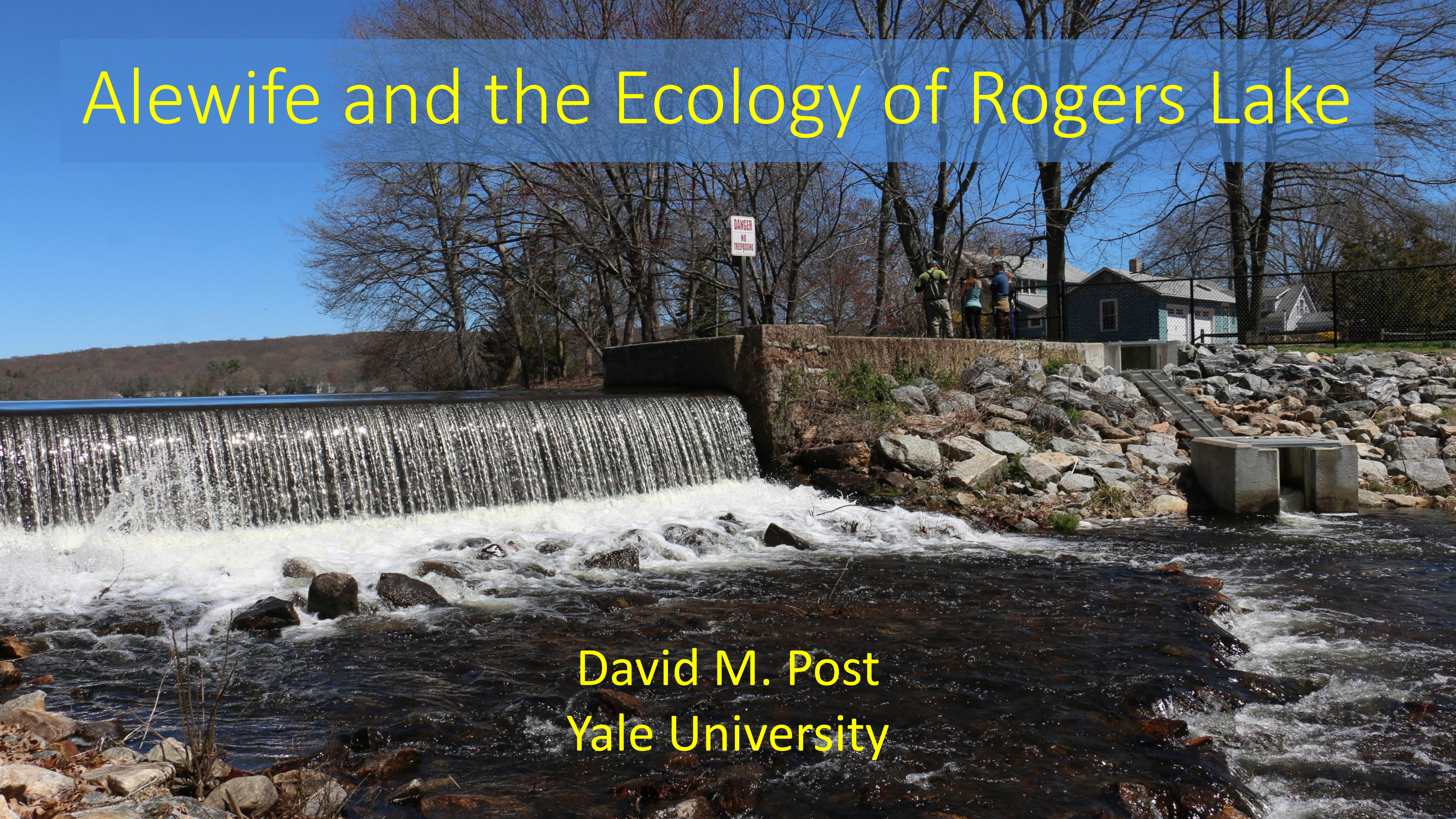
Alewife and the Ecology of Rogers Lake



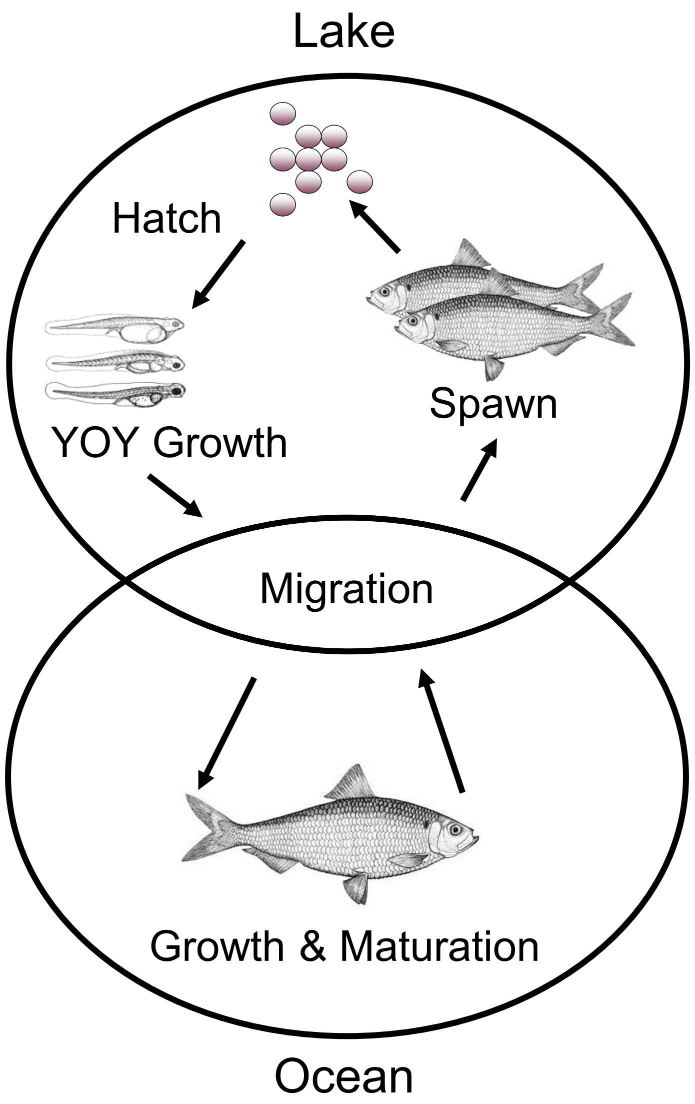
David M. Post
Yale University

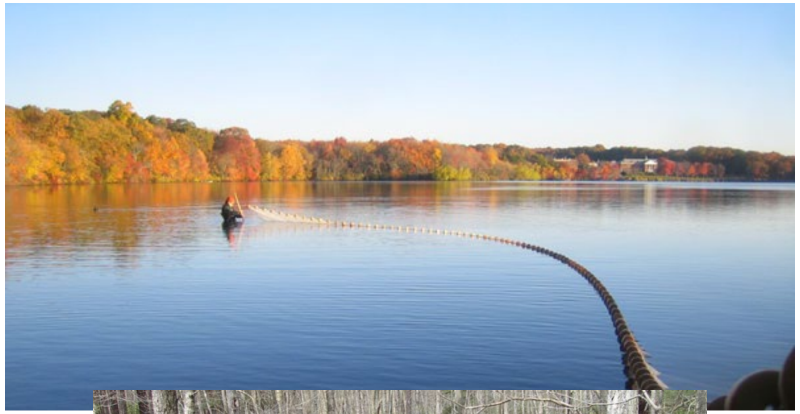
Alewife

- River Herring
  - Blueback herring
  - Alewife

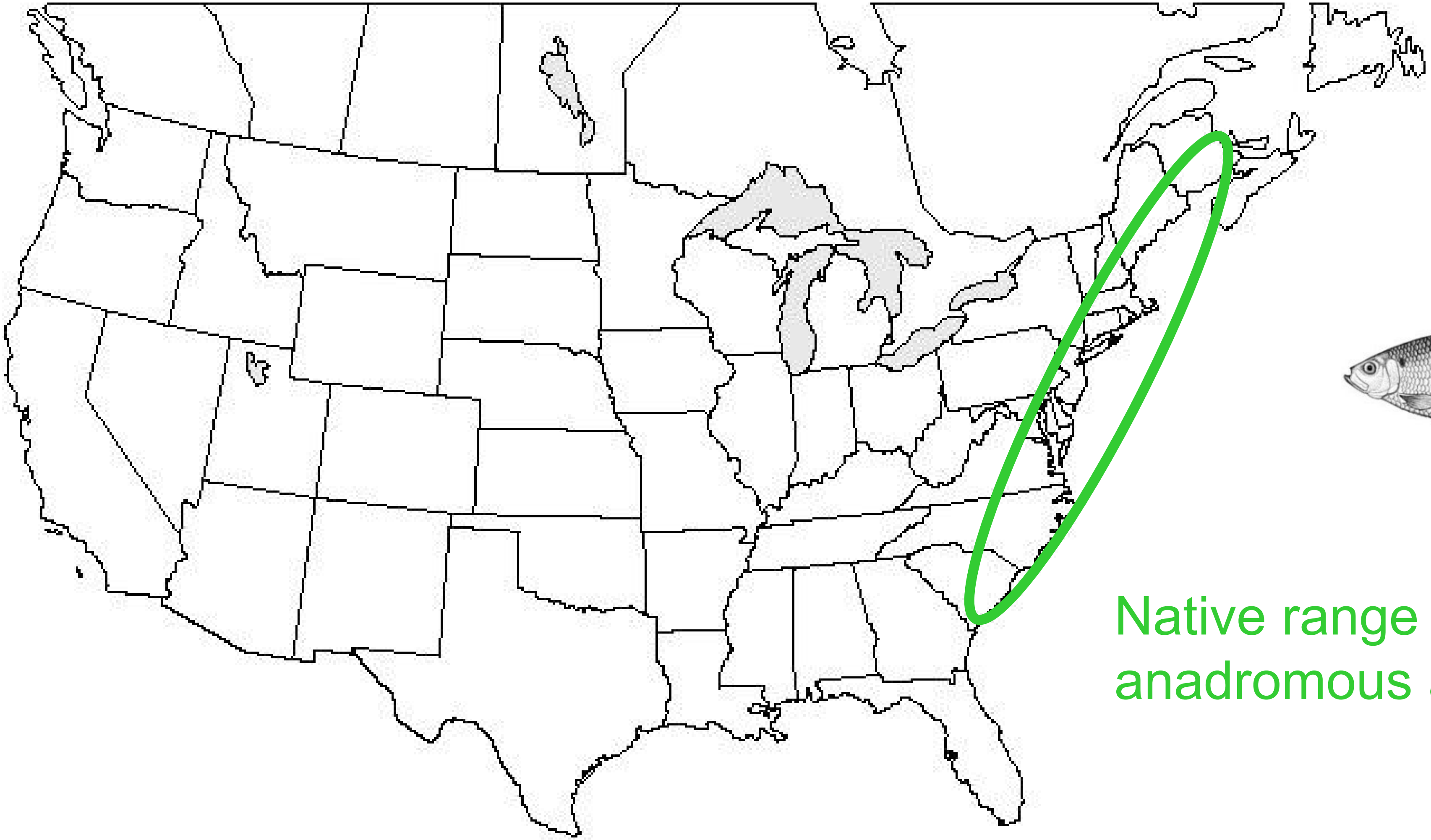
Alewife - Anadromous (migratory, sea run)

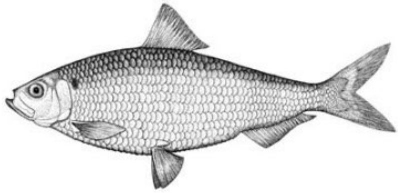
- Ancestral form





Alewife

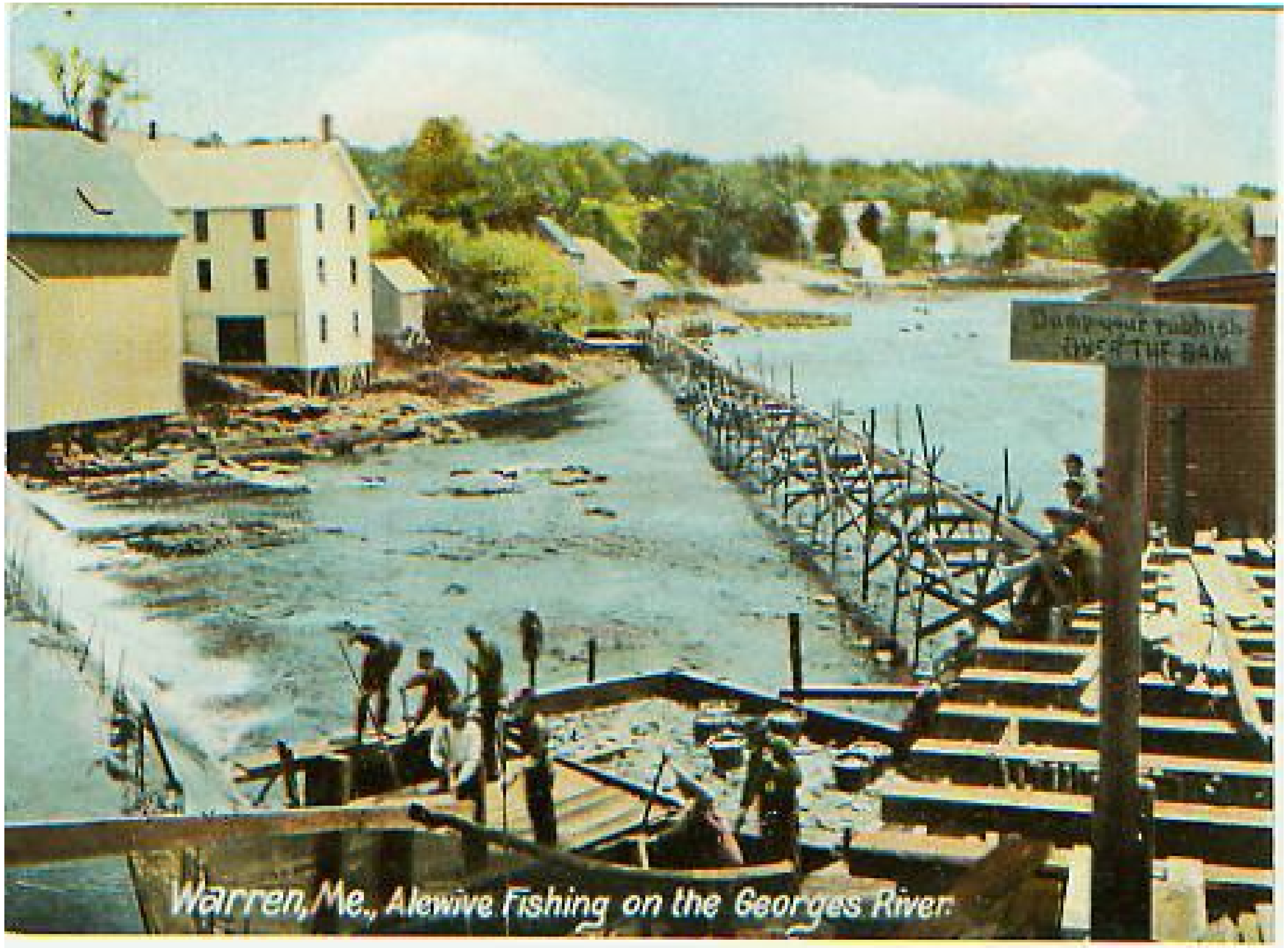




Native range of anadromous alewife

Alewife - Anadromous

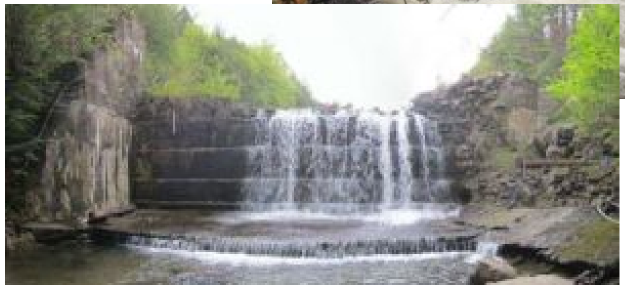
- Historically important
  - Native Americans
  - Fertilizer
  - Commercial fishery
    - Human consumption
    - Bait for other fisheries



Dams - Anadromous Fish

- Early Colonial Americans built dams in many coastal ecosystems
  - Low head mill dams
  - Late 1600s - early 1700s

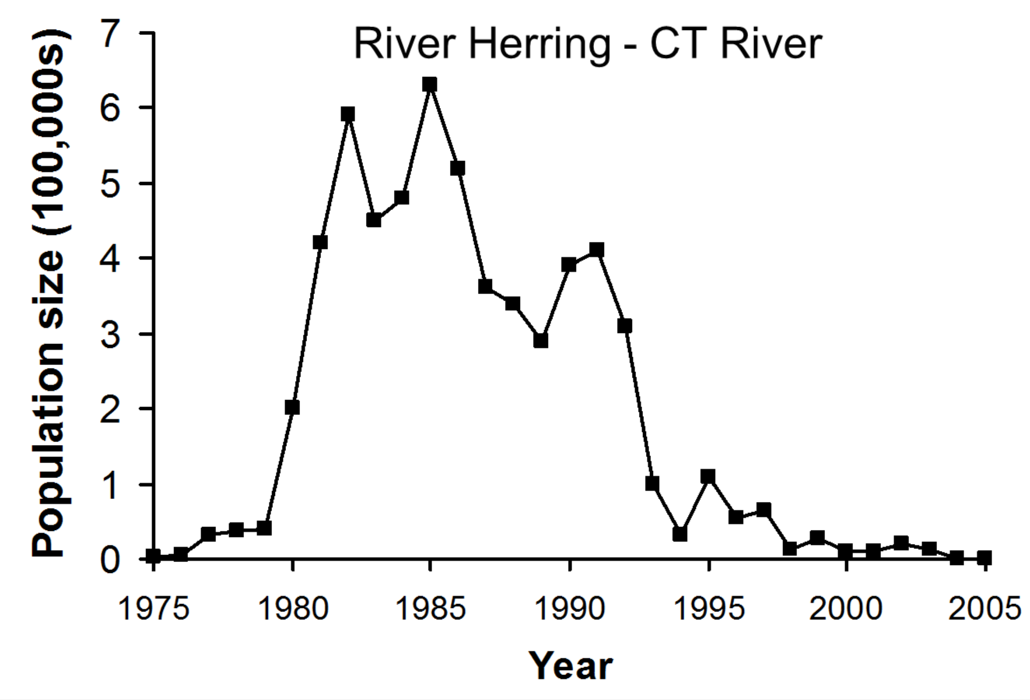
- Isolated inland water from coastal ocean
  - Blocked historically important spawning habitat for anadromous fish
  - Isolated remnant populations



Alewife - Anadromous

- Federally listed species of conservation concern

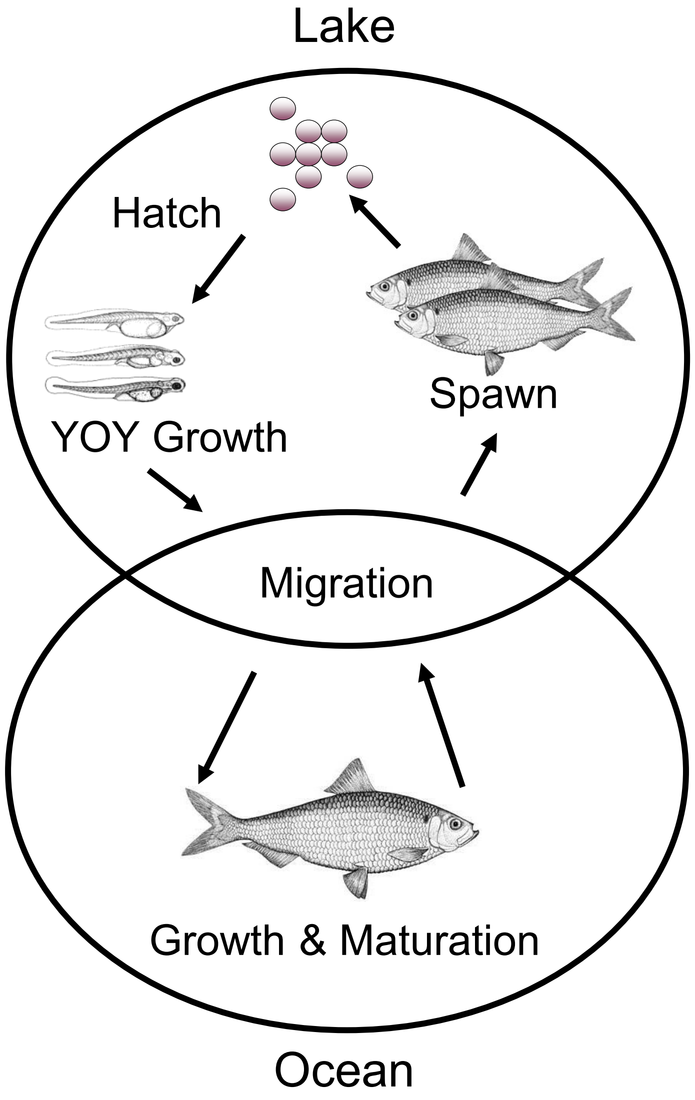
- Dams and Habitat loss
- Harvesting (bycatch)
- Costal predators

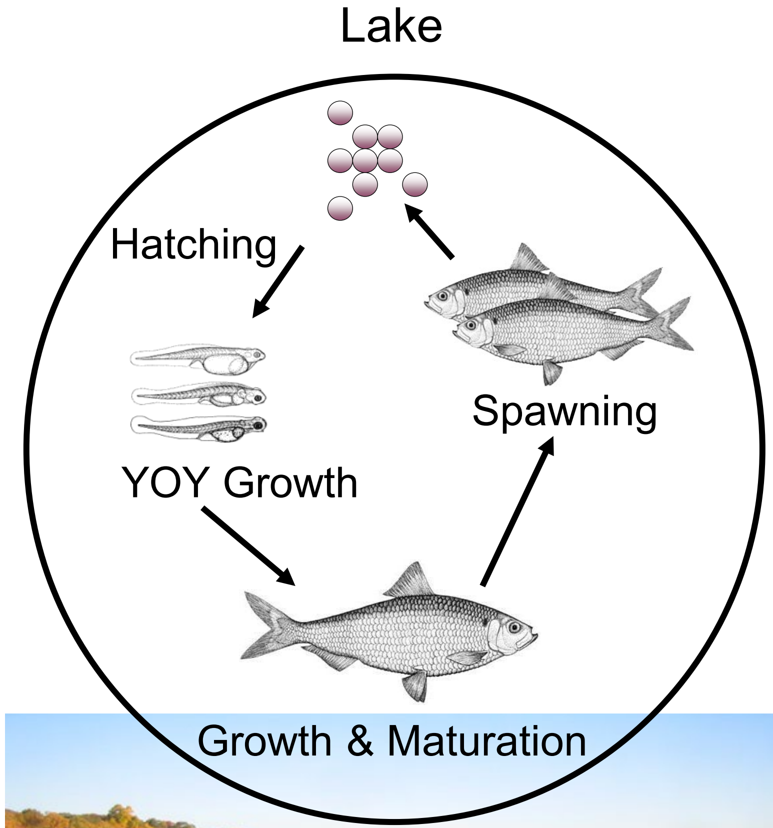


Alewife - Anadromous

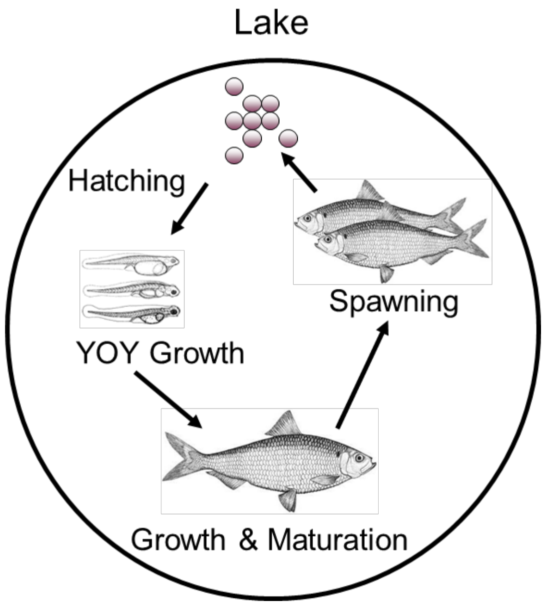
- Dams block migration

Alewife - Landlocked (resident)

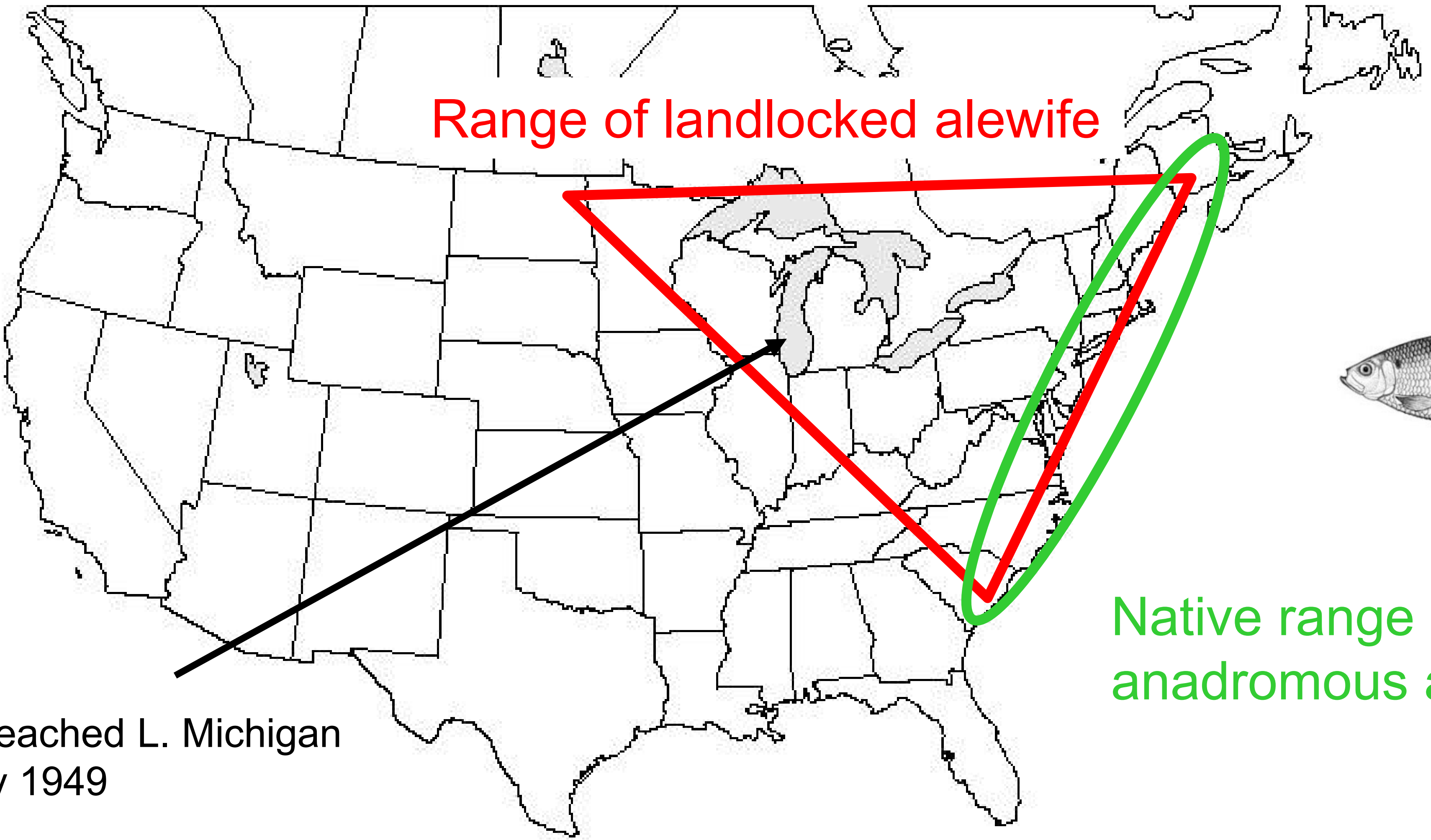


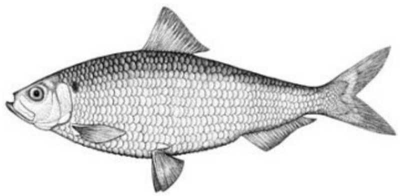


Alewife - Landlocked

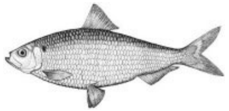


Alewife





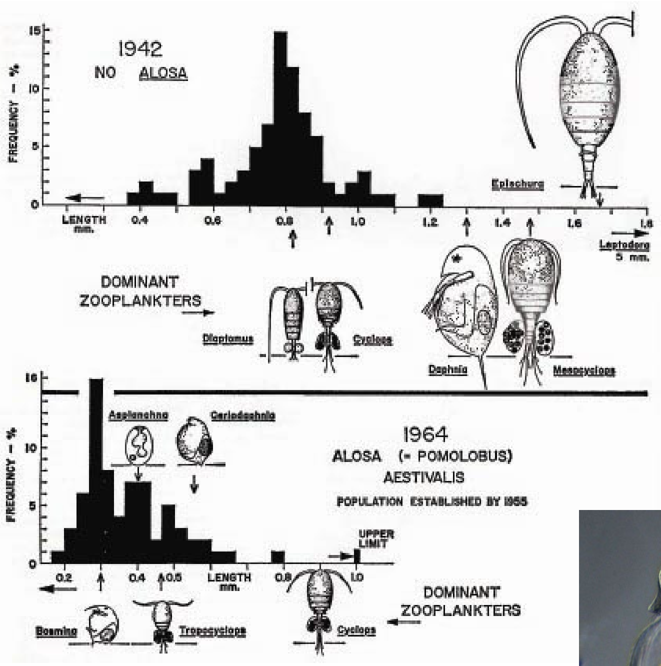
Native range of
anadromous alewife



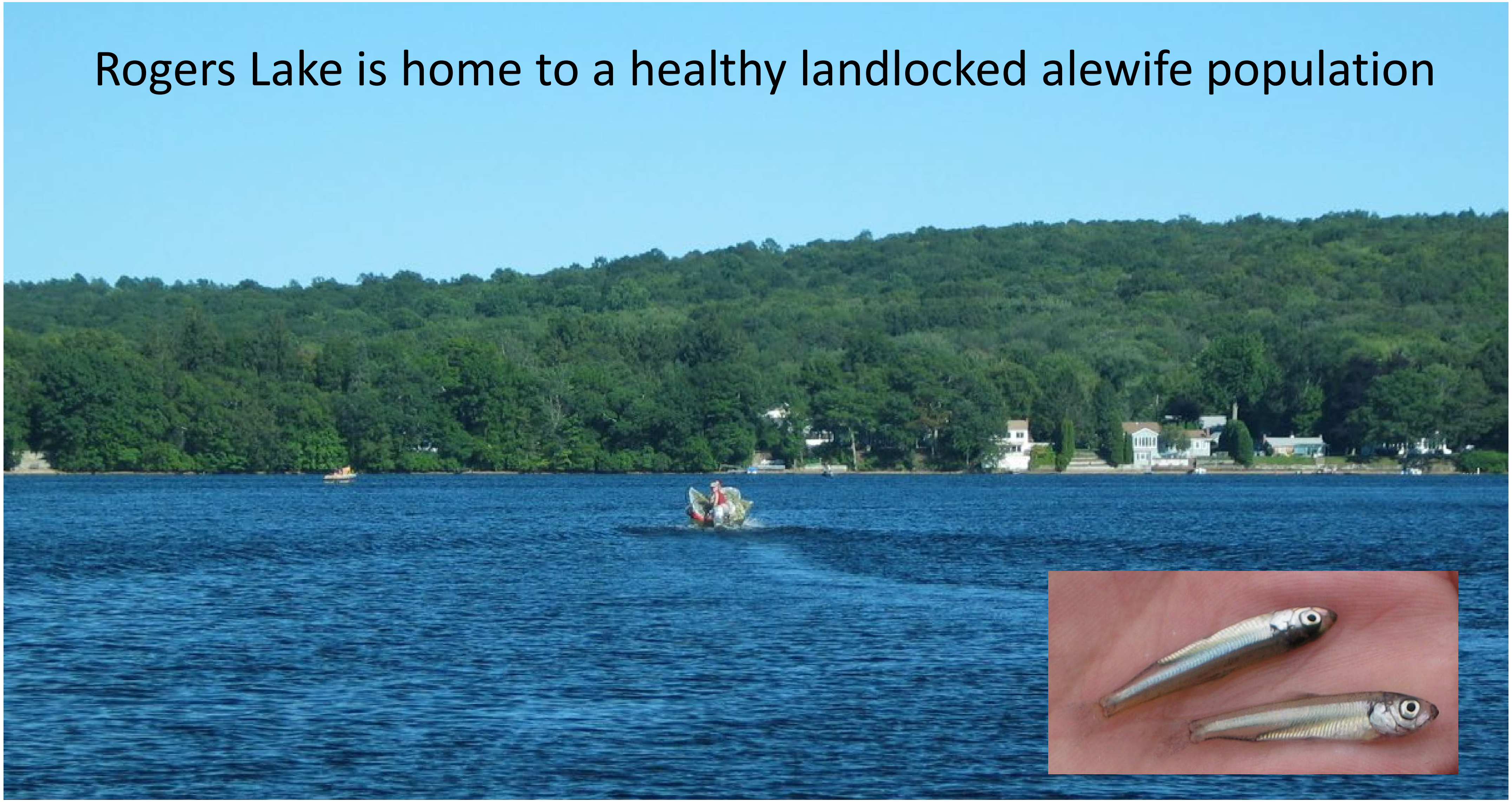
Reached L. Michigan
by 1949

Alewife - Landlocked

- Invasive species
- Well studied
  - Support major fisheries
  - Structure food web



Alewife - Landlocked



History of Rogers Lake

- Cornelia (Lily) Twining
  - Senior Thesis and Masters Thesis at Yale on alewife and the Environmental history of Rogers and other lakes

History of Rogers Lake

- 1672: dam at Lower Millpond
  - grist (corn) mill
- 1677: dam at Upper Millpond
  - saw mill and then a grist mill

- Originally two separate basins
  - Marvin's Pond to the north
  - Great (Rogers) Pond to the south
  - Marshy region between

1792 state survey map of mills in the Lyme region

History of Rogers Lake

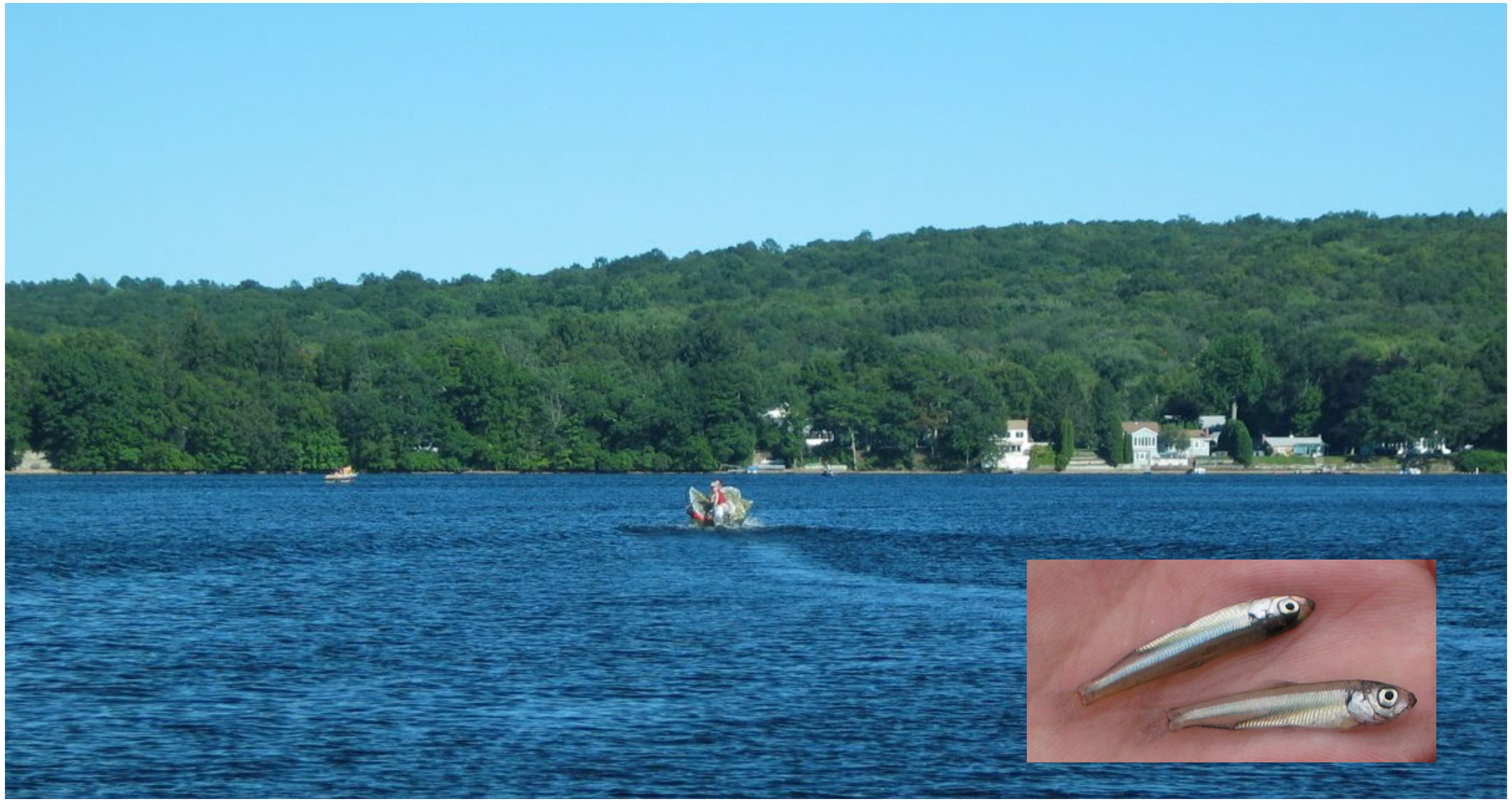
- 1798: plan to build paper mill at outlet of Great (Rogers) Pond
  - Rogers Lake as we know it is formed by 1813

- Migration between the ocean and Rogers Lake likely lost in the 1670s (certainly after 1798)

1813 state survey map of mills in the Lyme region

Alewife - Landlocked

- Rogers Lake landlocked population formed ~350 YBP?

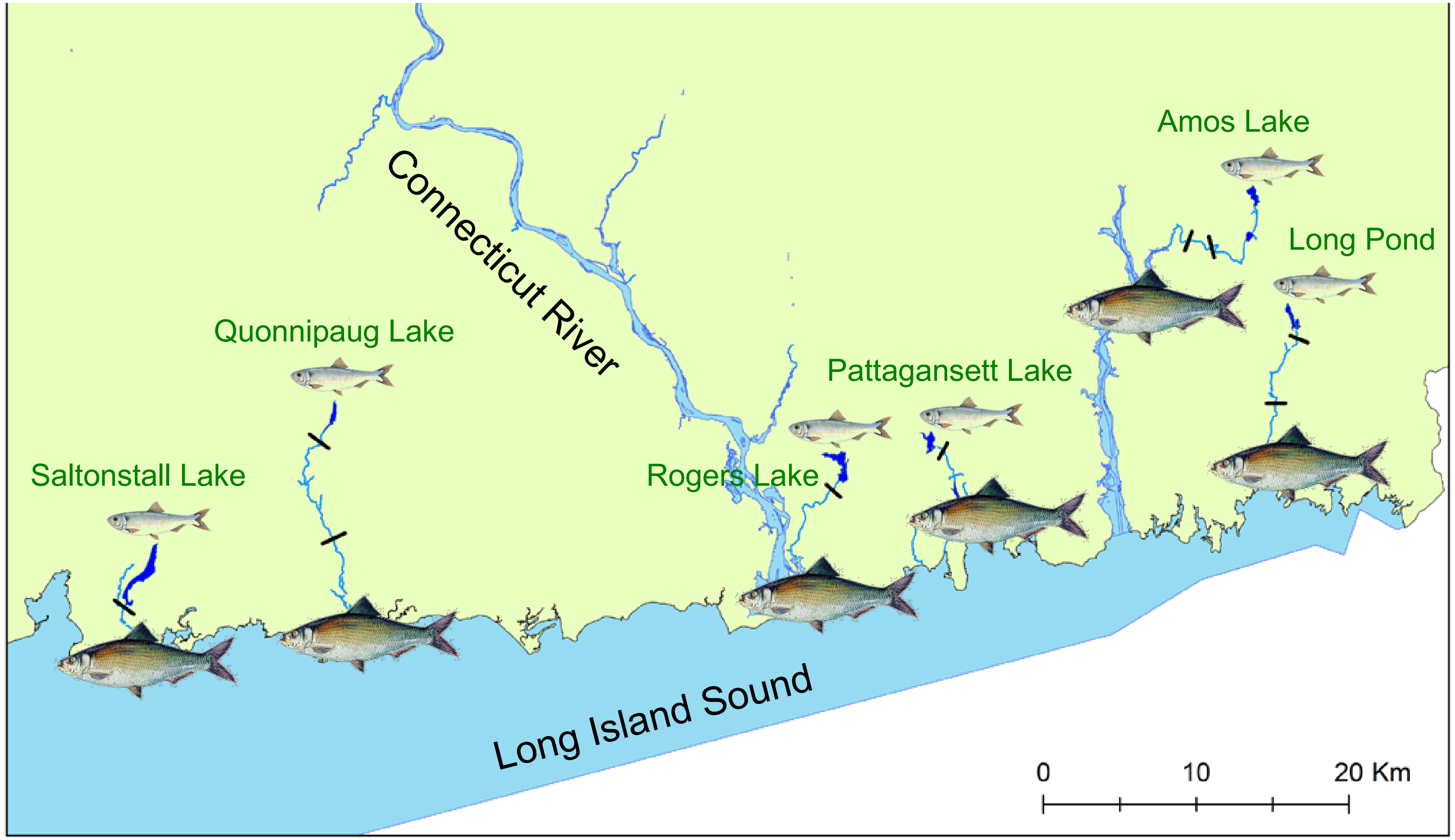


Origin of Landlocked Populations?

- Many inland populations were stocked
  - E.g., Uncas Lake
- Origin of coastal populations such as the landlocked alewife population in Rogers Lake?
  - No record of stocking

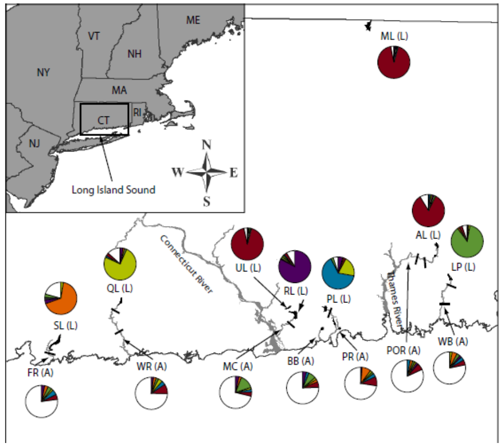
Origin of Landlocked Populations?

- Coastal populations



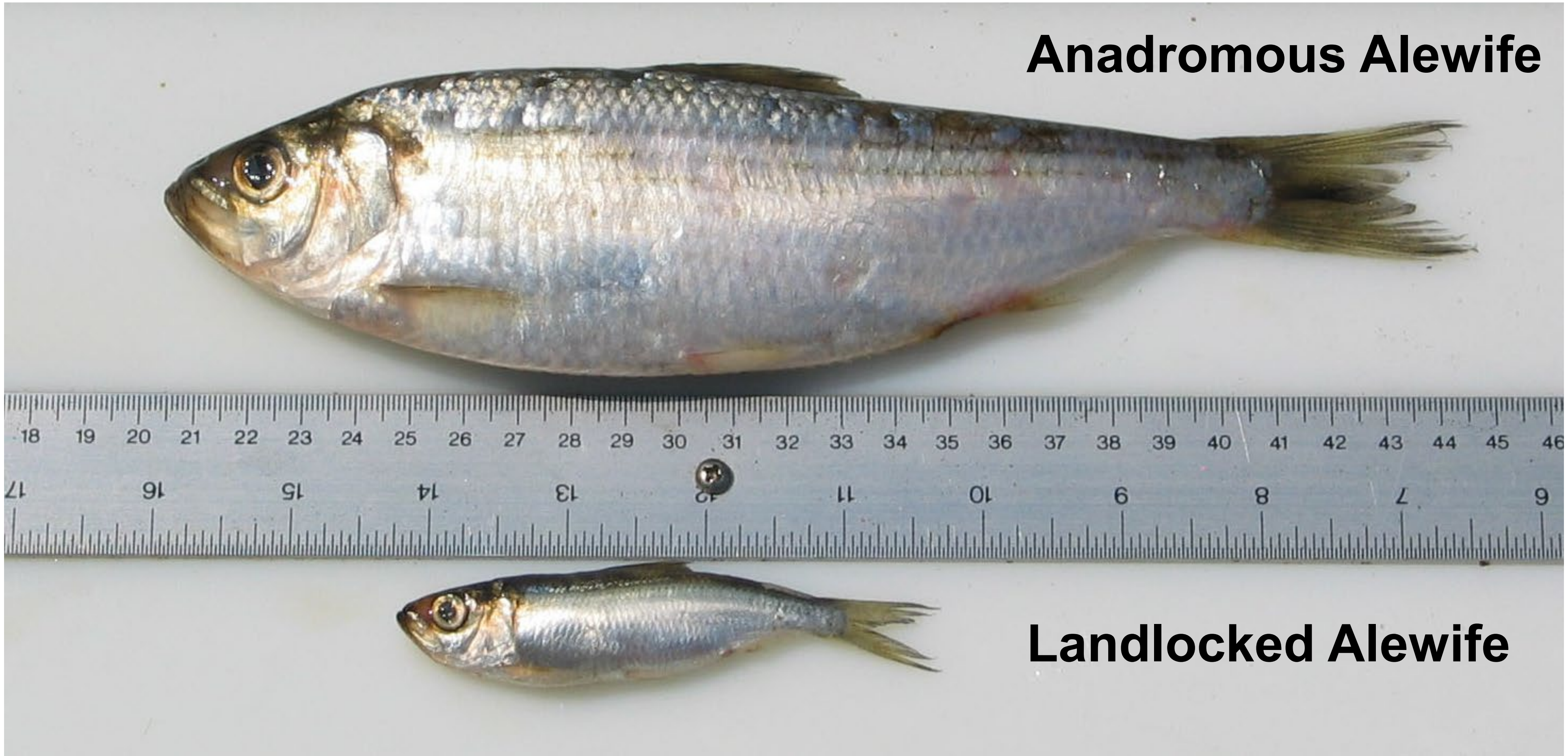
Origin of Landlocked Populations?

- Coastal populations
  - Anadromous Populations became landlocked
    - Divergence time from genetic data: 270 – 522 YBP
    - Paleolimnological data: late 1600s
    - Dams on Upper and Lower millponds built in the 1670s (350 YBP)



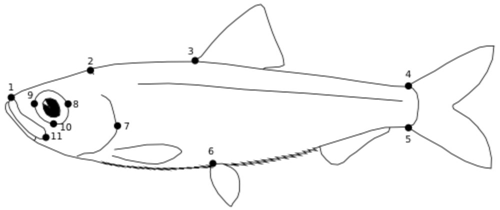
Palkovacs et al. 2008, Twining and Post 2013

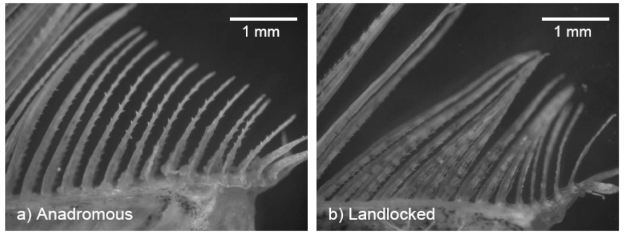
Alewife – Life history differences



Alewife – Life history differences

	Anadromous	Landlocked
Duration of residence in fresh water	Summer-fall	Year round
Morphology		
Gape		Smaller
Gill raker spacing		Narrower
Body shape		More fusiform
		Smaller head
Prey size selectivity	Positive	Neutral
Habitat/resource use	Open water and near shore	Open water only

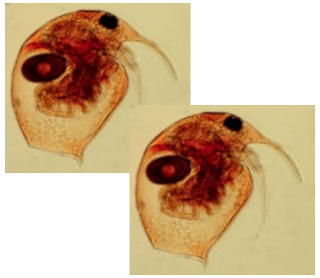




Post et al. 2008; Palkovacs and Post 2008; Schielke et al. 2011, Jones et al. 2013

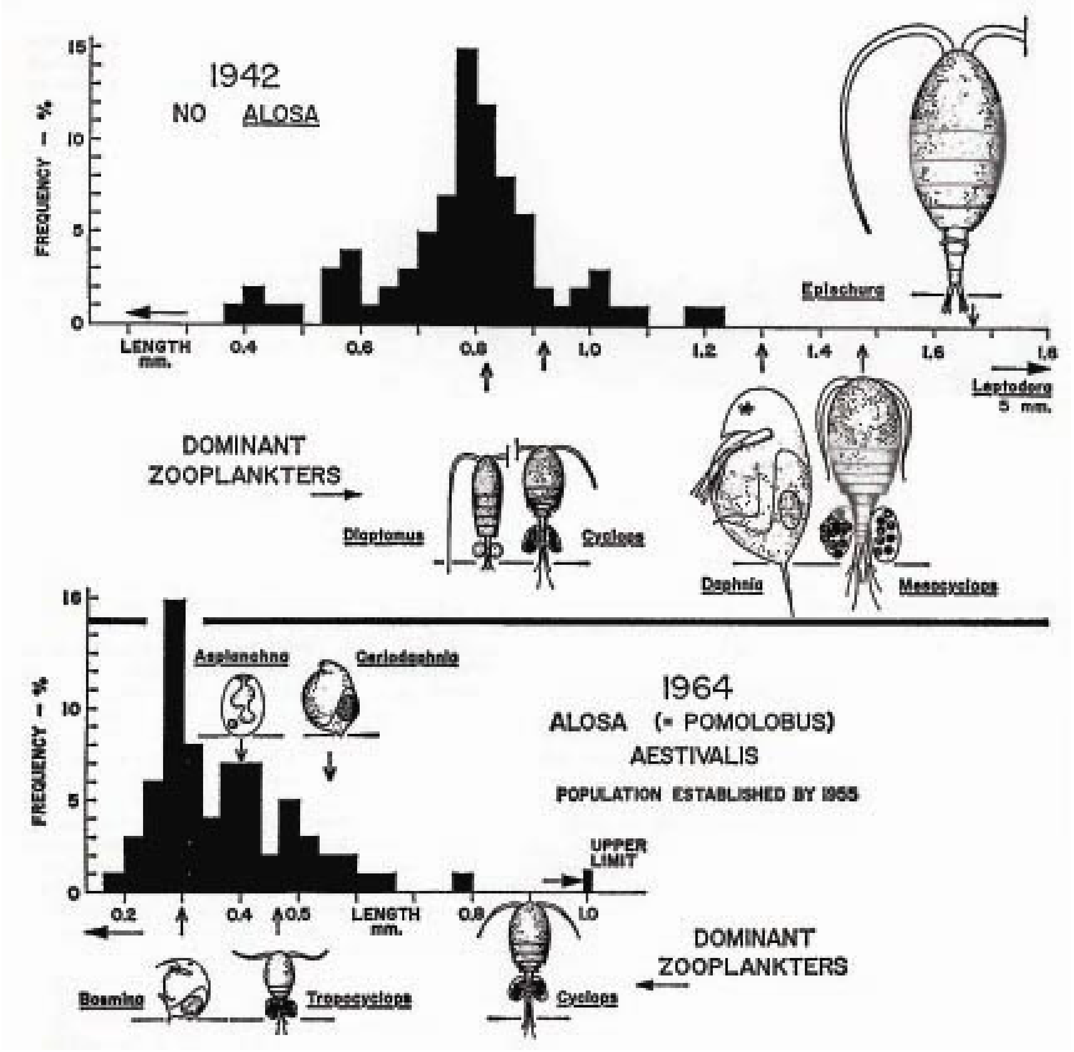
Alewife – Ecological effects

- Alter Zooplankton Communities
  - Large-bodied grazers (*Daphnia*)
  - Large-boded predators (*Mesocyclops*)
  - Small-bodied grazers (*Bosmina*)



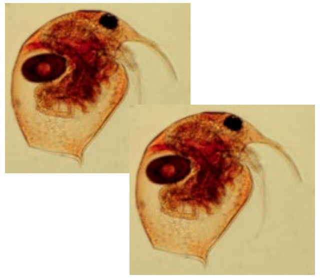
Alewife – Ecological effects

- Alter Zooplankton Communities
  - Brooks and Dodson 1965
  - Connecticut lakes including Rogers
- No Landlocked alewife
  - large-bodied grazers
  - large-boded predators
- Landlocked alewife
  - Small-bodied grazers



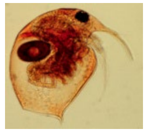
Alewife – Ecological effects

- Large-bodied zooplankton grazers
  - Very effective grazers
  - Important for juvenile fish
- Large-bodied predators
  - Prey upon small-bodied zooplankton
  - Important for juvenile fish
- Small-bodied grazers
  - Less effective grazers
  - Less valuable for juvenile fish



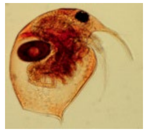
Alewife – Ecological effects

- Lakes with landlocked alewife
  - Low density of small-bodied zooplankton year-round




- Lakes with anadromous alewife
  - High densities of large-bodied zooplankton in the spring
  - Low densities of small-bodied zooplankton in the late summer and fall

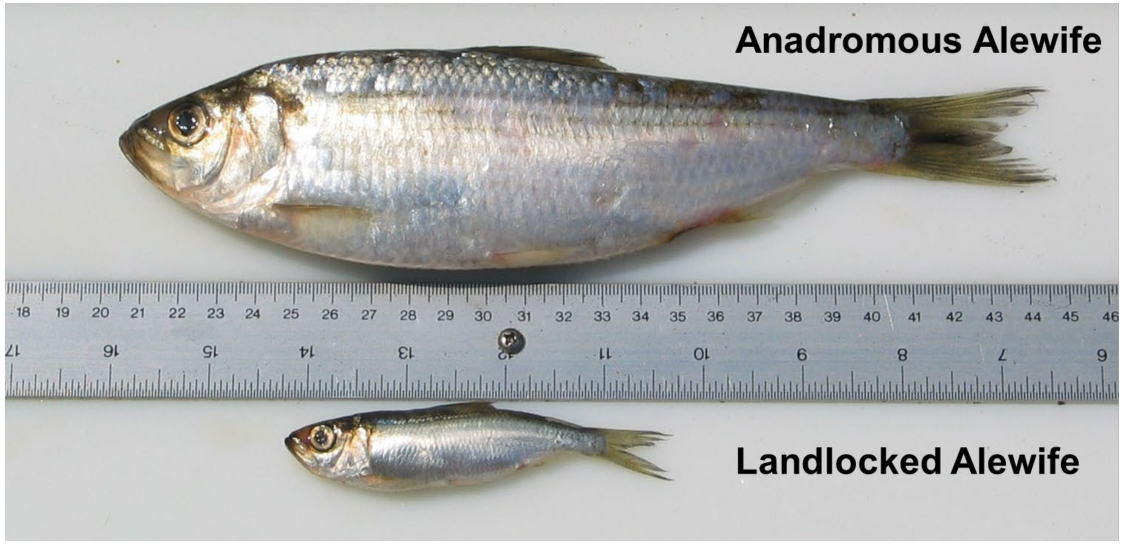




  - Anadromous alewife migrate late summer and fall
    - Large-bodied zooplankton in the ocean

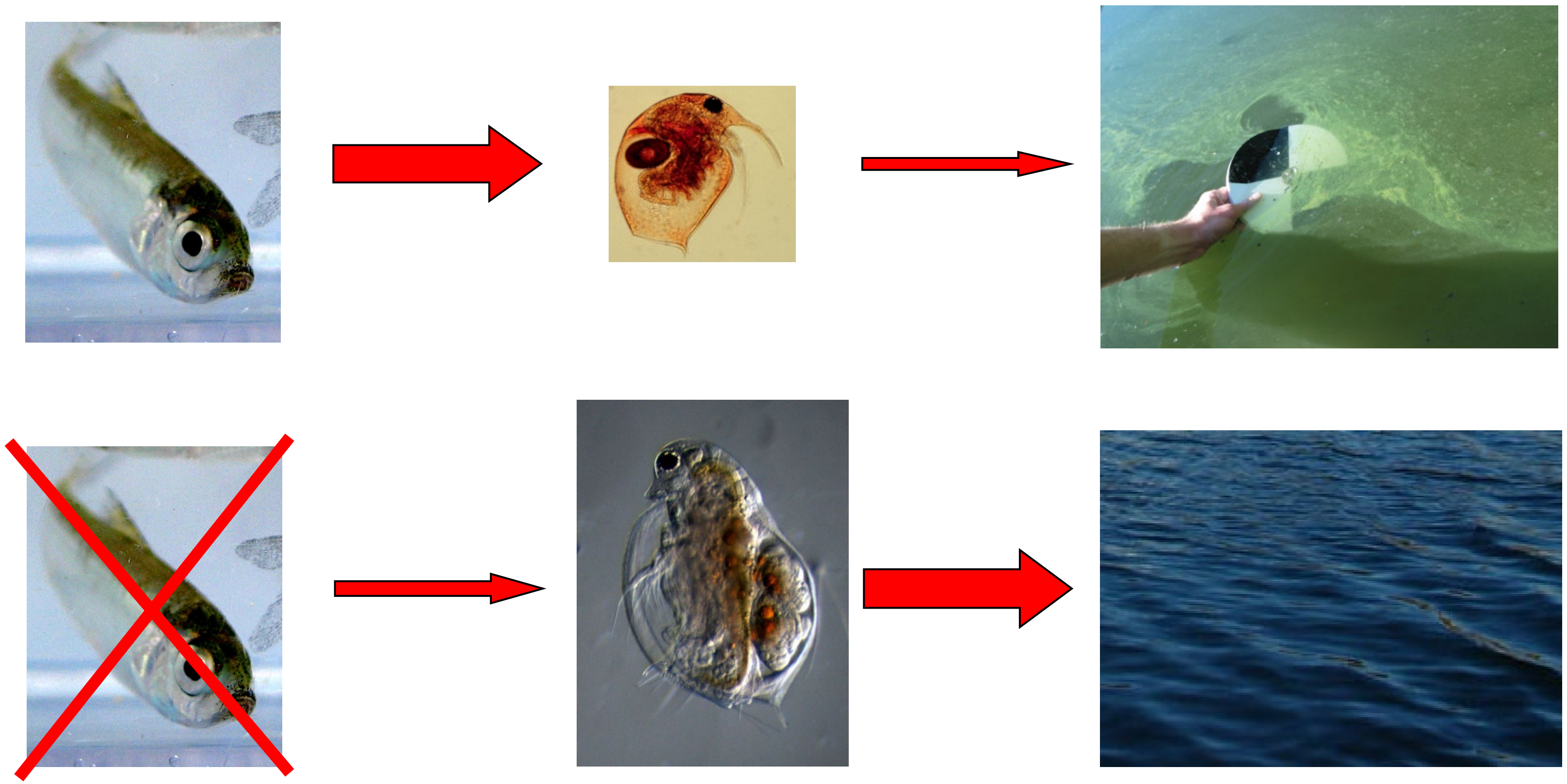
Post et al. 2008

Alewife – Life history differences

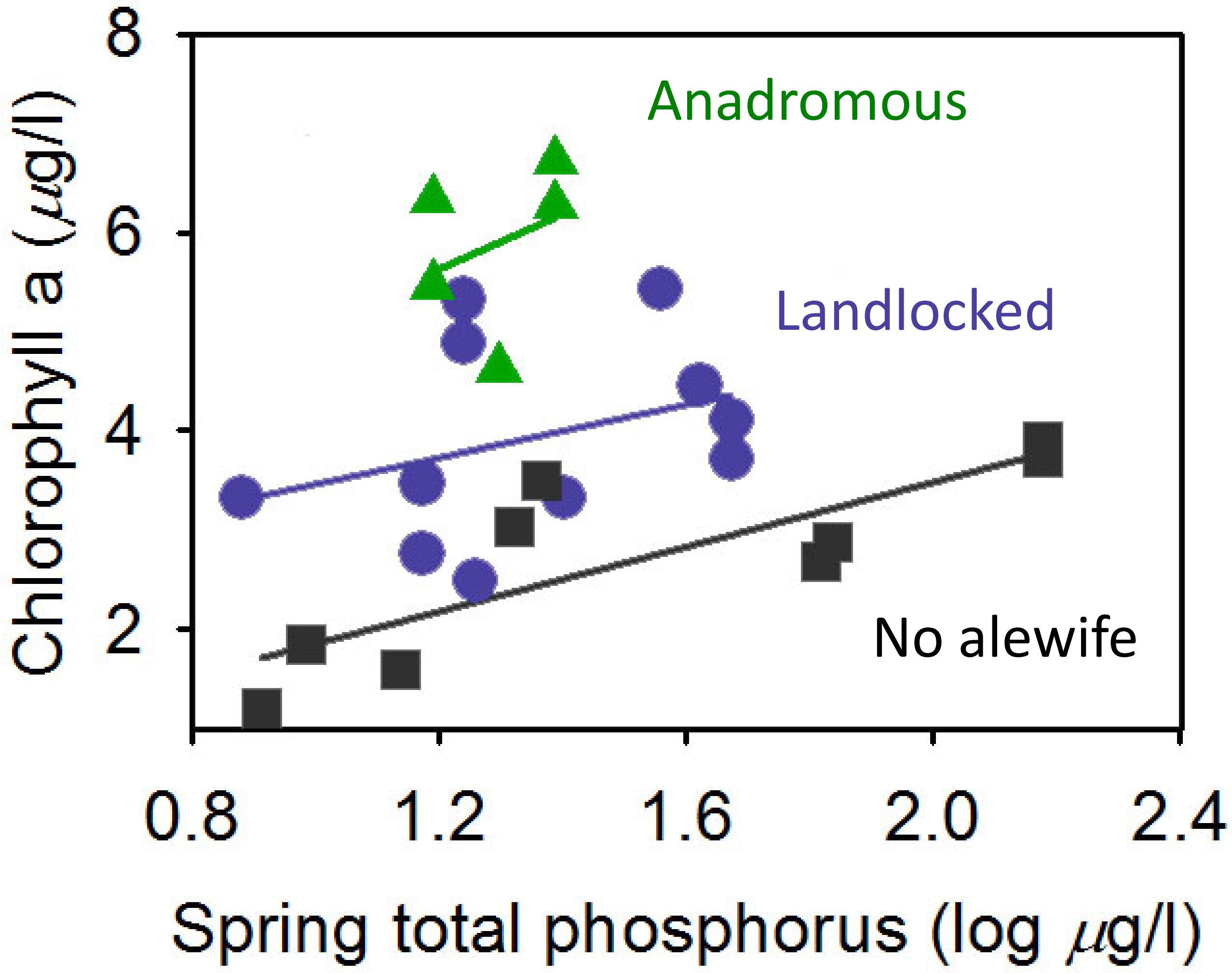


Effects on algae

- Trophic cascade (reciprocal trophic control)

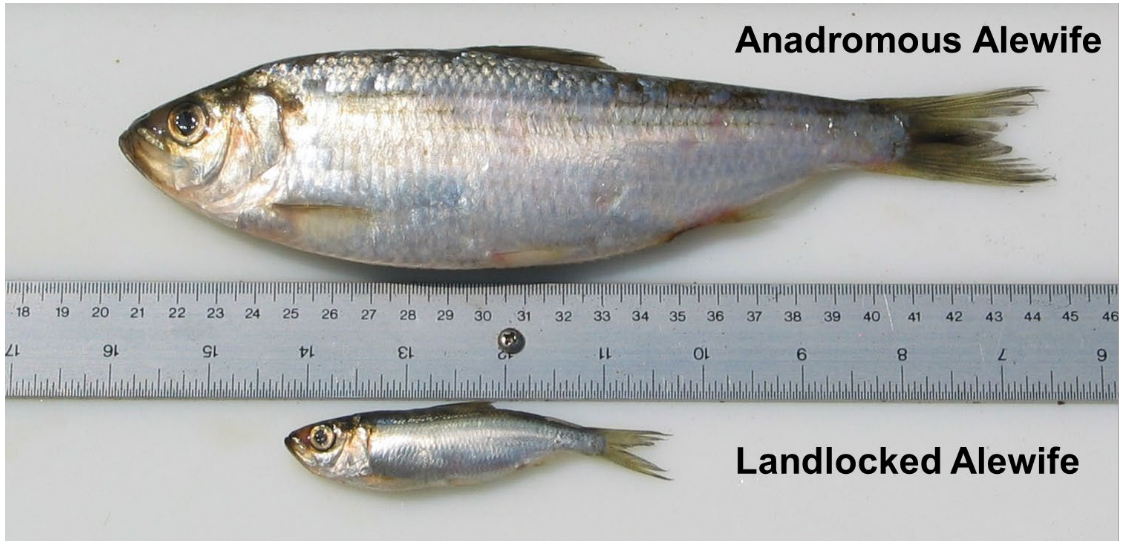


Effects on algae



Post et al. 2008

Alewife – Life history differences



The rest of the food web?

- Differences between anadromous and landlocked alewife
  - Drive evolution in the *Daphnia*, the dominate grazer in lakes

Walsh and Post 2011, 2012, Walsh et al. 2012

The rest of the food web?

- Differences between anadromous and landlocked alewife
  - Drive evolution in the *Daphnia*, the dominate grazer in lakes
  - *Daphnia* in lakes with anadromous alewife
    - Grow faster
    - Mature earlier
    - Have more offspring
    - Invest more in sexual reproduction
    - Regulate algal biomass better than *Daphnia* from lakes with landlocked alewife

Walsh and Post 2011, 2012, Walsh et al. 2012

The rest of the food web?

- Differences between anadromous and landlocked alewife
  - Drive evolution in the *Daphnia*
  - Alter foraging morphology and efficiency of bluegill

Huss et al. 2014

The rest of the food web?

- Differences between anadromous and landlocked alewife
  - Drive evolution in the *Daphnia*
  - Alter foraging morphology and efficiency of bluegill
  - Bluegill from lakes with landlocked alewife
    - Grow better on small-bodied zooplankton
    - Prey upon all sizes of zooplankton
    - Have foraging morphology better able to capture small-bodied zooplankton

Huss et al. 2014

The rest of the food web?

- Differences between anadromous and landlocked alewife
  - Drive evolution in the *Daphnia*
  - Alter foraging morphology and efficiency of bluegill
  - Alter habitat use and lipid storage in chain pickerel

Brodersen et al. 2015

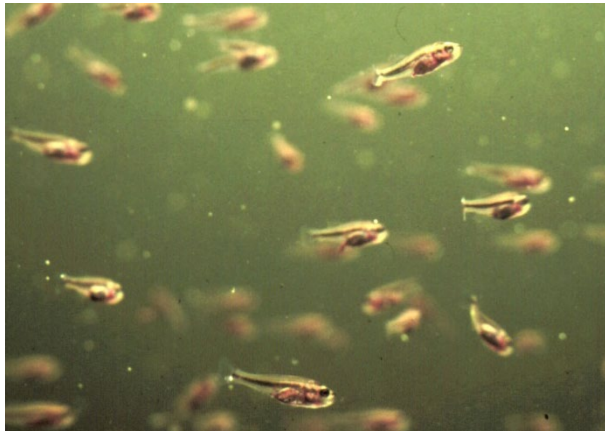
The rest of the food web?

- Differences between anadromous and landlocked alewife
  - Drive evolution in the *Daphnia*
  - Alter foraging morphology and efficiency of bluegill
  - Alter habitat use and lipid storage in chain pickerel
  - In lakes with landlocked alewife
    - Found in open water
    - Prey upon alewife more often
  - In lakes with either form of alewife
    - Have much greater lipid storage (25%)

Brodersen et al. 2015

The rest of the food web?

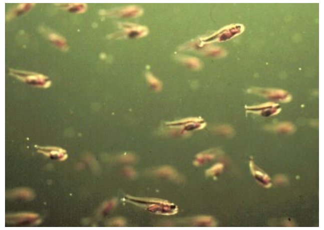
- Differences between anadromous and landlocked alewife
  - Drive evolution in the *Daphnia*
  - Alter foraging morphology and efficiency of bluegill
  - Alter habitat use and fat storage in chain pickerel
  - Growth rates in young-of-the-year largemouth bass



Boel et al. 2018

The rest of the food web?

- Differences between anadromous and landlocked alewife
  - Drive evolution in the *Daphnia*
  - Alter foraging morphology and efficiency of bluegill
  - Alter habitat use and fat storage in chain pickerel
  - Growth rates in young-of-the-year largemouth bass
  - In lakes with landlocked alewife
    - Have slower growth rates in first year of life
    - Switch to insects and fish as prey more slowly



    - Preliminary data suggest adults may have faster growth rates in lakes with landlocked or anadromous alewife

Boel et al. 2018

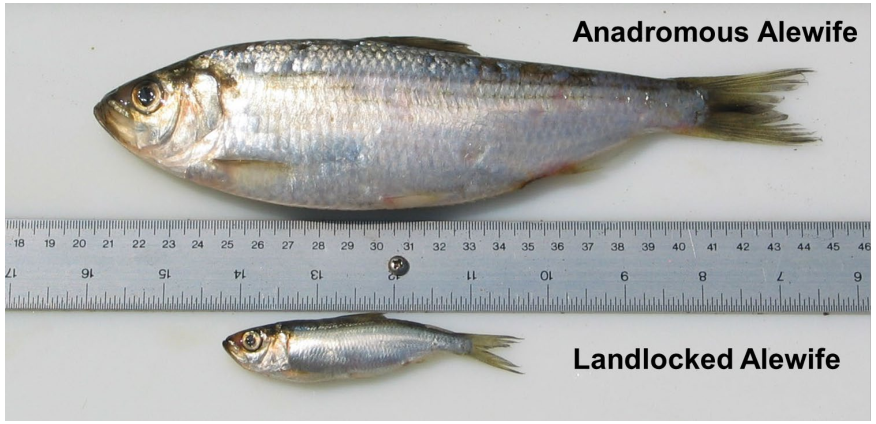
History of Rogers Lake

- Migration between the ocean and Rogers Lake likely lost as early as 1670s

- Fishway opened in the spring of 2014
  - Anadromous alewife in Rogers Lake for the first time around 350 years!
  - But there is also an existing landlocked population in Rogers Lake

Secondary Contact

- What happens when anadromous alewife are reintroduced into a lake that already contains a landlocked alewife population?



Secondary Contact

- What happens when anadromous alewife are reintroduced into a lake that already contains a landlocked alewife population?

- Secondary Contact: when lineages that were isolated and have evolved in isolation come back into contact

Secondary Contact

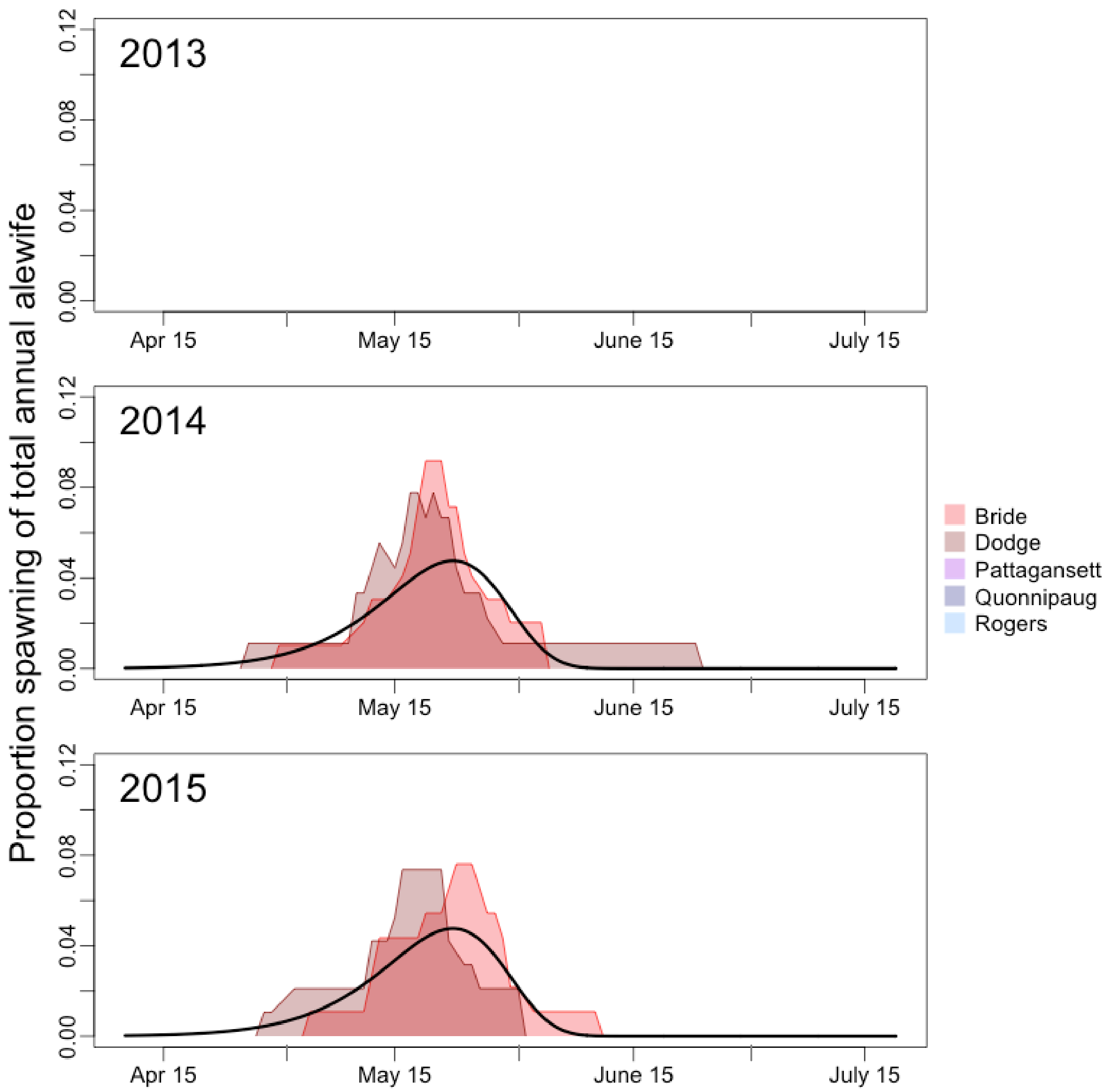
- What happens when anadromous alewife are reintroduced into a lake that already contains a landlocked alewife population?
  - Can they reproduce with each other (hybridize)?
    - If no – outcome of competition?
    - If yes – How much hybridization? Direction of gene flow?
      - will they still compete?

Spawning Time

- Anadromous alewife spawn earlier than landlocked alewife
  - How much earlier?
  - How much overlap in spawning?

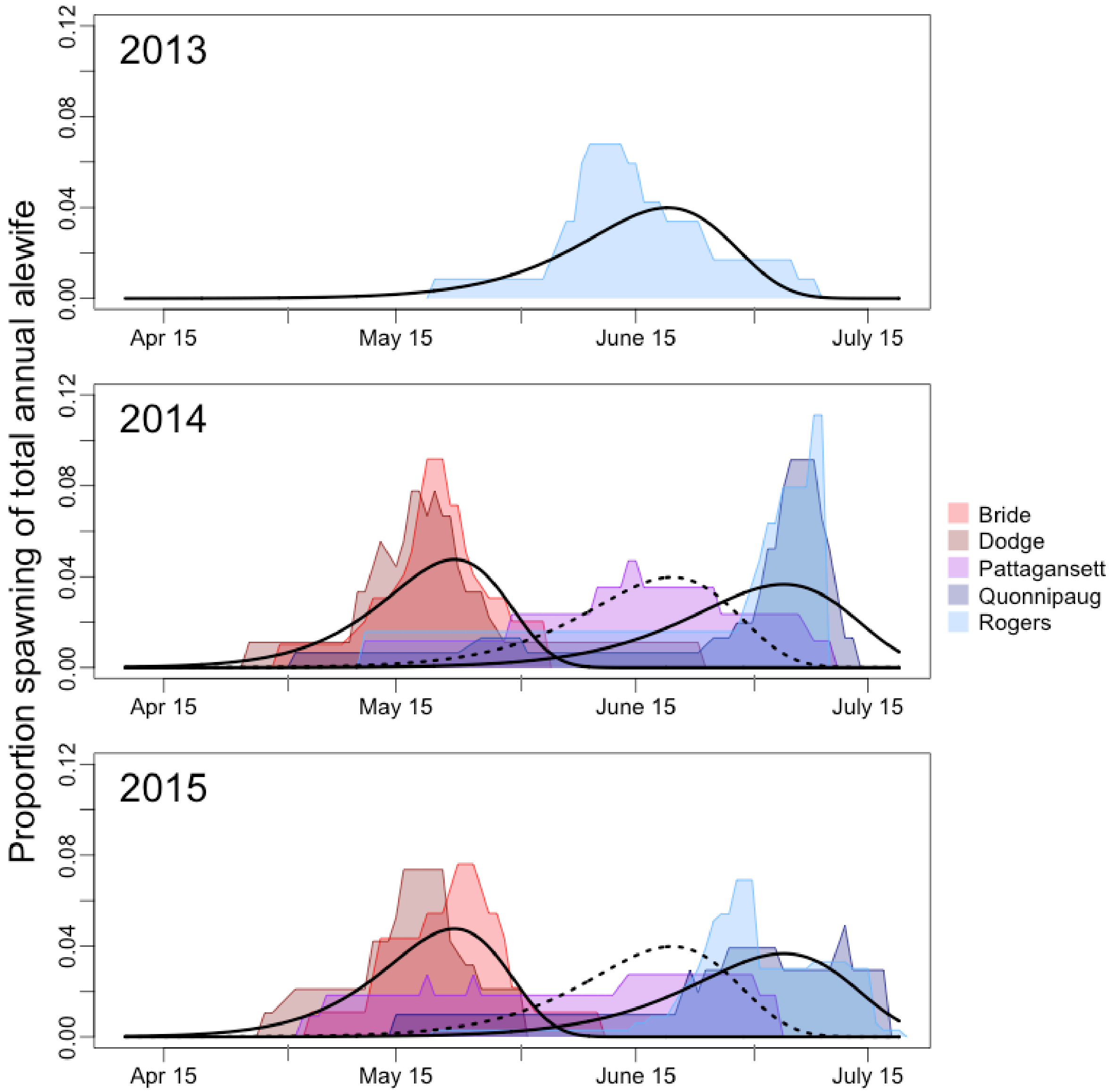
Spawning Time

- Anadromous populations
  - Runs start early April
  - Spawning begins late April
  - Peak spawning in May
    - 18°C
  - No significant difference among populations or years



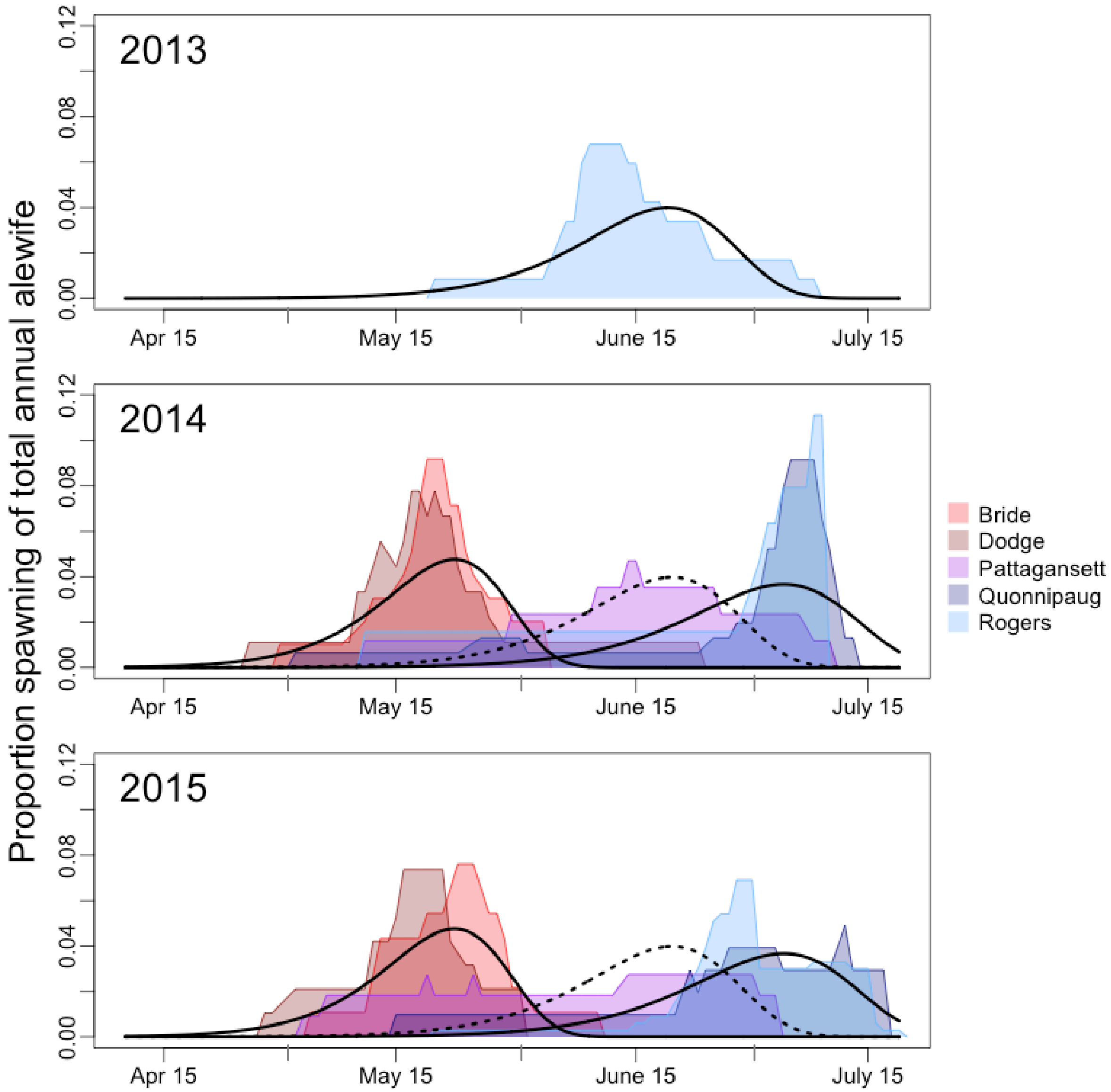
Spawning Time

- Landlocked populations
  - Spawning begins in May
  - Peaks in June and July
    - 22-26 °C
  - Longer spawning period
  - Significant differences among lakes and years
    - Rogers
      - Early in 2013
      - Late in 2014 and 2015



Spawning Time

- Rage of overlap
  - Rogers Lake: 0% - 10%
    - Some years of overlap
    - Some years of no overlap
  - Pattagansett: 20-30%
    - Likely to be greater overlap



History of Rogers Lake

- Fishway opened in the spring of 2014

Status of restoration

- Fishway opened

	Adult returns	
Year	Stocked	Natural
2015	134	
2016	1144	
2017	2787	
2018	3392	
2019	3358	286
2020	5404	2842
2021	4621	2506
2022	2492	239
2023		1245
2024		13545

Status of restoration

- Are anadromous alewife successfully spawning?
- Is their gene flow between anadromous and landlocked alewife?
- Collected 1000s of Young-of-the-Year alewife in August of each year
  - Genotyped all of them to identify landlocked, anadromous, hybrids
  - Estimated density
  - Measured traits such as length, weight, diet, habitat, age and spawning date

Status of restoration

- Are anadromous alewife spawning successfully?

Year	Percent	
	Landlocked	Anadromous
2015	100.0%	0.0%
2016	93.5%	6.5%
2017	79.6%	15.5%
2018	81.2%	5.7%
2019	90.1%	1.4%
2020	67.8%	8.7%
2021	43.8%	6.2%

Yes!

Status of restoration

- Are anadromous alewife spawning successfully?

Anadromous and landlocked alewife are hybridizing in Rogers Lake

Year	Percent		
	Landlocked	Anadromous	Hybrid
2015	100.0%	0.0%	0.0%
2016	93.5%	6.5%	0.0%
2017	79.6%	15.5%	5.2%
2018	81.2%	5.7%	13.2%
2019	90.1%	1.4%	8.5%
2020	67.8%	8.7%	23.6%
2021	43.8%	6.2%	49.9%

Status of restoration

- Are anadromous alewife spawning successfully?

Year	Percent		
	Landlocked	Anadromous	Hybrid
2015	100.0%	0.0%	0.0%
2016	93.5%	6.5%	0.0%
2017	79.6%	15.5%	5.2%
2018	81.2%	5.7%	13.2%
2019	90.1%	1.4%	8.5%
2020	67.8%	8.7%	23.6%
2021	43.8%	6.2%	49.9%

In 2017

Considerable overlap in spawning between L and A

First generation hybrids from anadromous and landlocked alewife spawning together

Status of restoration

- Are anadromous alewife spawning successfully?

Year	Percent		
	Landlocked	Anadromous	Hybrid
2015	100.0%	0.0%	0.0%
2016	93.5%	6.5%	0.0%
2017	79.6%	15.5%	5.2%
2018	81.2%	5.7%	13.2%
2019	90.1%	1.4%	8.5%
2020	67.8%	8.7%	23.6%
2021	43.8%	6.2%	49.9%

From 2018 onward

Less overlap in spawning between L and A

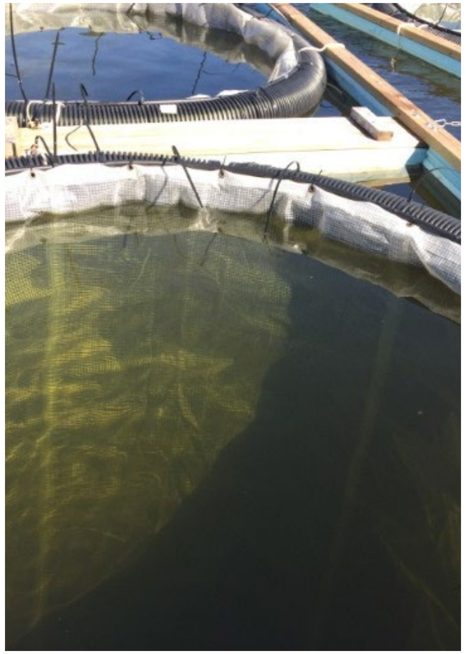
Second generation hybrids (backcross) from hybrids (2017) and landlocked alewife spawning together

Secondary Contact

- What happens when anadromous alewife are reintroduced into a lake that already contains a landlocked alewife population?
  - Can they reproduce with each other (hybridize)?
    - If no – How will they compete?
    - If yes – How much? What direction of gene flow?
      - How will they compete?

Secondary Contact

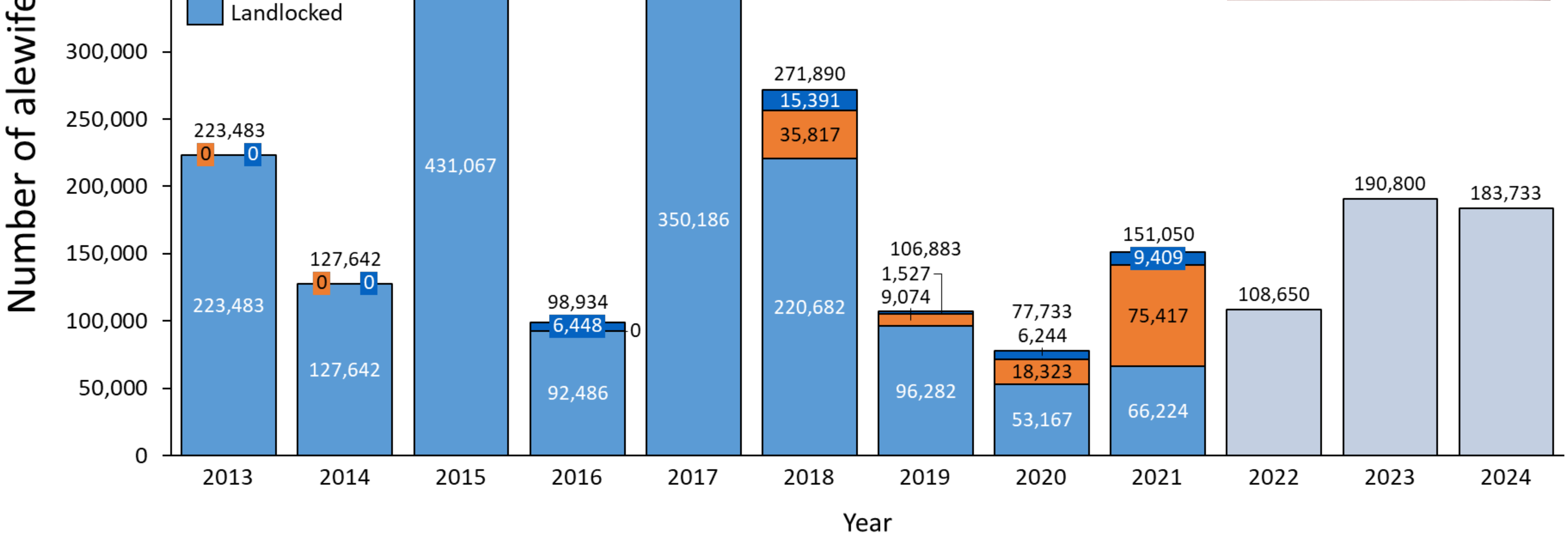
- Competition?
  - Yes and No
  - Considerable overlap in diet
  - Landlocked alewife are better at foraging on small-bodied zooplankton
  - Anadromous alewife can access nearshore resources that are not available to landlocked alewife
  - Anadromous alewife leave Rogers Lake each autumn



Long-term dynamics in Rogers Lake

- August of each year 2013 - 2024
- Young-of-the-year alewife
  - Genotype
  - Density and habitat use
  - Length, mass, growth rates, spawning date and age

Rogers – juvenile alewife numbers

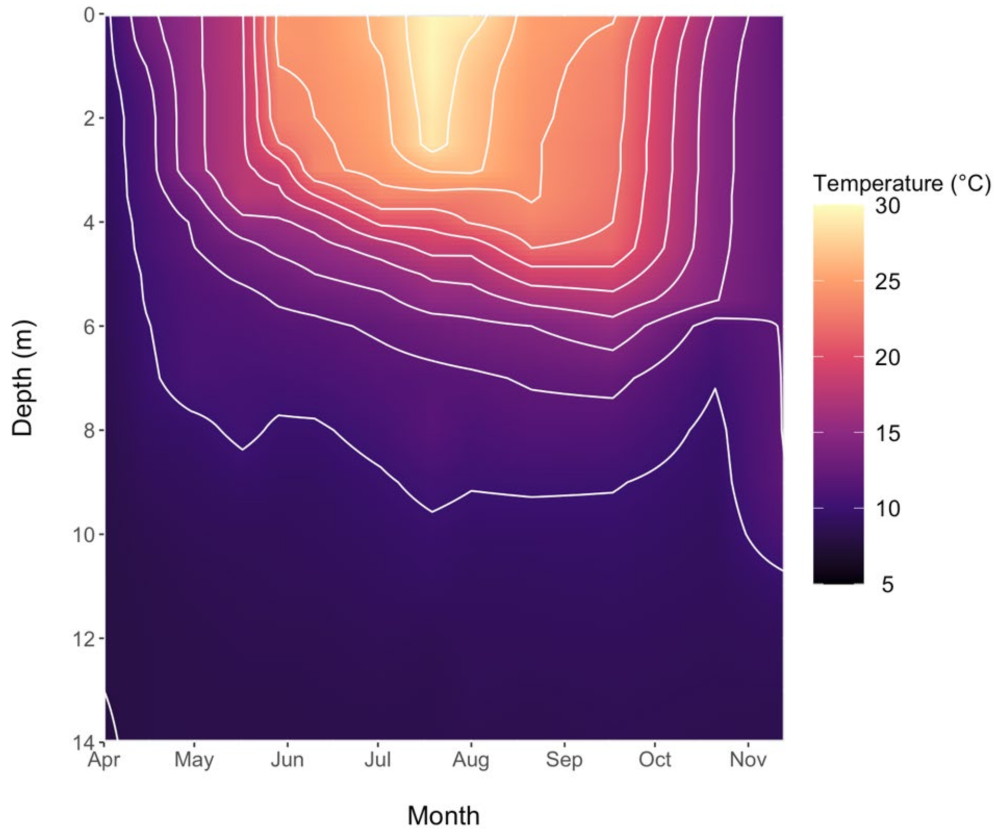


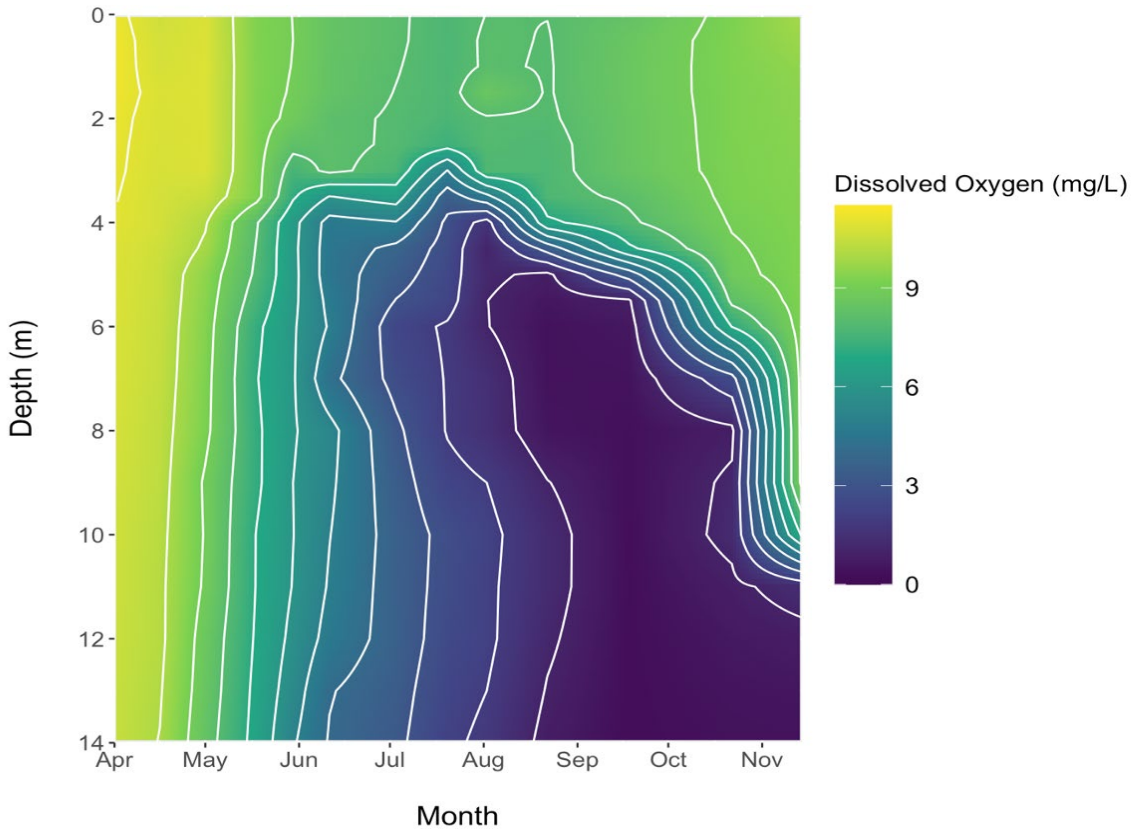
Long-term dynamics in Rogers Lake

- Sample April – September (November); 2005 - 2011, 2013 - 2024
  - Physical limnology
    - Temperature, dissolved oxygen, water clarity
  - Nutrients
    - Nitrogen and Phosphorus
  - Algae
    - Biomass
  - Zooplankton
    - Biomass and composition

Long-term dynamics in Rogers Lake

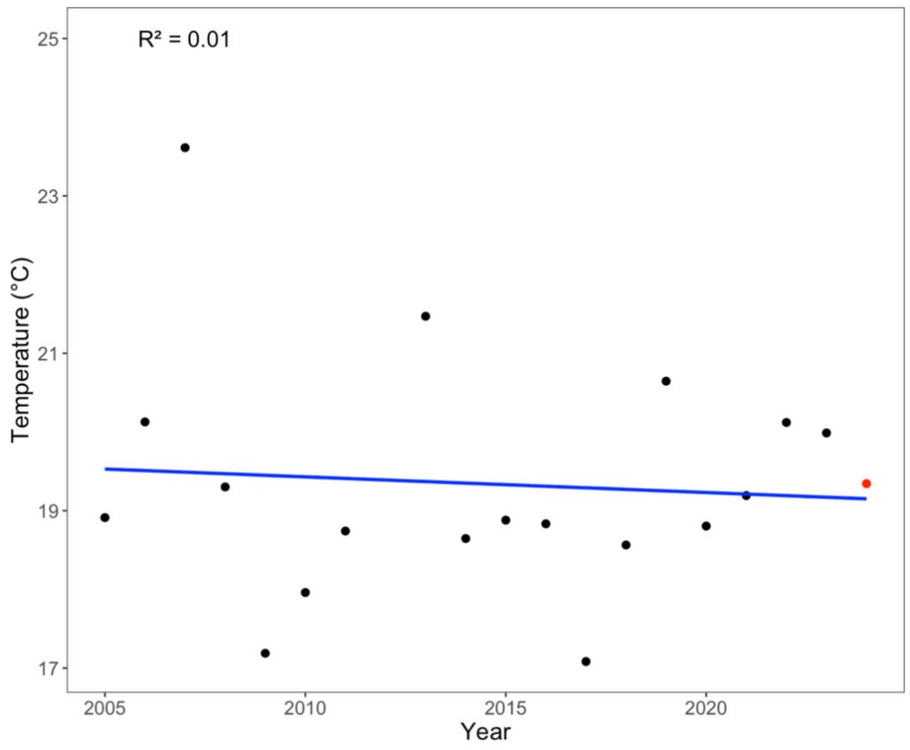
- Temperature and Oxygen - 2024

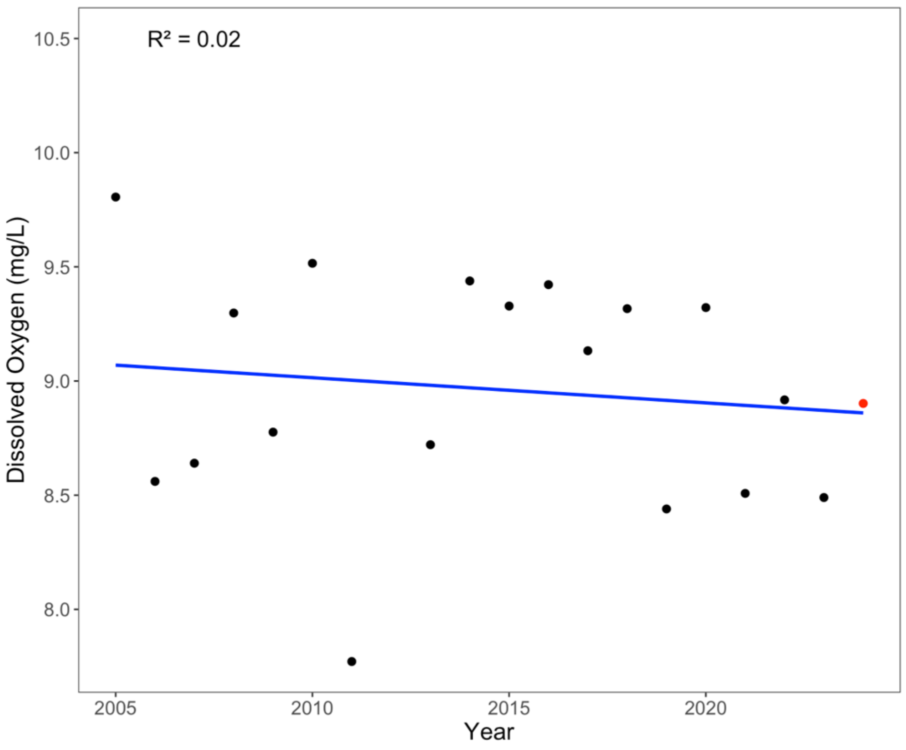




Long-term dynamics in Rogers Lake

- Temperature and Oxygen – Long Term (annual mean)

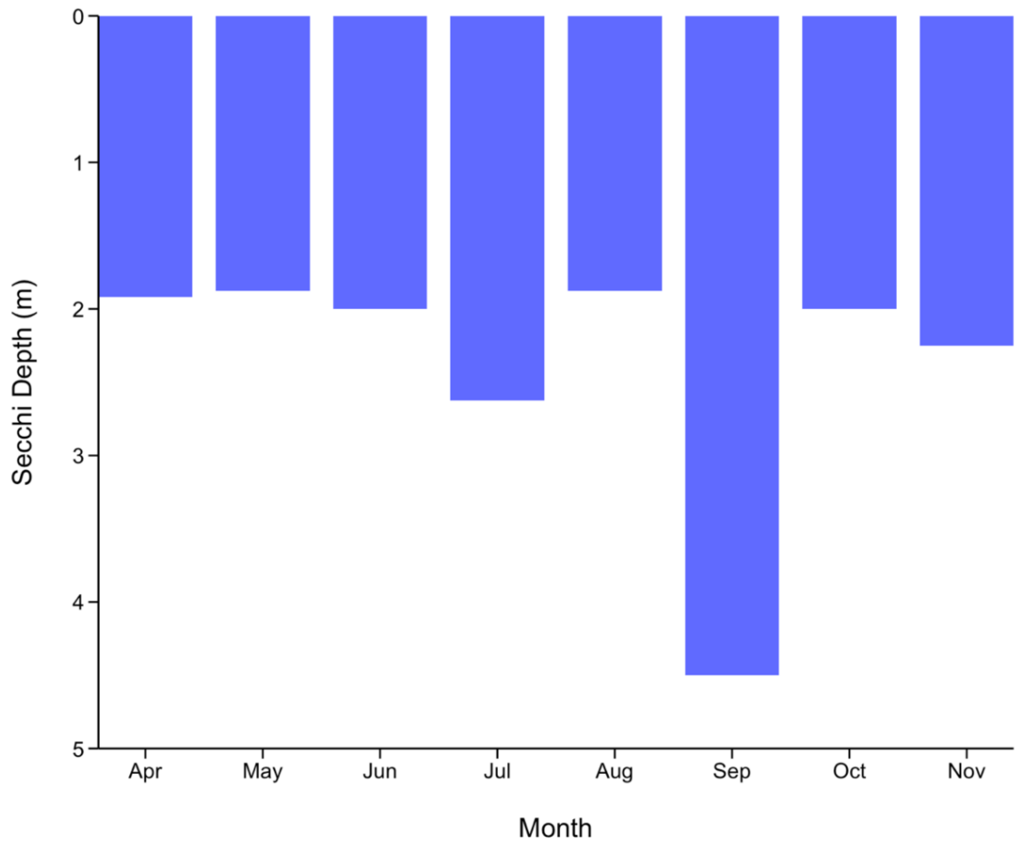




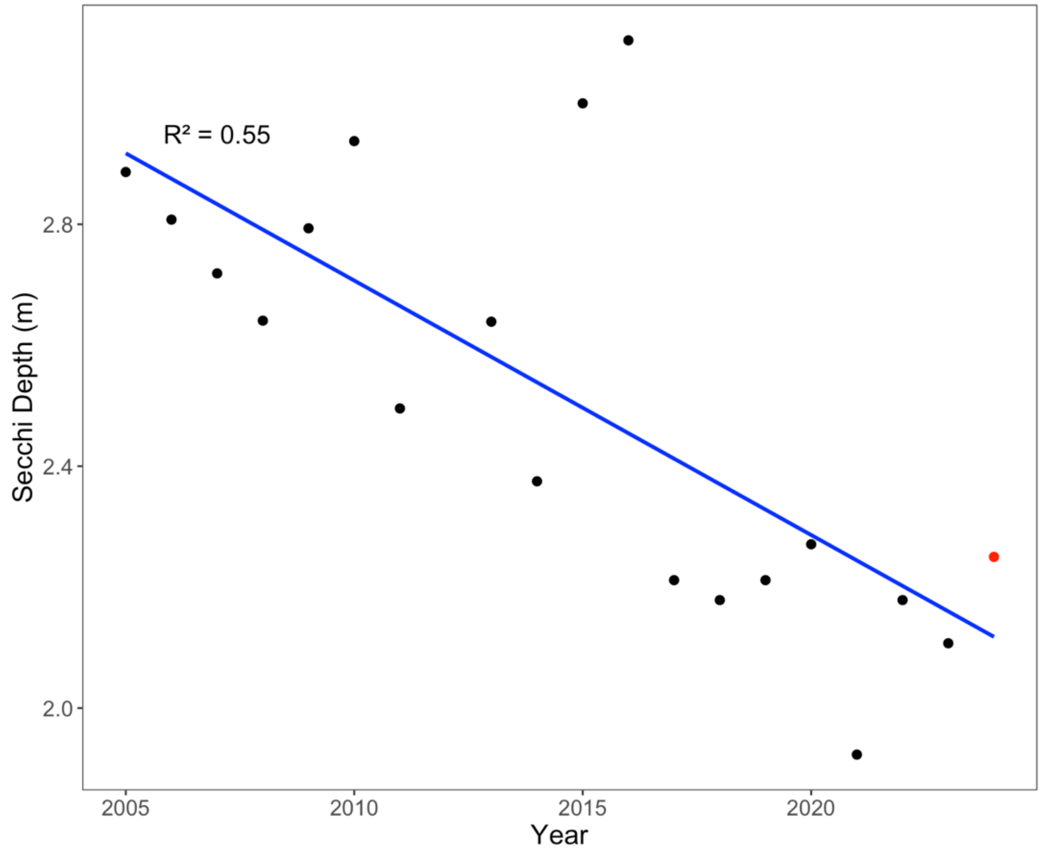
Long-term dynamics in Rogers Lake

- Water Clarity

2024

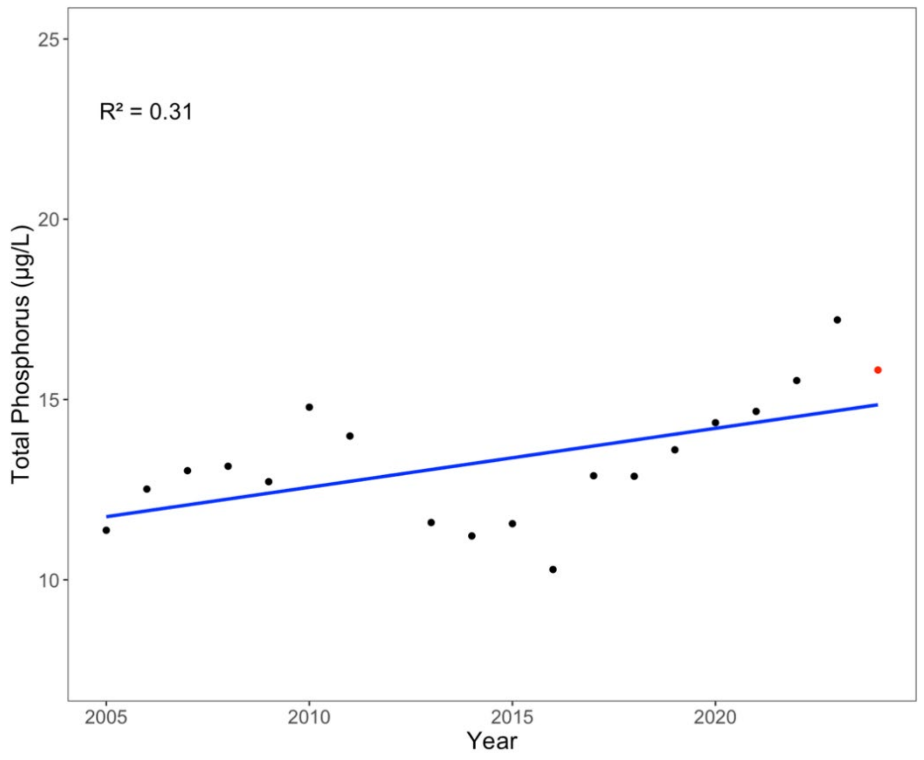


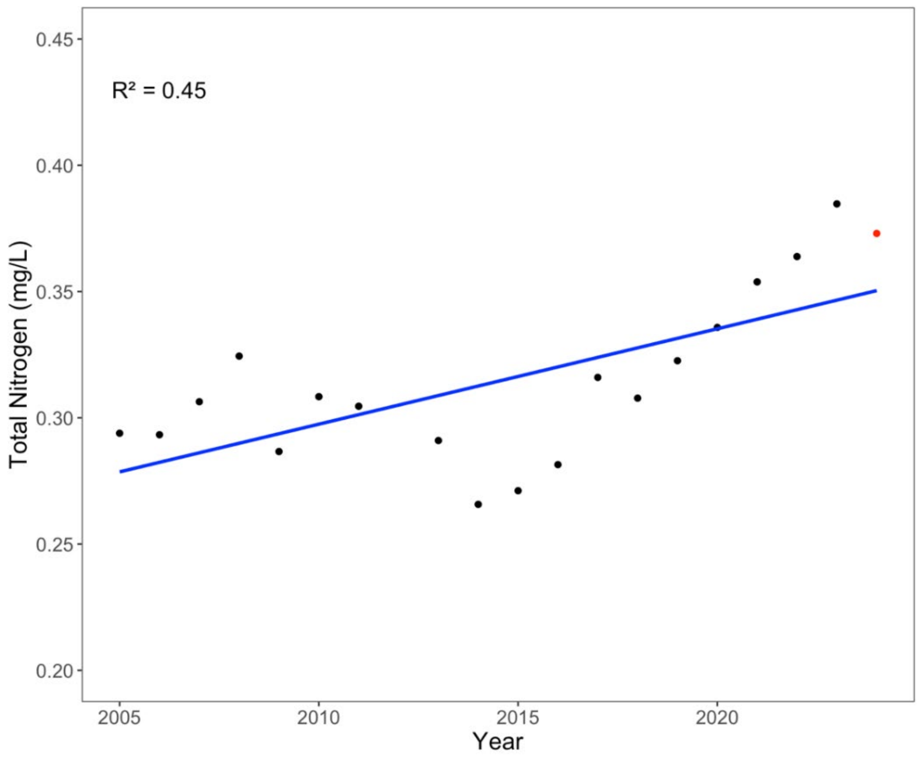
Long-term (annual mean)



Long-term dynamics in Rogers Lake

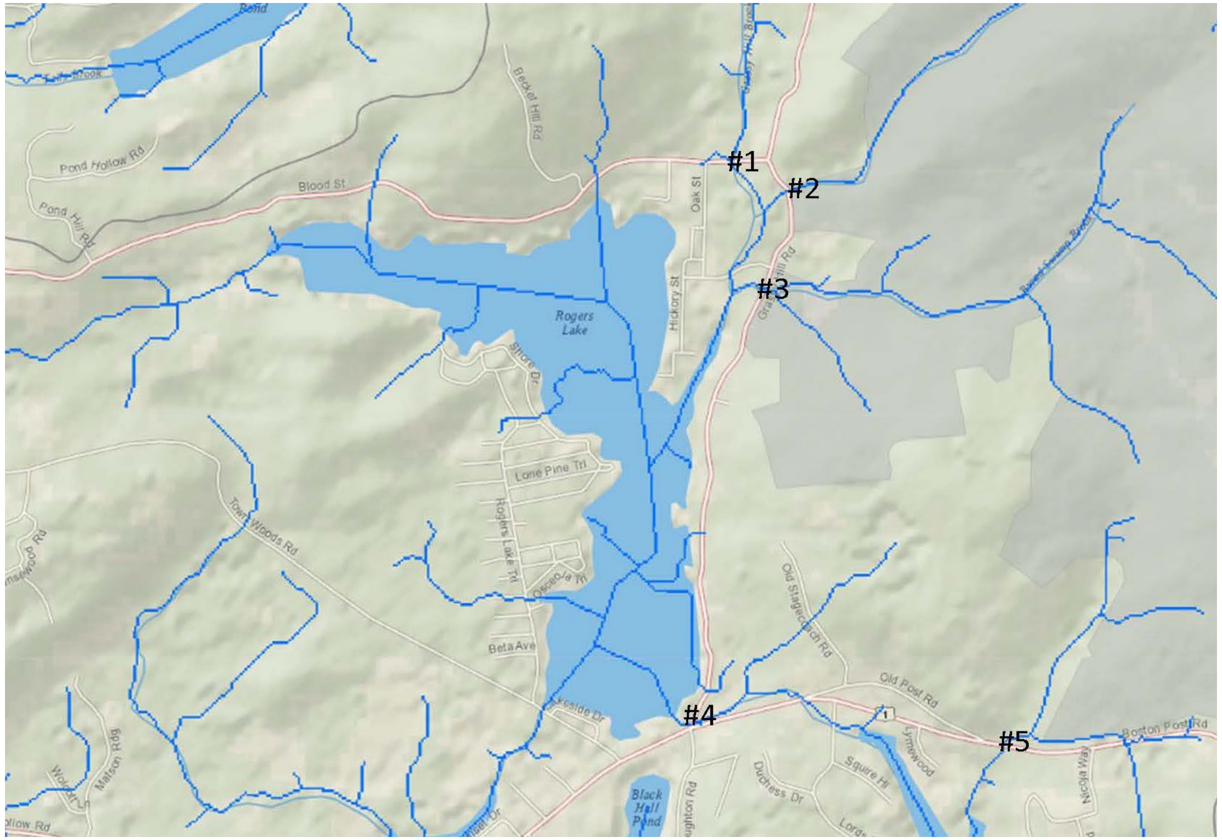
- Nutrients – Phosphorus and Nitrogen





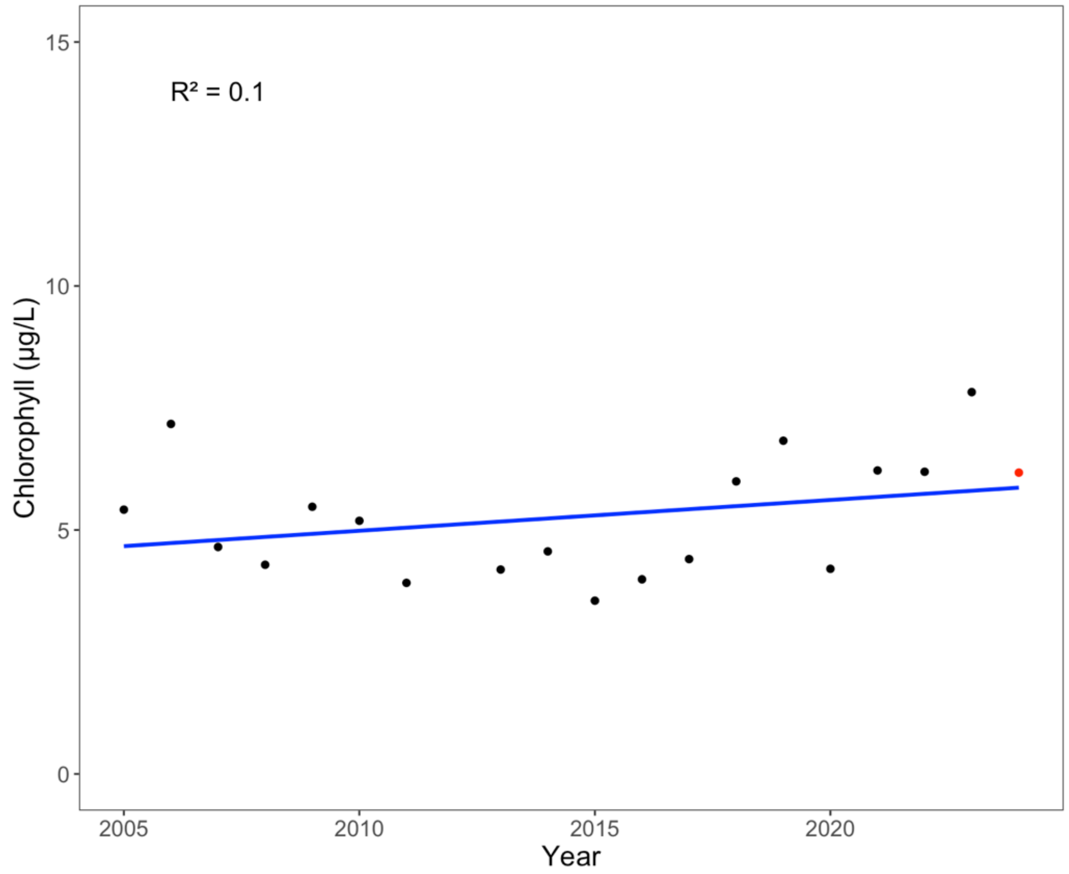
Long-term dynamics in Rogers Lake

- Nutrients – Phosphorus and Nitrogen
  - High concentrations
  - Very high at #5



Long-term dynamics in Rogers Lake

- Algal biomass
  - No major long-term change
    - Might be changes in blooms
    - Or composition
    - Or distribution



Conclusions

- Long-term increases in nutrient concentrations
- Long-term decrease in water clarity
- No other significant changes in the ecology of Rogers Lake
- Significant ongoing evolution among resident alewife

Ongoing Research

- National Science Foundation funding until early 2026
  - Continue genetic sampling
    - Interannual variation in hybridization and gene flow
  - Continue ecological sampling

Acknowledgements

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WHERE DISCOVERIES BEGIN

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Thank you!