surface area (91% of definitions), depth (48%), permanence (48%), origin (i.e., natural or human-made; 33%), and standing water (33%; Fig. 2a). When surface area or depth were included in definitions, they were often mentioned qualitatively (e.g., "small" and "shallow").

International definitions. At an international level, there is no consensus on how to discriminate among ponds, lakes, and wetlands. In North America, wetlands are generally considered to be shallow: < 2 m in Canada[22] and < 2.5 m in the US[23], which differentiates them from lakes. Some nations, such as Australia, South Korea, and Uganda, explicitly include ponds and lakes in federal wetland definitions[24] (see also[22]). The inclusion of ponds and some lakes within wetland definitions often stems from the Ramsar Convention, an international body

Current U.S. Federal and State definitions. In the US, waterbody definitions vary among federal agencies, with implications for both legal protection and monitoring. The US Environmental Protection Agency (EPA) and the US Army Corps of Engineers (ACE) define wetlands based on saturated soils and hydrophytic vegetation, which has the potential to include ponds within the category of wetlands. Conversely, the US Fish and Wildlife Service (USFWS) distinguishes among wetlands and lakes based on surface area, depth, and emer-

Reflecting political and geographic variability at the national scale, most US states have their own waterbody protections[25]. We surveyed US state agencies to examine state definitions of ponds, lakes, and wetlands (see "Methods"). Our survey responses included 42 of 50 (84%) states (Fig. 3). Only one state (Michigan) explicitly defined ponds, 11 states defined lakes (26%), and 30 states defined wetlands (71%). While only one state defined ponds, half of the surveyed states used the term "pond" in their legislation. Specifically, ponds were referenced



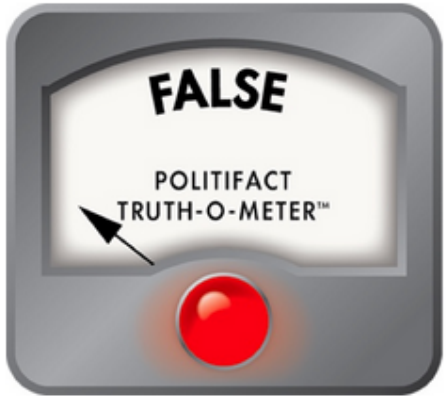
15,809,784

11,842

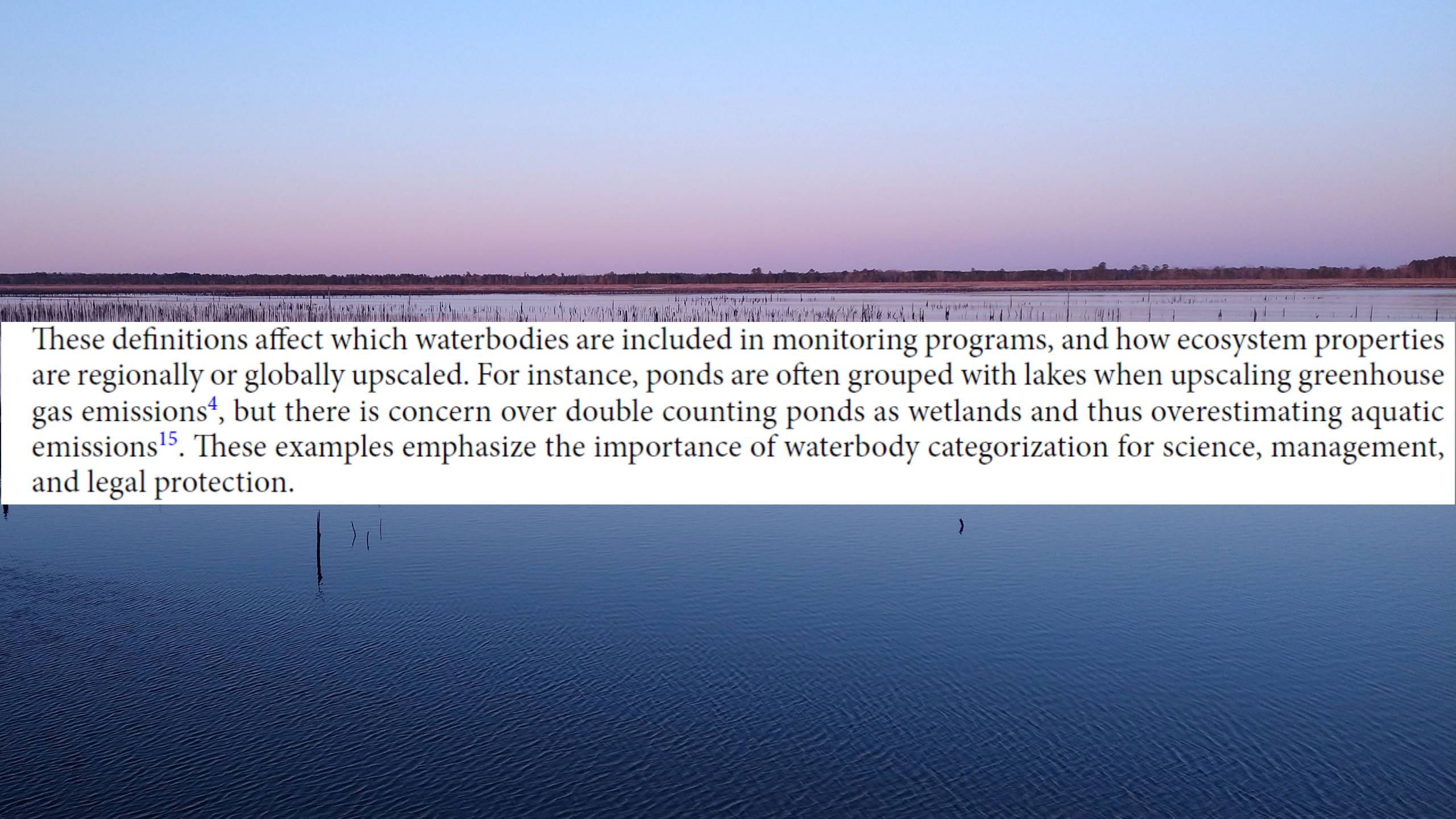
Sara Meaney

stated on May 9, 2019 in a WTMJ radio appearance:

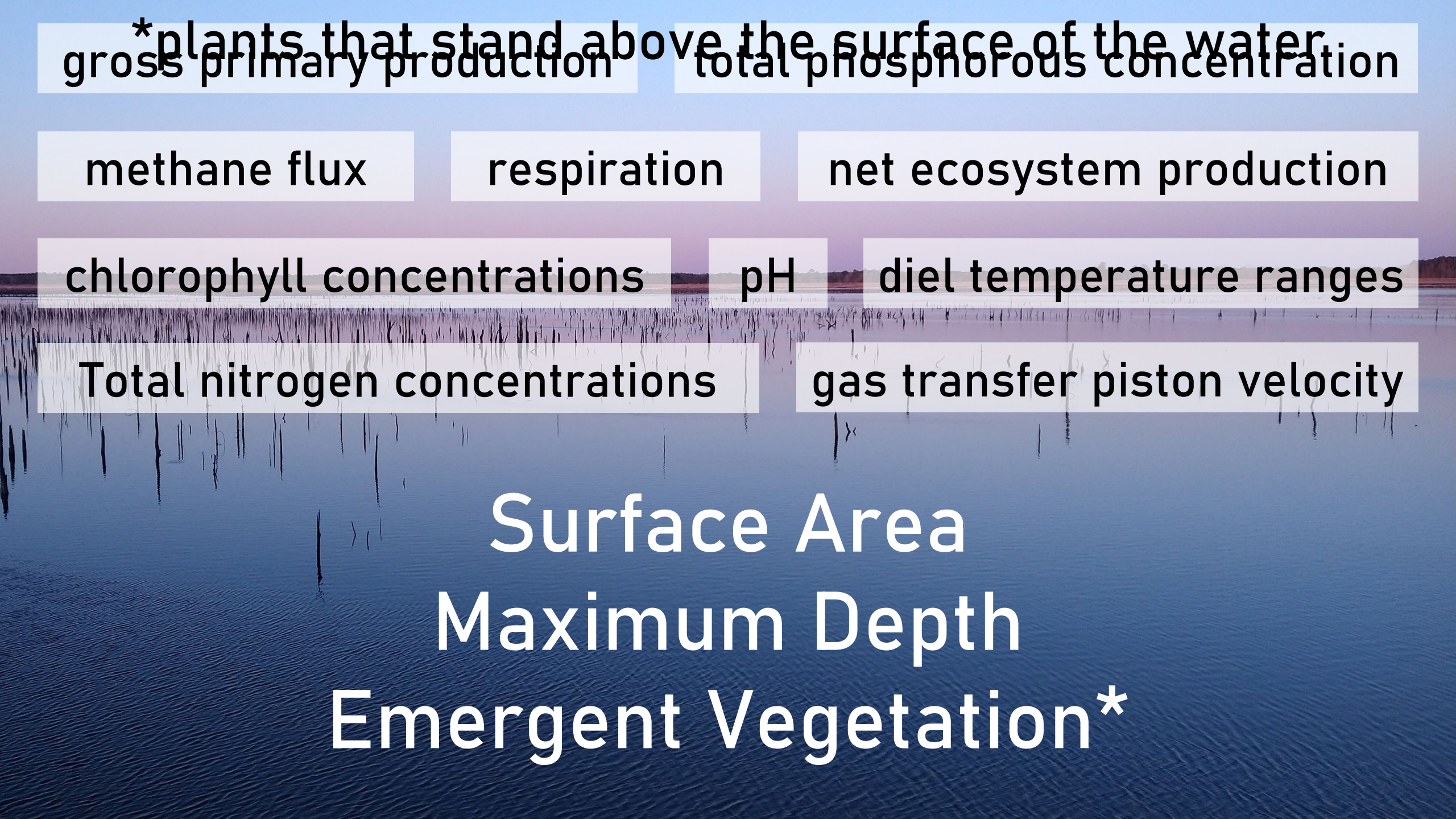
> **"Wisconsin, many people may not be aware, actually has 15,000 freshwater lakes. ... More than Minnesota."**

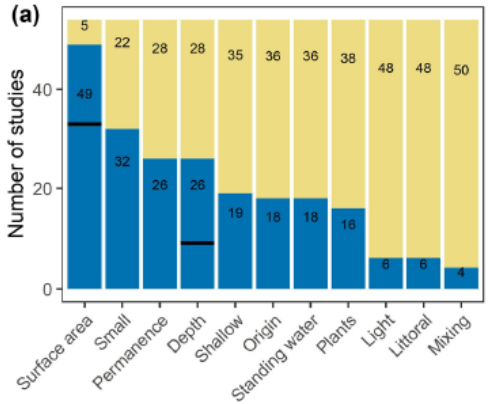


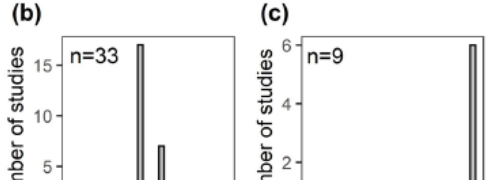
WATER | WISCONSIN | SARA MEANEY

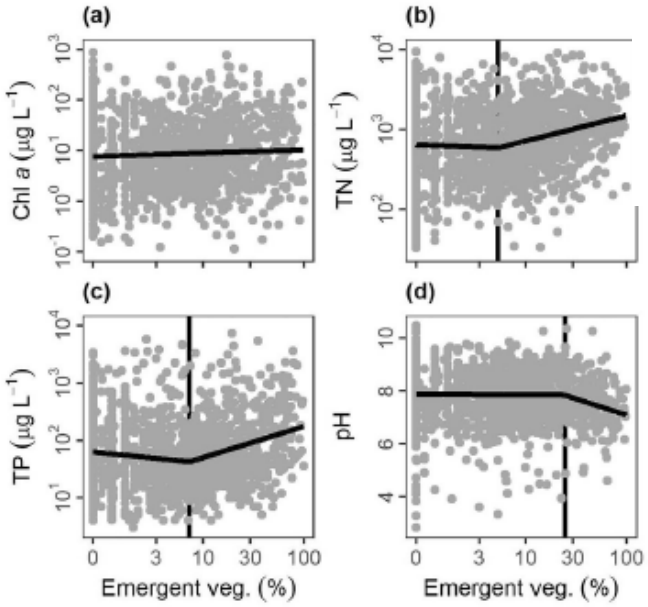


These definitions affect which waterbodies are included in monitoring programs, and how ecosystem properties are regionally or globally upscaled. For instance, ponds are often grouped with lakes when upscaling greenhouse gas emissions[4], but there is concern over double counting ponds as wetlands and thus overestimating aquatic emissions[15]. These examples emphasize the importance of waterbody categorization for science, management, and legal protection.


*plants that stand above the surface of the water
gross primary production
total phosphorous concentration
methane flux
respiration
net ecosystem production
chlorophyll concentrations
pH
diel temperature ranges
Total nitrogen concentrations
gas transfer piston velocity
Surface Area
Maximum Depth
Emergent Vegetation*







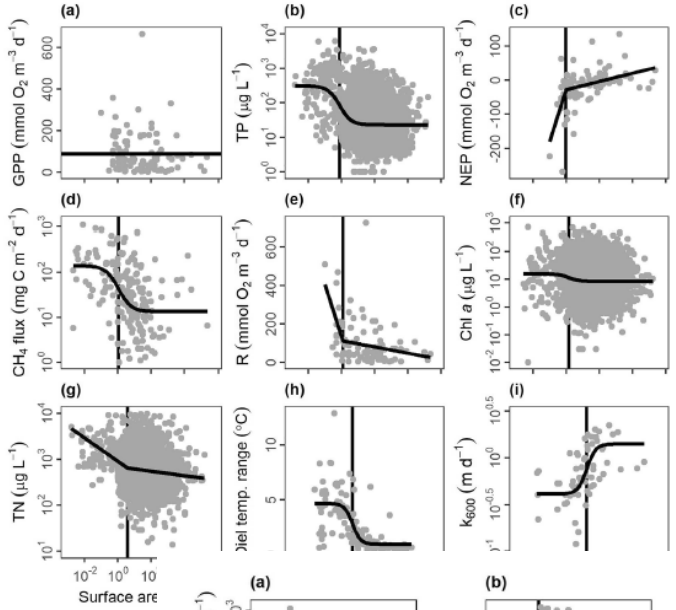
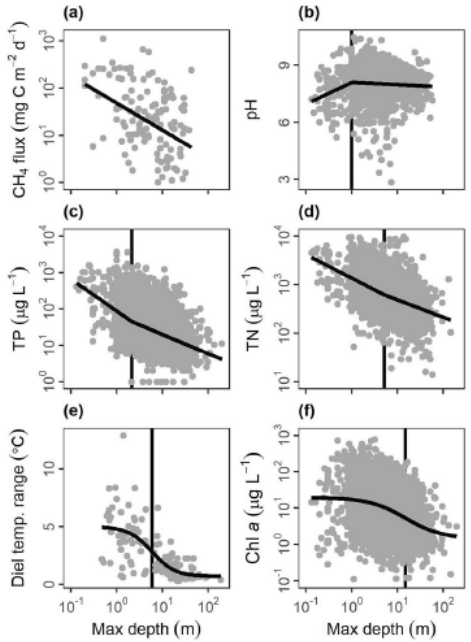
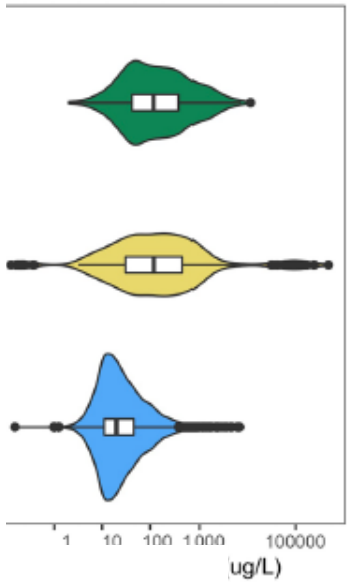
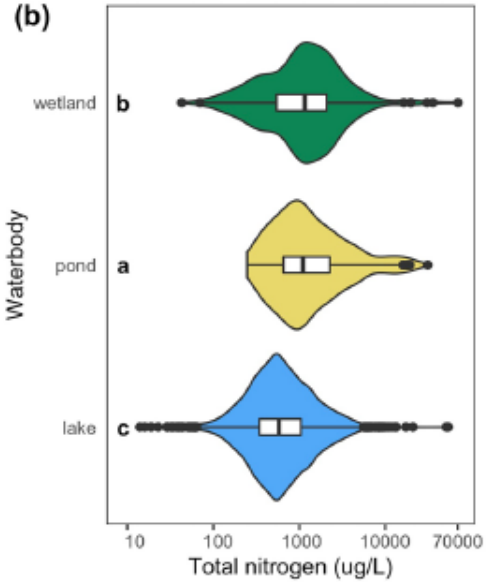


Figure 5. Relationship
function metrics: (a) gr
ecosystem production
(Chl a), (g) total nitrog
velocity (k_{600}). Optimal
nonlinear segmented a
defined by model breal







(d)

Ecosystem metric	Surface area Boundary est. ± SE (ha)	Max. depth Boundary est. ± SE (m)	Emergent veg. cover Boundary est. ± SE (%)
GPP	NA	–	–
TP	0.8 ± 1.2	2.1 ± 1.2	8.2 ± 1.2
NEP	1.0 ± 1.4	–	–
CH_4 flux	1.1 ± 1.7	NA	–
R	1.2 ± 1.5	–	–
Chl *a*	1.5 ± 1.7	14.9 ± 1.2	NA
pH	1.7 ± 1.5	1.0 ± 1.4	26.0 ± 1.3
TN	3.8 ± 1.4	5.2 ± 1.4	6.0 ± 1.3
DTR	4.6 ± 1.3	5.9 ± 1.3	–
k_{600}	17.5 ± 1.5	–	–
Mean	3.7 ± 1.8	5.8 ± 2.5	13.4 ± 6.3
Median	1.5	5.2	8.2

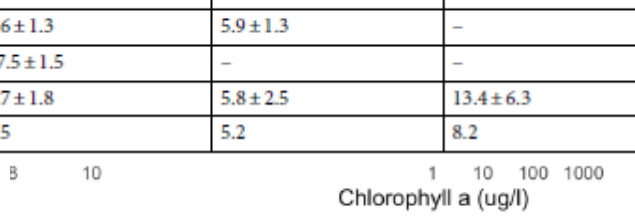


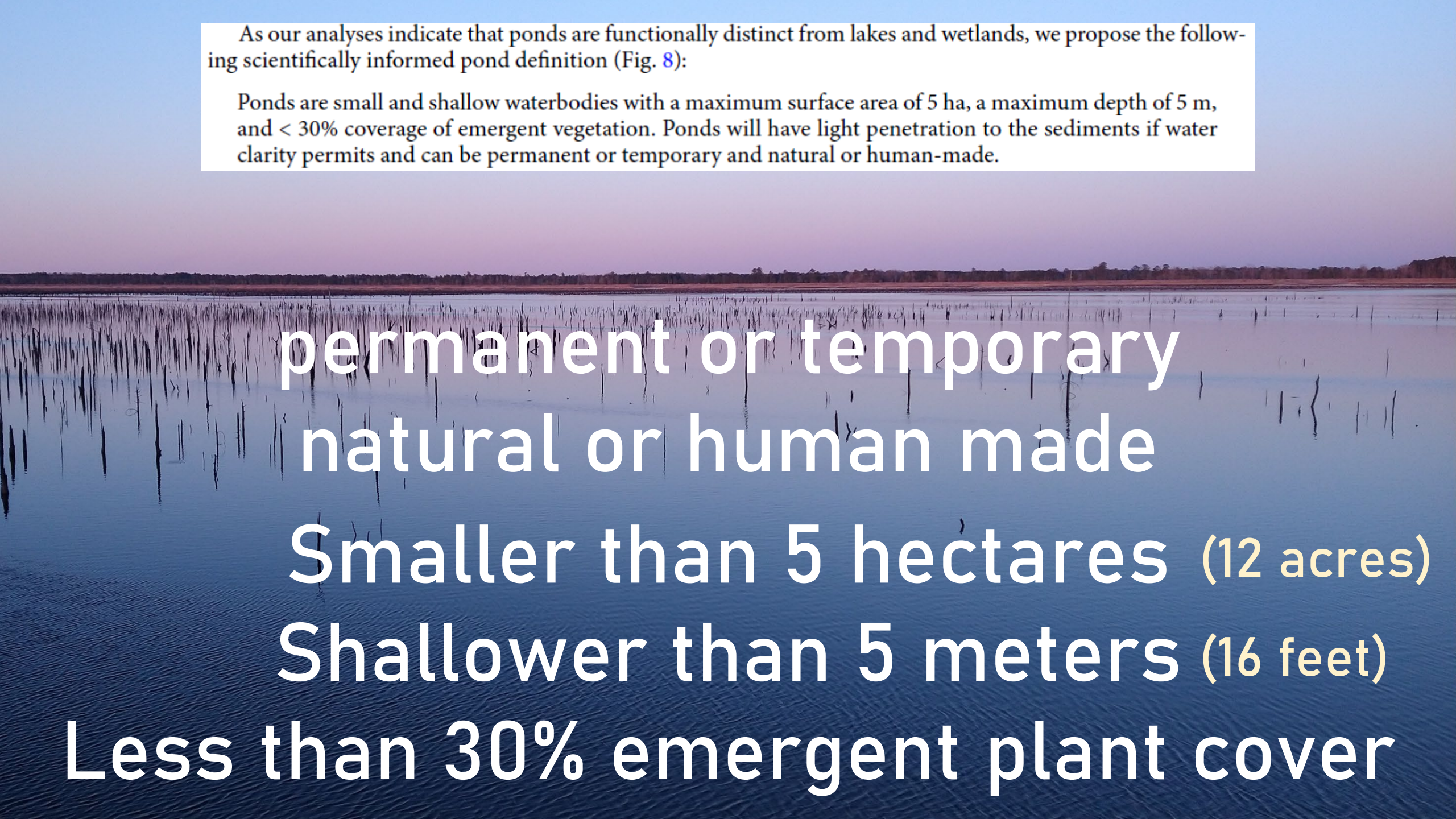
Figure 7. Relationships between lentic waterbody emergent vegetation cover (En
ecosystem structure and function metrics: (**a**) chlorophyll *a* concentrations (Chl *a*
concentrations (TN), (**c**) total phosphorus concentrations (TP), (**d**) pH from litera
optimal model fits from null, linear or null, segmented linear, and logistic curves i
nonlinear segmented and logistic models (**b–d**), plots are ordered by model breakp
(vertical background lines), indicative of boundaries between ponds and wetlands

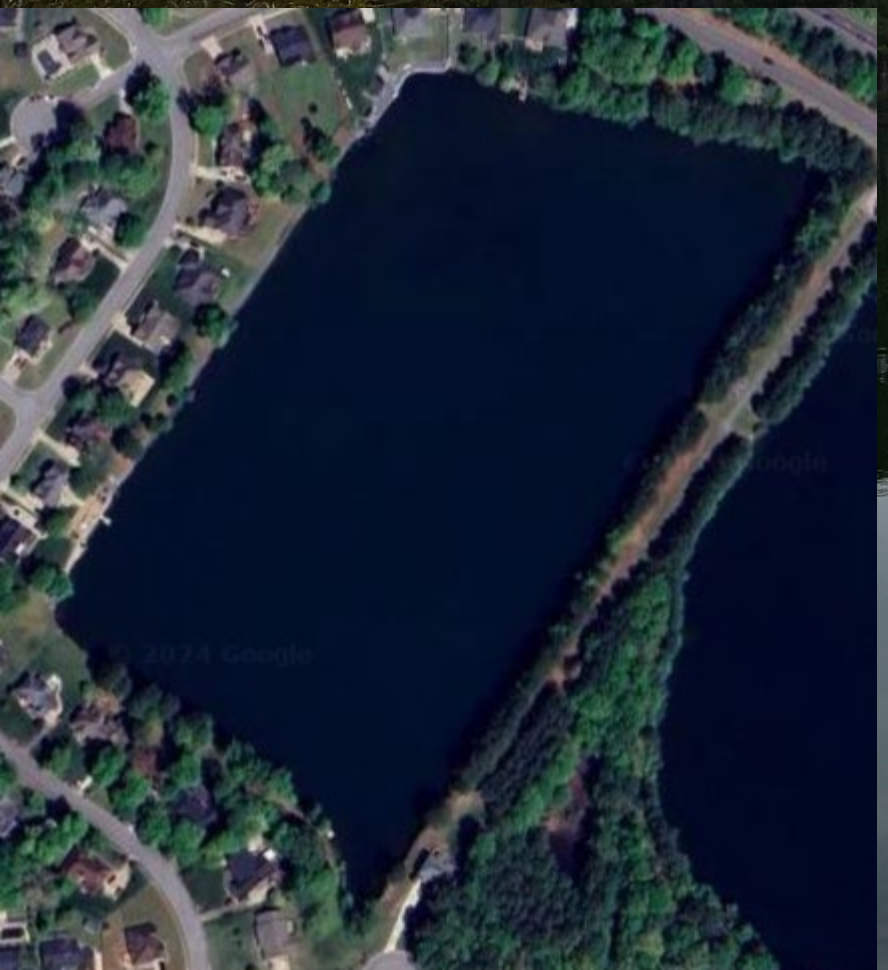
Figure 6. Relationships between lentic waterbody maximum depth (Max depth) and various ecosystem structure and function metrics: (**a**) methane fluxes (CH_4 flux), (**b**) pH, (**c**) total phosphorus concentrations (TP), (**d**) total nitrogen concentrations (TN), (**e**) diel temperature ranges (DTR), and (**f**) chlorophyll *a* concentrations (Chl *a*) from literature data extraction with optimal model fits from null, linear or null, segmented linear, and logistic curves in bold foreground lines. For nonlinear segmented and logistic models (**b–f**), plots are ordered by model breakpoints or inflection points (vertical background lines), indicative of boundaries between ponds and lakes.

hemical and biological parameters across wetlands, ponds, and lakes, with
rm used by publishing scientists and managers (Table S2). Violin plots
characteristics, the white box indicates 25th to 75th percentile with median
×interquartile range, and outliers are black closed circles. Letters inside the
in means (LSD, alpha = 0.05). Note all x-axes have logarithmic scales.

As our analyses indicate that ponds are functionally distinct from lakes and wetlands, we propose the following scientifically informed pond definition (Fig. 8):

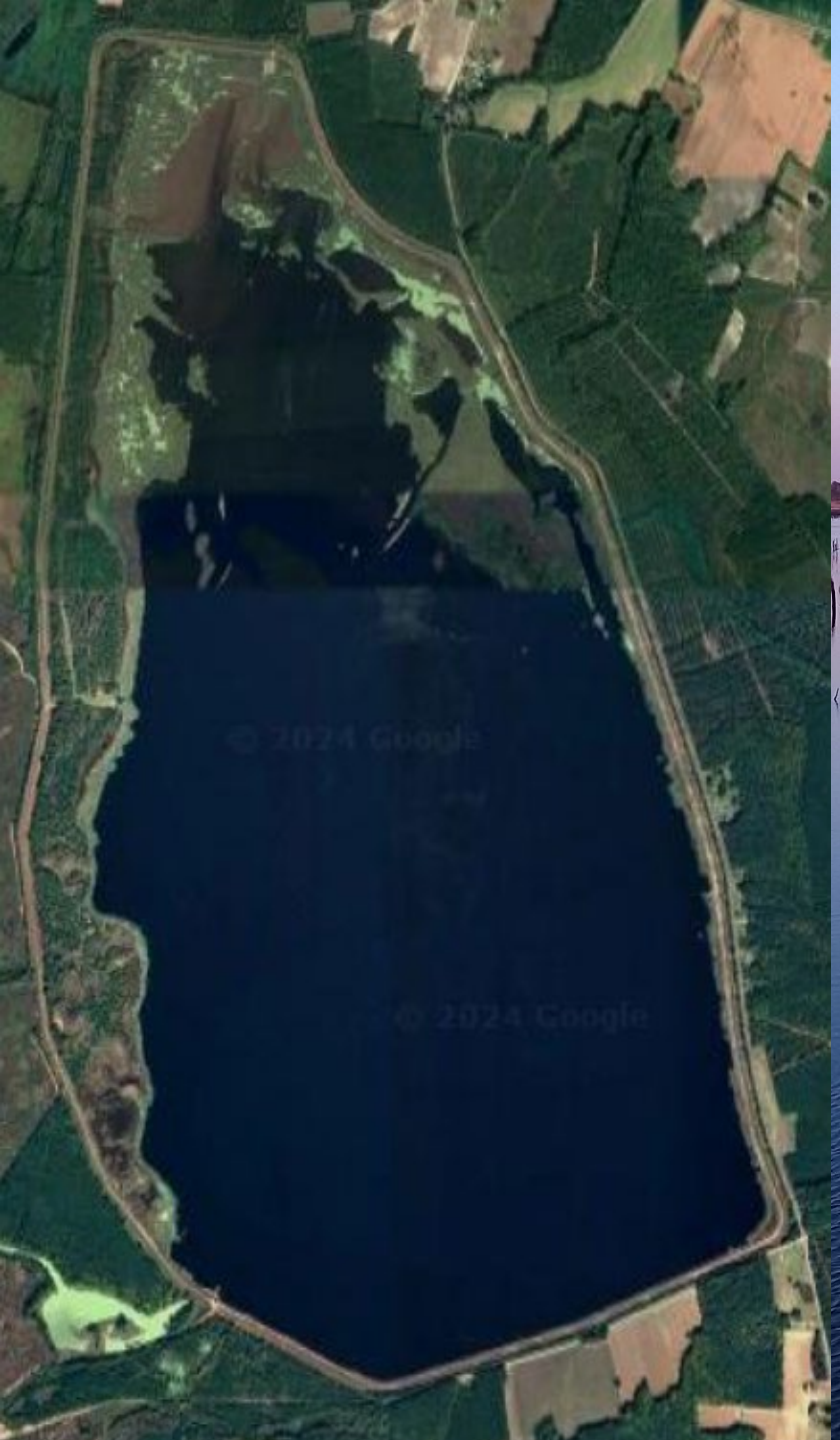
Ponds are small and shallow waterbodies with a maximum surface area of 5 ha, a maximum depth of 5 m, and < 30% coverage of emergent vegetation. Ponds will have light penetration to the sediments if water clarity permits and can be permanent or temporary and natural or human-made.



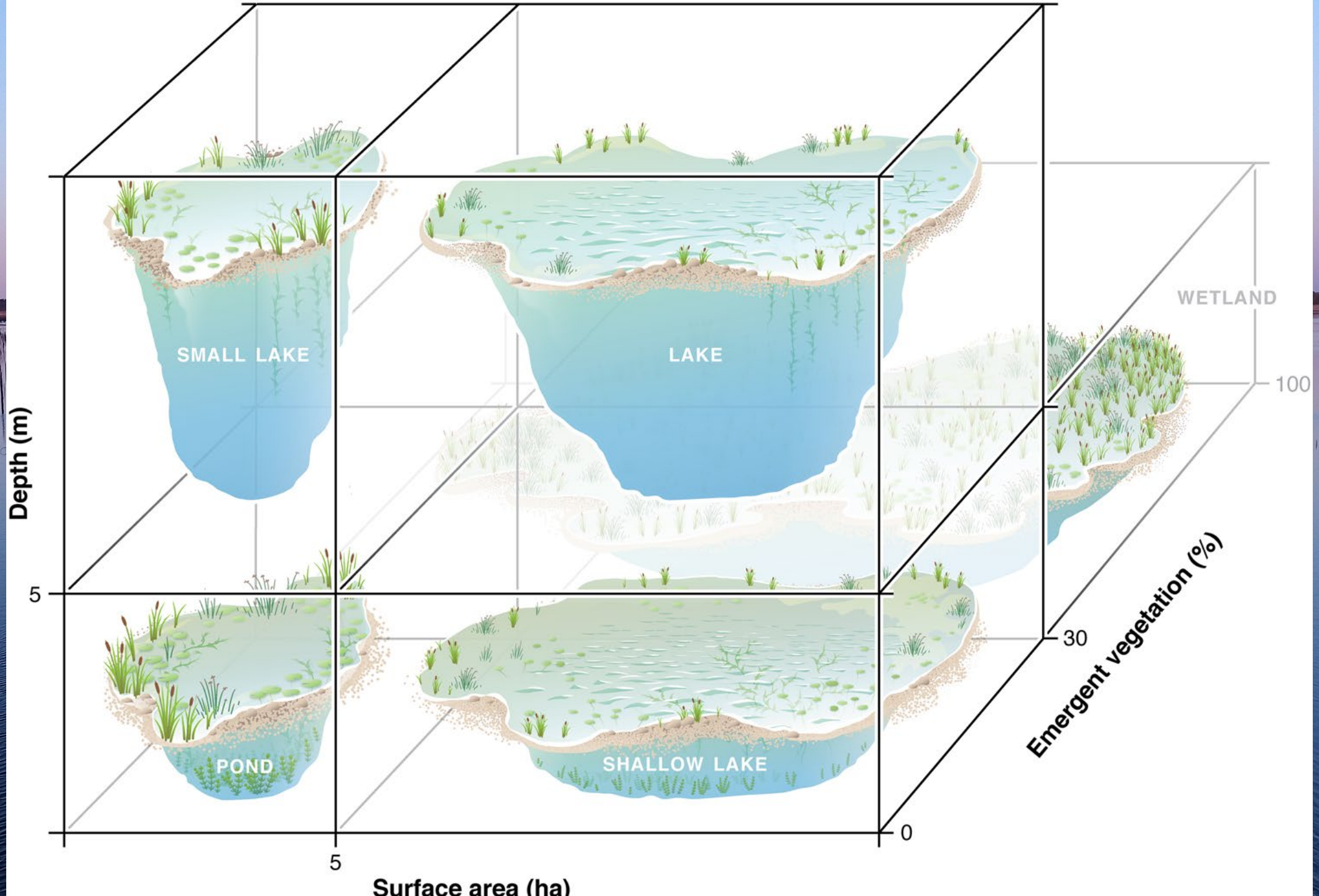


5.81 hectares… lake!

4.85 hectares… pond!



480 hectares... lake lol


SMALL LAKE
LAKE
POND
SHALLOW LAKE
WETLAND
Depth (m)
5
5
Surface area (ha)
0
30
100
Emergent vegetation (%)

nature functional pond definition

01 - Ditch

02 - Tire Pile

03 - Artificial Container - Other

04 - Crypt - Root/Natural

05 - Crypt - Concrete

06 - Blow Down

07 - Field Depression

08 - Marsh

09 - Pond - Natural

10 - Pond - Stormwater Retention

11 - Puddle - Curbside

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13 - Runoff Channel

14 - Septic

15 - Swale

16 - Swamp

17 - Tire Rut

18 - Treehole

19 - Woodland Pool

20 - Outfall

01 - Long puddle

02 - Rubber puddles

03 - Fake puddle

04 - Deep puddle

05 - Spooky puddle

06 - Tree puddle

07 - Grassy puddle

08 - Salty puddle

09 - Big puddle

10 - Big puddle (fake)

11 - Road puddle

12 - Puddle classic

13 - Long puddle

14 - Smelly puddle

15 - Long puddle (grass)

16 - Squish puddle

17 - Car puddle

18 - High puddle

19 - Shade puddle

20 - Flush puddle