Factors affecting density and growth of juvenile river herring: Insights from 32 coastal New England lakes

Matt Devine[1,2], Allison Roy[1,2,3], Andrew Whiteley[4], Benjamin Gahagan[5], Michael Armstrong[5], and Adrian Jordaan[1]

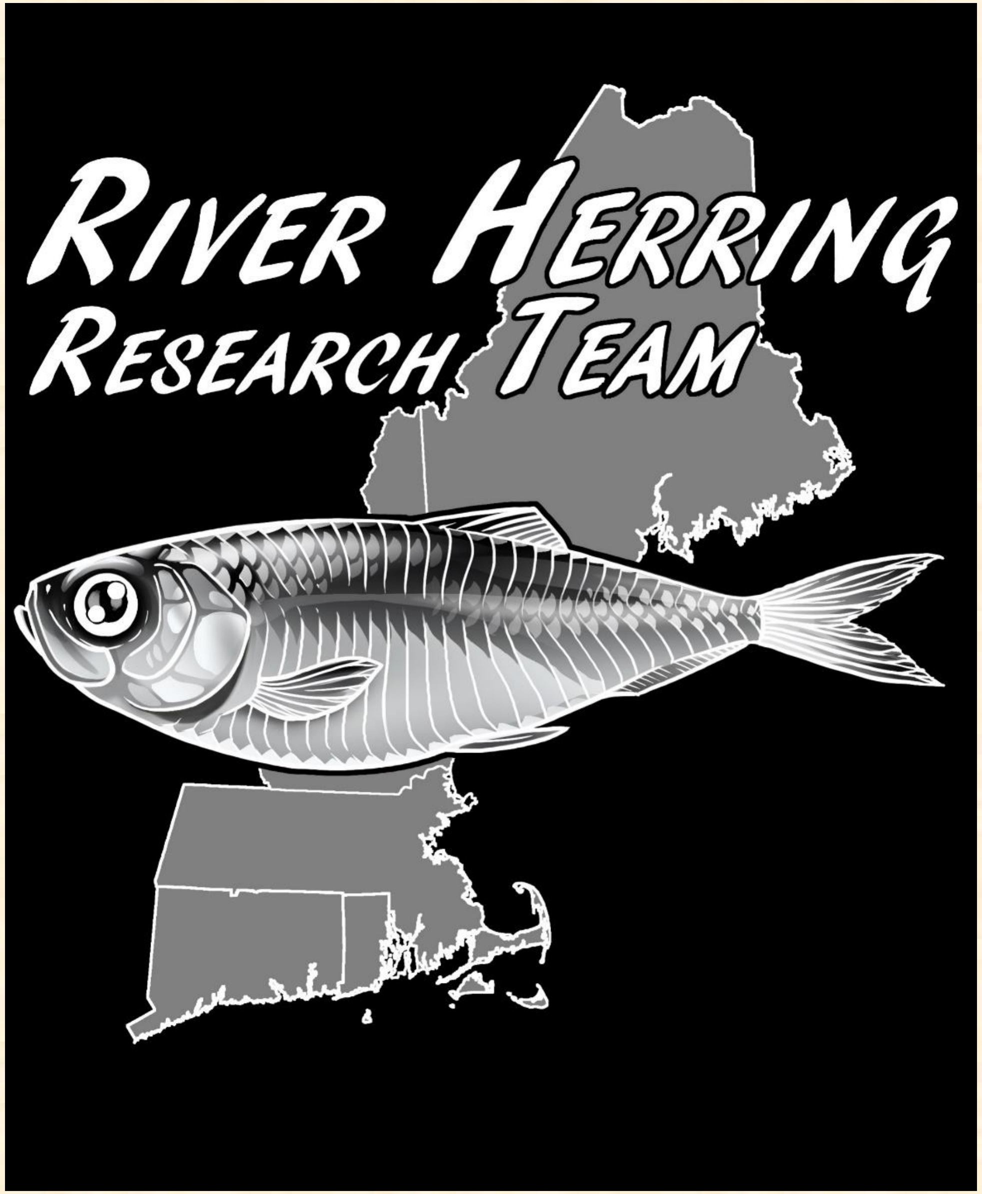
[1]Department of Environmental Conservation, University of Massachusetts, Amherst
[2]Massachusetts Cooperative Fish & Wildlife Research Unit
[3]U.S. Geological Survey, Massachusetts
[4]Department of Ecosystem and Conservation Sciences, University of Montana
[5]Massachusetts Division of Marine Fisheries

Funding

National Fish and Wildlife Foundation
Atlantic States Marine Fisheries Commission
Massachusetts Division of Marine Fisheries
The Nature Conservancy

Collaborators

US Fish and Wildlife Service
Connecticut DEEP
Rhode Island DEM
Massachusetts DMF
Massachusetts DER
New Hampshire DFG
Maine DMR
Lake Associations & Conservation Commissions

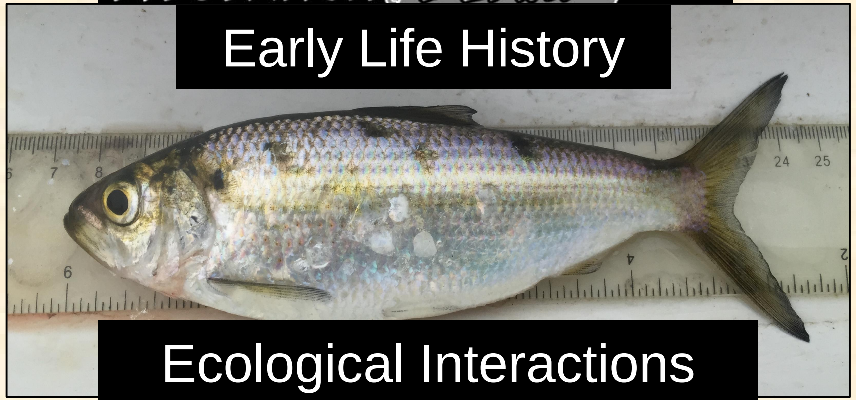


UMass Amherst Research and Contributions

RIVER HERRING RESEARCH TEAM

-Delay between migration & spawning
-Adults present in lakes longer
Rosset et al. 2017 *TAFS*

Early Life History



Ecological Interactions

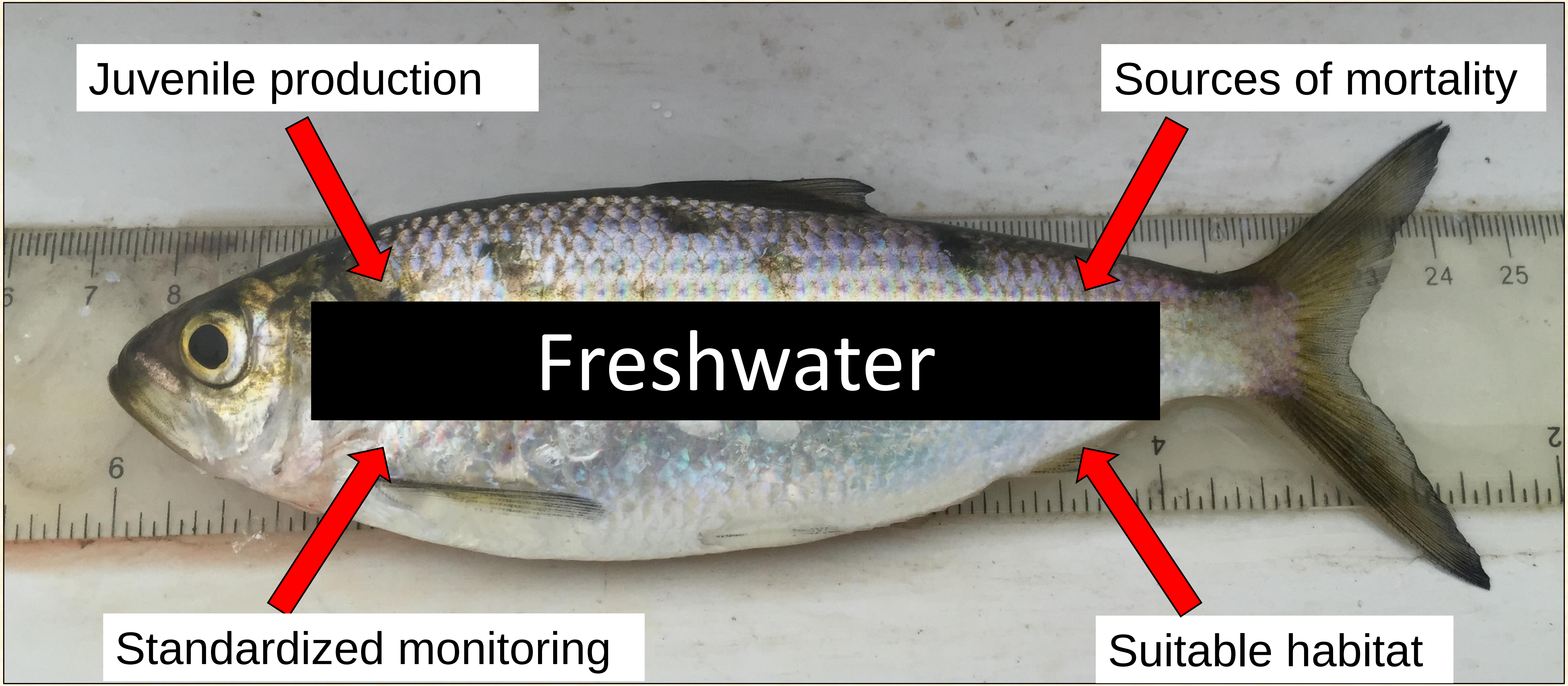
-Alewife increase sportfish condition
Mattocks et al. 2017 *BioScience*

-Adults spawn multiple times w/ multiple mates
-Females more successful than males
-Larger, earlier arriving fish more successful
Marjadi et al. 2018 *CJFAS*

-Size-selective feeding habits
-Dietary overlap between adults & juveniles
Bittner et al. *In Prep*

-Juvenile growth temp & food limited
-Decreases lake temps (>25°C)

Data Gaps


Juvenile production
Sources of mortality
Freshwater
Standardized monitoring
Suitable habitat

M.S. Research Questions

- What are most effective sampling approaches for estimating juvenile densities in FW lakes?
  - When and how much to sample?
- What are juvenile density, growth, and mortality rates in FW lakes?
  - How do these estimates vary across the landscape?
- What is the relationship between adult counts and juvenile densities?
- What biotic/abiotic factors influence juvenile productivity?

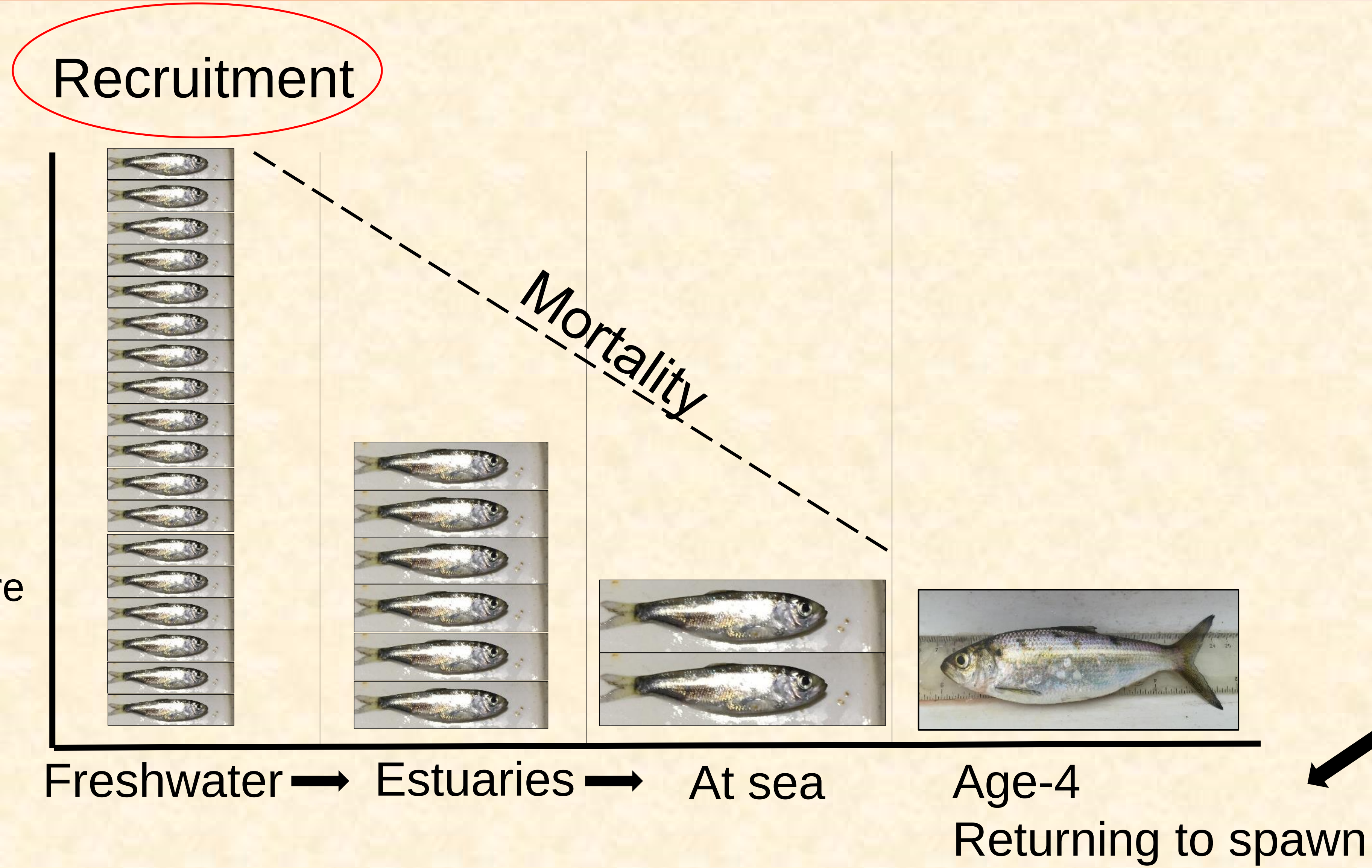
Population Data From Adult Run Counts

- Monitored a number of ways:
  - Electronic
  - Video
  - Citizen science

- Providing data on:
  - Number of adults returning annually
  - Timing of returns
  - Adult size/age structure

How Many Fish Are There Initially?

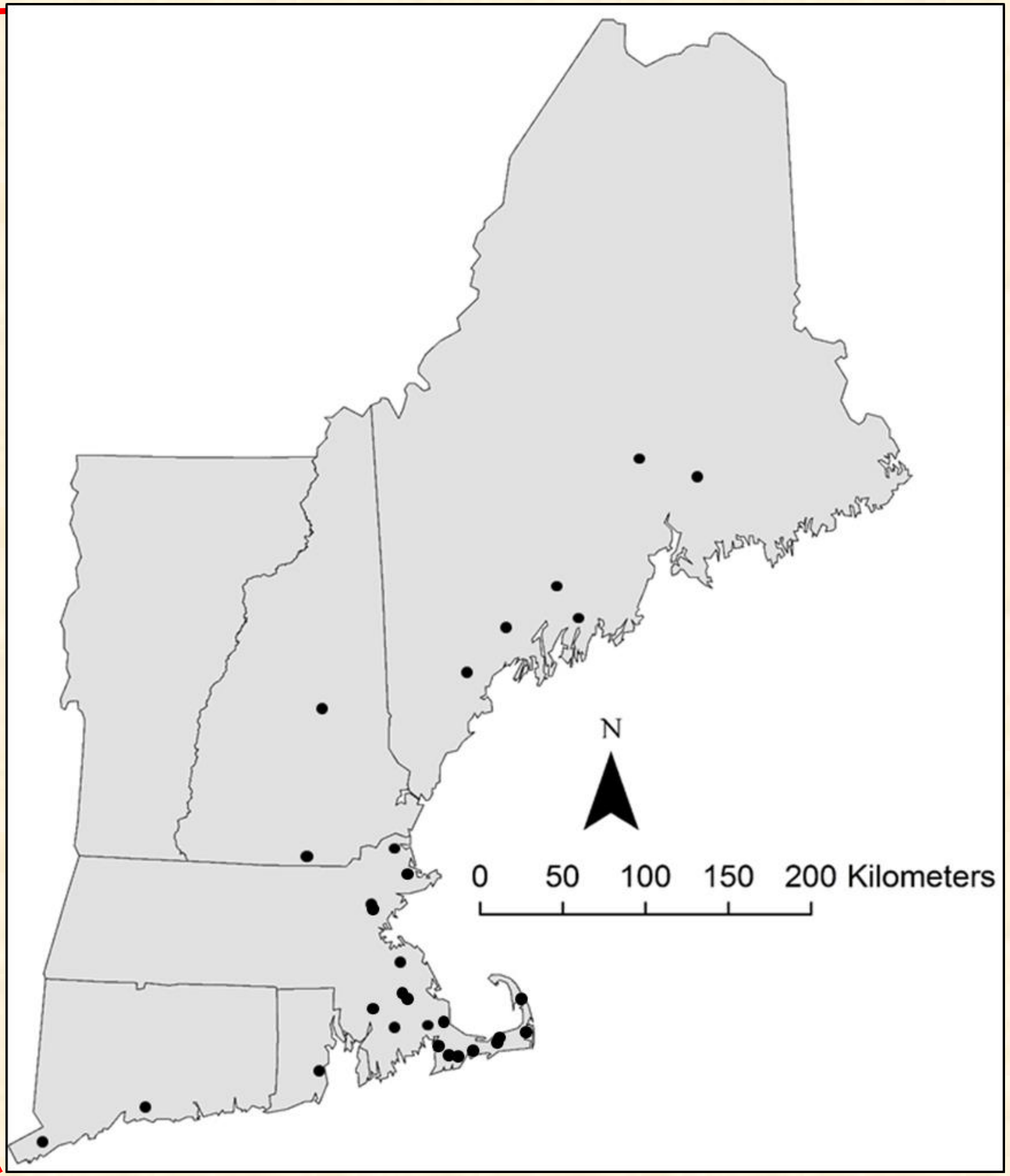
Should be counted here



Counted here

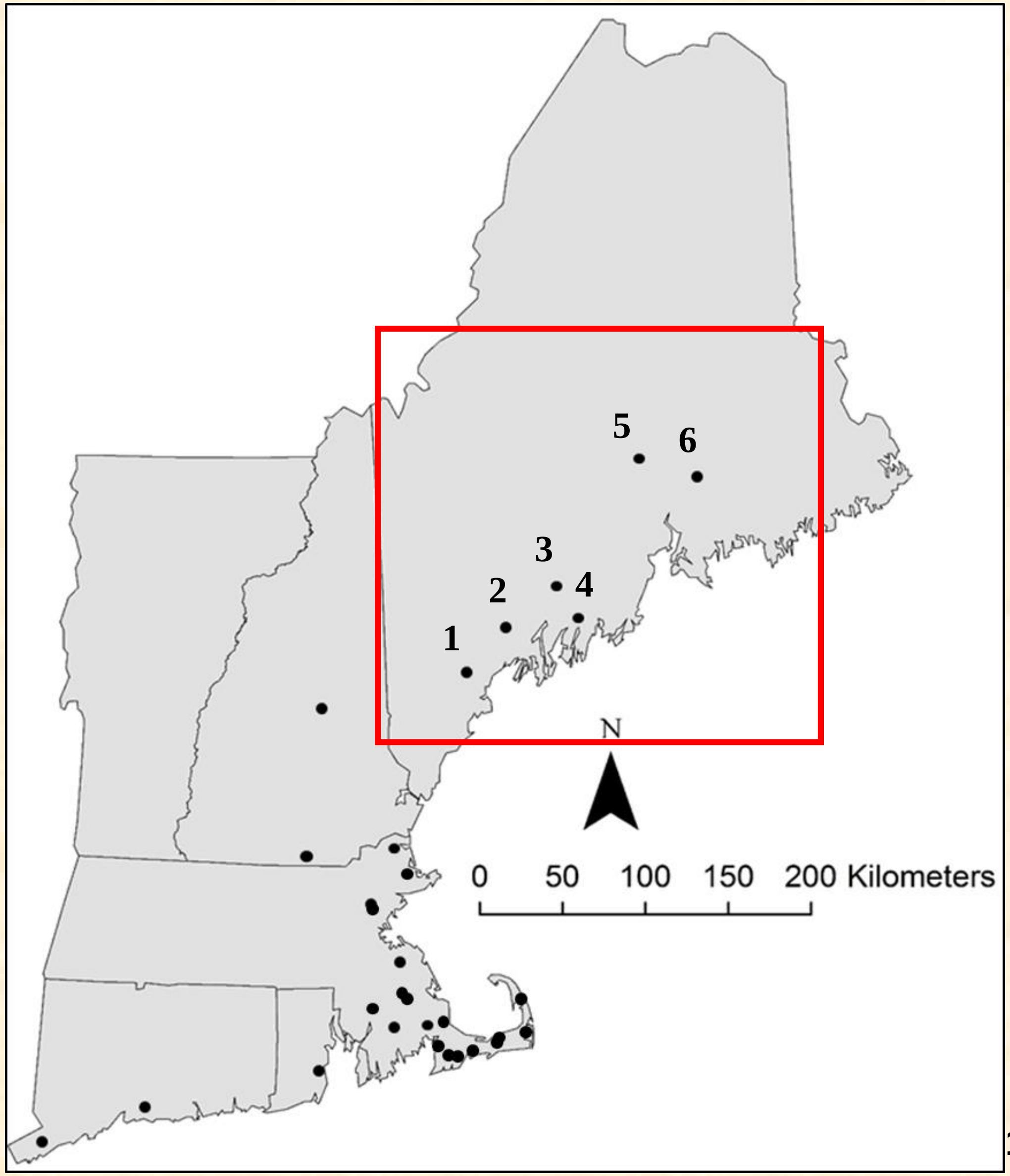
Study Lakes

- 2014–2018
- Sampled 32 coastal lakes
- 5 lakes sampled all years
- Estimate of adults
- Stocked & natural runs



Study Lakes - Maine

1. Highland (Portland)
2. Sabattus (Lewiston)
3. Togus (Augusta)
4. Darmariscotta (Jefferson)
5. Pushaw (Bangor)
6. Chemo (Eddington)



Study Lakes – Physical & Chemical Summary

Variable	Min	Max	Mean	Std. Dev
Area (ha)	8.01	1894	305.66	528.20
Mean depth (m)	1.50	15.20	4.78	3.48
Maximum depth (m)	1.80	53.10	10.07	9.26
Shoreline length (km)	1.38	64.69	10.58	13.82
Elevation (m)	-0.54	146.66	23.95	30.70
Surface temperature (°C)	17.66	28.74	24.16	2.46
Dissolved organic carbon (mg C l^{-1})	1.49	11.10	4.64	1.89
Secchi Depth (m)	0.20	5.80	1.86	1.02
Total phosphorous (µg P l^{-1})	0.61	71.50	25.11	14.71
Total nitrogen (mg N l^{-1})	0.12	1.86	0.50	0.33
Chlorophyll-a (µg l^{-1})	0.33	160.77	15.47	24.34

Study Lakes – Trophic State Summary

SITE	TSI VALUE	TROPHIC STATE	SITE	TSI VALUE	TROPHIC STATE	SITE	TSI VALUE	TROPHIC STATE
Billington	61.8	Eutrophic	Highland	46.3	Mesotrophic	Robbins	60.5	Eutrophic
Cedar	58.0	Eutrophic	Johns	48.1	Mesotrophic	Sabbatia	55.5	Eutrophic
Charlie	48.9	Mesotrophic	L. Mill	54.2	Eutrophic	Sabattus	64.7	Eutrophic
Chebacco	54.8	Eutrophic	L. Mystic	52.8	Mesotrophic	Santuit	60.7	Eutrophic
Chemo	49.3	Mesotrophic	Long	55.2	Eutrophic	Snipatuit	55.6	Eutrophic
Coonamesset	48.9	Mesotrophic	Mianus	54.2	Eutrophic	G. Stuart	55.2	Eutrophic
Damariscotta	46.3	Mesotrophic	Oldham	56.4	Eutrophic	Togus	60.0	Eutrophic
Furnace	54.6	Eutrophic	Pentucket	48.0	Mesotrophic	U. Mill	53.7	Mesotrophic
G. herring	51.3	Mesotrophic	Pilgrim	52.7	Mesotrophic	U. Mystic	53.6	Mesotrophic
L. Guilford	55.9	Eutrophic	Potanipo	49.7	Mesotrophic	Whitmans	55.0	Eutrophic
Gull	44.3	Mesotrophic	Pushaw	44.7	Mesotrophic	Winnisquam	34.9	Oligotrophic

- 17/32 Eutrophic (53%)
- 14/32 Mesotrophic (44%)
- 1/32 Oligotrophic (3%)

Carlson 1977. A trophic state index for lakes.

Criterion	Trophic State Index (TSI)
$TSI \leq 24$	Ultraoligotrophic
$24 < TSI \leq 44$	Oligotrophic
$44 < TSI \leq 54$	Mesotrophic
$54 < TSI \leq 74$	Eutrophic
$TSI > 74$	Hypereutrophic

Fish Sampling Methods

100' X 15'   1/16" mesh

- 5–10 hauls/**night**
- June, July, August
- Random sampling
- Enumerated all herring
- 30/haul for age & growth


USGS


USGS

Night Time…Is the Right Time

North American Journal of Fisheries Management

Article

Precision and Relative Effectiveness of a Purse Seine for Sampling Age-0 River Herring in Lakes

Matthew T. Devine, Allison H. Roy, Andrew R. Whiteley, Benjamin I. Gahagan, Michael P. Armstrong, Adrian Jordaan

First published: 22 March 2018 | https://doi.org/10.1002/nafm.10065

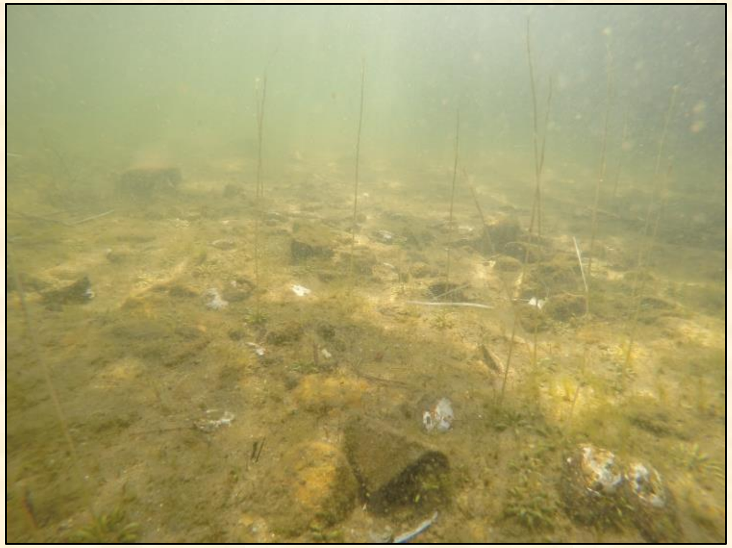
Habitat Quantity and Quality

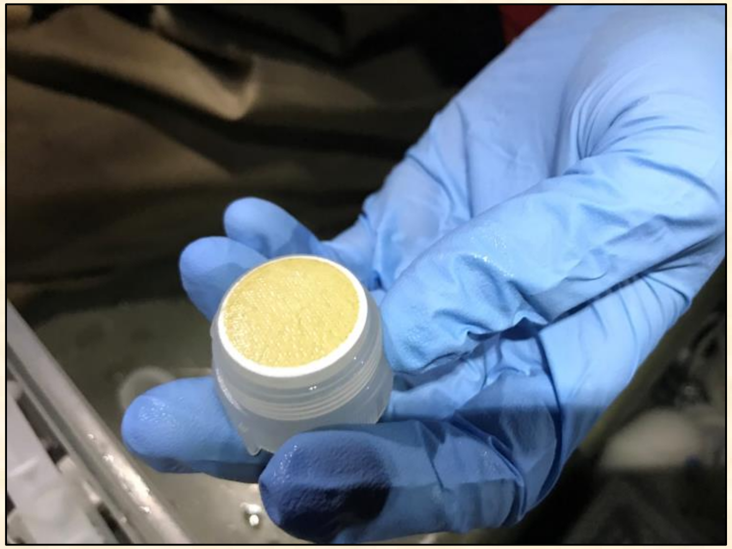
<u>Quantity</u>

- Surface area
- Depth
- Shoreline distance

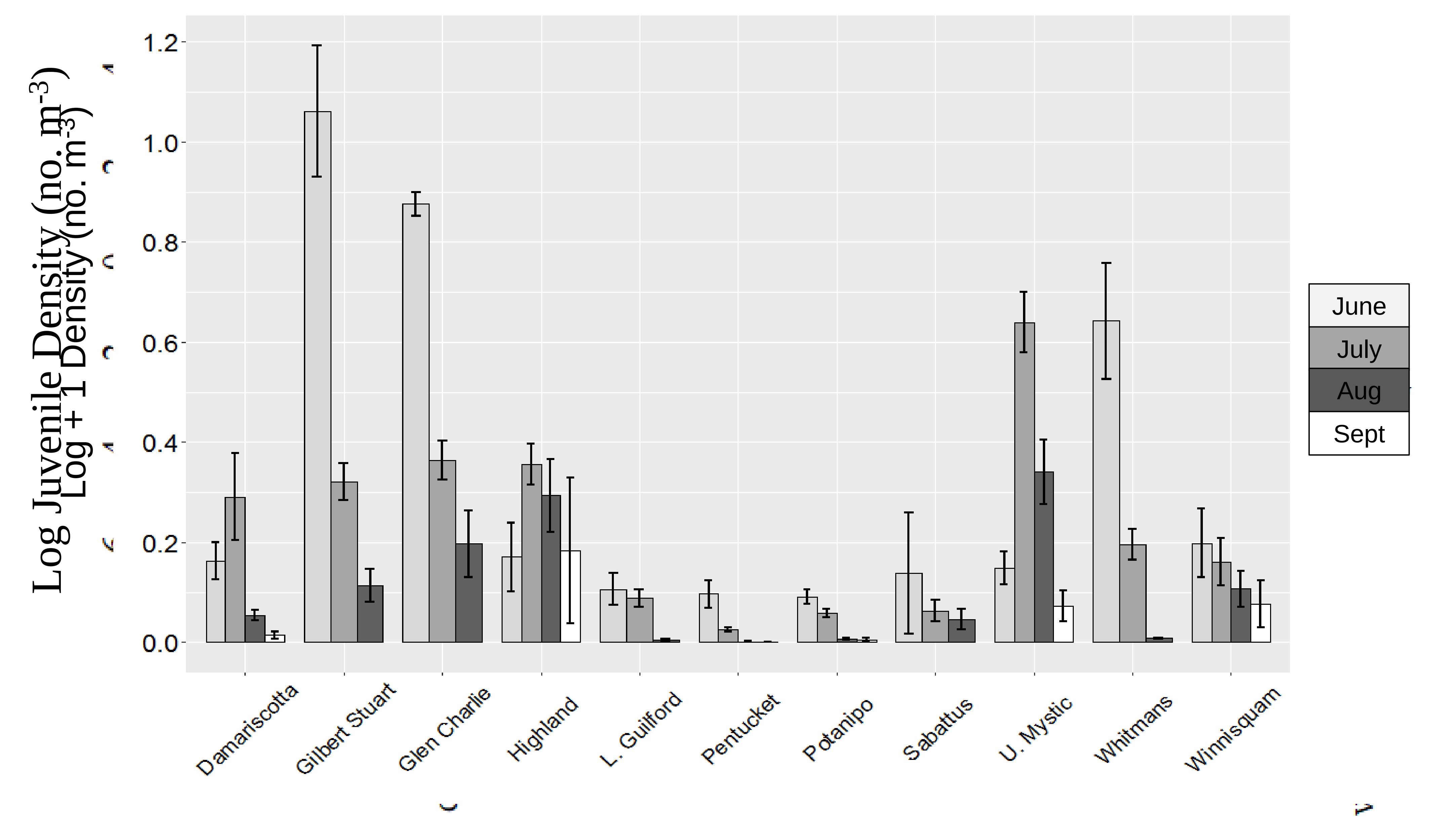
<u>Quality</u>

- Phosphorous
- Nitrogen
- Dissolved Organic Carbon
- Chlorophyll-a
- Temperature
- Dissolved Oxygen
- Secchi depth
- Zooplankton



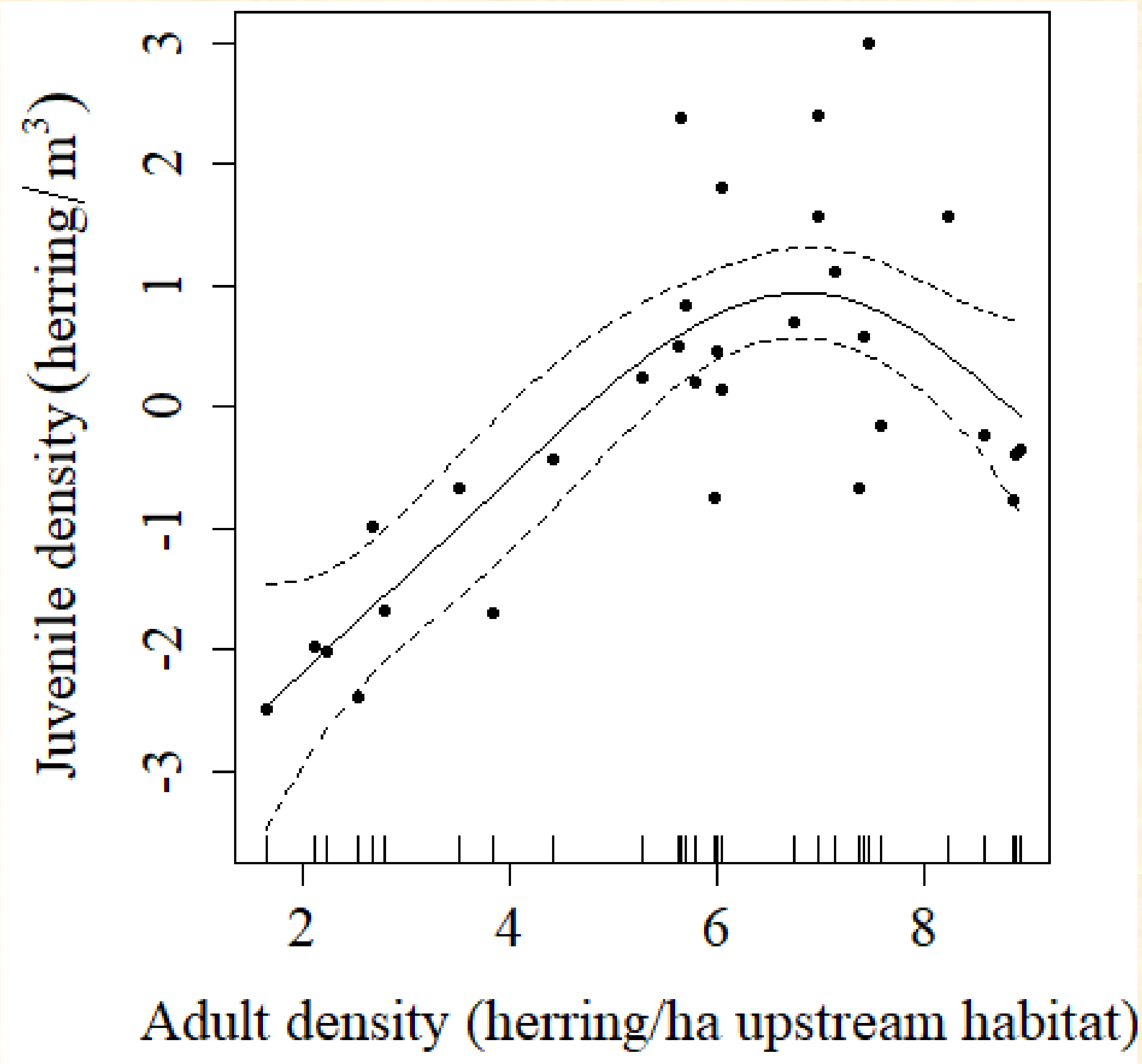


Density: Variation Within and Among Lakes

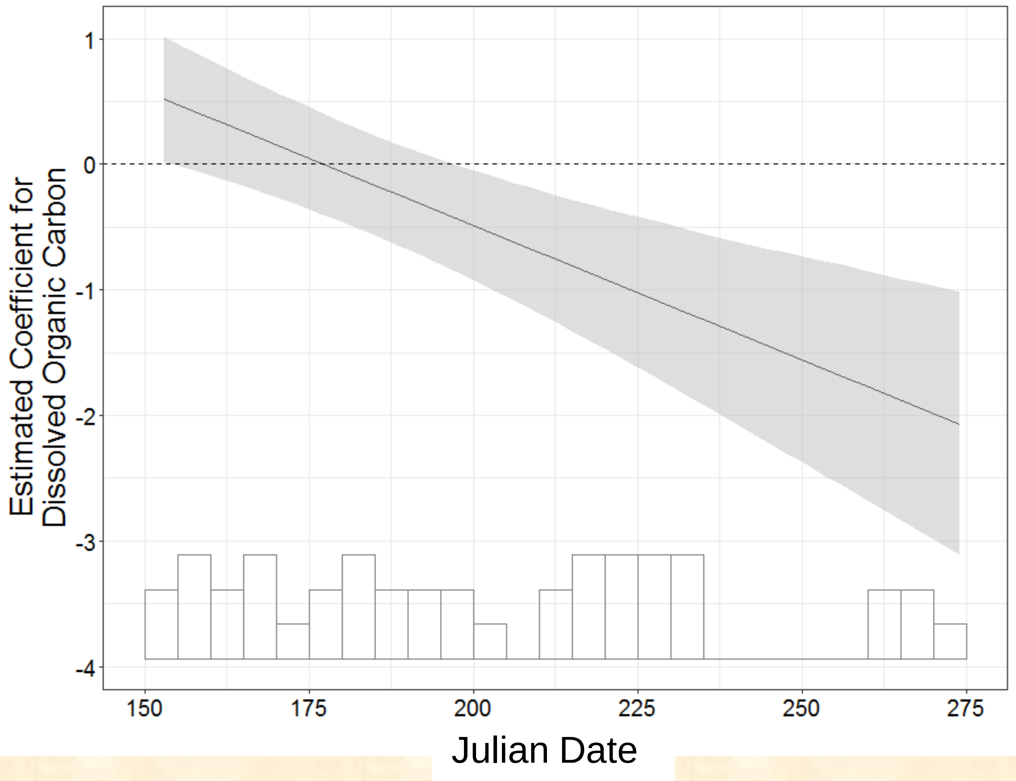


Density-Dependent Recruitment

- 64% deviance explained (GAM)
- Non-linear
- Uncertainty at high densities
- Decline in production (1k/ha)



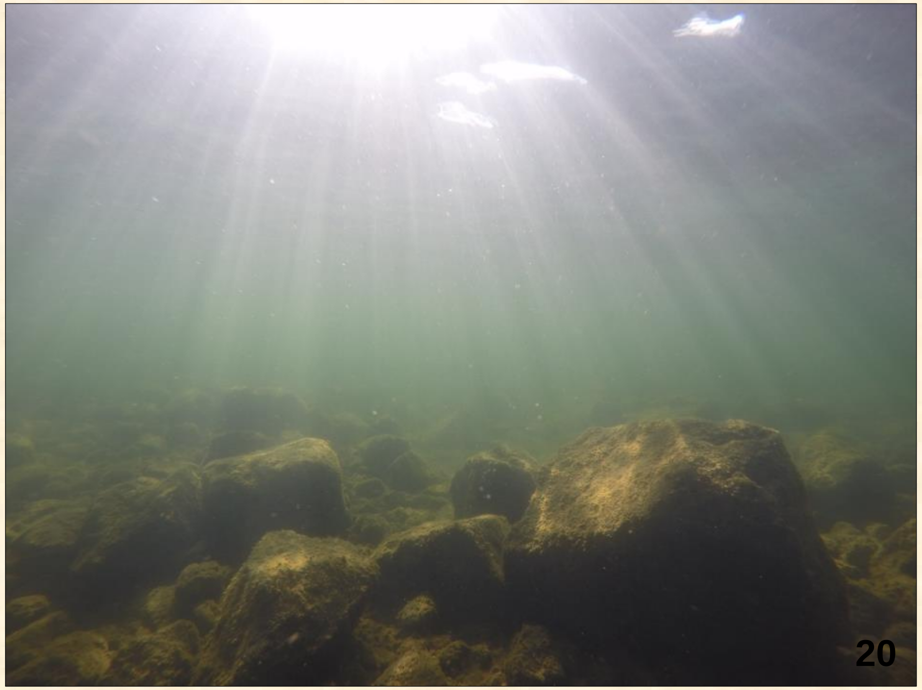
Negative Effects of Dissolved Organic Carbons



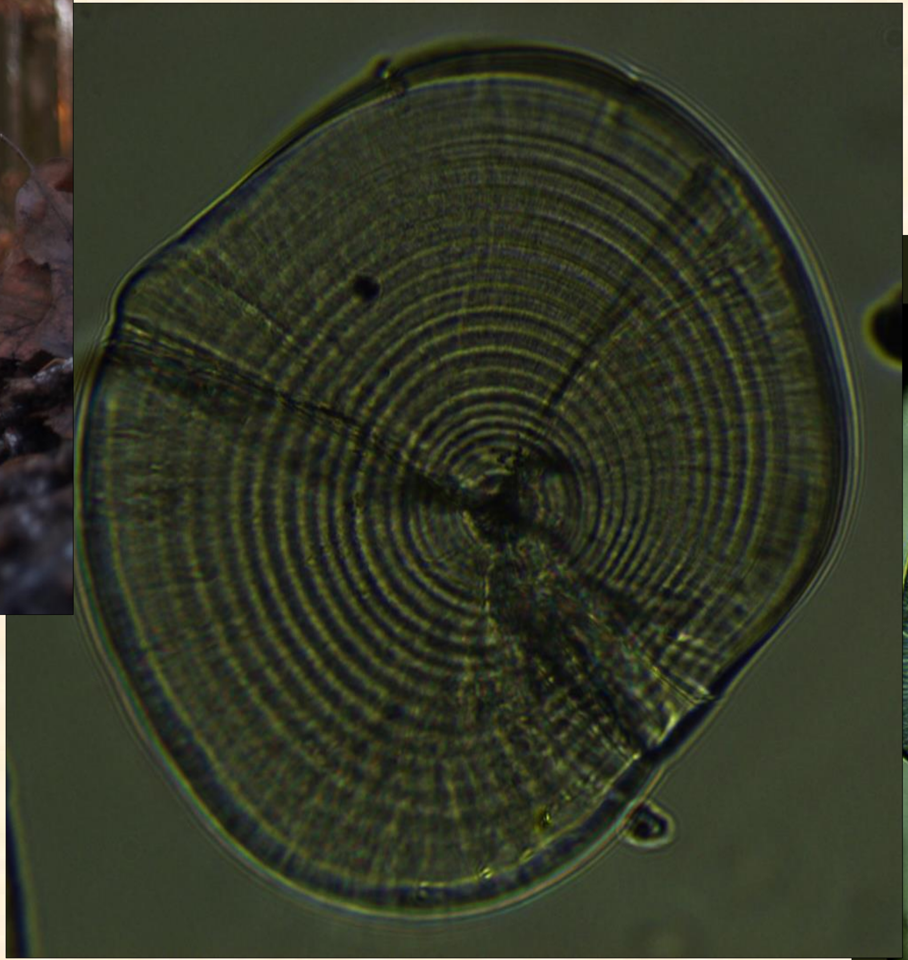
- Density negatively related to DOC
- "Browning" of water limits productivity
- Complex physical/biological effects

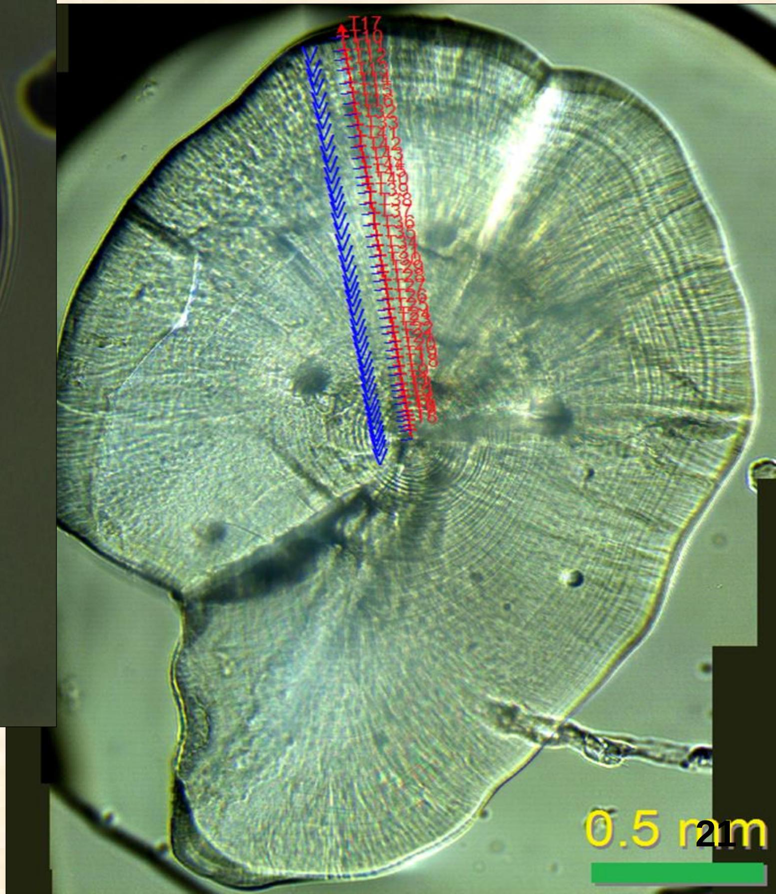
Karlsson et al. 2009 Finstad et al. 2014; Craig et al. 2017

Candidate Models	k	AICc	ΔAICc	w_i	R^2
★ DOC * Julian	6	153.31	0.00	0.94	0.76
Temp	4	160.52	7.21	0.03	0.30
Chl-a	4	161.51	8.26	0.02	0.34
DOC + Julian	4	162.33	9.02	0.01	0.23
Temp + Chl-a	5	163.24	9.82	0.01	0.33

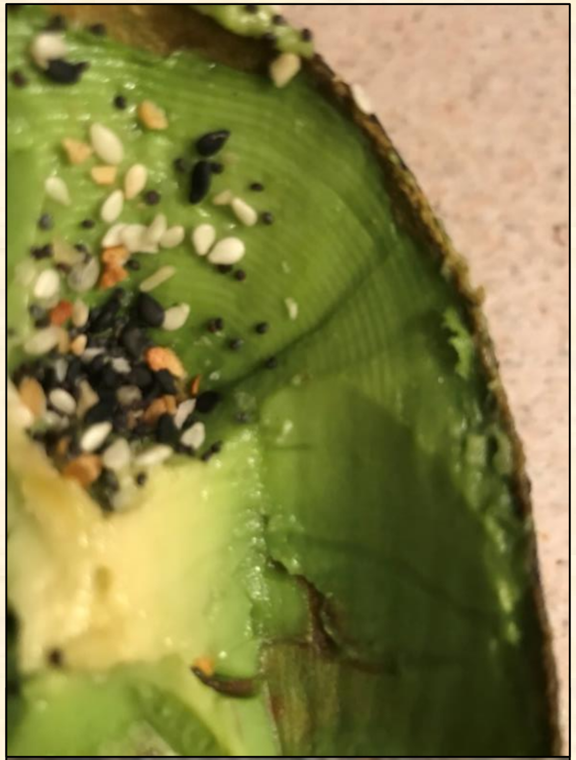


Otoliths Provide Growth History

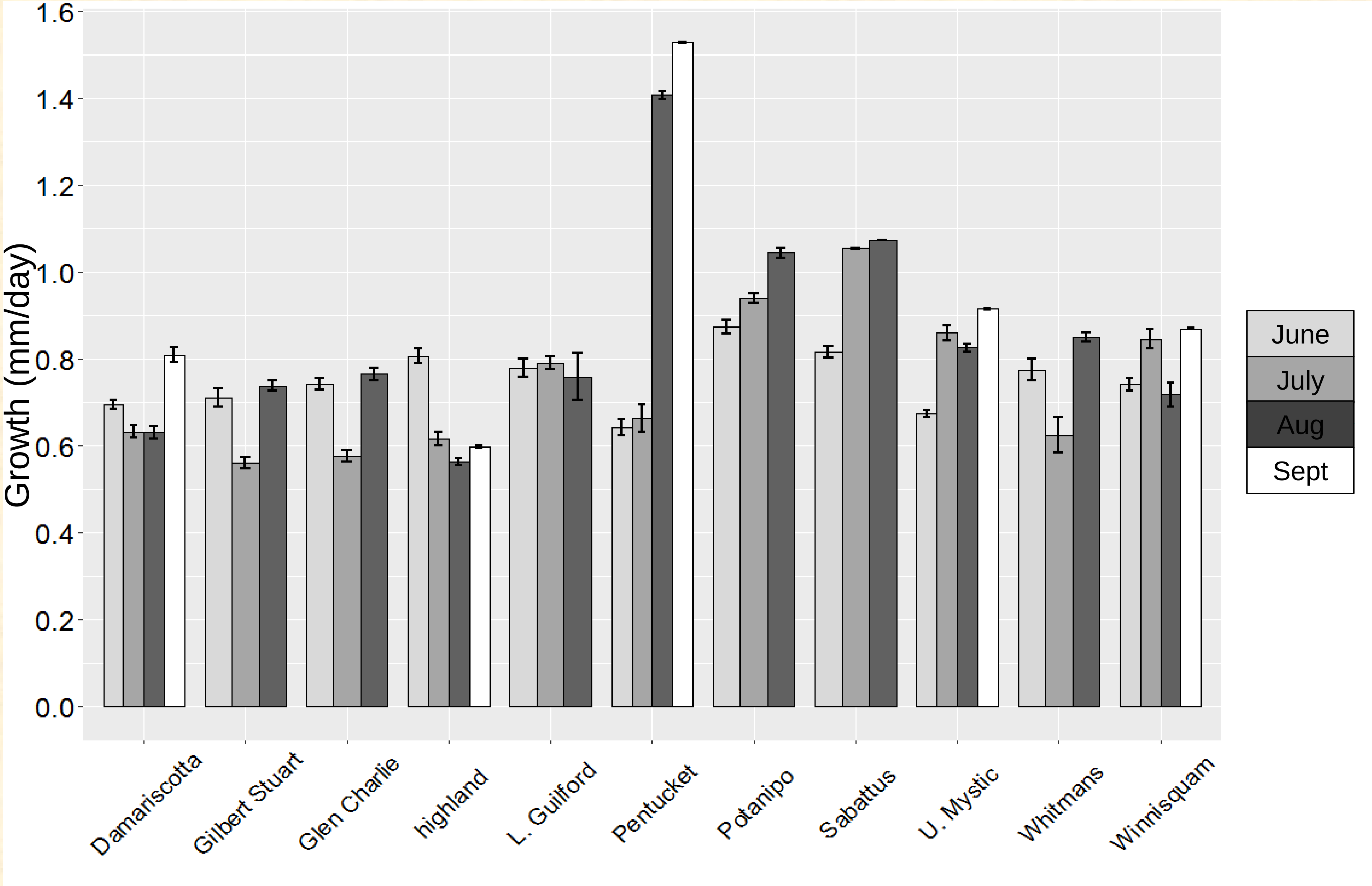




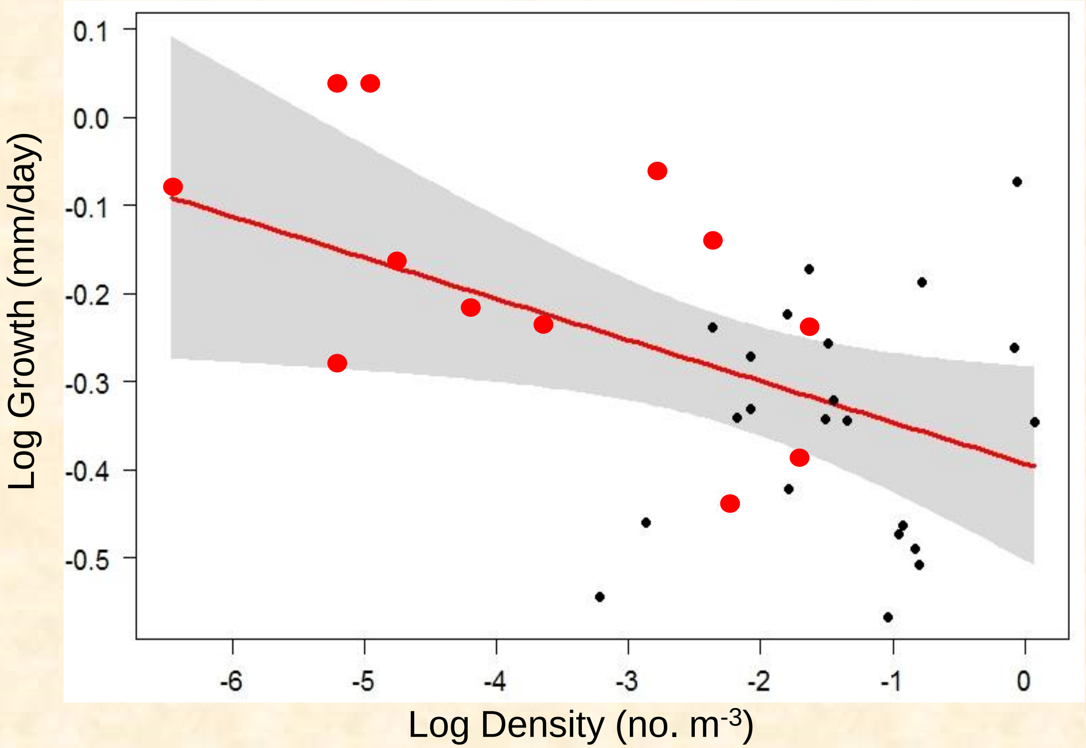
Otoliths on the Mind



Growth: Variation Within and Among Lakes



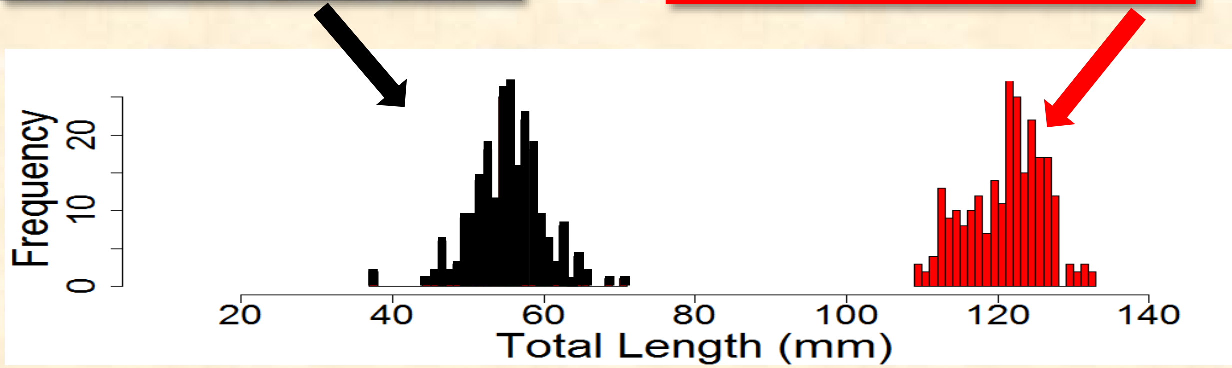
Density-Dependent Individual Growth



- Growth negatively related to density
- Leads to variation in size-at-age

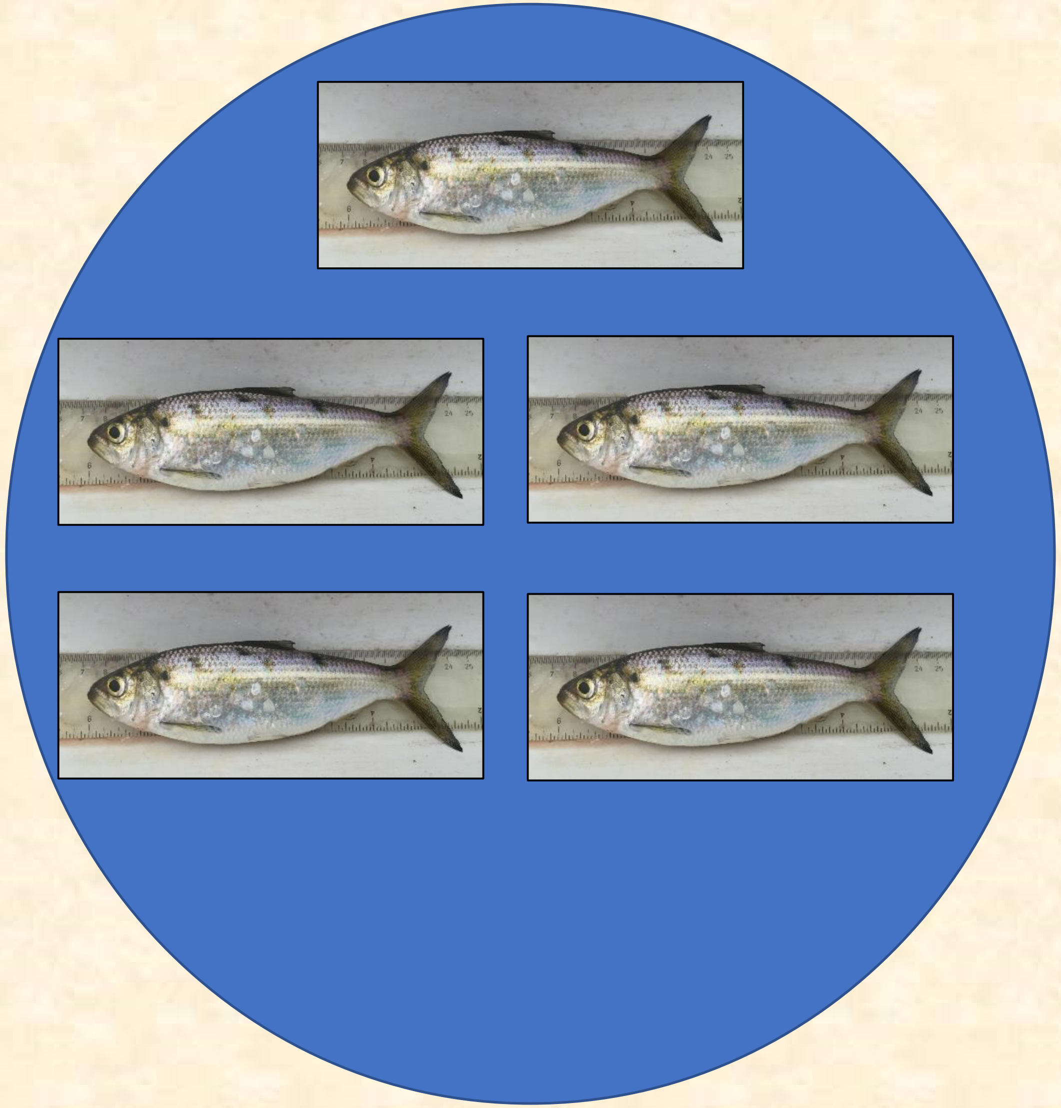
August 2015

August 2015

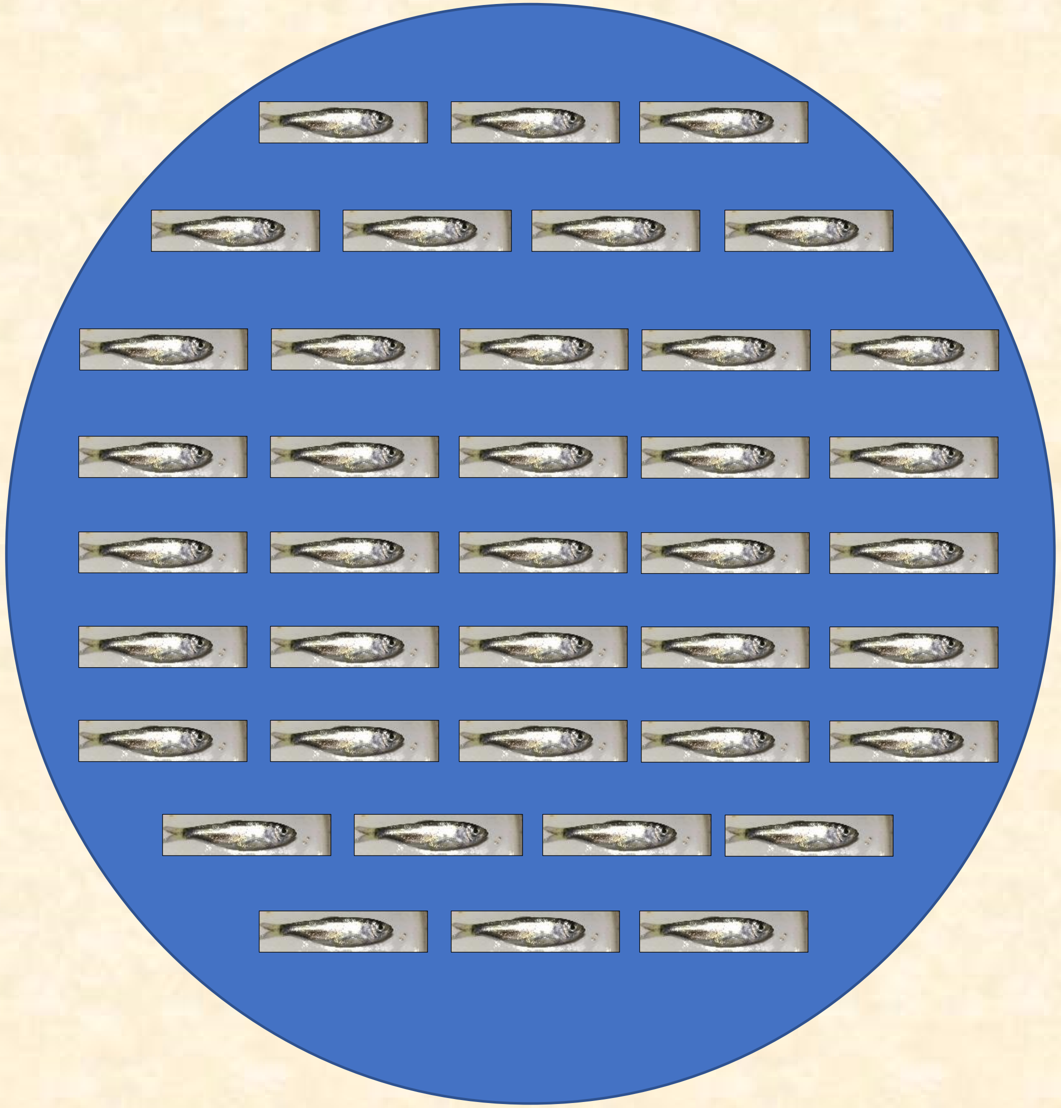


Density-Dependent Individual Growth

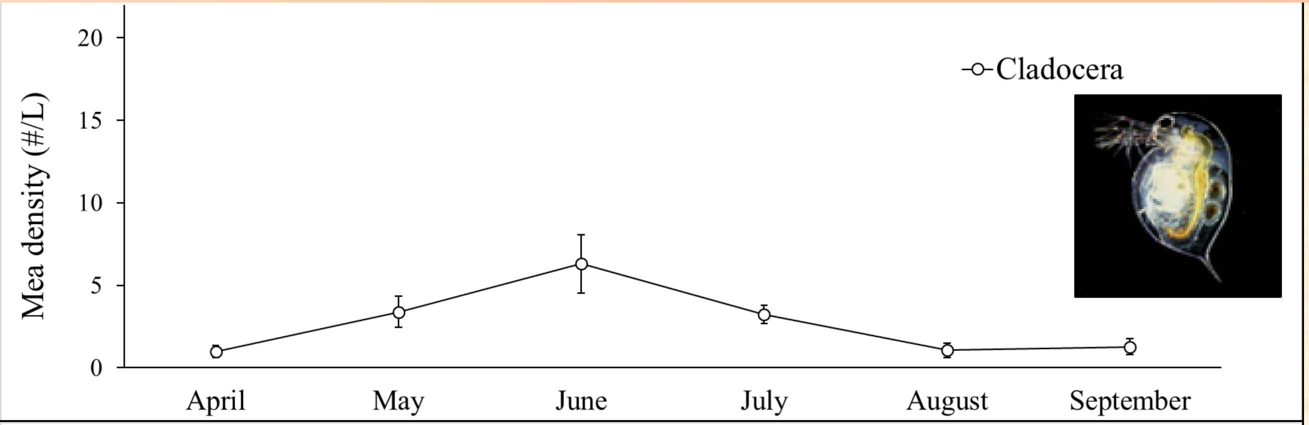
Low fish density = faster growth



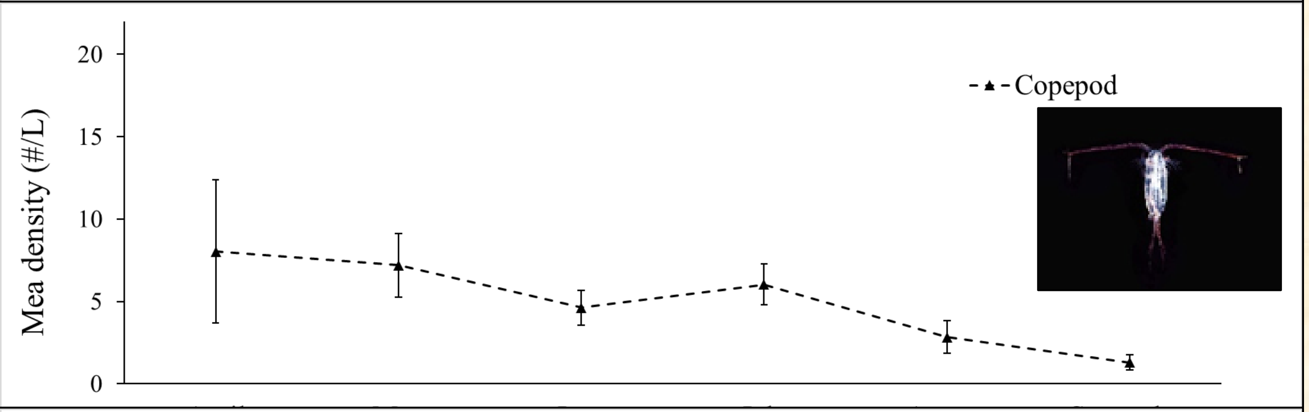
High fish density = slower growth



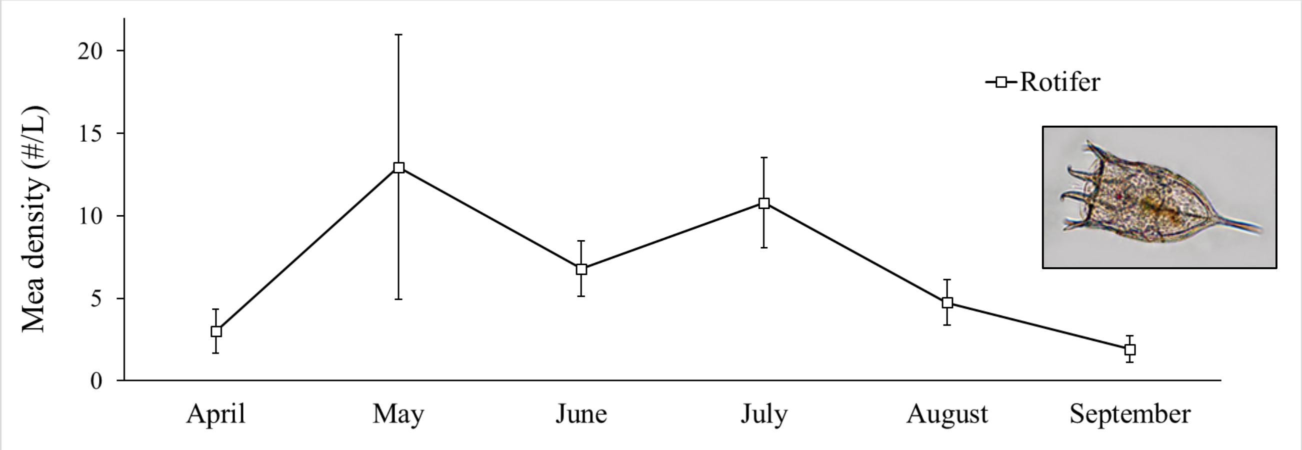
Zooplankton Dynamics



- Larger bodied
- Preferred by herring
- Peak in June – then steady decline

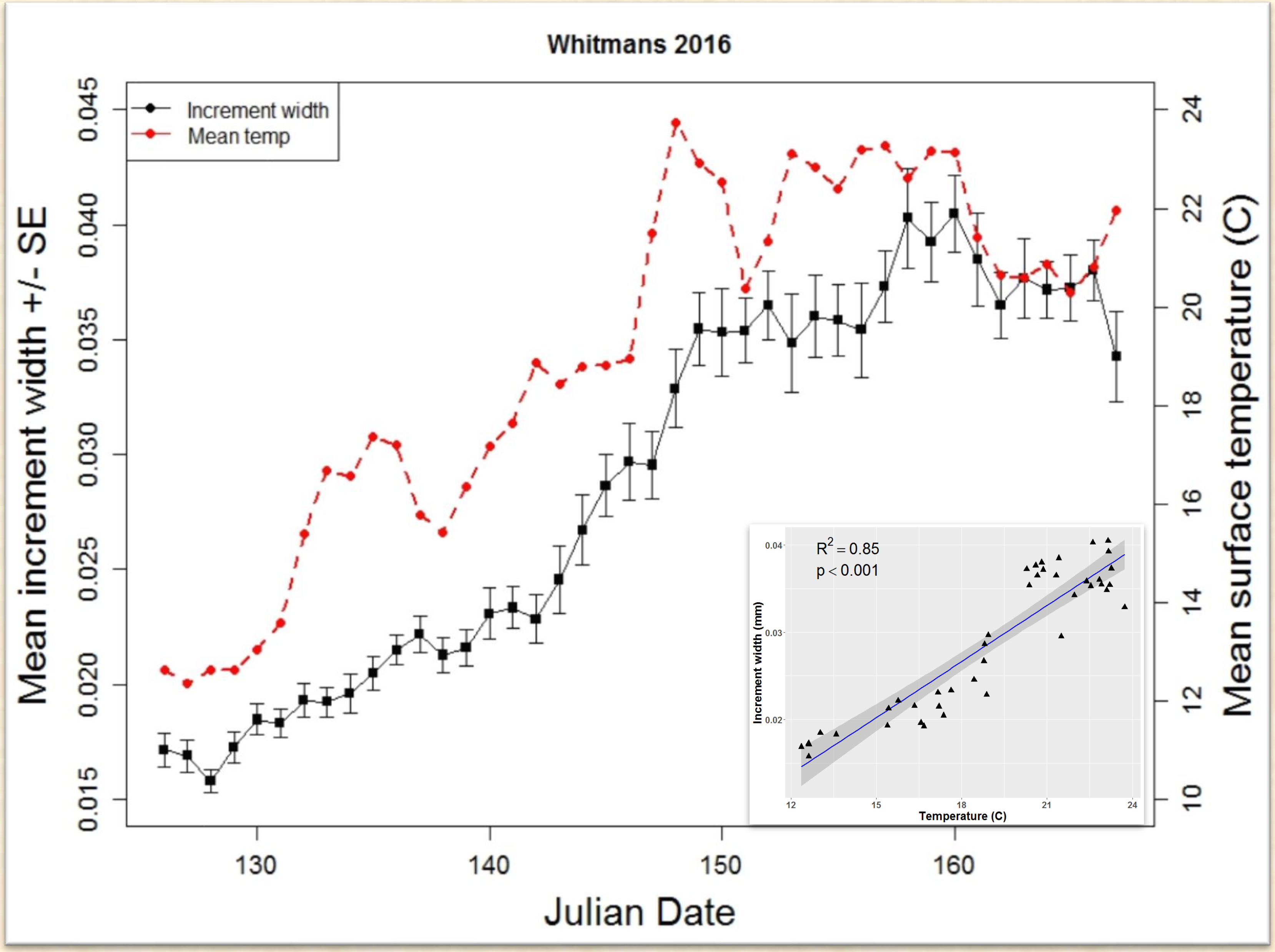


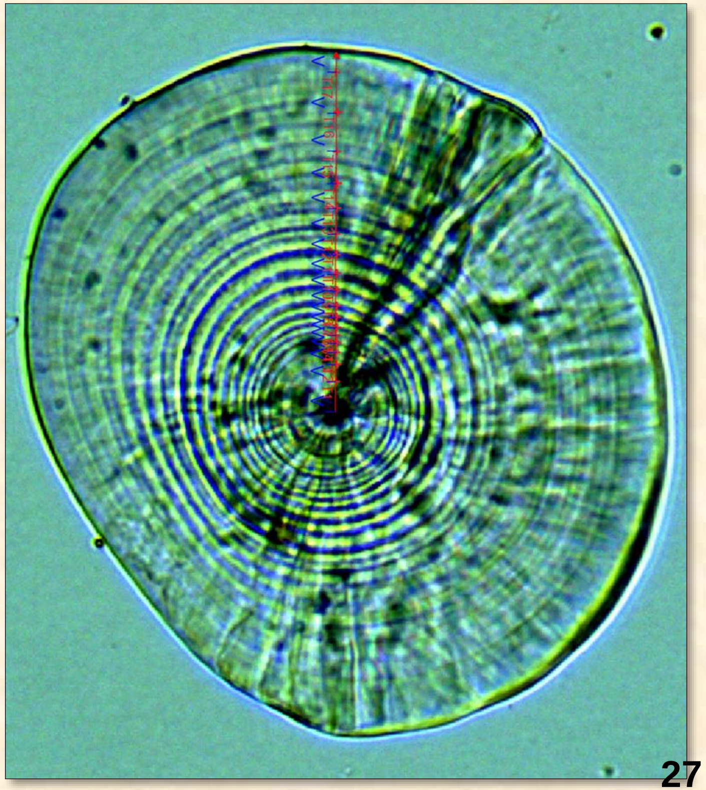
- Common, small crustaceans
- More abundant than cladocerans
- General decline



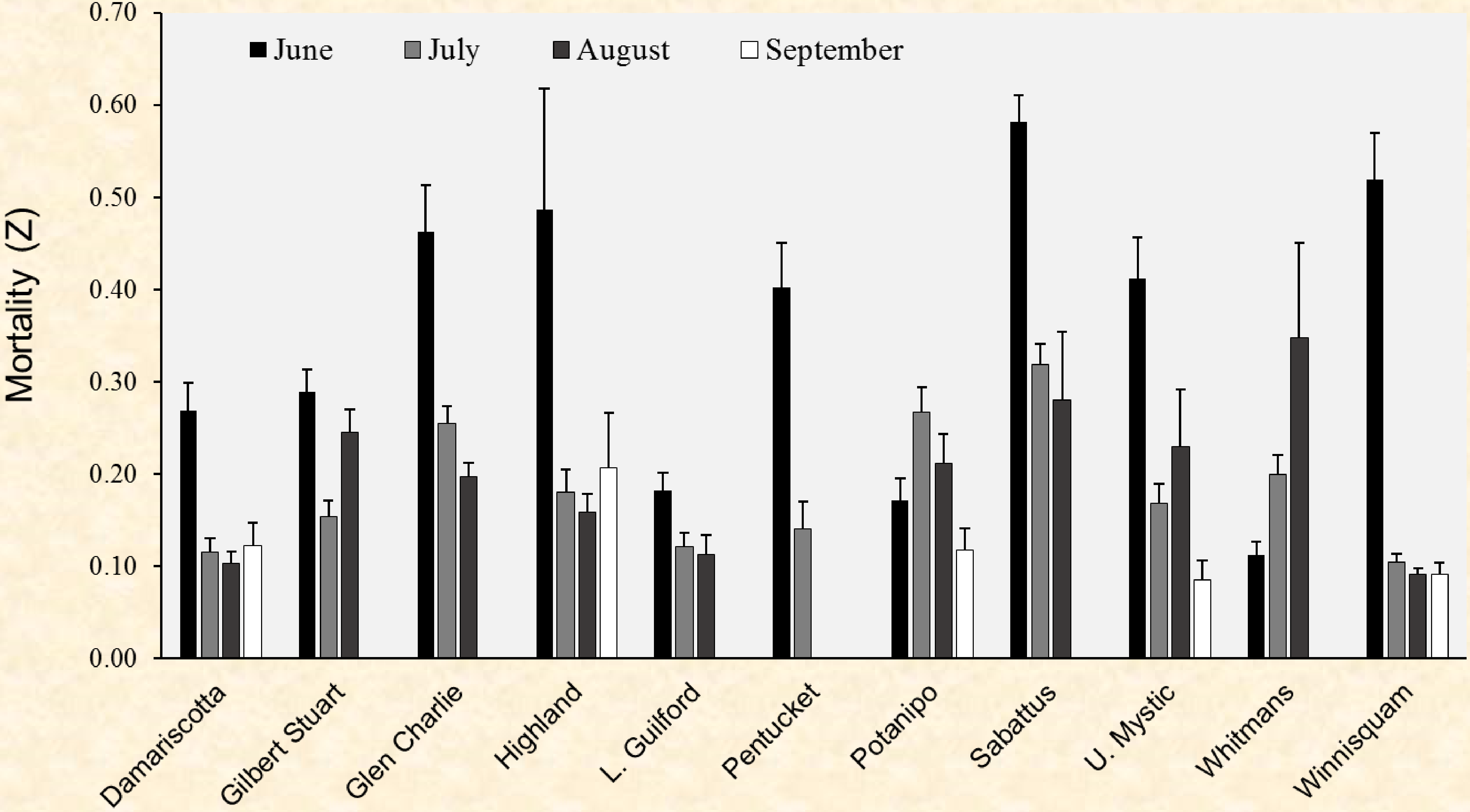
- Most abundant/smallest order
- Largest variation across lakes
- Heavy predation by larvae

Daily Growth Related to Temperature

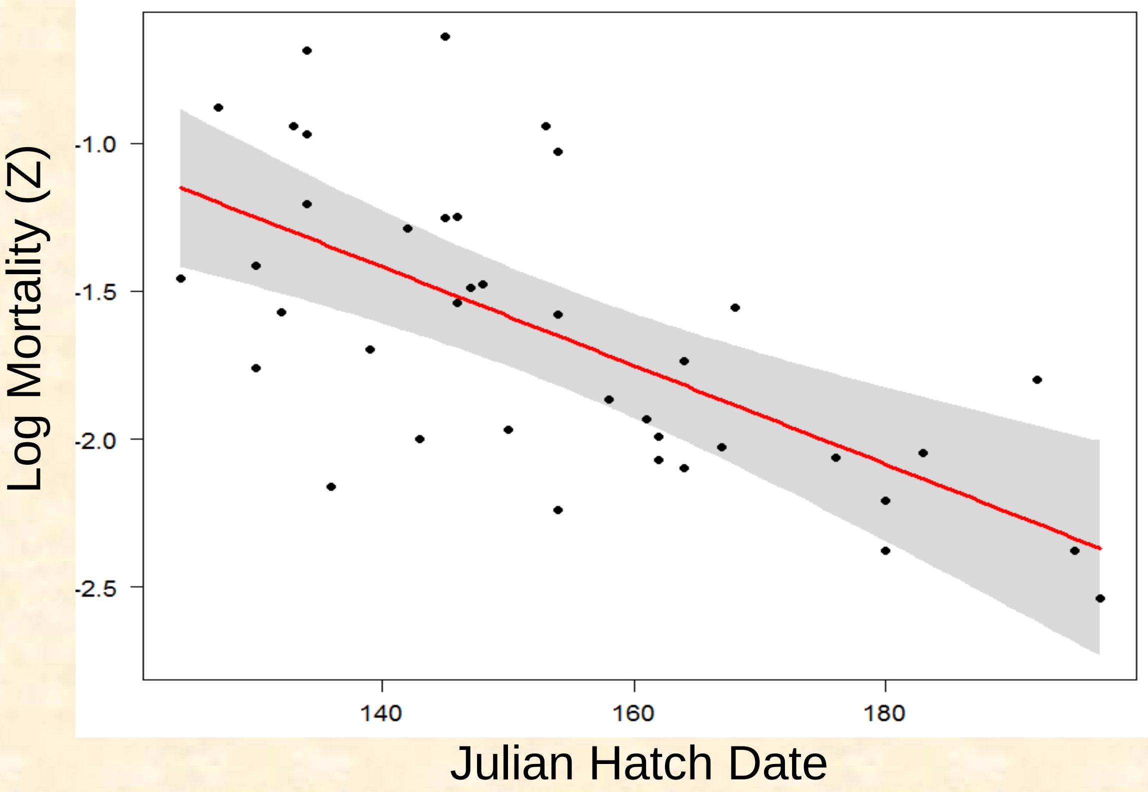




Mortality: Variation Within and Among Lakes



Mortality



- Hatch date & mortality inversely related
- Hatch early, die young
- Cooler water temperature, predation, starvation


Density, Growth, & Mortality Summary

<u>Juvenile Density</u>

- Adult run size plays a significant role
- DOC best water quality predictor
- Habitat quality <u>and</u> quantity?

<u>Juvenile Growth</u>

- Fish density strongest driver of growth
- Daily growth correlated with temperature
- Weak influence of TP, TN, chlorophyll-a

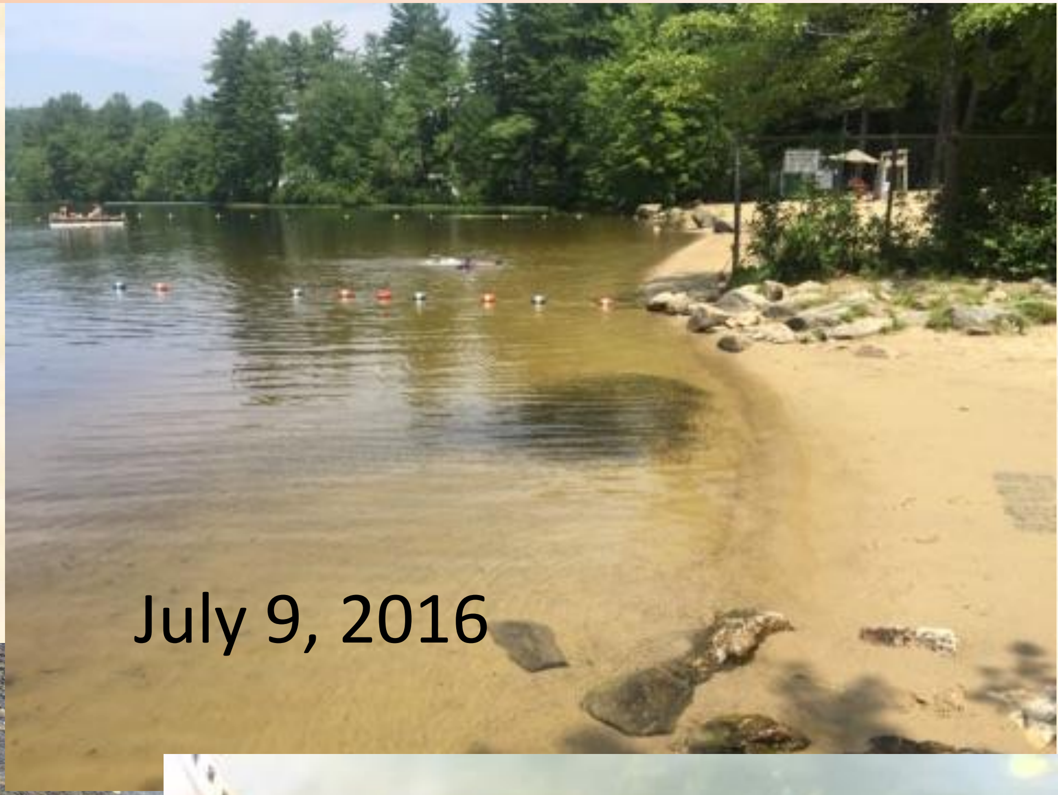
<u>Juvenile Mortality</u>

- Early hatching correlated with high mortality
- Not a “closed” system
- Most likely <u>overestimating</u> mortality

Grow Fast, Leave Early: Recipe for Survival?

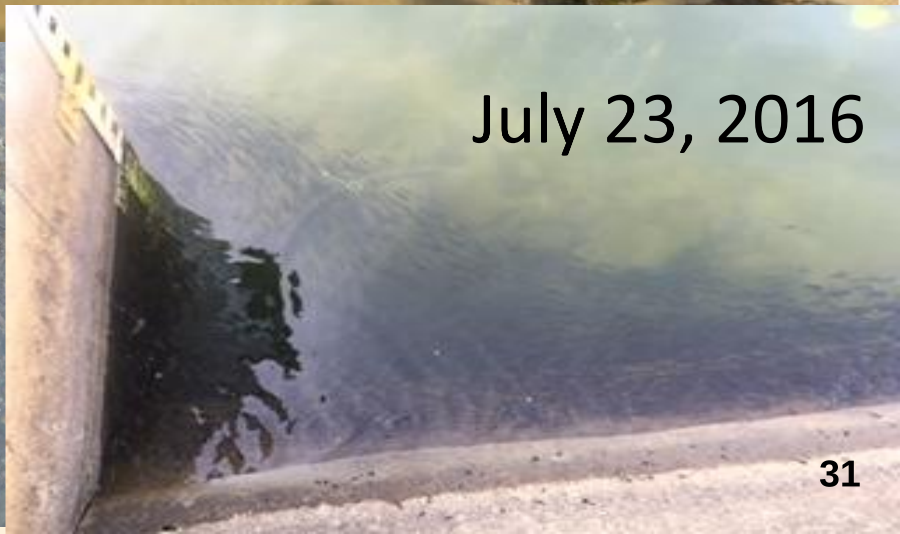
Consequences of Stranded in Lakes

- Increased competition
- Slower growth rates
- Thermal stressors
- Altered diet (less preferable items)
- Limited nutrient flux



Challenges to Emigration

- Drought
- Lake drawdowns
- Low flow events



Ongoing and Future Research

Interannual Variability

- How does density, growth, mortality vary year to year?

Estuary Production

- What is the most effective sampling method?
- To what extent do estuaries contribute to year-class strength?
- Identify bottlenecks in production

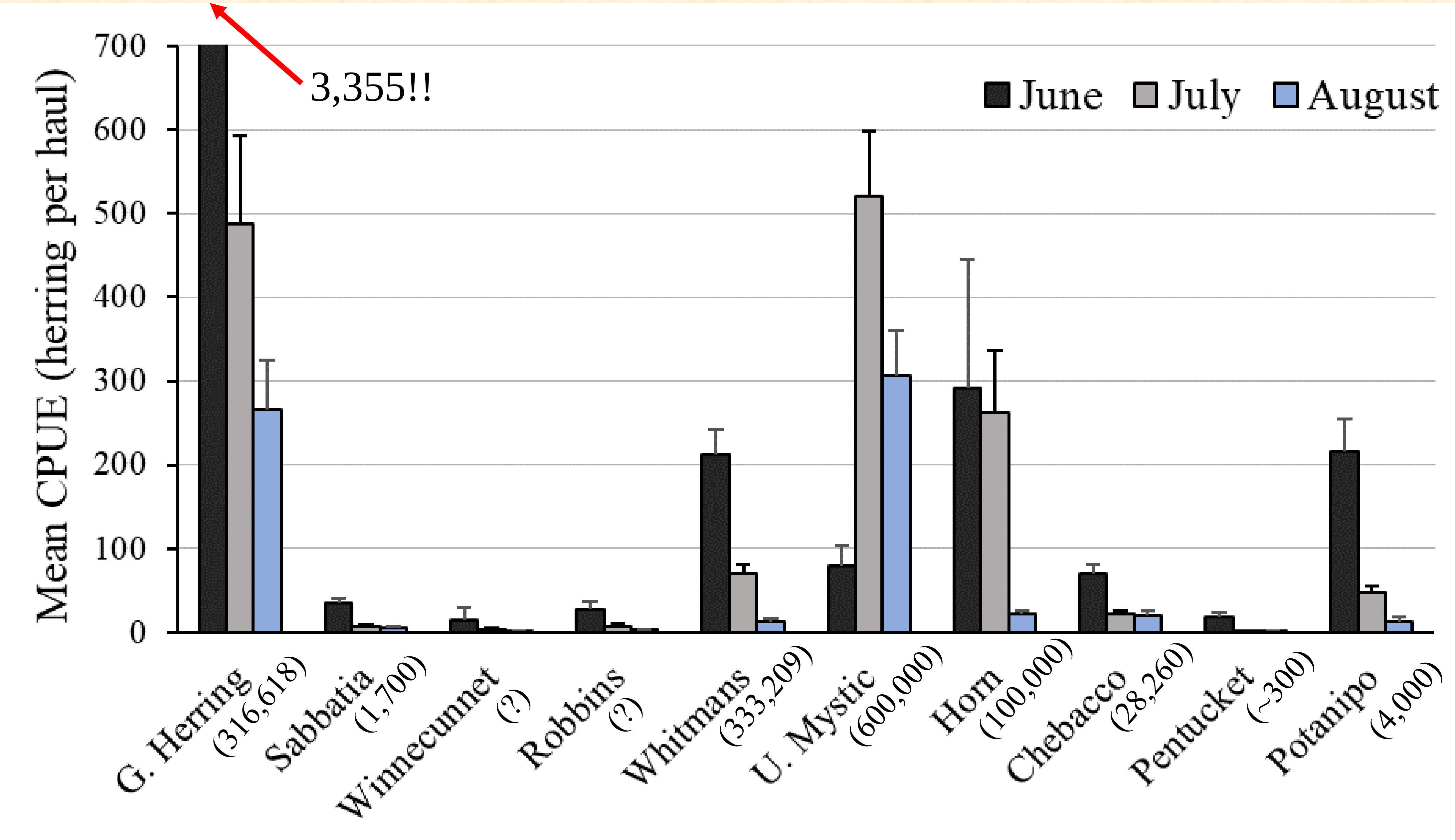
Response to Dam Removal

- What is the magnitude and timing of recovery?
- How does production compare to natural runs?

Thank You

mtdevine@umass.edu

Initial Results



Management Implications: Habitat

- Measures of *effective* habitat
  - -Lacking information on spatial distribution

- DOC negatively related to thermocline
  - -Factors affecting water clarity will also likely affect thermal gradients, and thus juvenile densities