Pond-breeding Amphibian Response to the Forestry Reclamation Approach and Wetland Creation on Legacy Surface Coal Mines in the Central Appalachians

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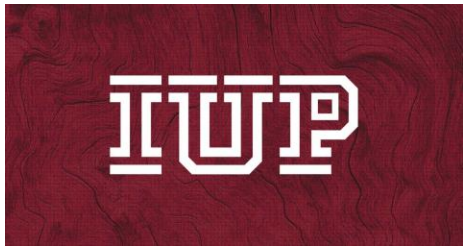


Forest Reclamation Approach (FRA)

- Restore ecosystem function and native vegetation
  - Soil de-compaction
  - Non-native species removal
  - Planting of native trees, shrubs, and herbaceous plants
- Counters arrested succession

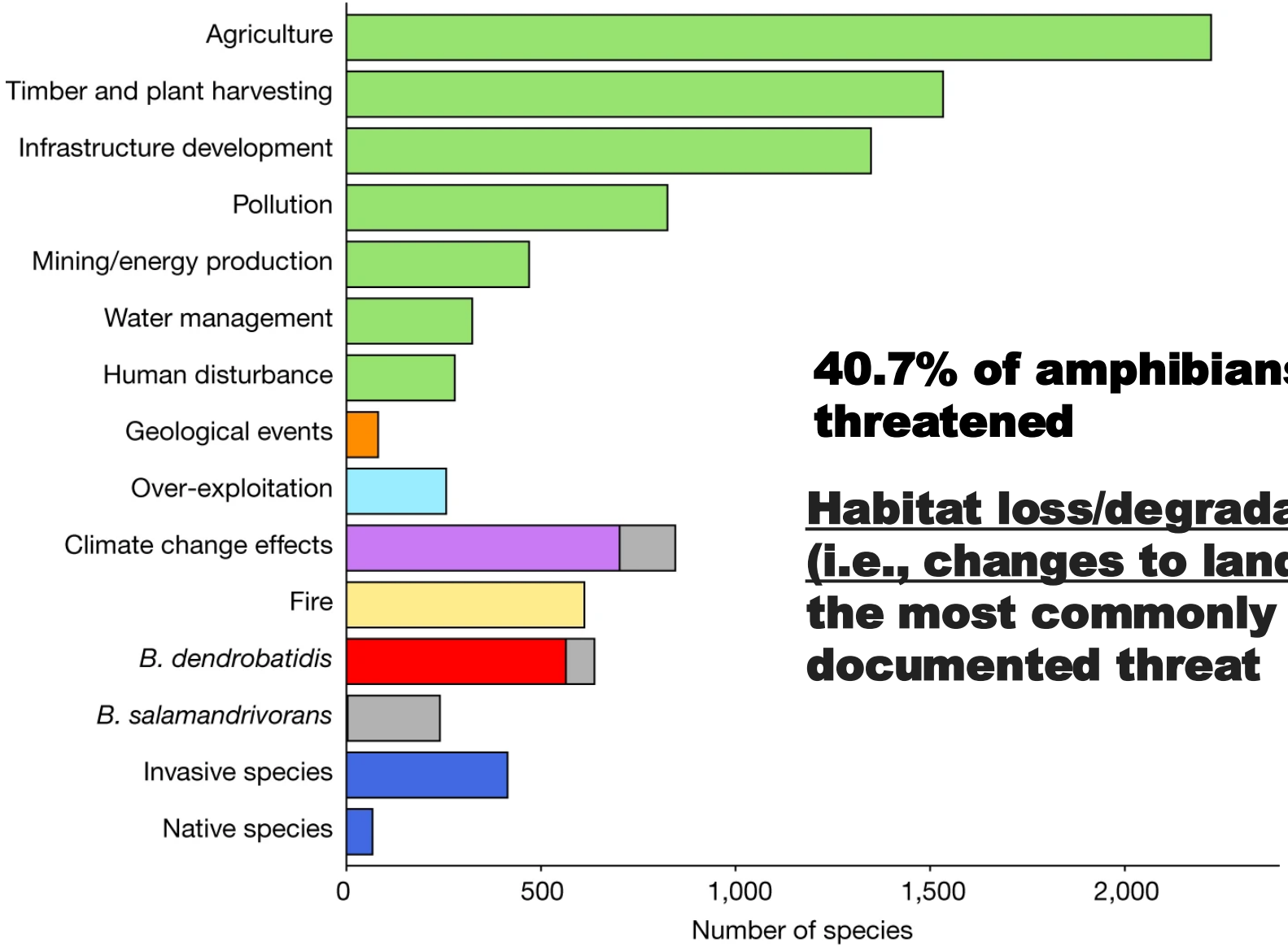
FRA and wetland creation on legacy surface mines

FRA Implementation

- **Monongahela National Forest (MNF) in West Virginia**
- **> 500,000 native trees and created >1400 wetlands across MNF**

- **How does wildlife respond to FRA and wetland creation on legacy surface mines?**

Amphibians and Threats

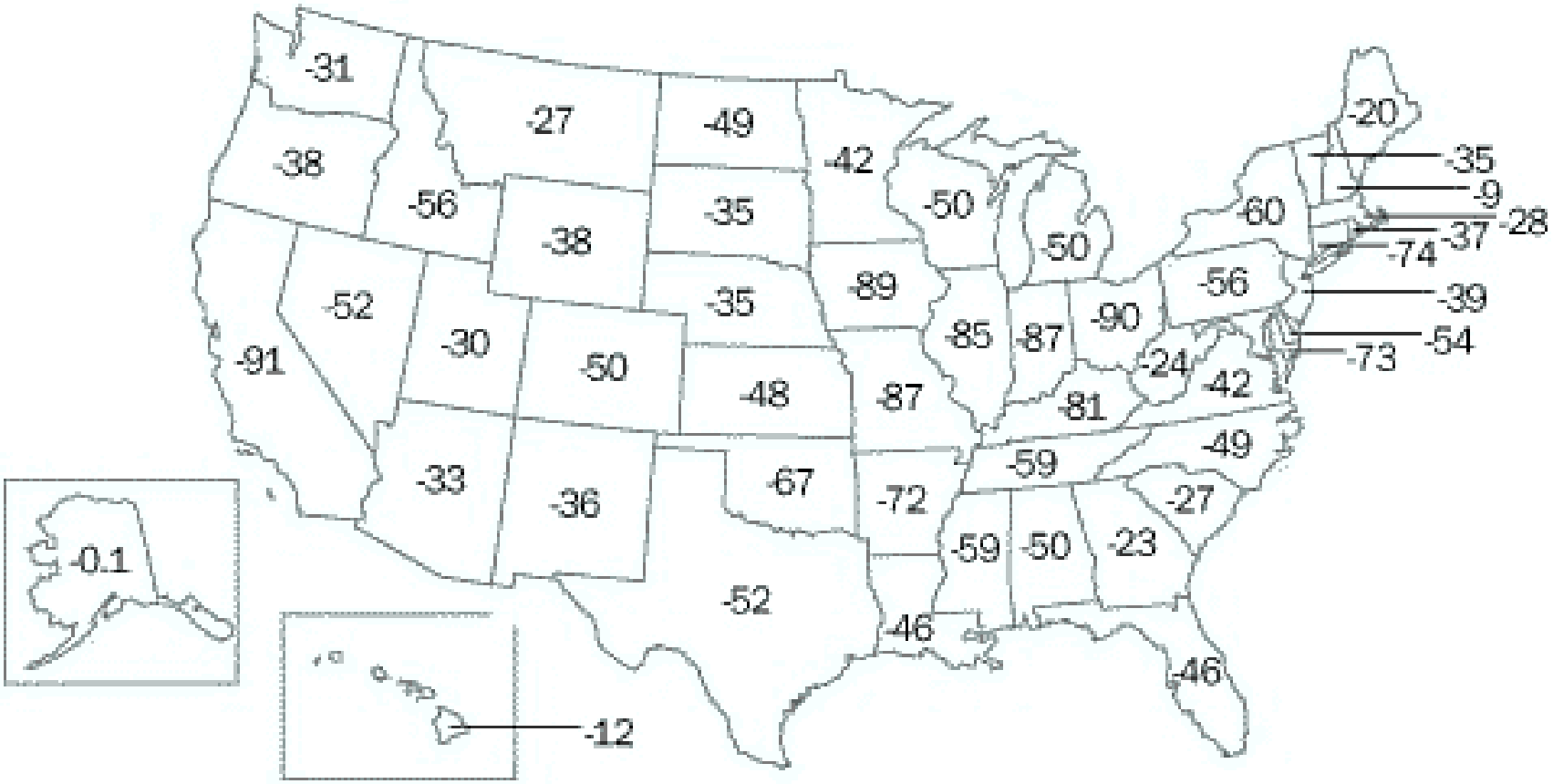


40.7% of amphibians threatened

Habitat loss/degradation (i.e., changes to land use) is the most commonly documented threat

Luedtke et al. 2023 – Nature –Ongoing declines for the world's amphibians…

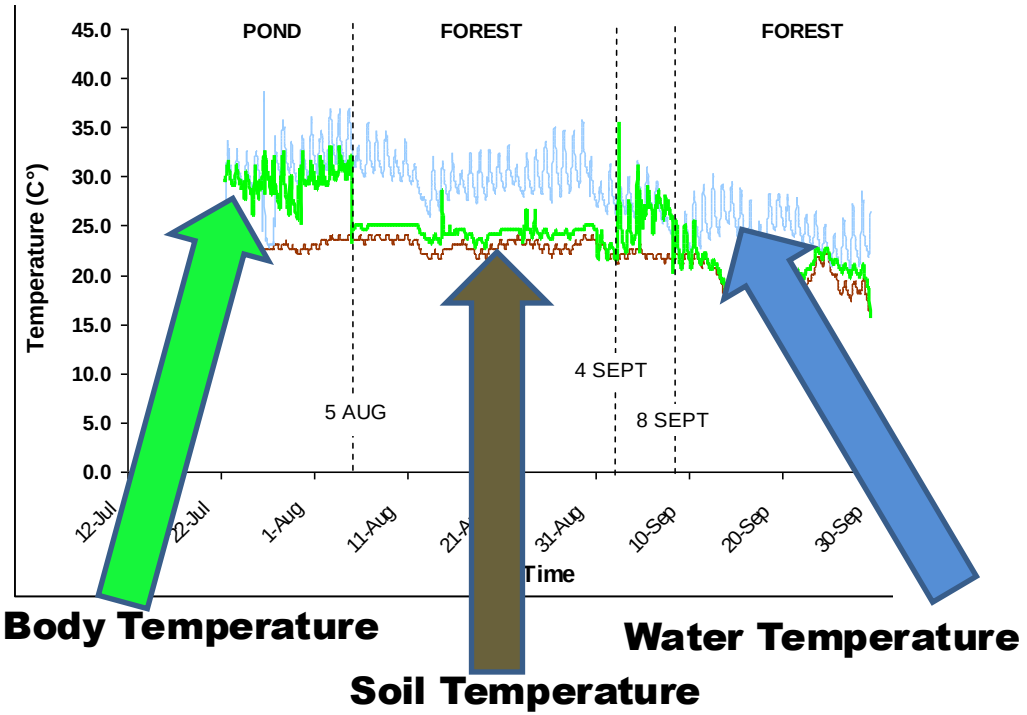
Percentage of Wetlands Acreage Lost, 1780's-1980's



Twenty-two states have lost at least 50 percent of their original wetlands. Seven states—Indiana, Illinois, Missouri, Kentucky, Iowa, California, and Ohio—have lost over 80 percent of their original wetlands. Since the 1970's, the most extensive losses of wetlands have been in Louisiana, Mississippi, Arkansas, Florida, South Carolina, and North Carolina.

Source: Mitch and Gosselink. Wetlands. 2nd Edition, Van Nostrand Reinhold, 1993

Ectotherm (cold-blooded)



Moisture

Amphibians have complex life cycles

Aquatic Larvae

What types of wetlands are important to amphibians?

Seasonal wetlands hydrology

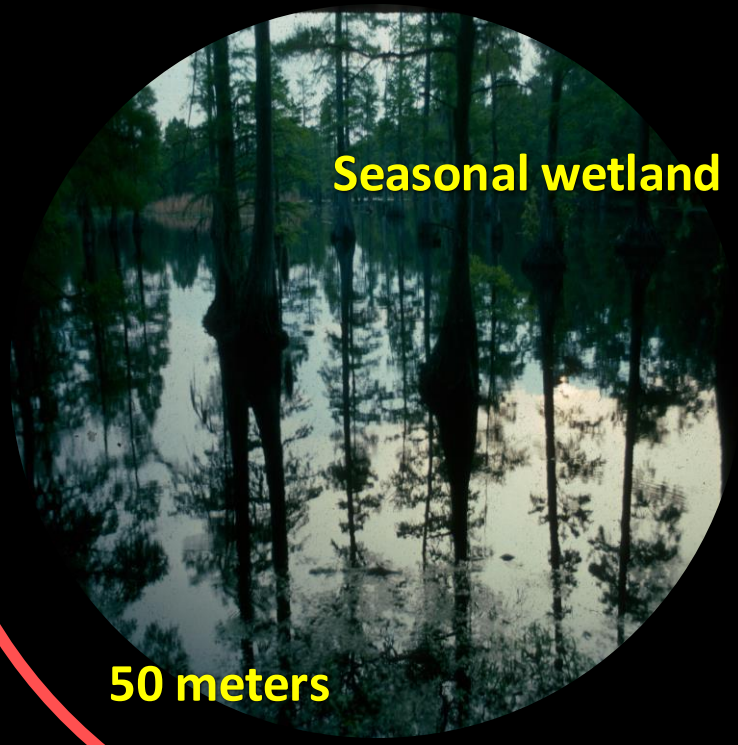
Complex life cycles

Metamorphosis

Amphibians migrate from wetlands into the forest – they need the forest too!

6 species of salamanders
mean = 164 m (500 ft)

max = 625 m (0.4 mi)



200 meters

Dispersal > 1 km (0.6 mi)

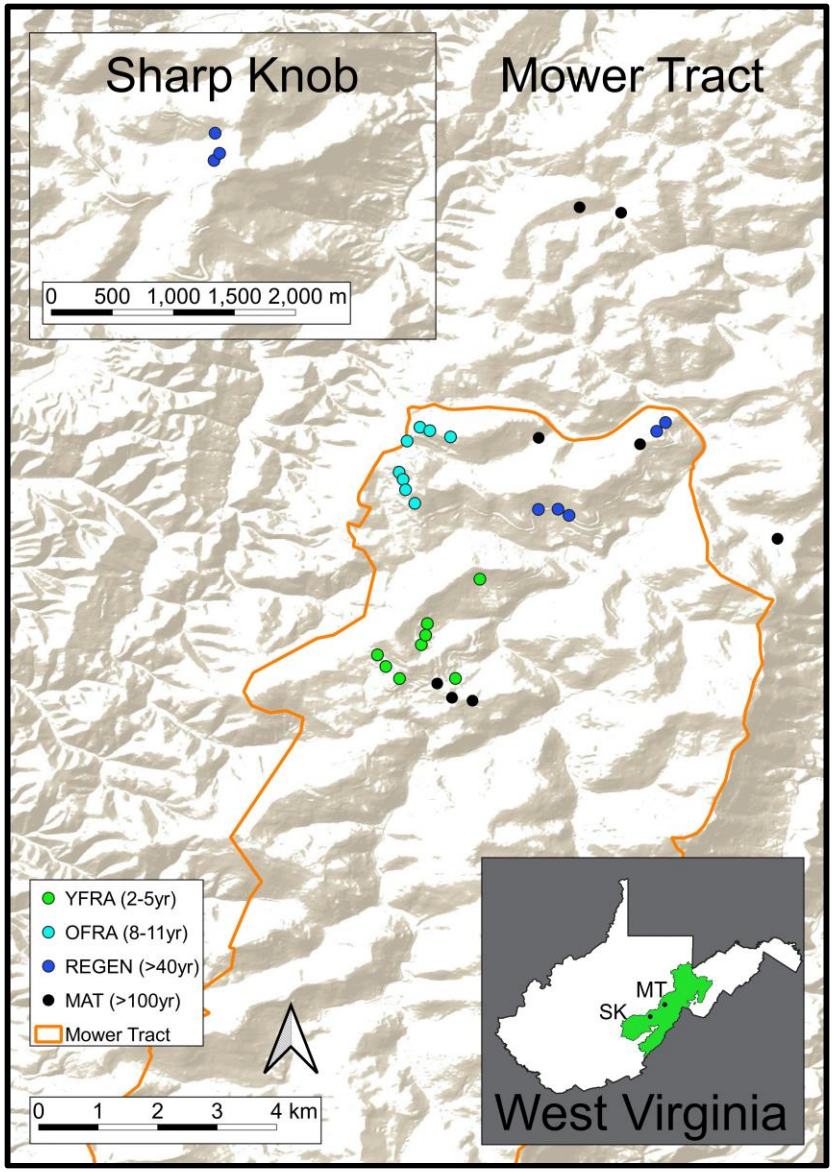
Marbled salamanders

Objective

- Assess amphibian response to FRA and wetland creation
  - Two FRA age-classes
  - Traditionally reclaimed sites
  - Mature, unmined forests
  - Wetland size

Study Sites: Monongahela National Forest

- **Red spruce/northern hardwood forest**
- **Surface mined in late 1970s**
- **Grassland and non-native conifer reclamation**
- **FRA implemented in 2008**



Study Design

- 4 treatments x 8 sites = 32 sites

<u>Young FRA (2-5 yrs since planting)</u>
Created Wetlands
Loaded with Woody Debris
Planted with Red Spruce/Northern Hardwood Mix
Extensive Herbaceous Groundcover
Seedlings < 1 m

Study Design

<u>Older FRA (8-11 yrs since planting)</u>
Created Wetlands
Planted with Red Spruce/Northern Hardwood Mix
Shrub and Herbaceous Groundcover
Saplings 2-4 m; young forest

Study Design

REGEN (Pre-SMCRA)

Wetlands created through mining activity

Initially reclaimed as grassland

Non-native conifers and natives

Arrested Succession

Study Design

MAT

Natural wetlands

Second-growth forest

No past mining activity

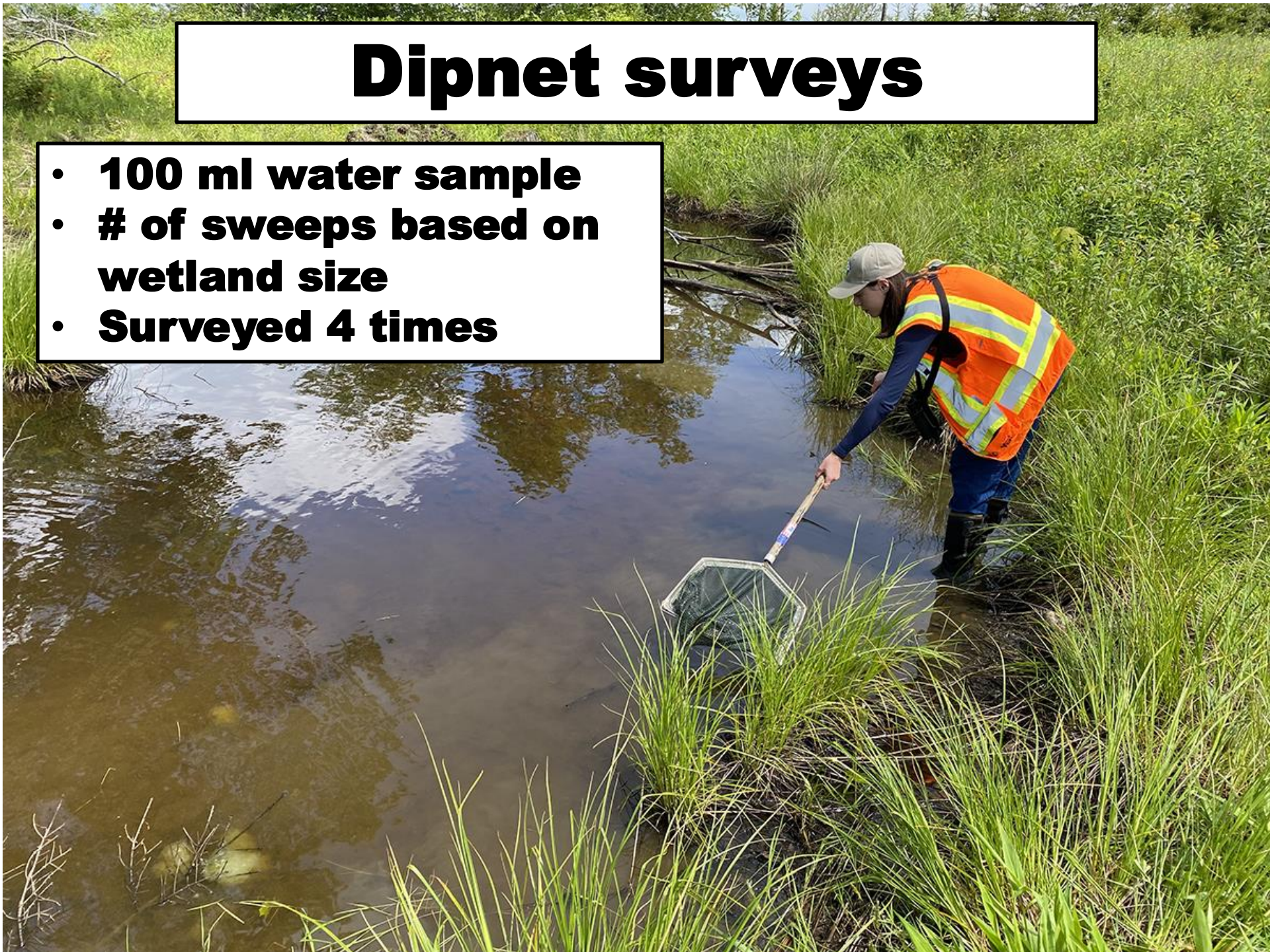
Field Methods

Automated Recording Units

- **Mid-March through early July**
- **15 min/hr from 4 pm to 1 am**
- **~170,800 mins recorded**

Dipnet surveys

- 100 ml water sample
- # of sweeps based on wetland size
- Surveyed 4 times



Occupancy and Abundance Models

Results: Anuran Vocalizations

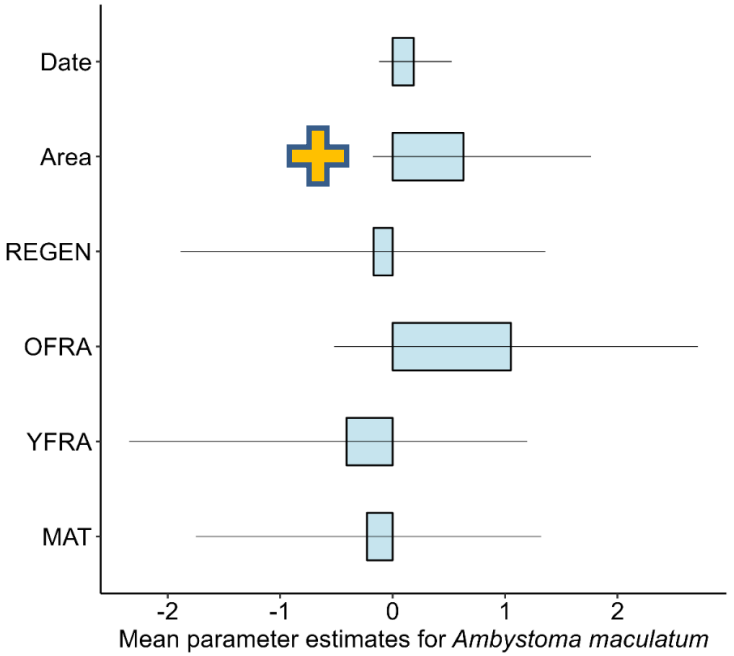
Processed 175 min each site (2100 min total)
Single Season occupancy model
Occupancy ~ 1.0 for most calling anurans across all site types

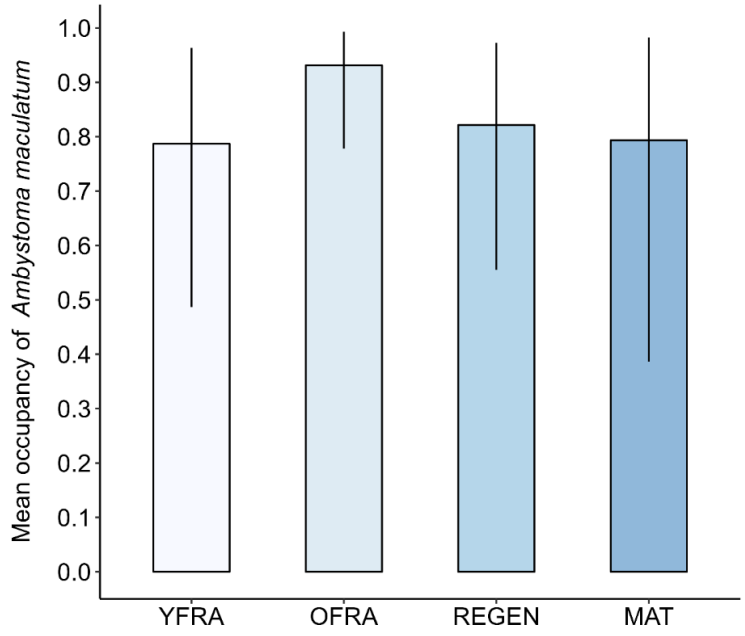
Results: Dipnet

Do occupancy rates differ among treatments?

Multi-species occupancy model

Spotted Salamander





Sherman et al. 2024 Water

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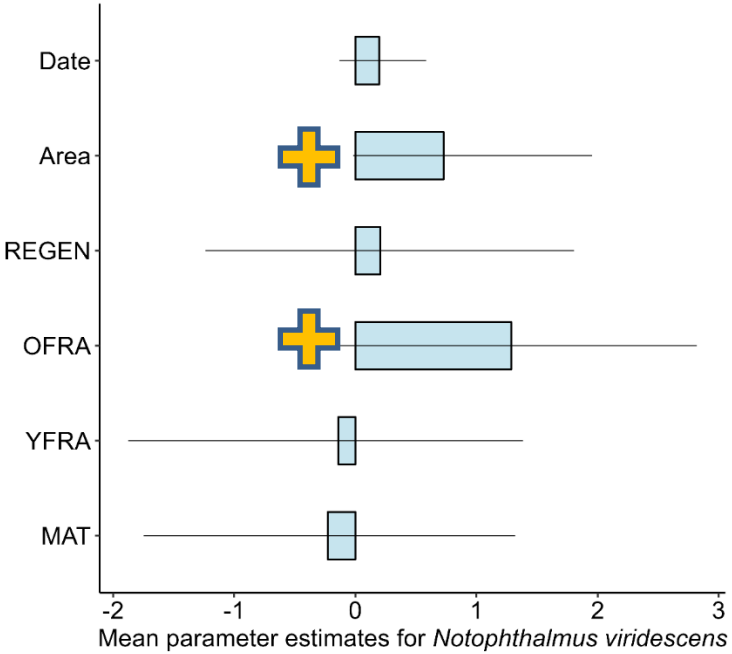
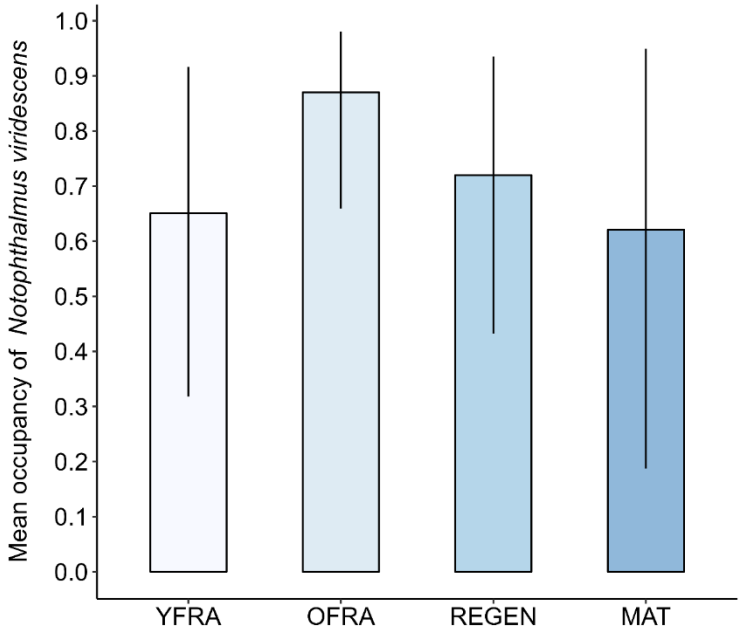


Eastern Newt



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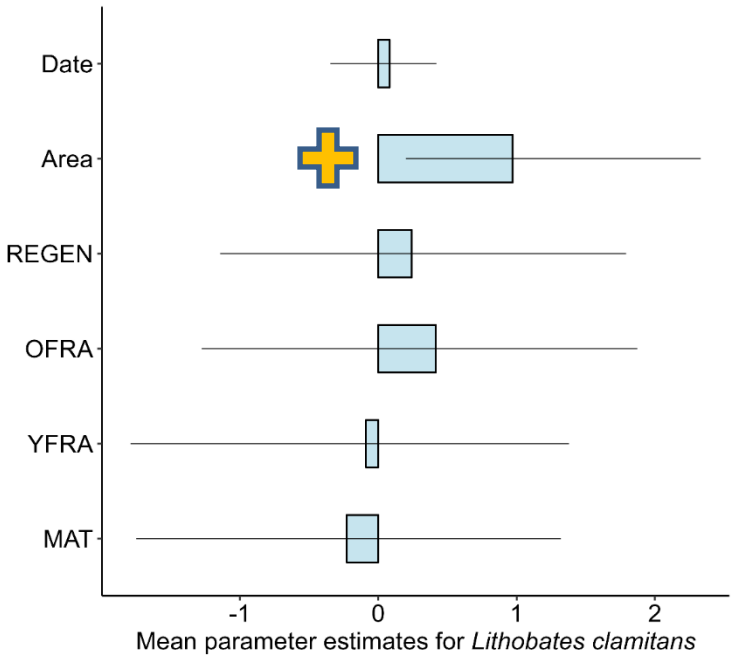
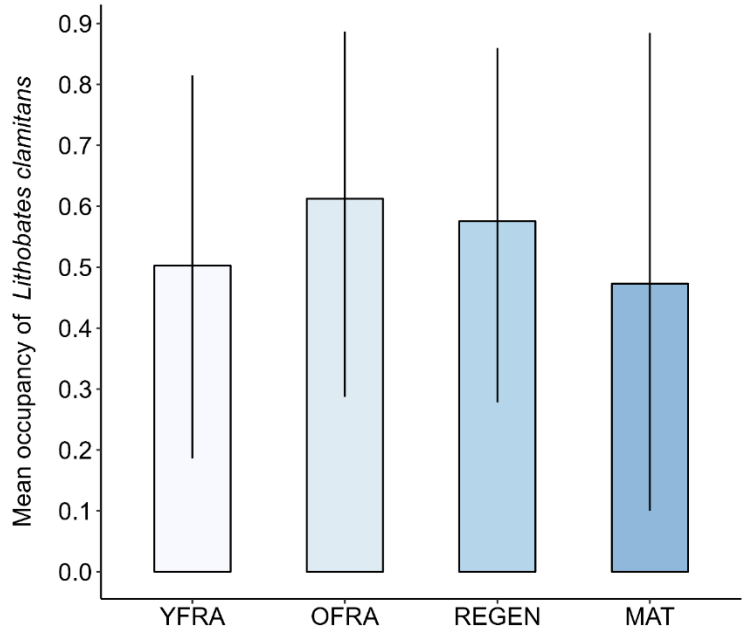
Green Frog





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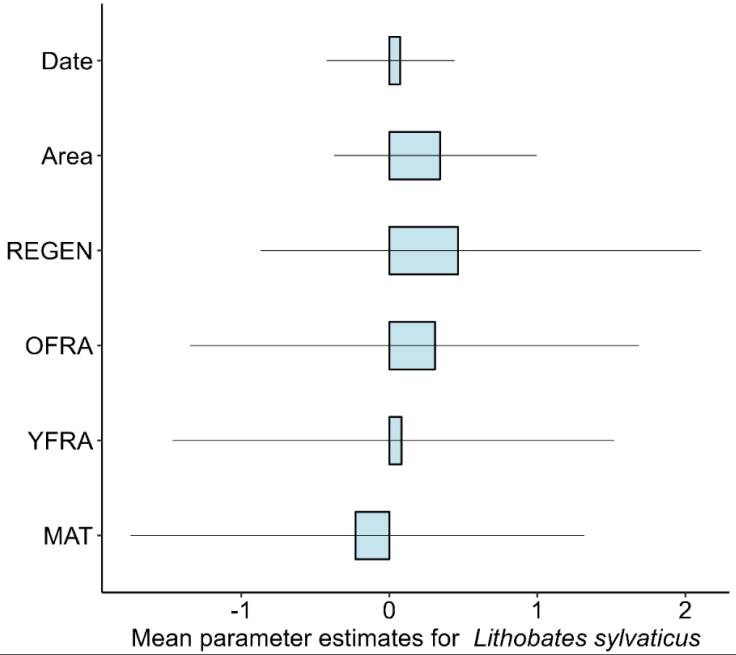
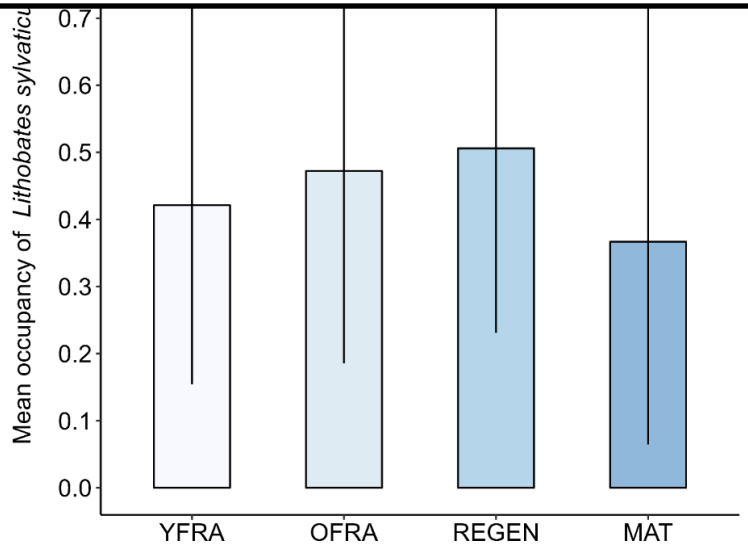


Multi-species occupancy model

Occupancy rates were similar across treatments

Wood Frog



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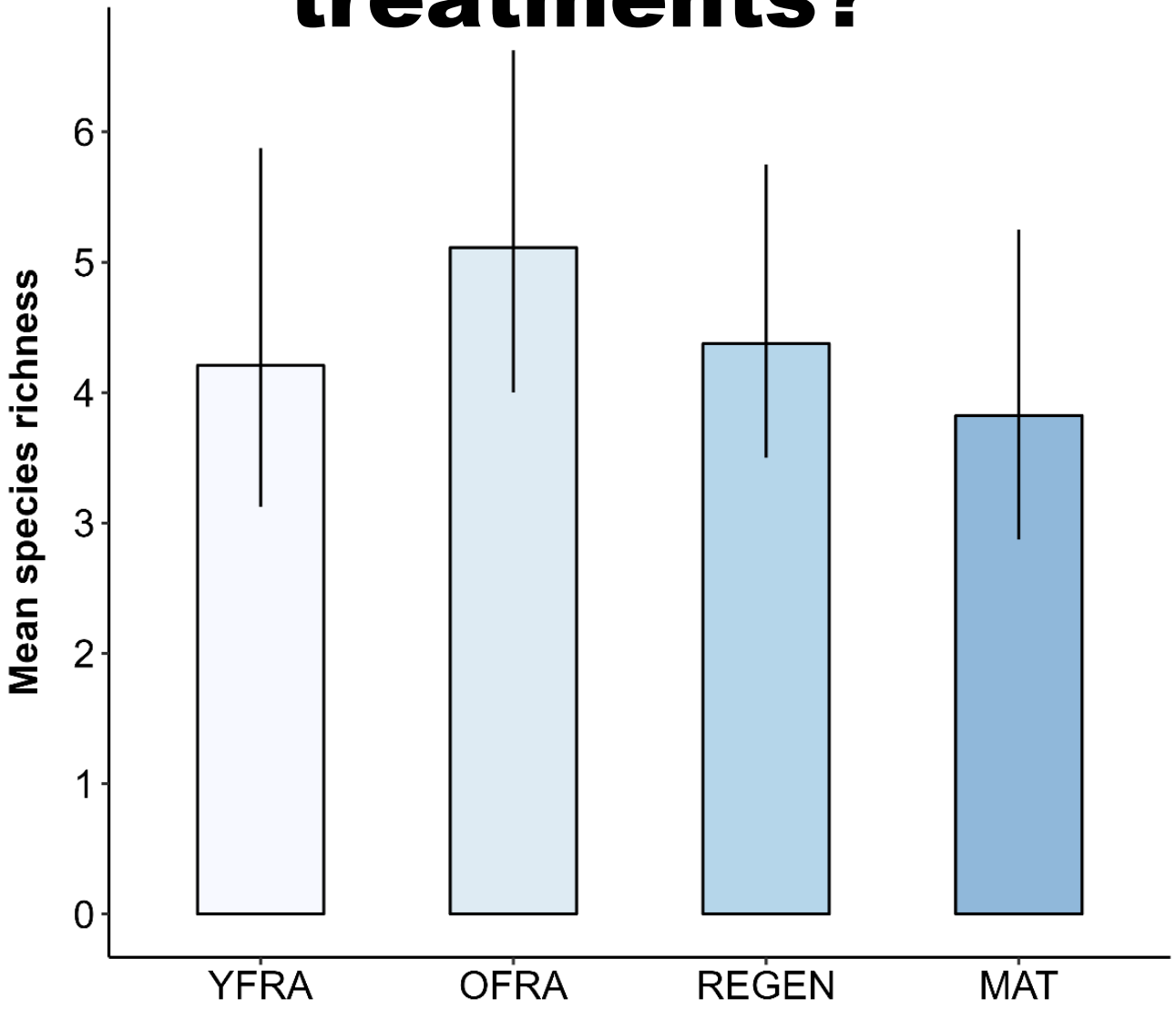
Does species richness differ among treatments?



Multi-species occupancy model

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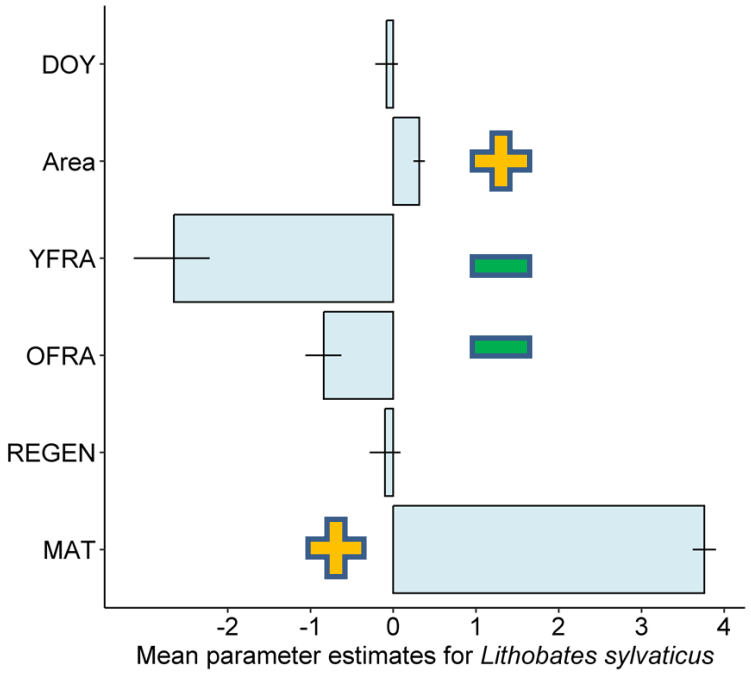
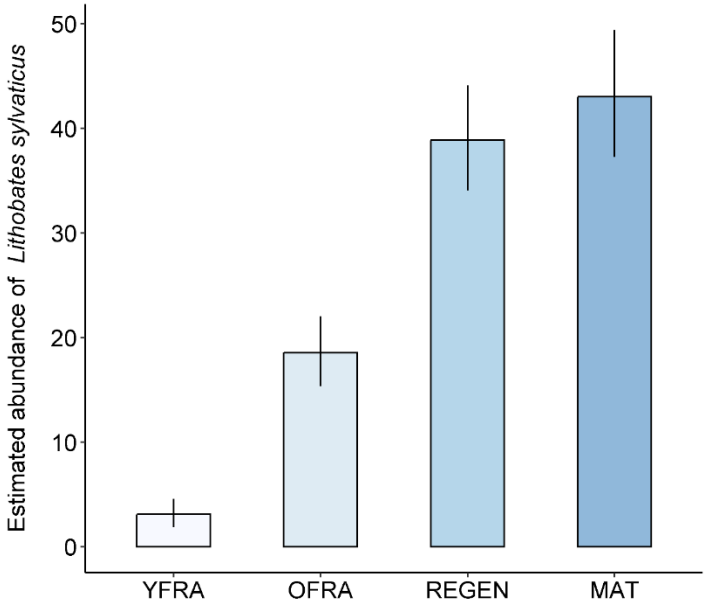
Do abundances differ among treatments?

N-mixture Model
Wood Frog





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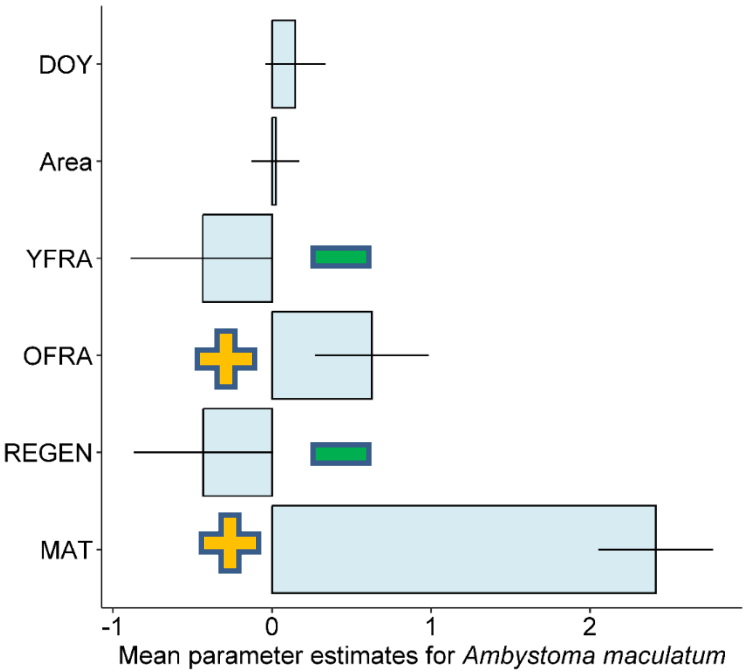

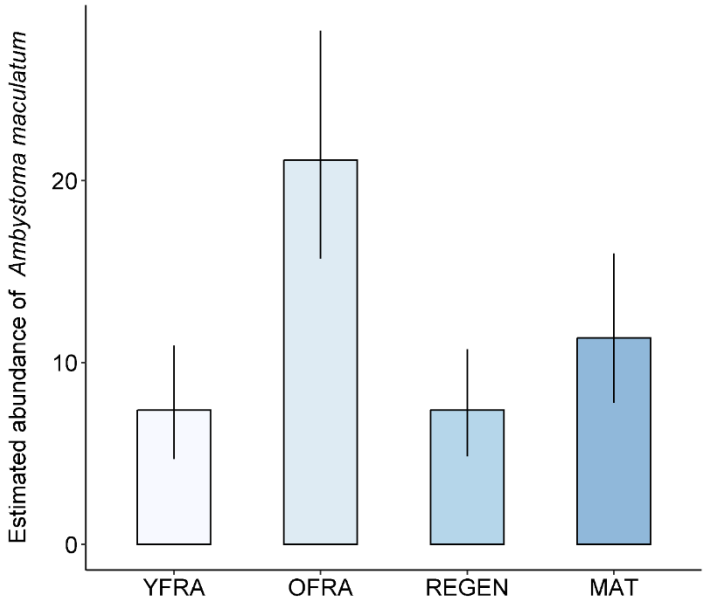

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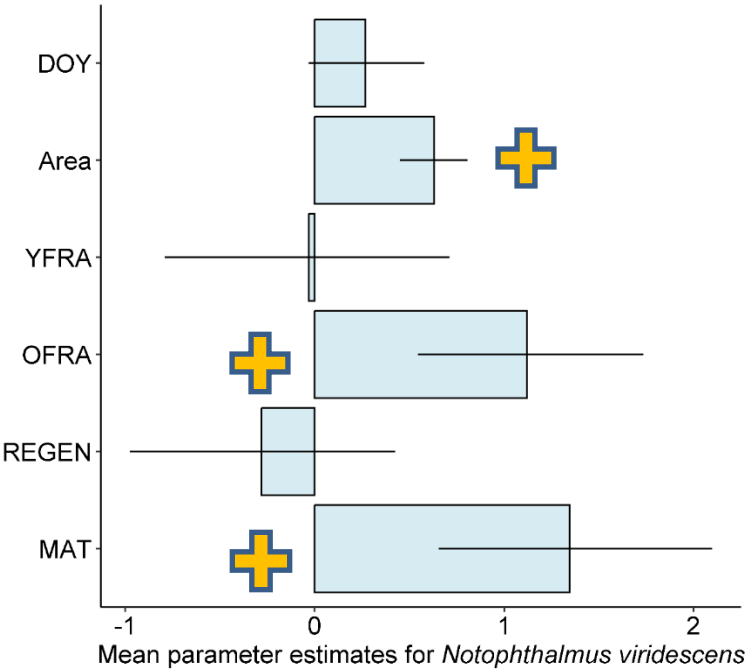

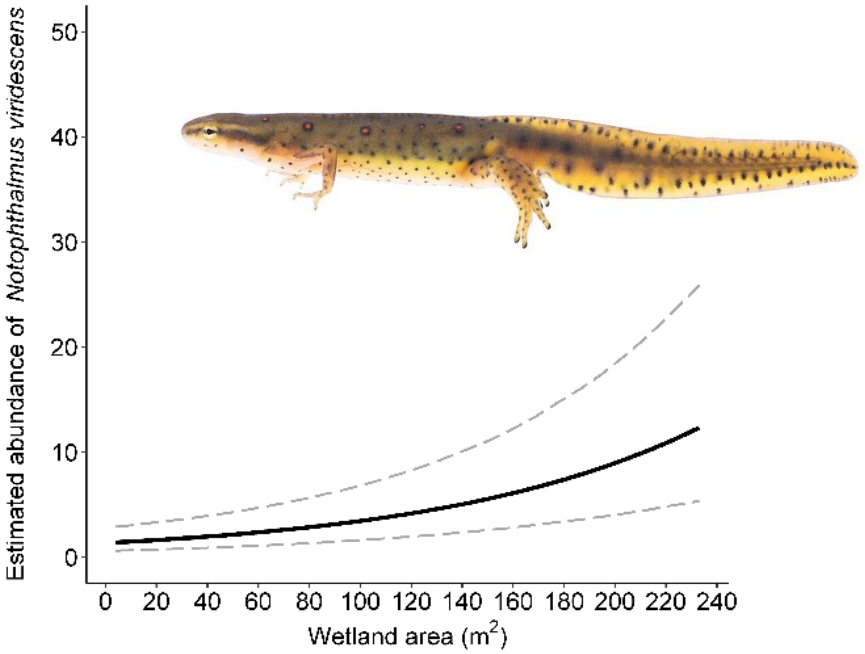

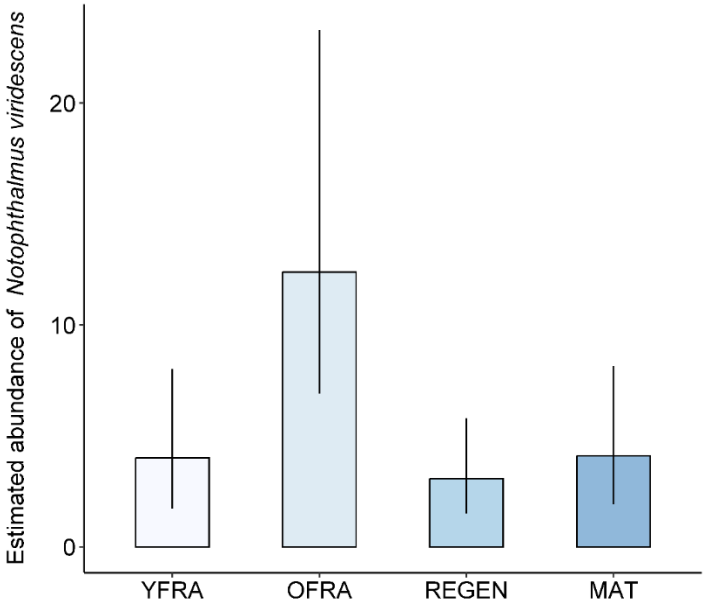

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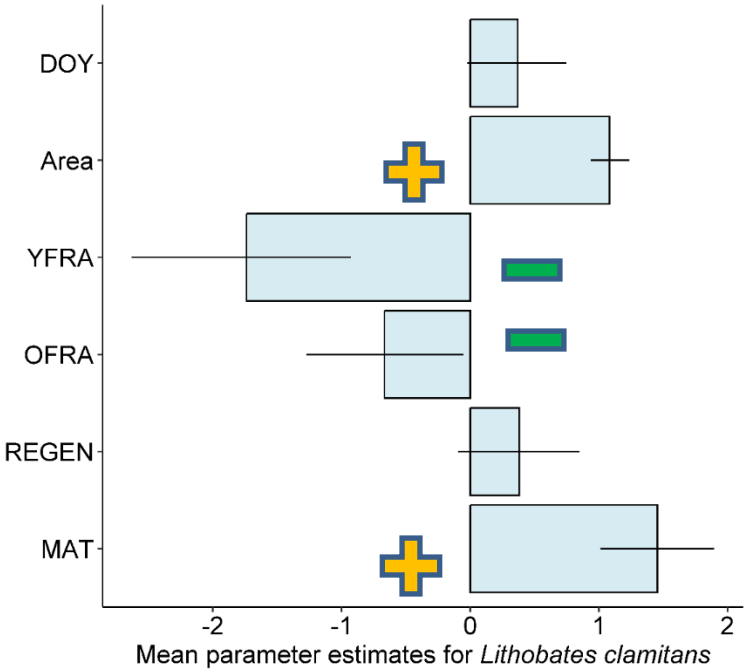

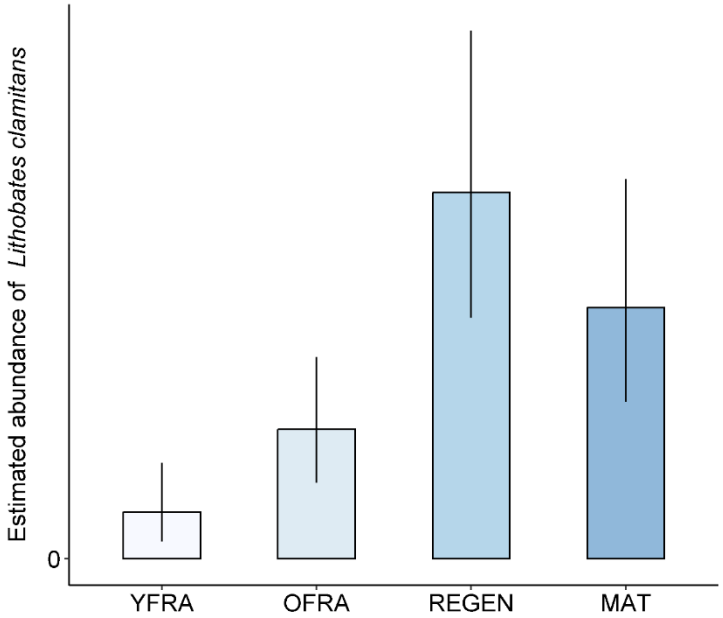

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What did we learn?

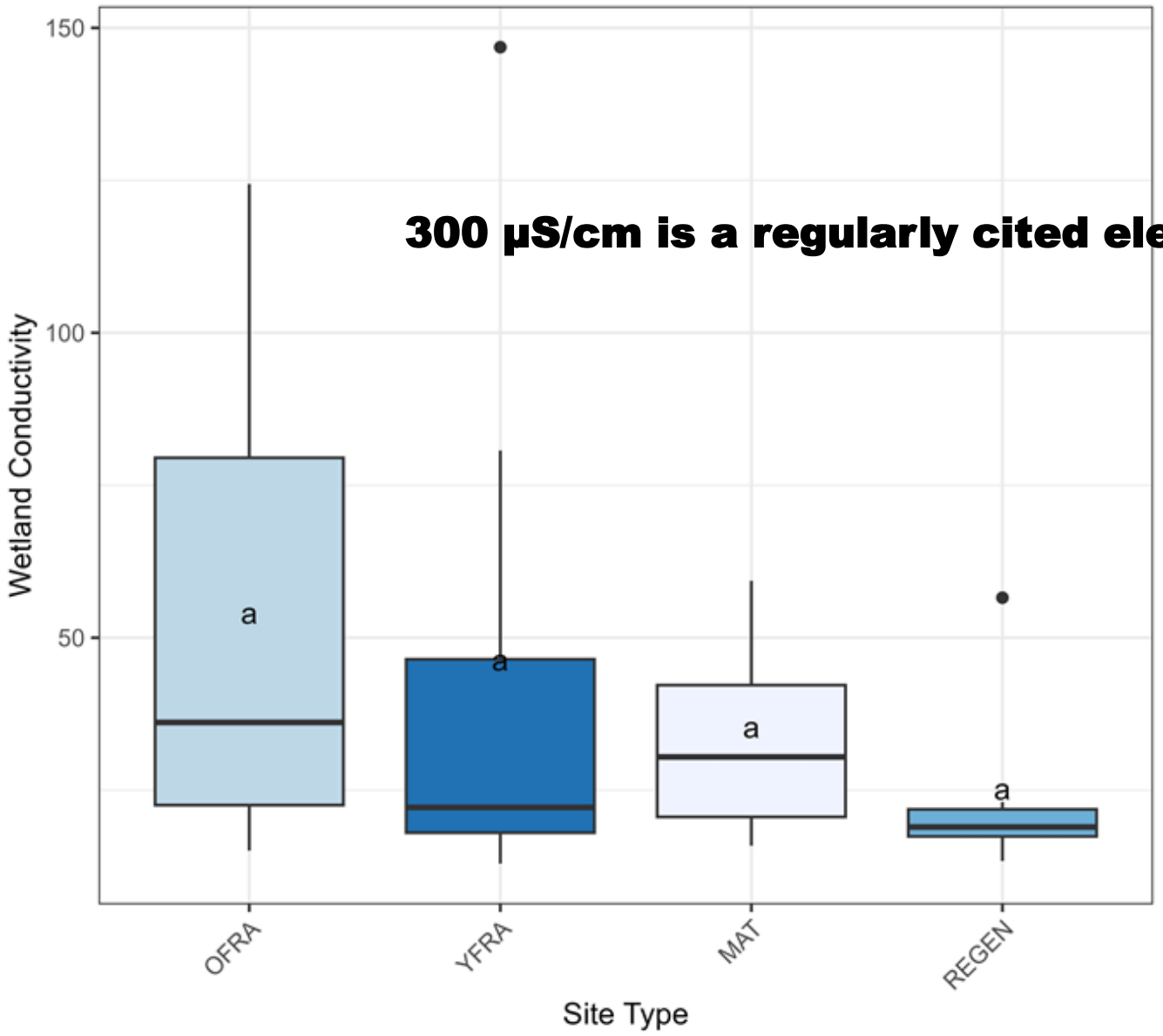
- **Pond-breeding amphibians use created wetlands on legacy mines for breeding and larval development (high occupancy)**
- **Abundances varied across treatments, but we see some positive effects of FRA**
- **Larger wetlands had higher occupancy rates and abundances**
- **REGEN sites had negative or no effects**

Mechanisms? Wetland Attributes

- **Water chemistry was similar between wetlands on FRA sites and other site types**

Variable	*p*-Value	F-Stat	YFRA	OFRA	REGEN	MAT
Wetland Area (m^2)	0.729	0.436	57.99 ^{a}	71.63 ^{a}	81.66 ^{a}	49.66 ^{a}
Canopy Cover (%)	0.004	5.67	0 ^{b}	10.45 ^{ab}	53.68 ^{a}	54.75 ^{a}
Conductivity ($\mu S\ cm^{-1}$)	0.316	1.23	44.4 ^{a}	52.09 ^{a}	23.24 ^{a}	33.39 ^{a}
pH (H+)	0.001	6.71	6.74 ^{a}	6.78 ^{a}	5.77 ^{b}	6.15 ^{ab}
NO_3-N ($mg\ L^{-1}$)	0.407	1	0.002 ^{a}	0 ^{a}	0 ^{a}	0 ^{a}
Turbidity (FTU)	0.328	1.2	8.57 ^{a}	4.02 ^{a}	6.35 ^{a}	2.88 ^{a}
TOC ($mg\ L^{-1}$)	0.022	3.76	3.75 ^{ab}	4.31 ^{a}	2.73 ^{b}	3.19 ^{ab}
Ca ($mg\ L^{-1}$)	0.47	0.87	4.77 ^{a}	6.78 ^{a}	1.78 ^{a}	5.14 ^{a}
Mg ($mg\ L^{-1}$)	0.131	2.04	3.04 ^{a}	2.78 ^{a}	1.03 ^{a}	0.49 ^{a}
Fe ($mg\ L^{-1}$)	0.397	1.02	1.74 ^{a}	3.9 ^{a}	7.81 ^{a}	1.74 ^{a}
NO_2-N ($mg\ L^{-1}$)	0.179	1.76	0.29 ^{a}	0.2 ^{a}	0.42 ^{a}	0.39 ^{a}
Al ($mg\ L^{-1}$)	0.054	2.87	0.15 ^{a}	0.1 ^{a}	0.68 ^{a}	0.3 ^{a}
Na ($mg\ L^{-1}$)	0.505	0.8	0.75 ^{a}	0.56 ^{a}	0.55 ^{a}	0.83 ^{a}
Mn ($mg\ L^{-1}$)	0.261	1.410	0.31 ^{a}	1.02 ^{a}	0.99 ^{a}	0.13 ^{a}
K ($mg\ L^{-1}$)	0.117	2.15	1.39 ^{a}	1.39 ^{a}	0.76 ^{a}	0.67 ^{a}
Cl ($mg\ L^{-1}$)	0.172	1.790	0.67 ^{a}	0.7 ^{a}	0.71 ^{a}	1.04 ^{a}
NH_4-N ($mg\ L^{-1}$)	0.569	0.685	0.02 ^{a}	0.01 ^{a}	0.1 ^{a}	0.01 ^{a}
SO_4 ($mg\ L^{-1}$)	0.188	1.71	4.77 ^{a}	2.23 ^{a}	2.74 ^{a}	2.42 ^{a}

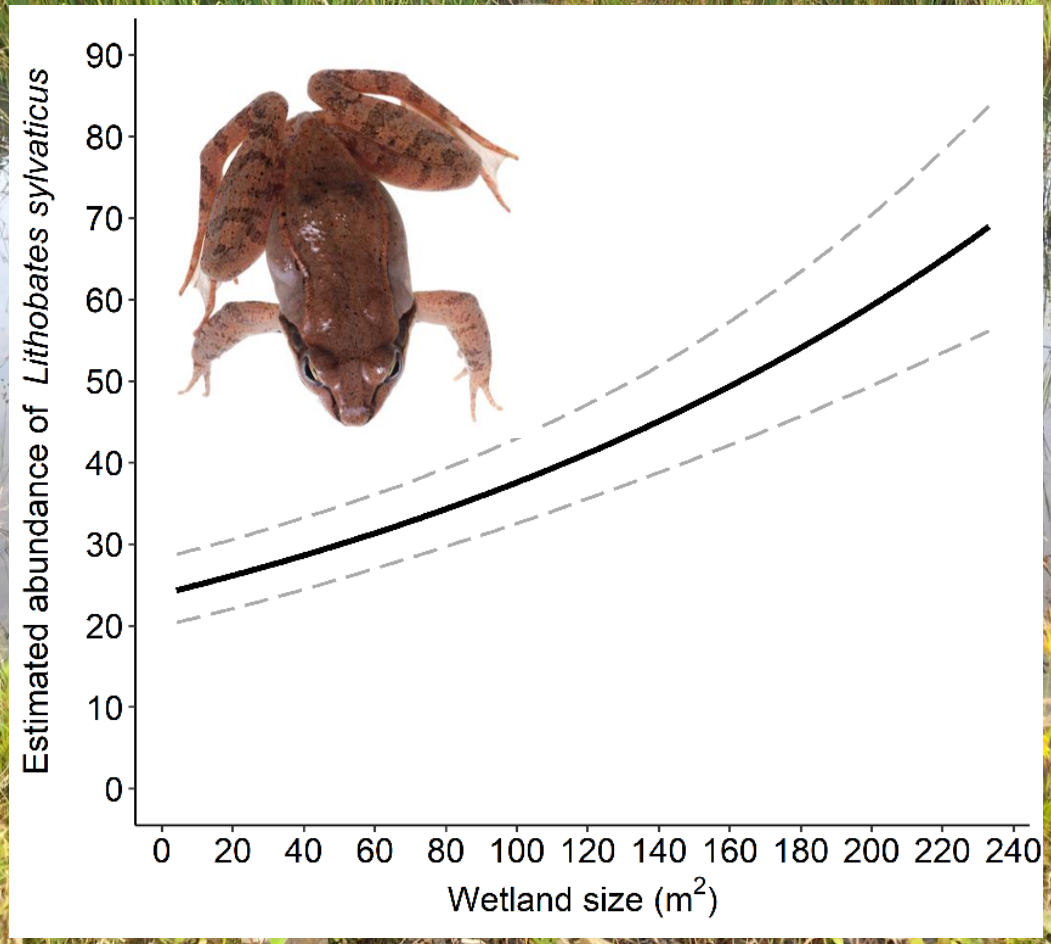
Water Chemistry



300 µS/cm is a regularly cited elevated level

Mechanisms?

- **Wetland hydrology**
- **Wetland density – > 1000 wetlands created**



Mechanisms?

- **Soil decompaction, coarse woody debris loading and tree planting**

Mechanisms?

- **MNF likely aided in colonization of created wetlands – landscape context is important**

Summary

- **Lack of occupancy differences between treatment types suggests that FRA coupled with wetland creation provides suitable habitat for many pond-breeding amphibian species**

- **Future studies on amphibians and other wildlife are needed to fully evaluate recovery on previously mined lands**

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