Lake Michigan CSMI Update

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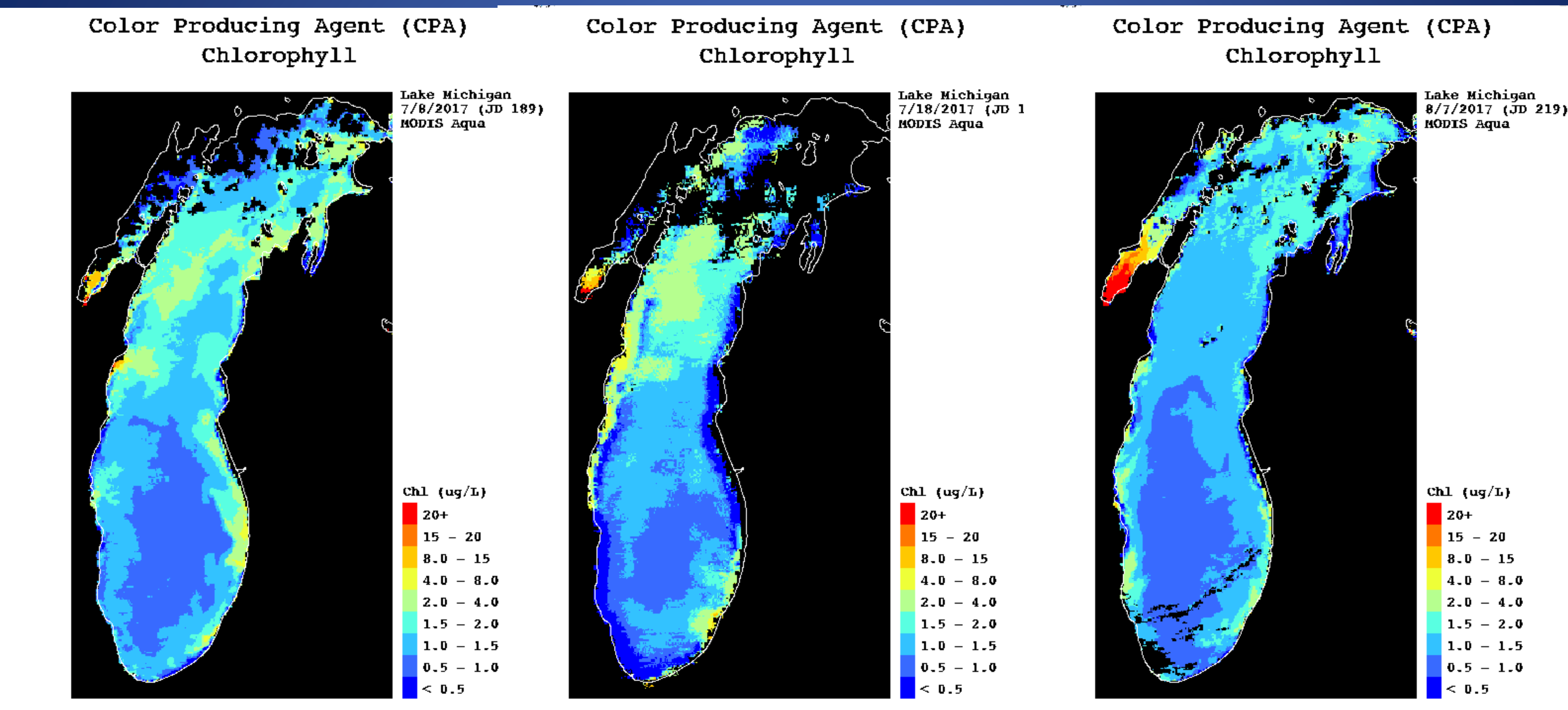
CSMI Priority:

Improve understanding of the distribution and abundance of nutrients and biota across a nearshore to offshore gradient.

Inform “nearshore strategy” called for in the 2012 Great Lakes Water Quality Agreement.

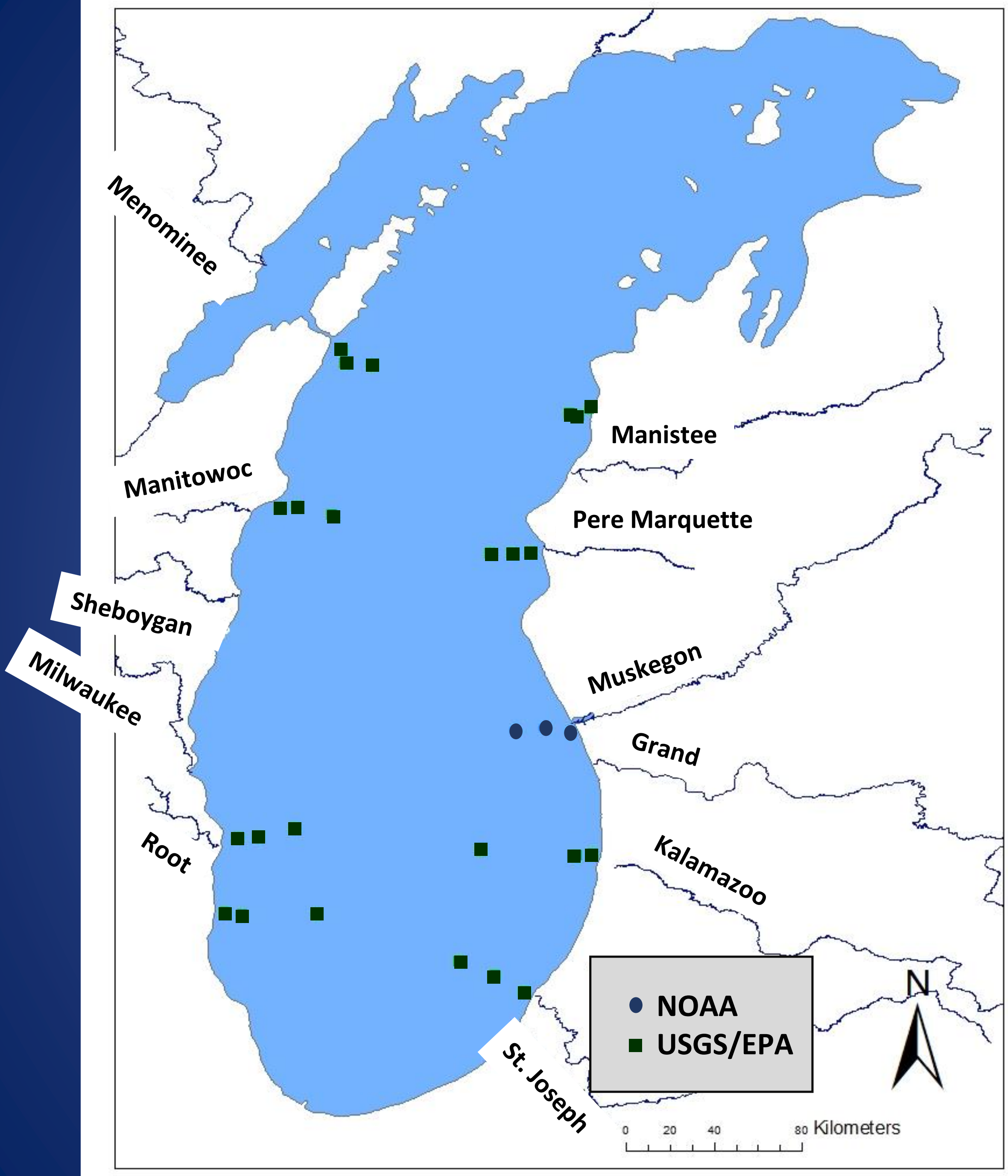
Lake Michigan Lower Trophic Level Task Team (2016-2017)

Enhanced nearshore productivity visible from remote sensing



NOAA CoastWatch Great Lakes

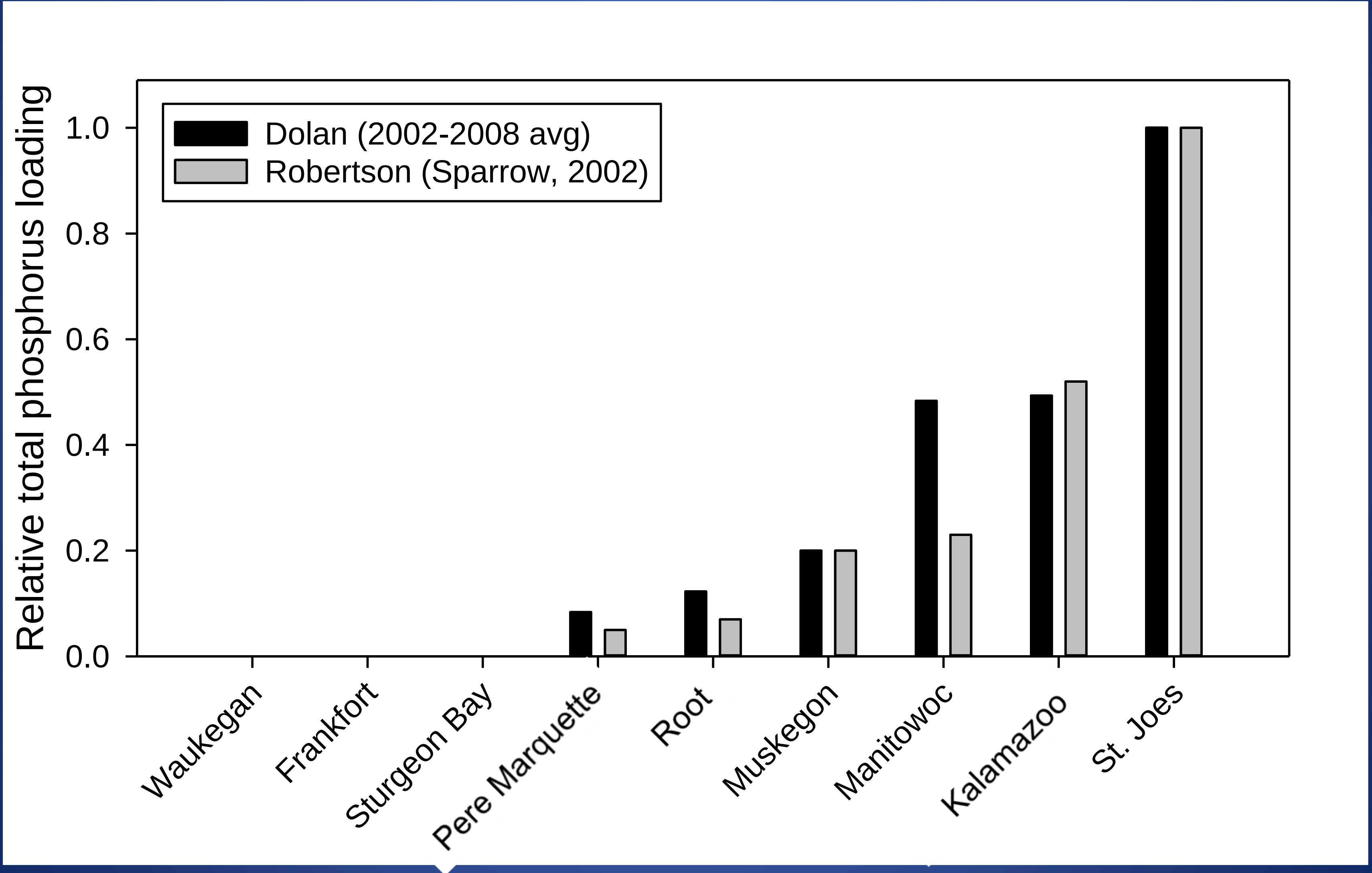
Michigan Tech Research Institute



2015 Sampling sites

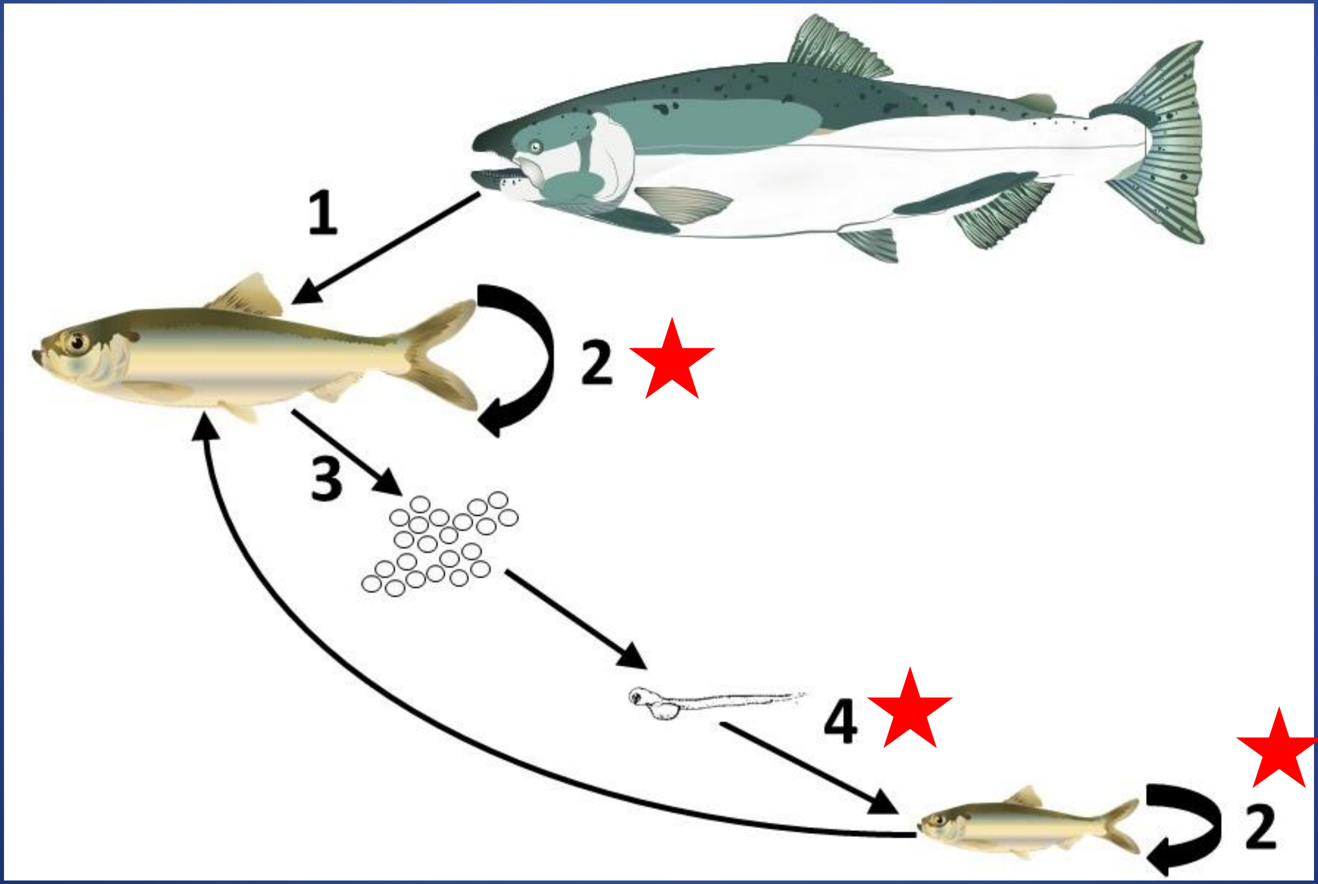
- USGS- Night work
- Spring, summer, autumn
- Three depths per site (18, 46, 90-110 m).

Phosphorus loading from adjacent tributaries



Hypothesis:

Larval fish growth and juvenile/adult energetic condition should be positively related to productivity.

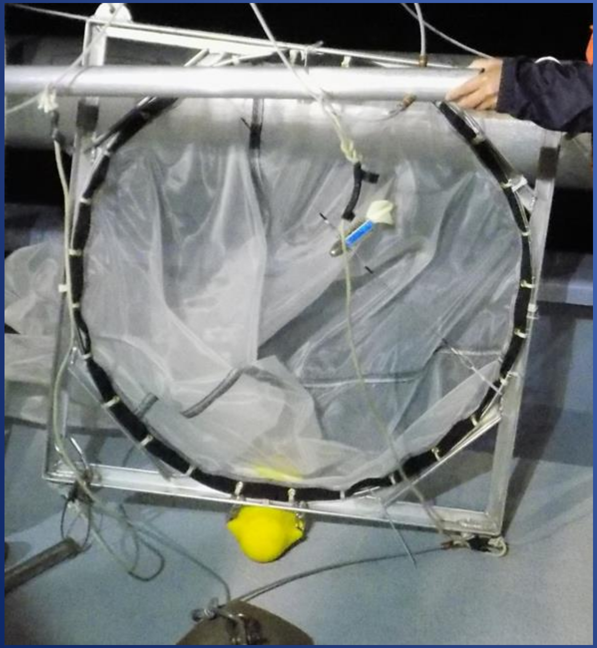


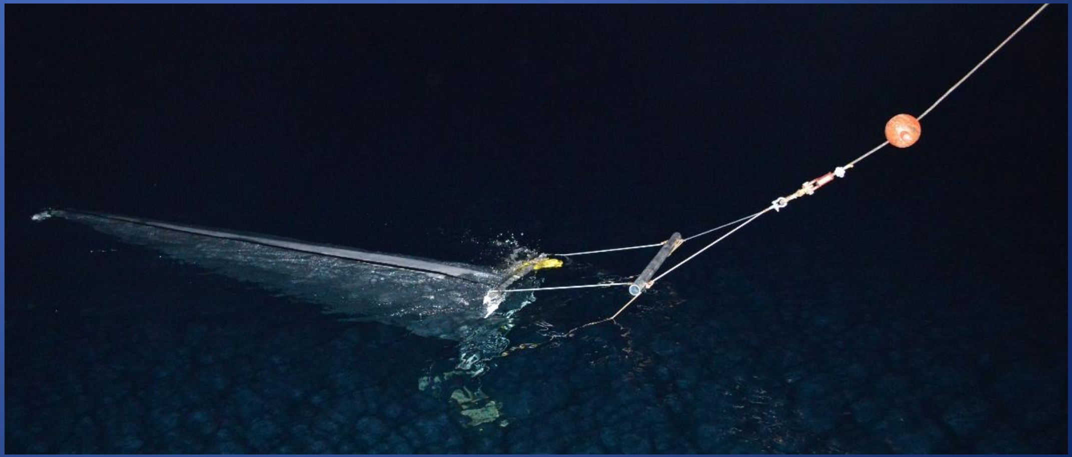
Bunnell et al. 2018 GLFC Technical Report

Methods- Larval alewife

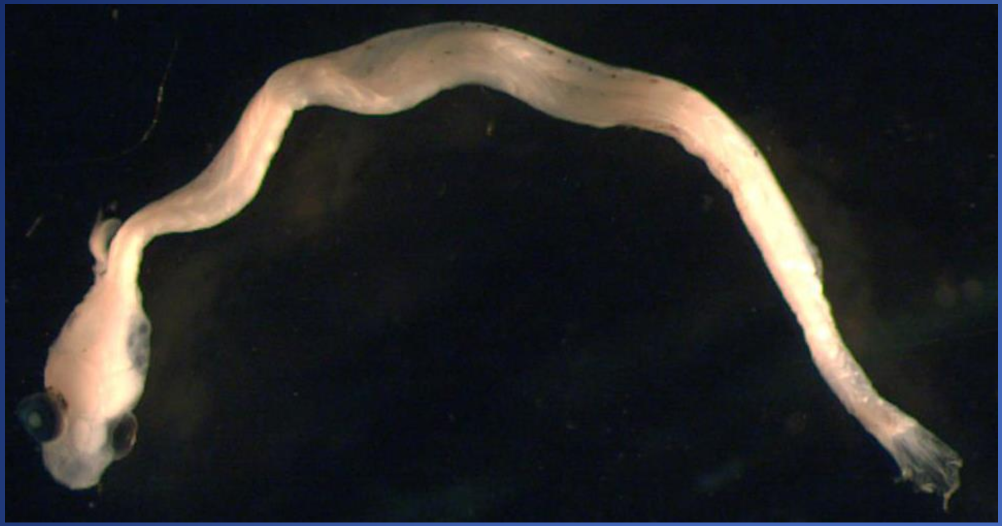
Larval fish growth rates

- Sampled 8-27 July 2015.
- 1-m diameter circular net
- Flowmeter estimated distance, Netmind provided real-time depth
- Two tows per site: Oblique (water column) and Surface





Methods- Larval alewife



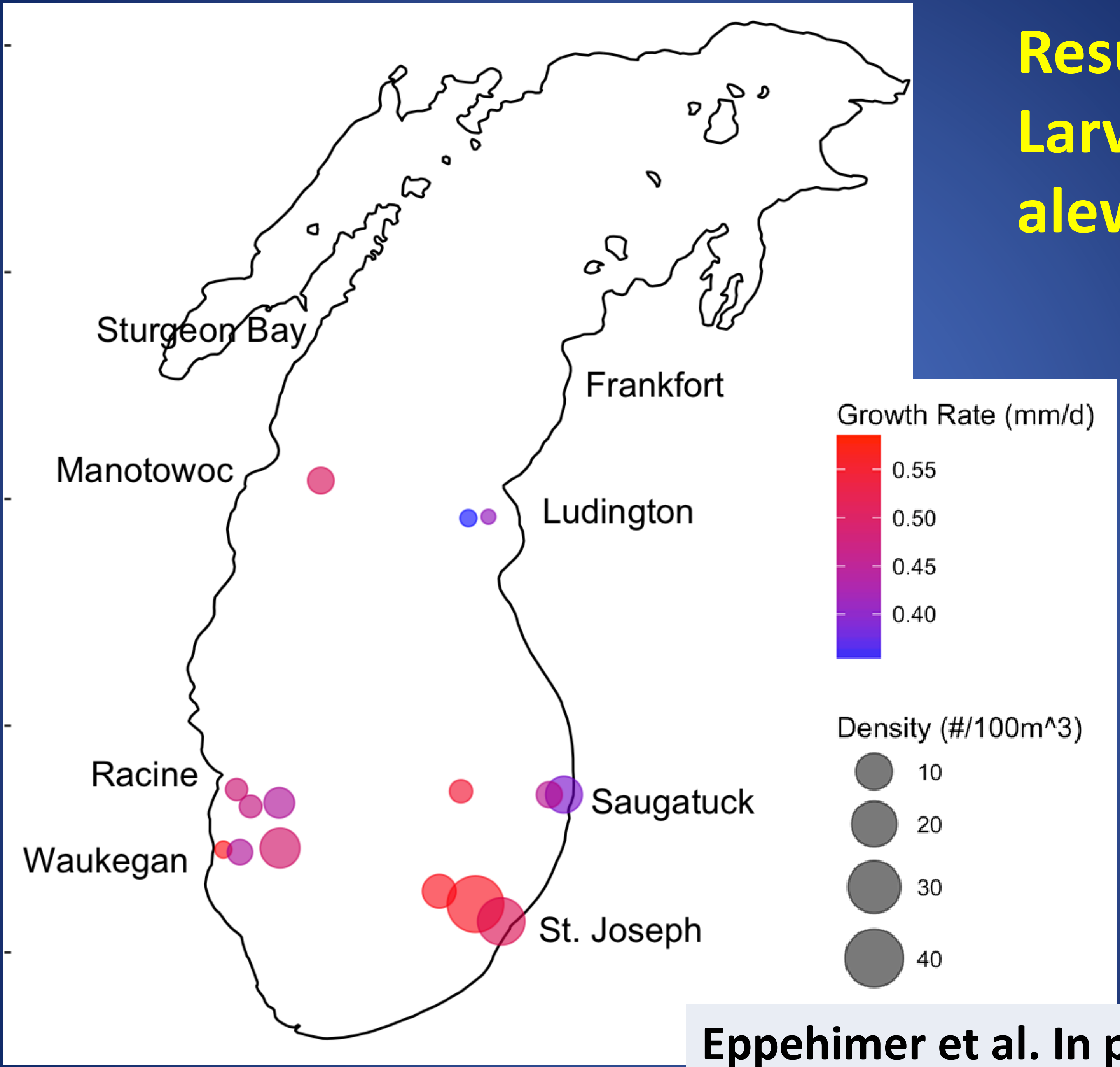
Larval alewife, TL @ hatch = 3-5 mm

28-day old alewife collected at 46 m

Instantaneous growth = (TL – 3.5 mm)/Age

(Essig and Cole 1986; Auer 1982)

Results: Larval alewife



Eppehimer et al. In preparation

Explanatory variables for larval growth

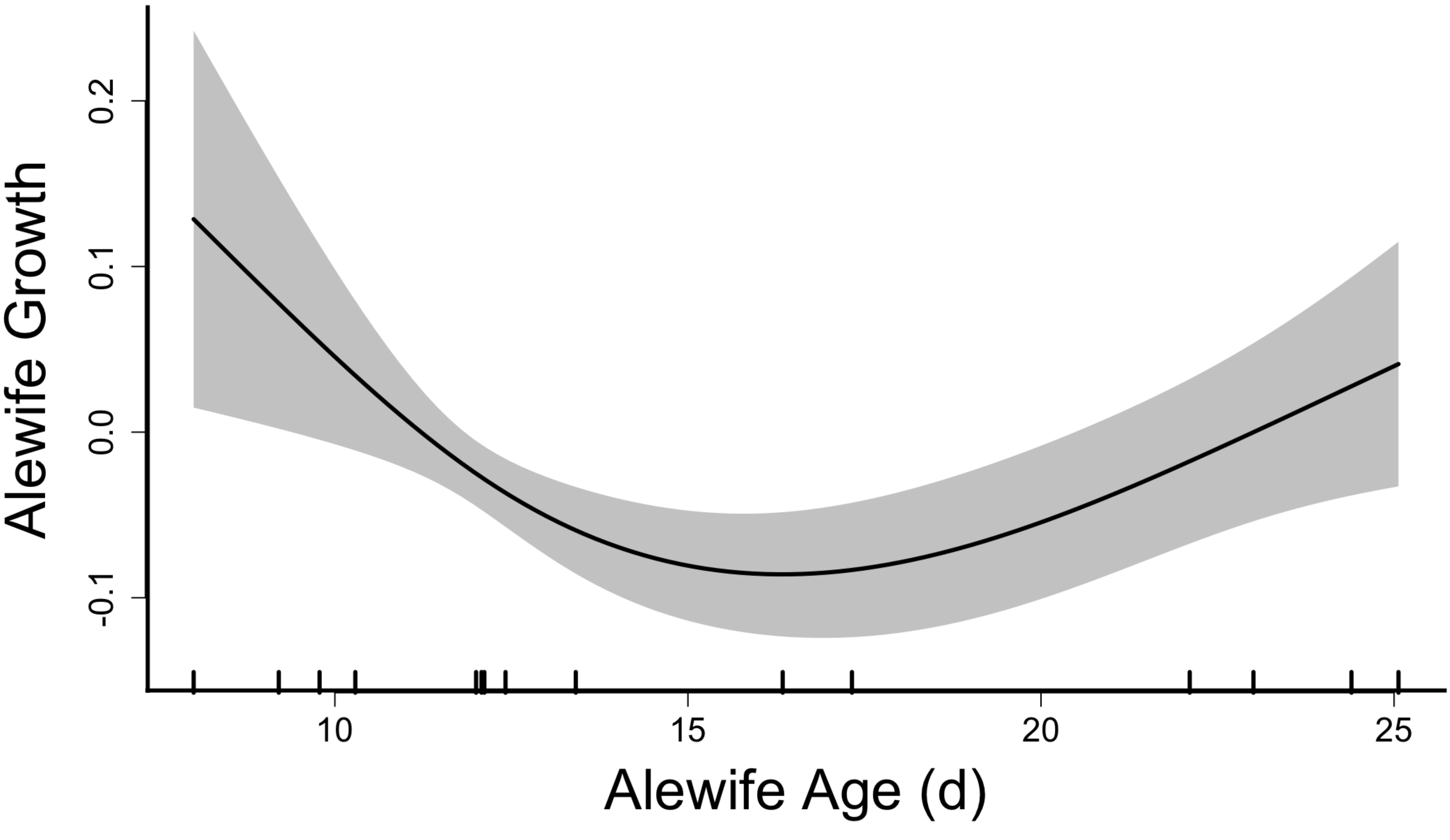
- **Zooplankton density (day of capture)**
- **Temperature (lifetime)**
- **Larval density (day of capture)**
- **Mean age (covariate)**

Generalized Additive Model

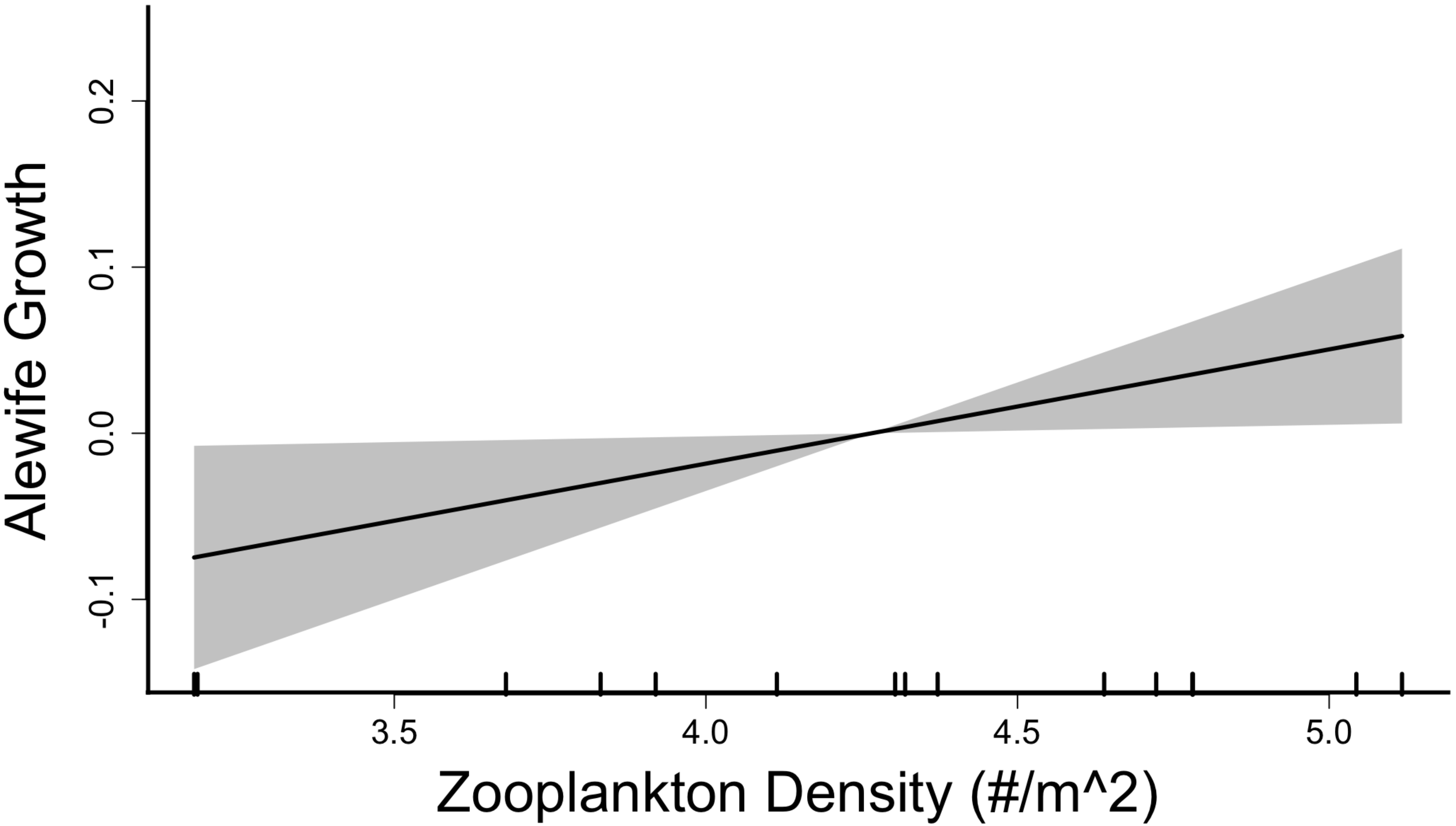
Results: Explain larval fish growth

Model	Age	ZP	Density	Temp.	AICc	Delta AICc	Weight
A	X				-45.49	0	0.48
B	X	X			-44.68	0.81	0.32
C		X			-42.66	2.83	0.12
D	X		X		-41.07	4.42	0.05
E	X			X	-40.18	5.31	0.03

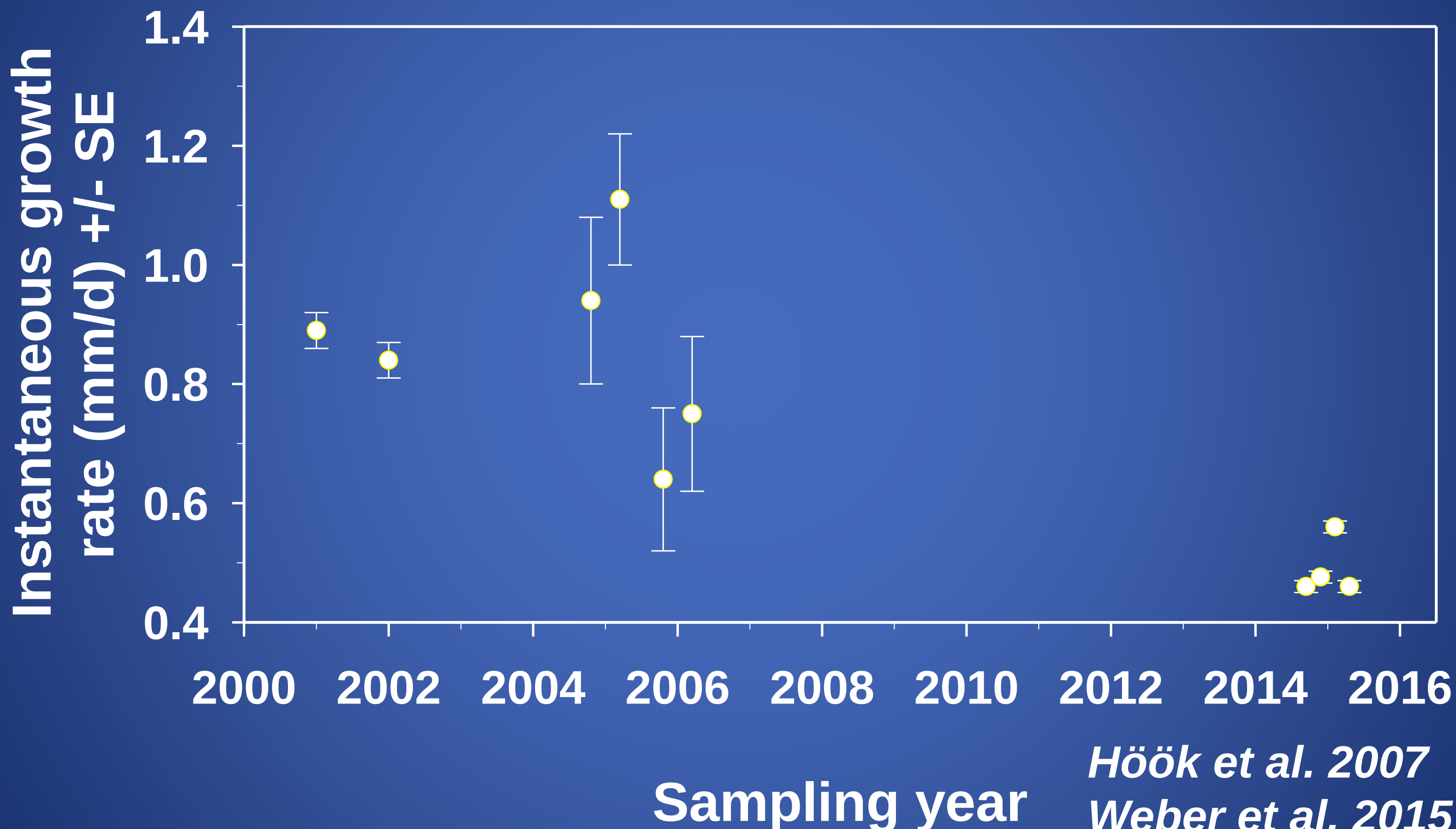
Larval growth rate varies with age



Larval growth increases with zooplankton density



Slower larval alewife growth in 2015



Höök et al. 2007
Weber et al. 2015

Comparing southern sites, only

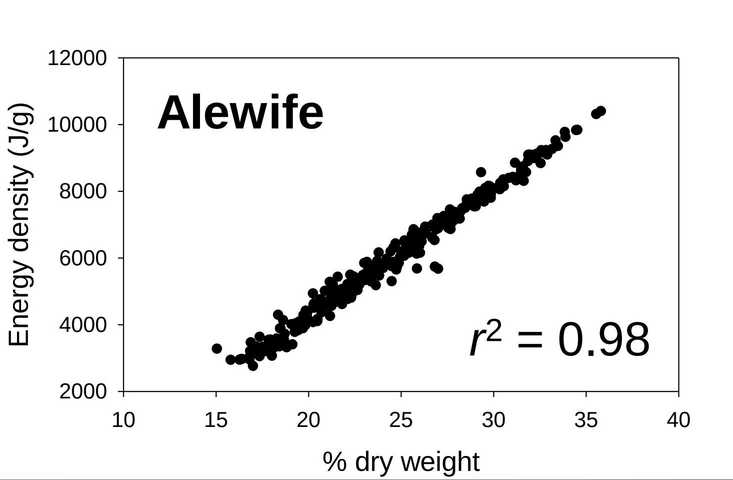
Methods: Fish condition

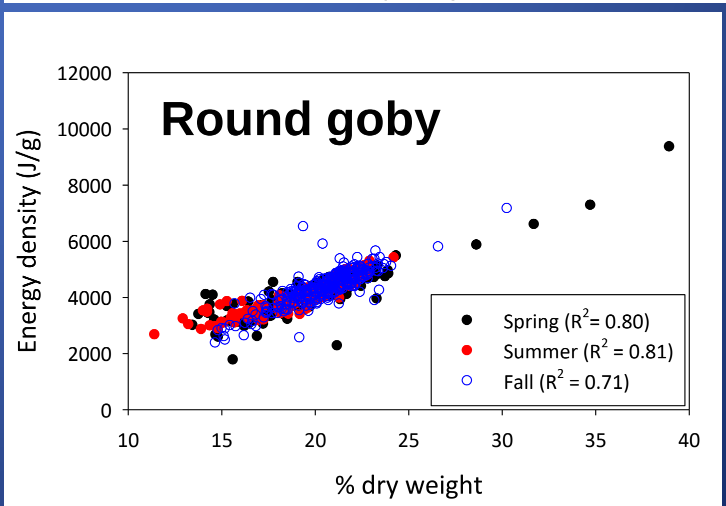
- Sampled juvenile and adult fish in April/May, July, Oct/November
- Bottom trawl and midwater trawl
- Focused on alewife and round goby

Methods: Fish condition

Juvenile & adult energetic condition

- Estimated dry weight (65 ^{0}C)
- Bomb calorimetry on a subset of fish



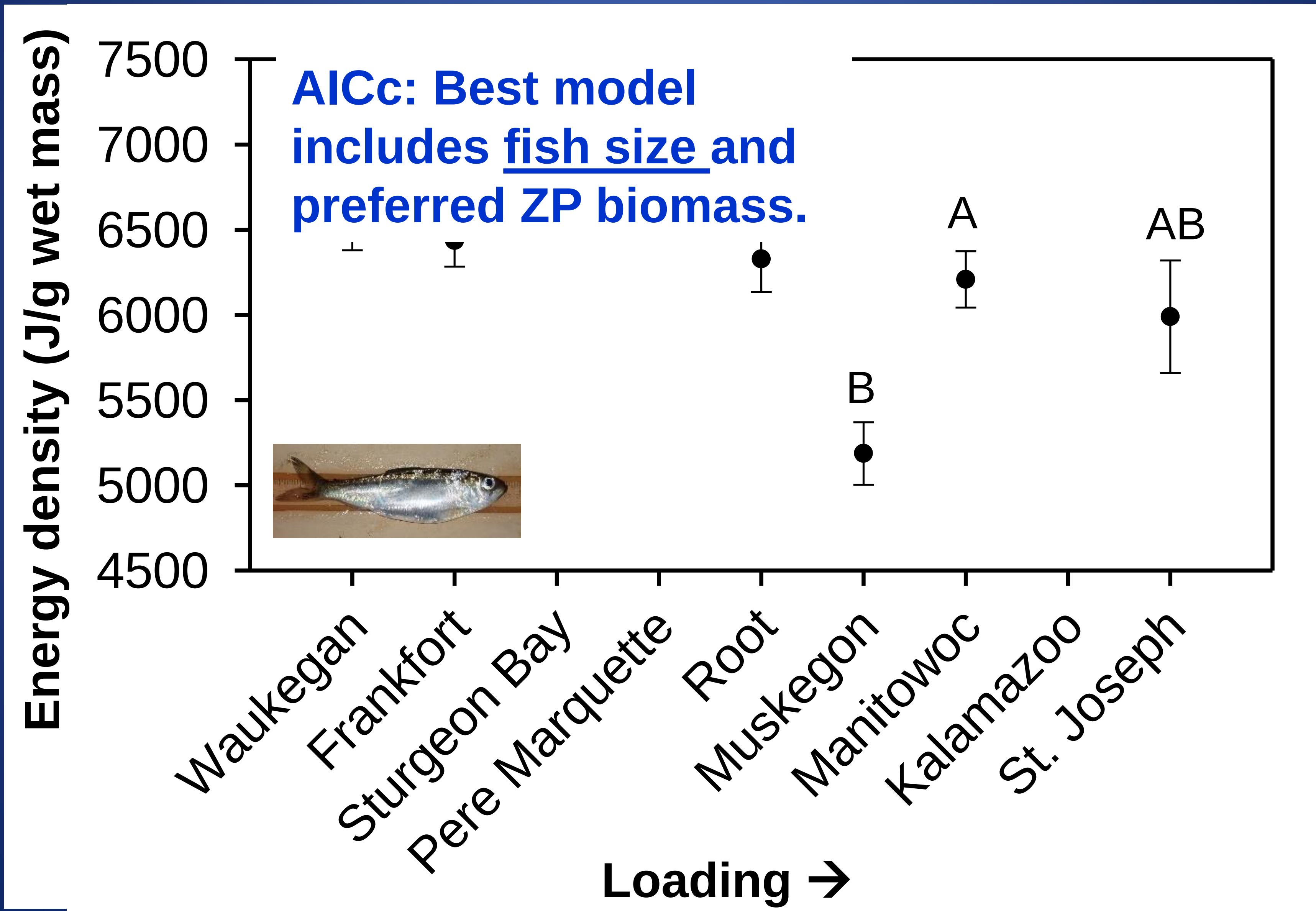


Explanatory variables for alewife energetic condition

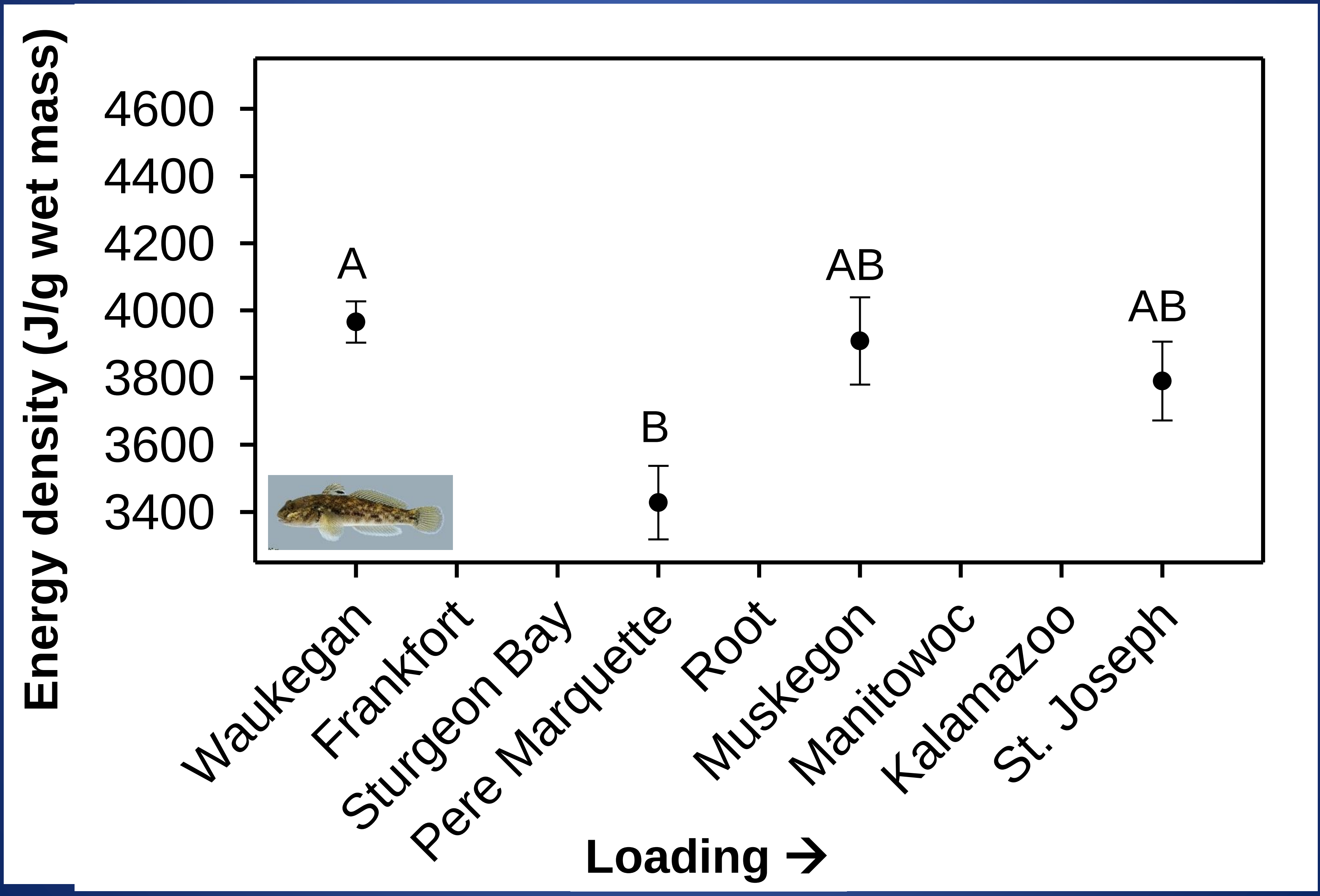
- Zooplankton biomass (total, “preferred”)
- Fish density
- Fish size

Generalized Linear Model

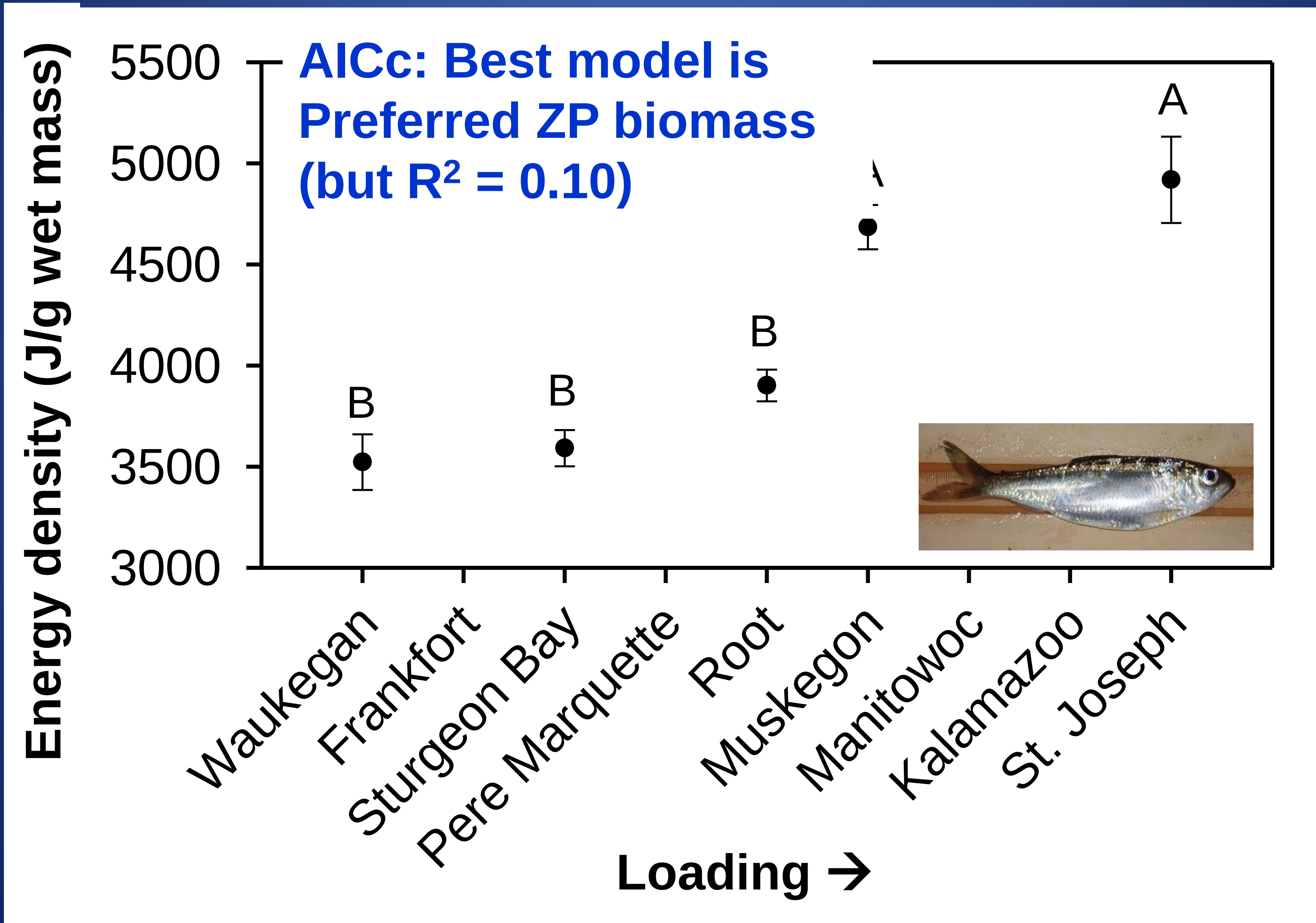
YOY Alewife condition: minimal spatial variation



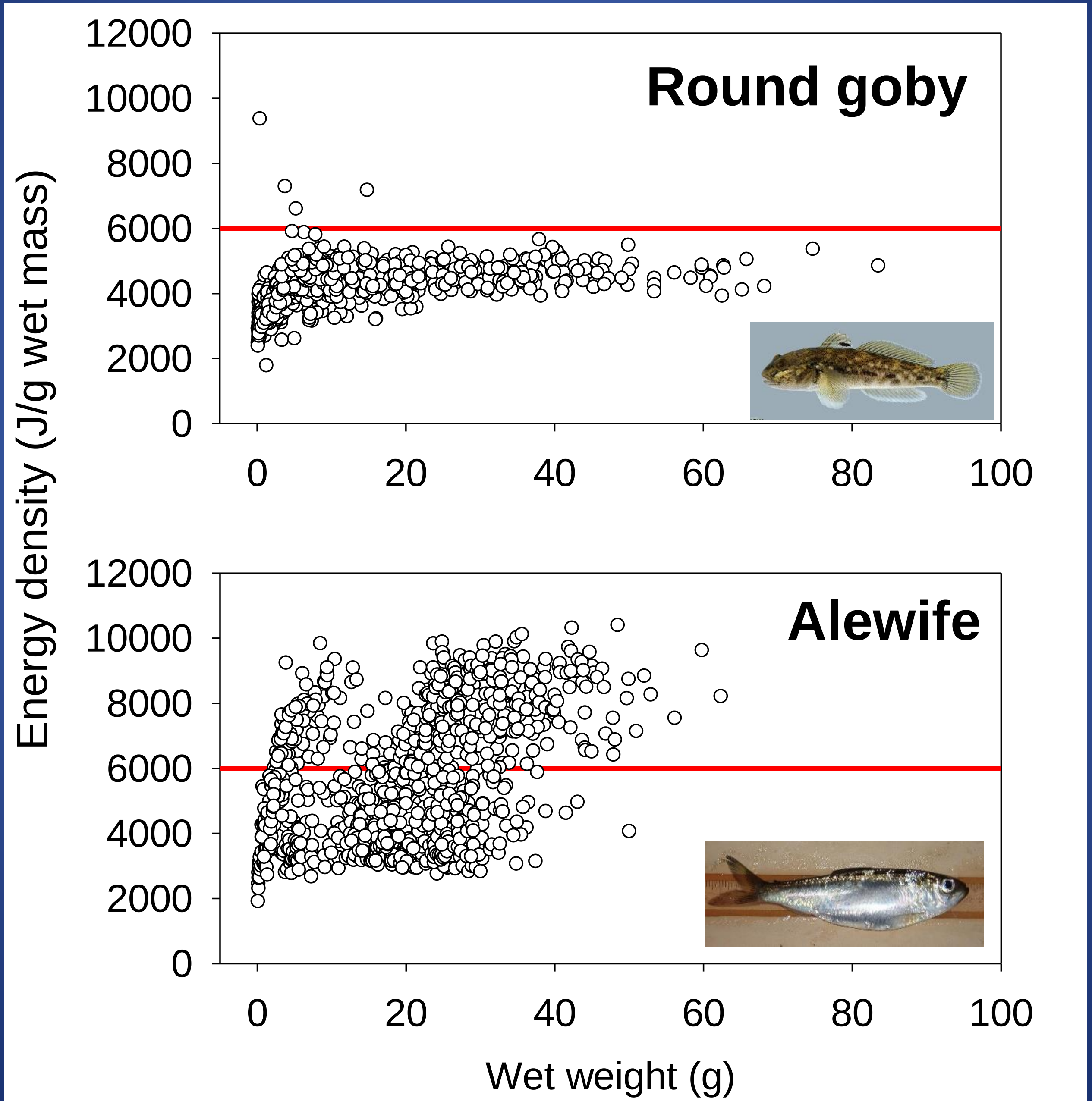
YOY Round goby condition: minimal spatial variation



Large alewife condition: some increase with productivity



Higher energetic payoff for alewife



Adult energy density has remained similar to 2002-2004 levels

Madenjian et al. 2006

No compensation despite fewer alewife…..

Summary

- Slow larval fish growth could contribute to low larval survival, and a bottleneck limiting prey fish abundance.

- Alewife energetic condition weakly linked to productivity and has not changed since 2002-2004. Juvenile and adult fish are not starving despite changing lower trophic levels.

- Alewife provide more energetic return than round goby to piscivores, on a per-weight basis.

Acknowledgements

USGS Vessel Crew in 2015: Erin Grivicich, Lyle Grivicich, Shawn Parsons.

Funded by EPA: Great Lakes RESTORATION

Implications for future CSMI

- No nearshore "hot spot" for larval fish growth or fish condition

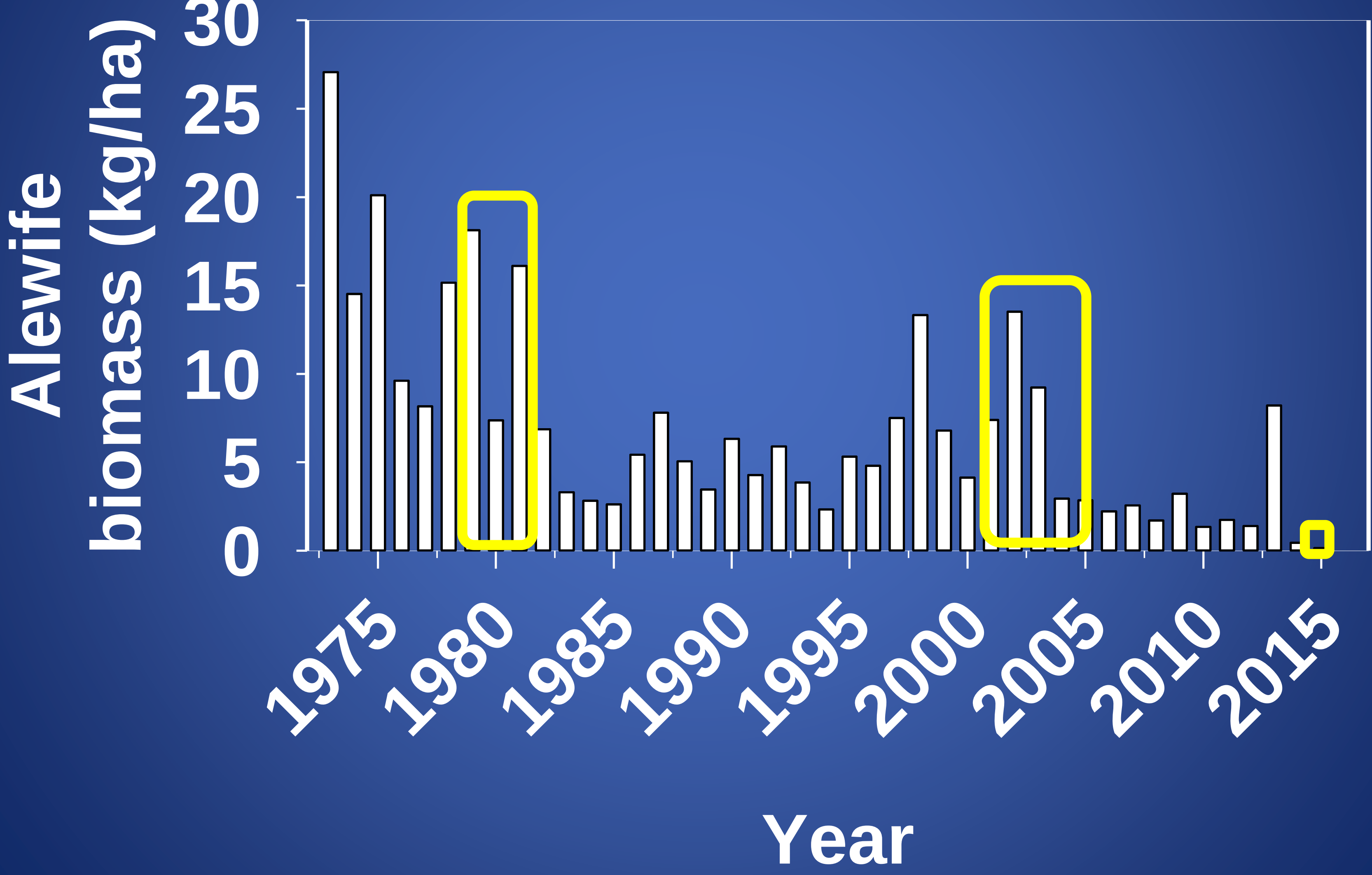
OR

- Not sampling close enough to tributaries?

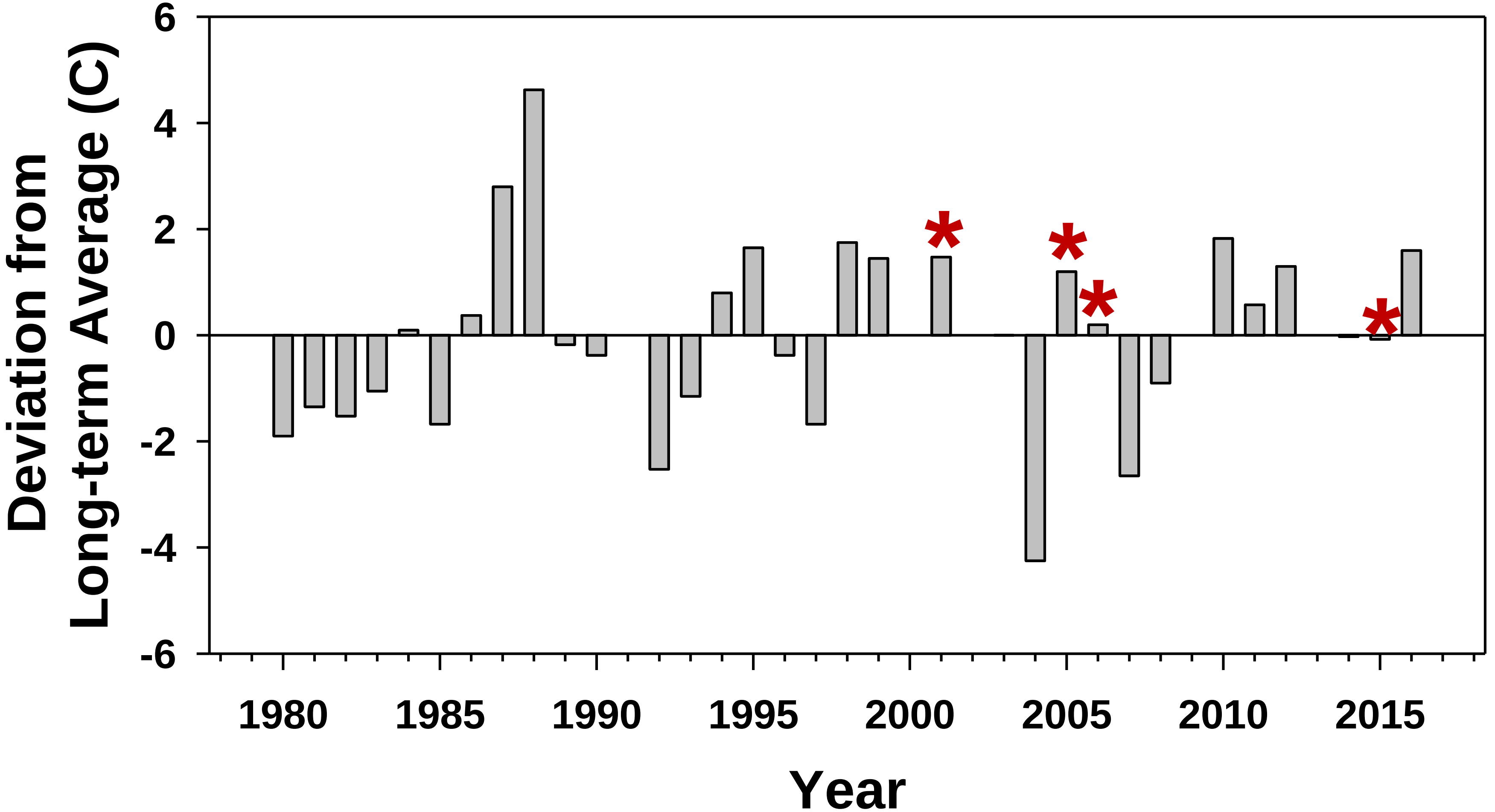
- Fish are mobile. So where we caught them not necessarily representative of where they obtained energy... Hydrological modeling would be helpful.

- How to better sample the nearshore?
  - Remote sensing or more frequent sampling– episodic events may be critical.
  - Sample even shallower waters? (given its relatively low area)

Far fewer alewife in 2015 than during previous energetic studies



May-August Water temperatures → Strong YC (Madenjian et al. 2005)



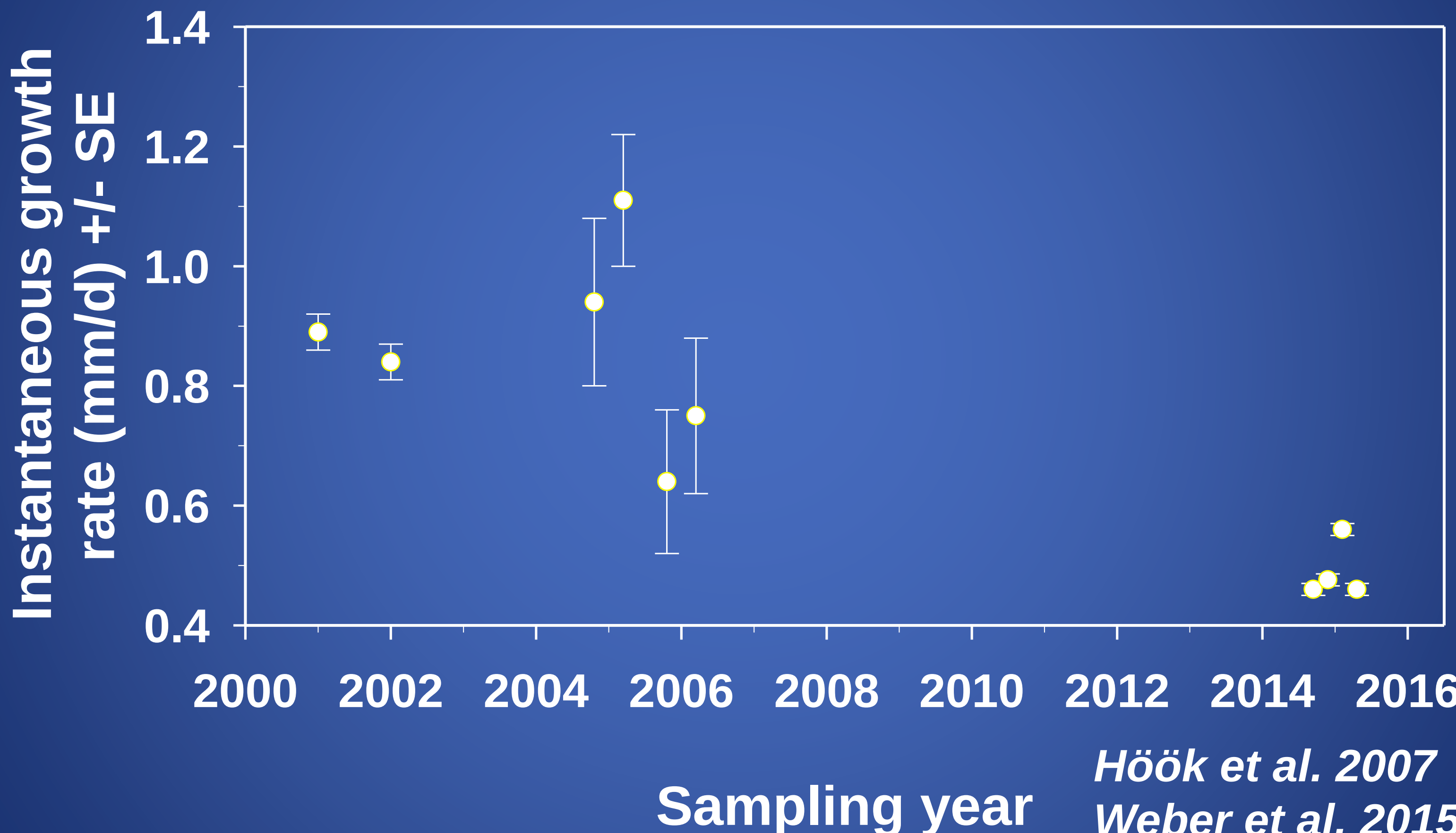
Warmest:

1988, 1987, 2010, 1998, 1995, 2016, 2001, 1999

Implications for fisheries management

- **Larval fish growth and survival could be a bottleneck limiting prey fish abundance.**
  - **67% of alewife diets (N = 313) were empty**

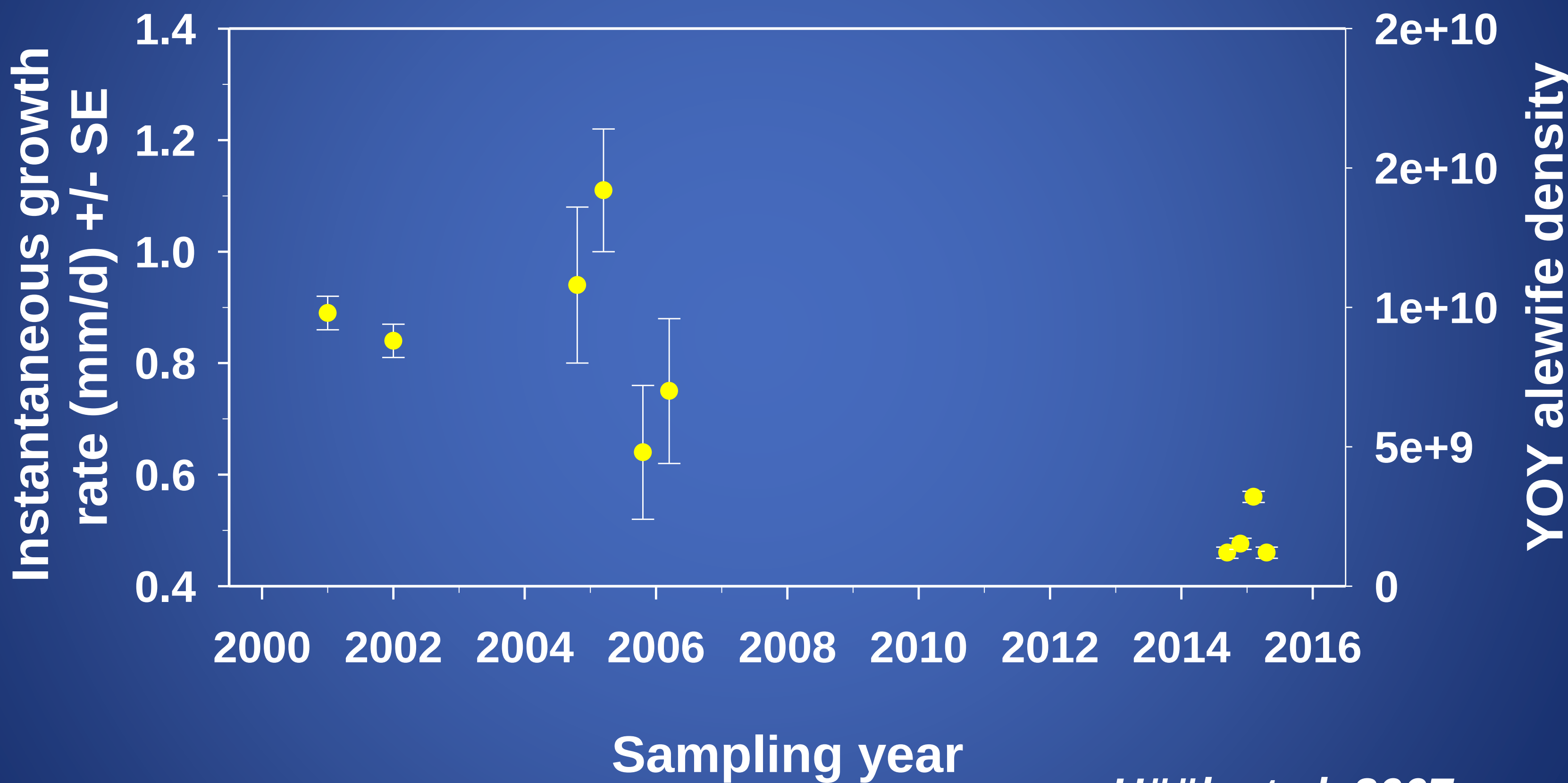
Slower larval alewife growth in 2015



Höök et al. 2007
Weber et al. 2015

Comparing southern sites, only

Does larval growth correspond to alewife year-class strength?



Höök et al. 2007
Weber et al. 2015

Implications for fisheries management

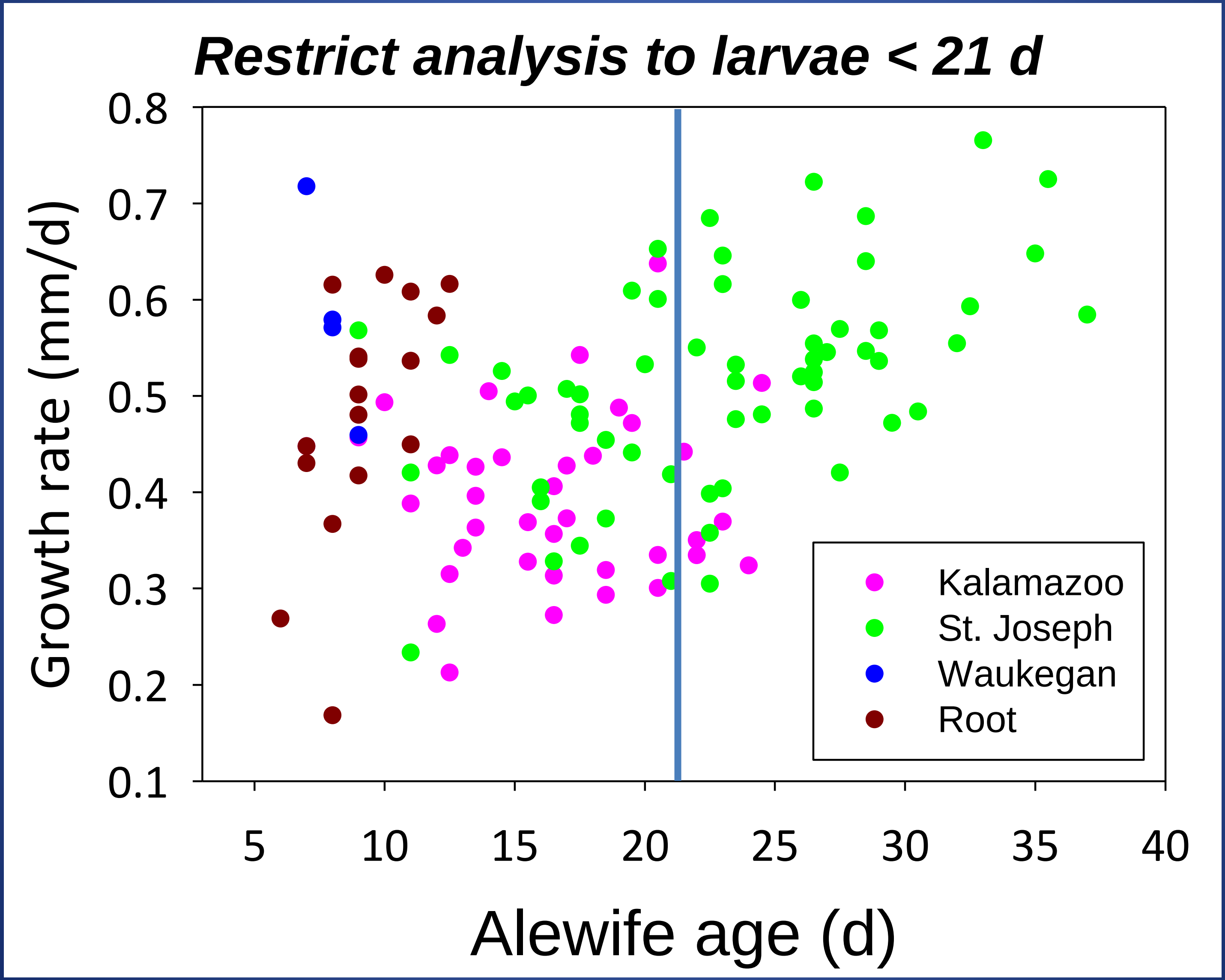
- Larval fish growth and survival could be a bottleneck limiting prey fish abundance.

- Alewife energetic condition has not declined since 2002-2004, so juvenile and adult fish are not starving despite lower pelagic productivity.

Implications for fisheries management

- Larval fish growth and survival could be a bottleneck limiting prey fish abundance.
- Juvenile and adult alewife are not starving.
- Alewife provide more energetic return than round goby to piscivores, on a per-weight basis.
- Nearshore CSMI data available to agencies (e.g., MI zonal management, Habitat Task Group Environmental Objectives)

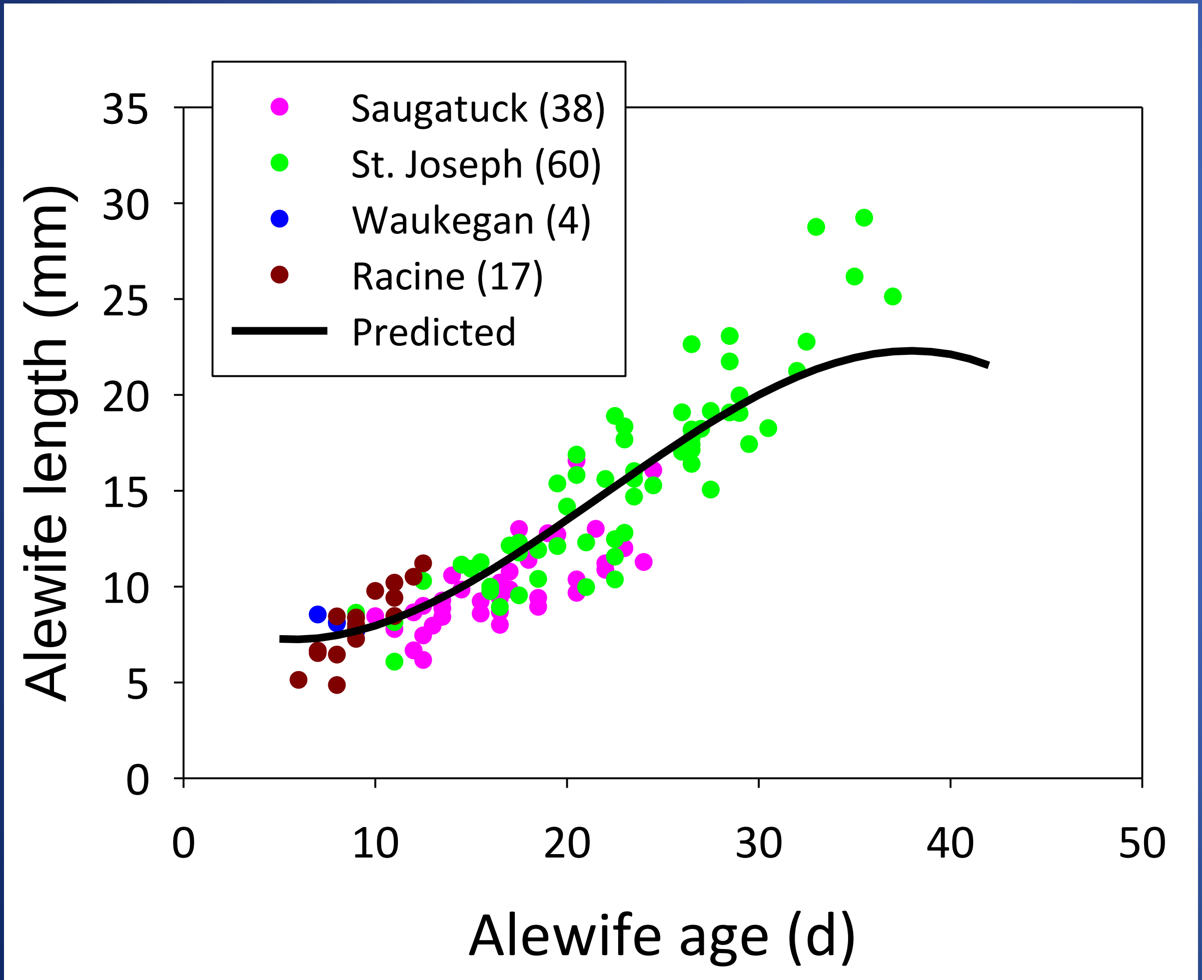
Older fish have slightly faster growth rates, and not all sites have older fish



Hypothesis 1:

Residual, predicted length

Among nearshore sites, productivity should be greater at sites near tributaries with high TP loading.



Port	Mean "growth" (residual)	Sig. Diff?
Saug.	-1.41	A
St. Joes	0.22	B
Racine	0.24	B

Results

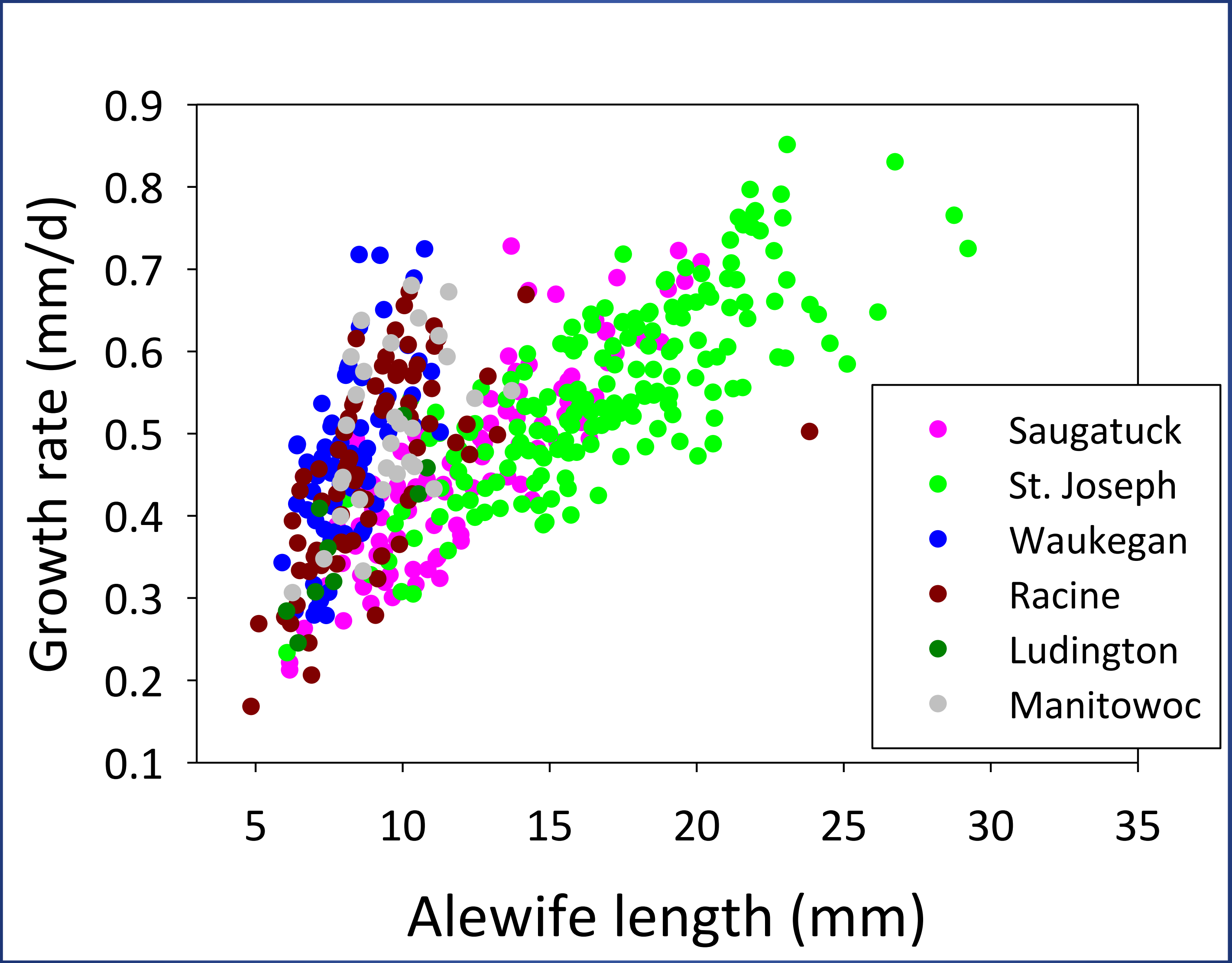
Larval fish community composition:

- 1813 alewife (91% surface tows)
- 83 bloater (89% oblique tows)
- 60 burbot (87% oblique tows)
- 48 yellow perch (90% surface tows)

Aged up to 30 fish per tow

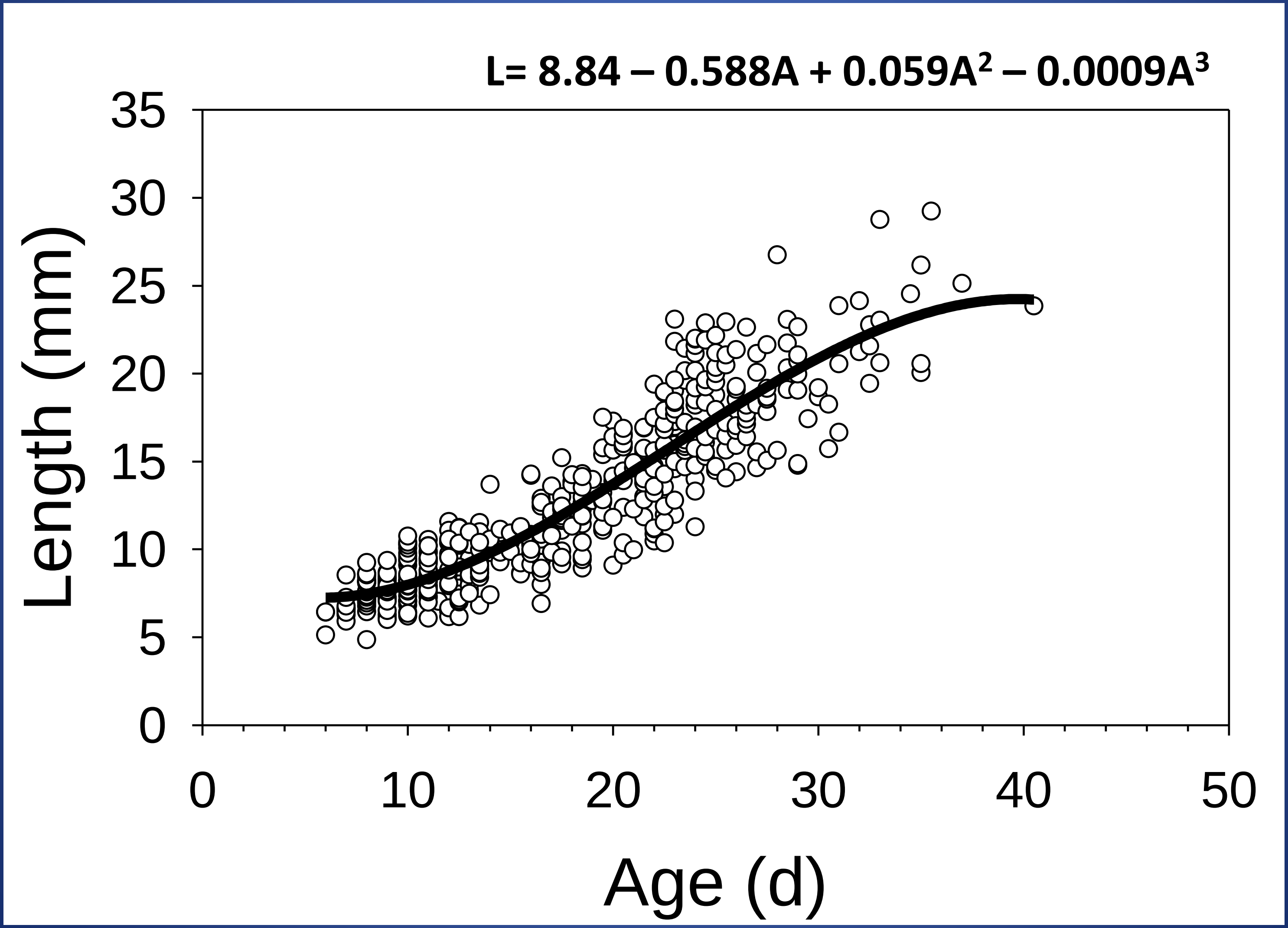
- 464 alewife: mean = 0.50 mm/d
- 72 bloater: mean = 0.21 mm/d

Larger fish have faster growth rates



Sites differ in their mean length of fish….

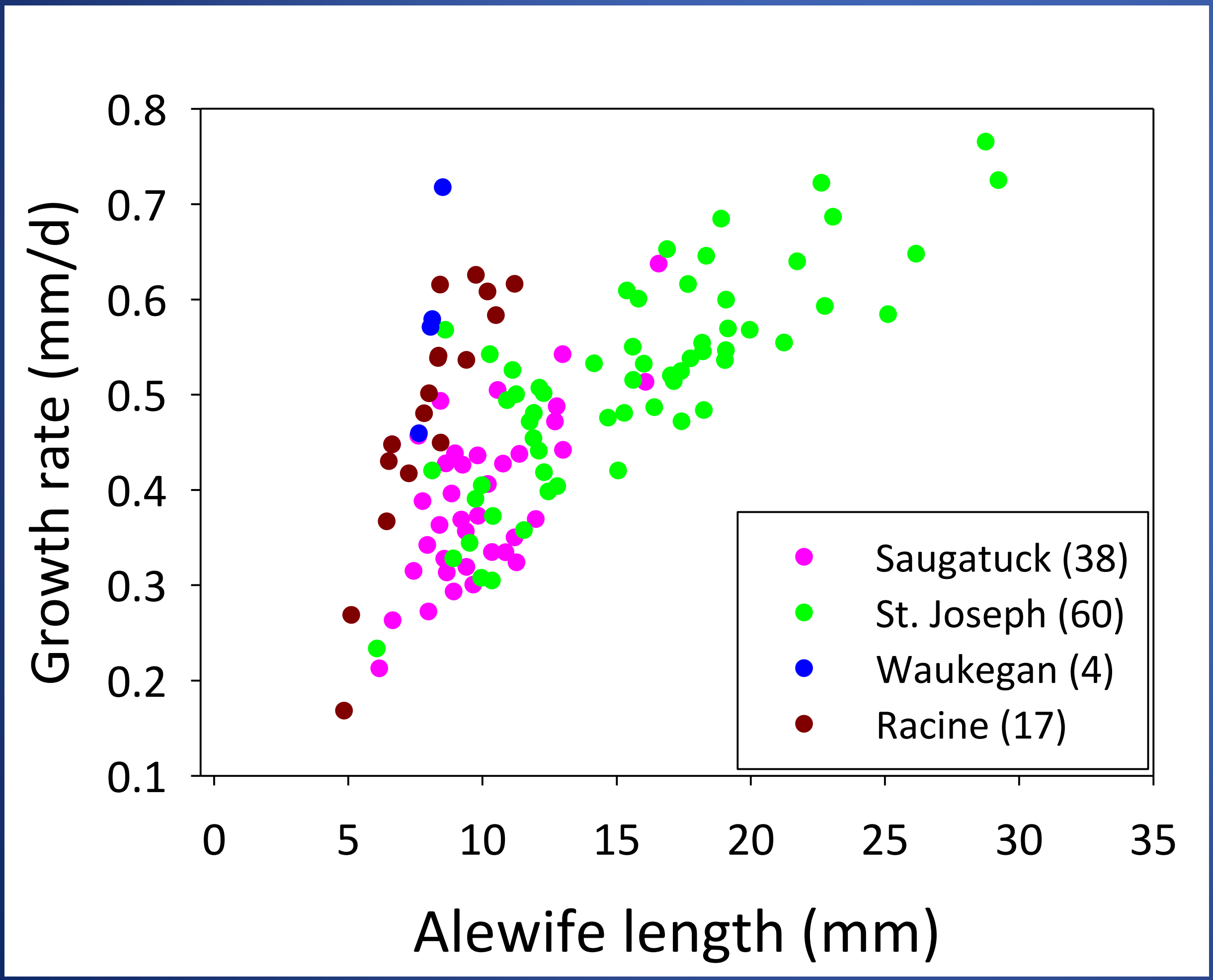
Use residuals, to remove size effect and estimate growth



Hypothesis 1:

LS Means, length covariate

Among nearshore sites, alewife growth should be greatest at sites near tributaries with high TP loading.



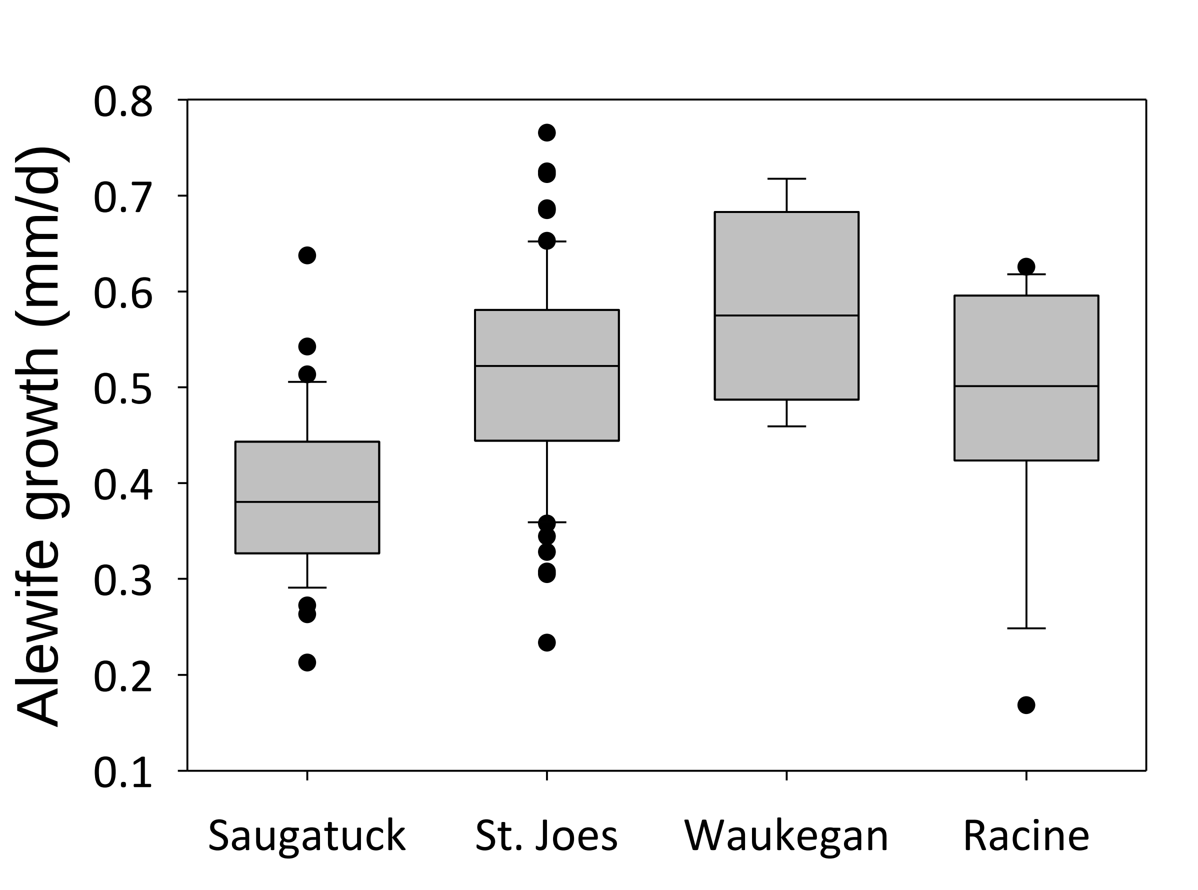
Port	LSMean growth	Sig. Diff?
Saug.	0.45	A
St. Joes	0.46	A
Racine	0.57	B

Hypothesis 1:

ANOVA, no age restriction

Among nearshore sites, productivity should be greater at sites near tributaries with high TP loading.

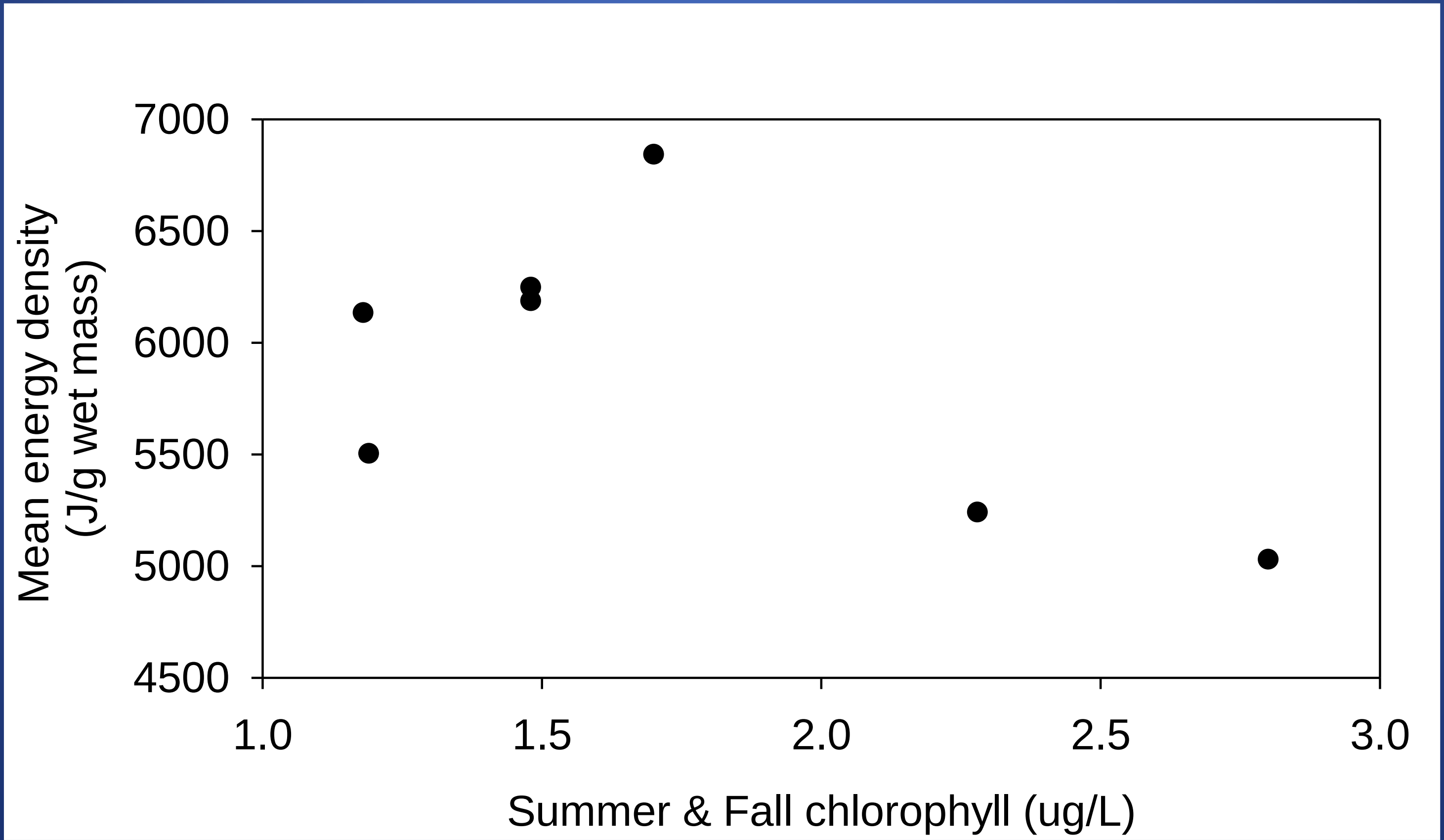
Growth rates of all nearshore alewife



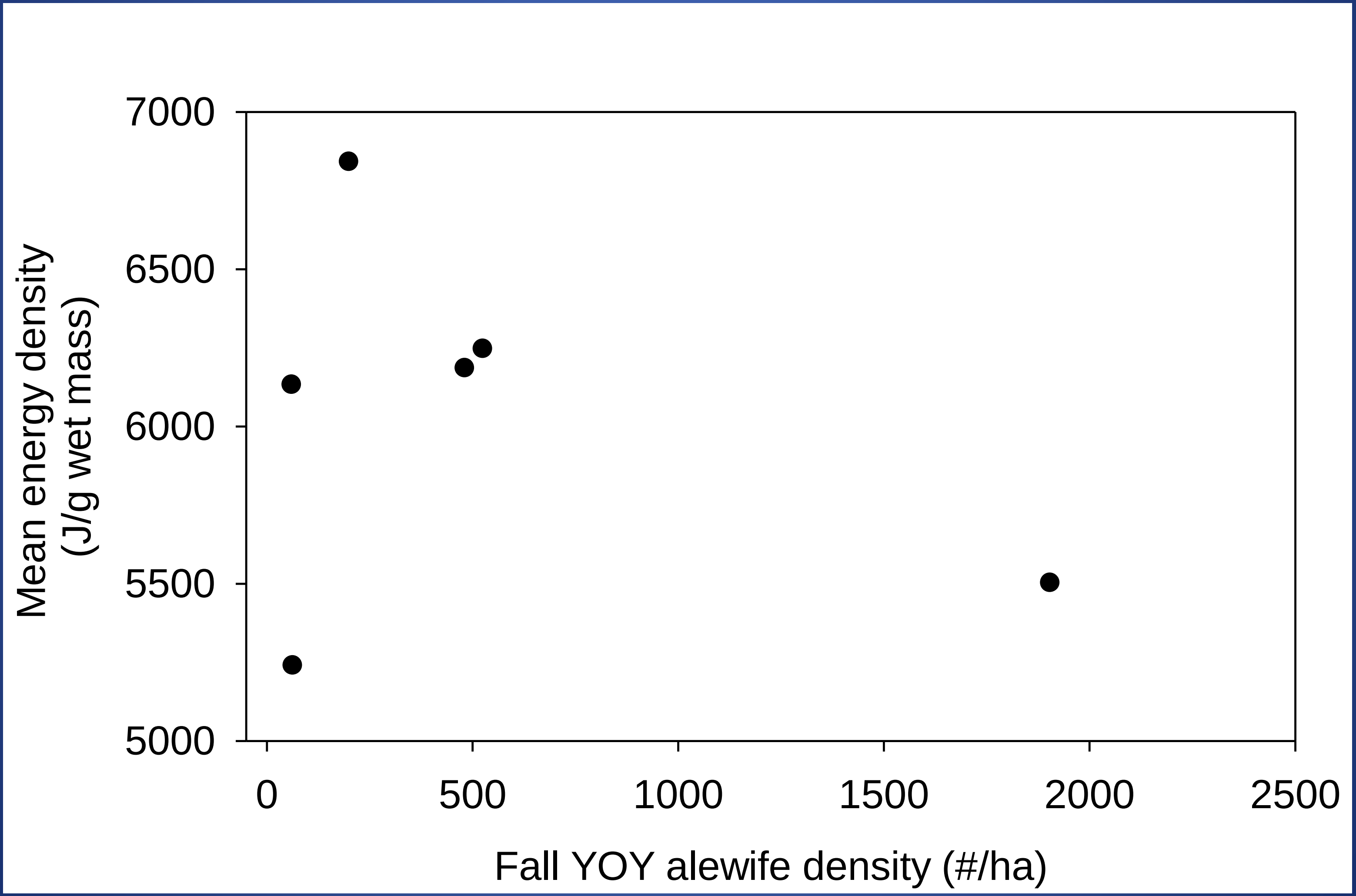
Port	Mean growth	Sig. Diff?
Saug.	0.39	A
St. Joes	0.51	B
Racine	0.48	B

Hypothesis 1:

Among nearshore sites, YOY alewife condition in the fall should be greater at sites near tributaries with high TP loading. ***No Support.***



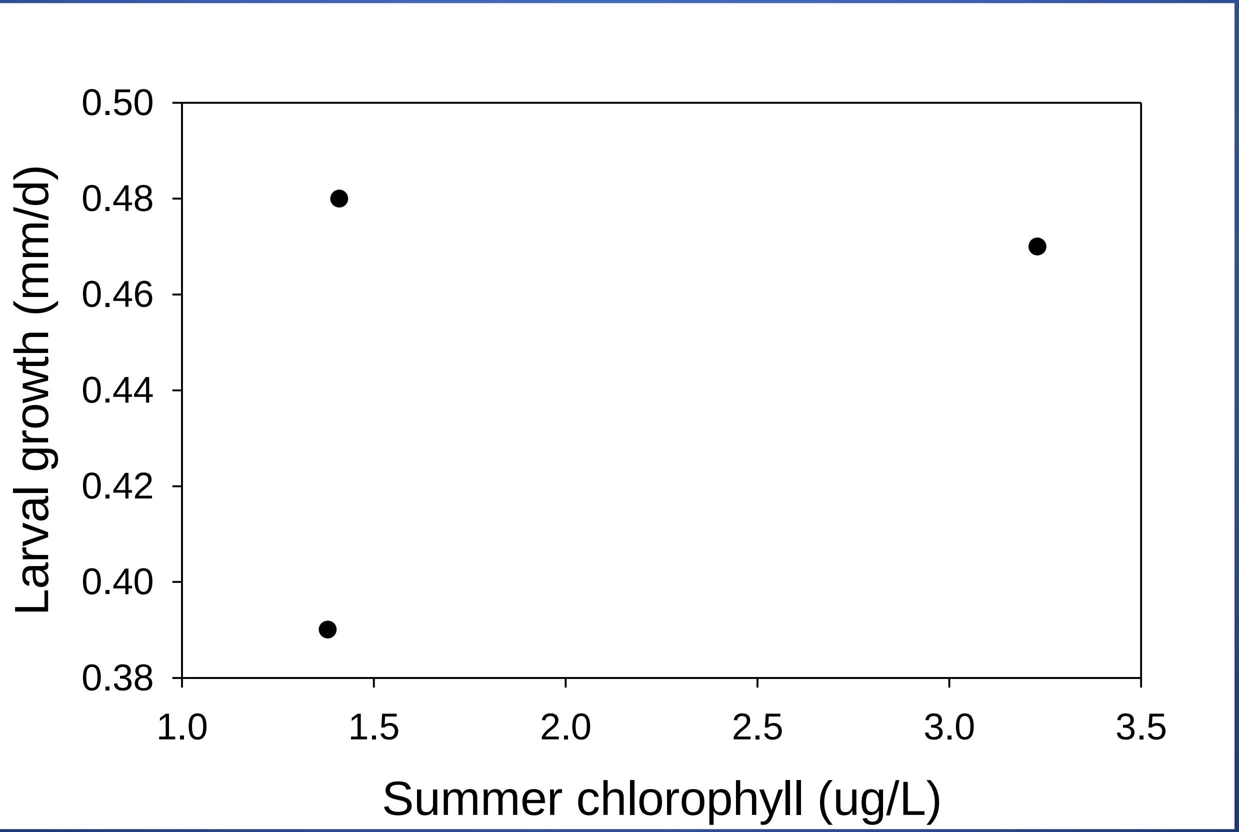
Nearshore energetic condition also not explained by density dependence….



Hypothesis 1:

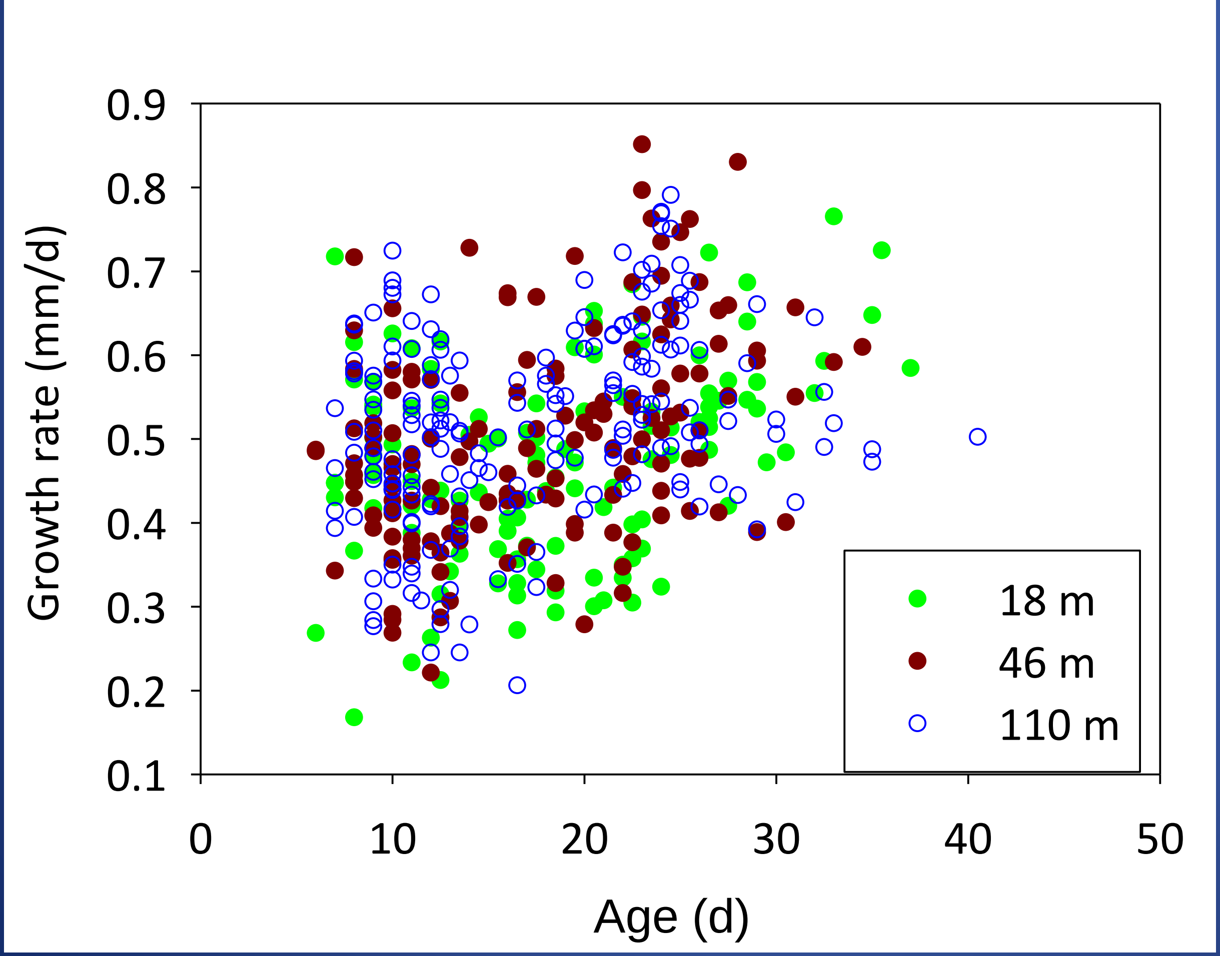
Among nearshore sites, larval alewife growth should be greatest at sites near tributaries with high TP loading.

No Support.



Hypothesis 2:

Larval alewife growth should be faster in the nearshore (18 m) than in offshore waters.



Age does not differ across depths (P = 0.43)

Hypothesis 1:

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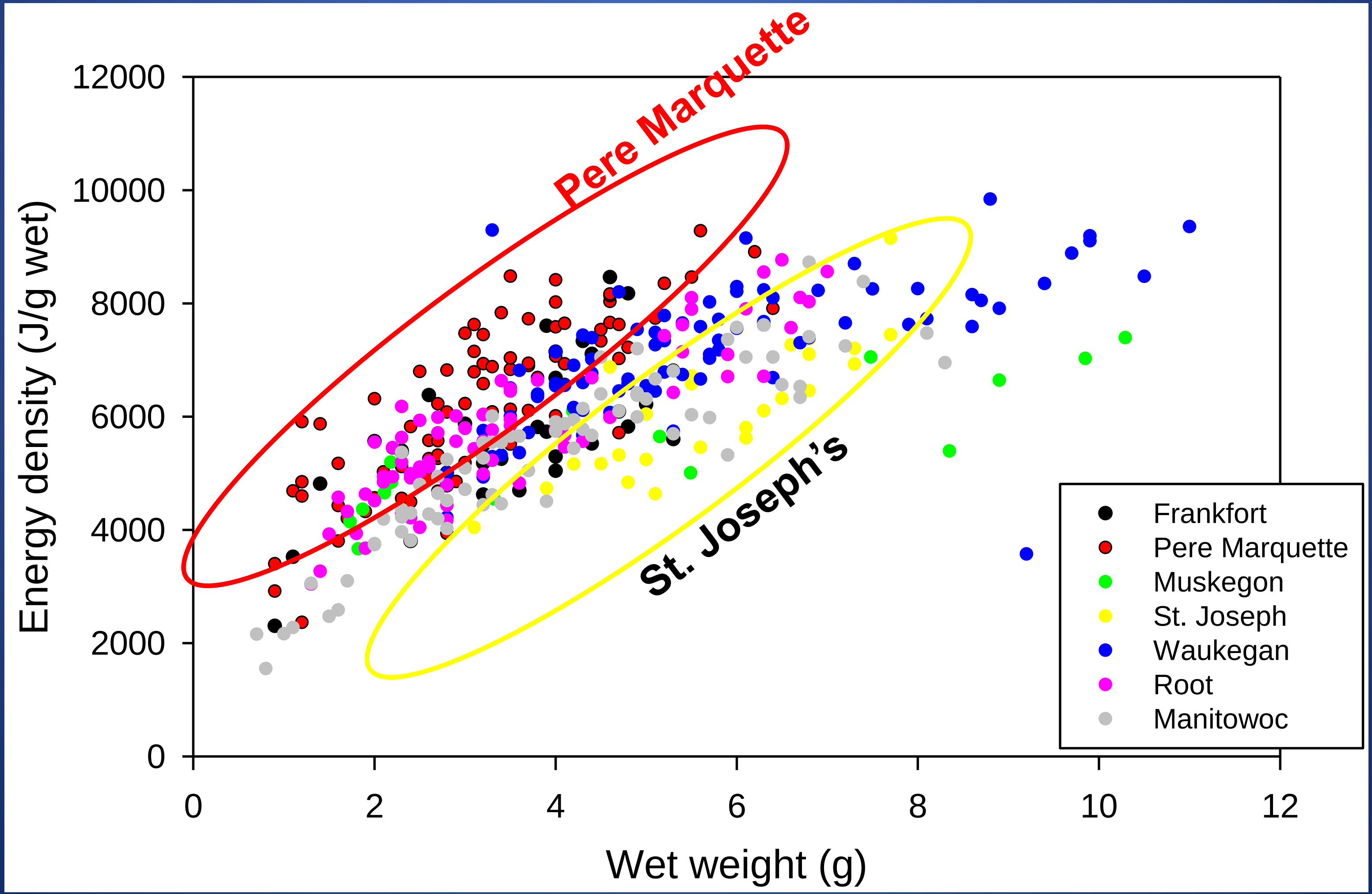

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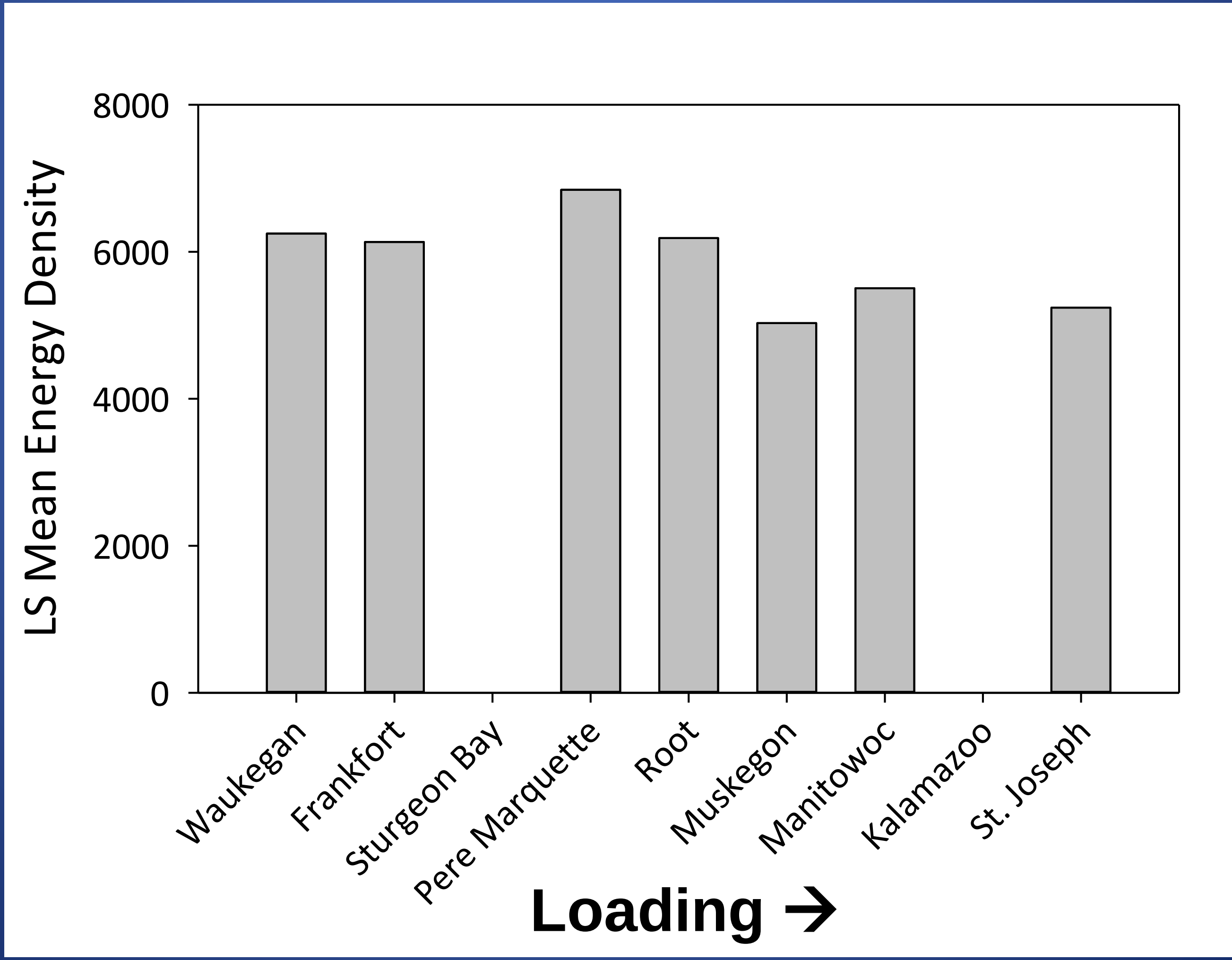
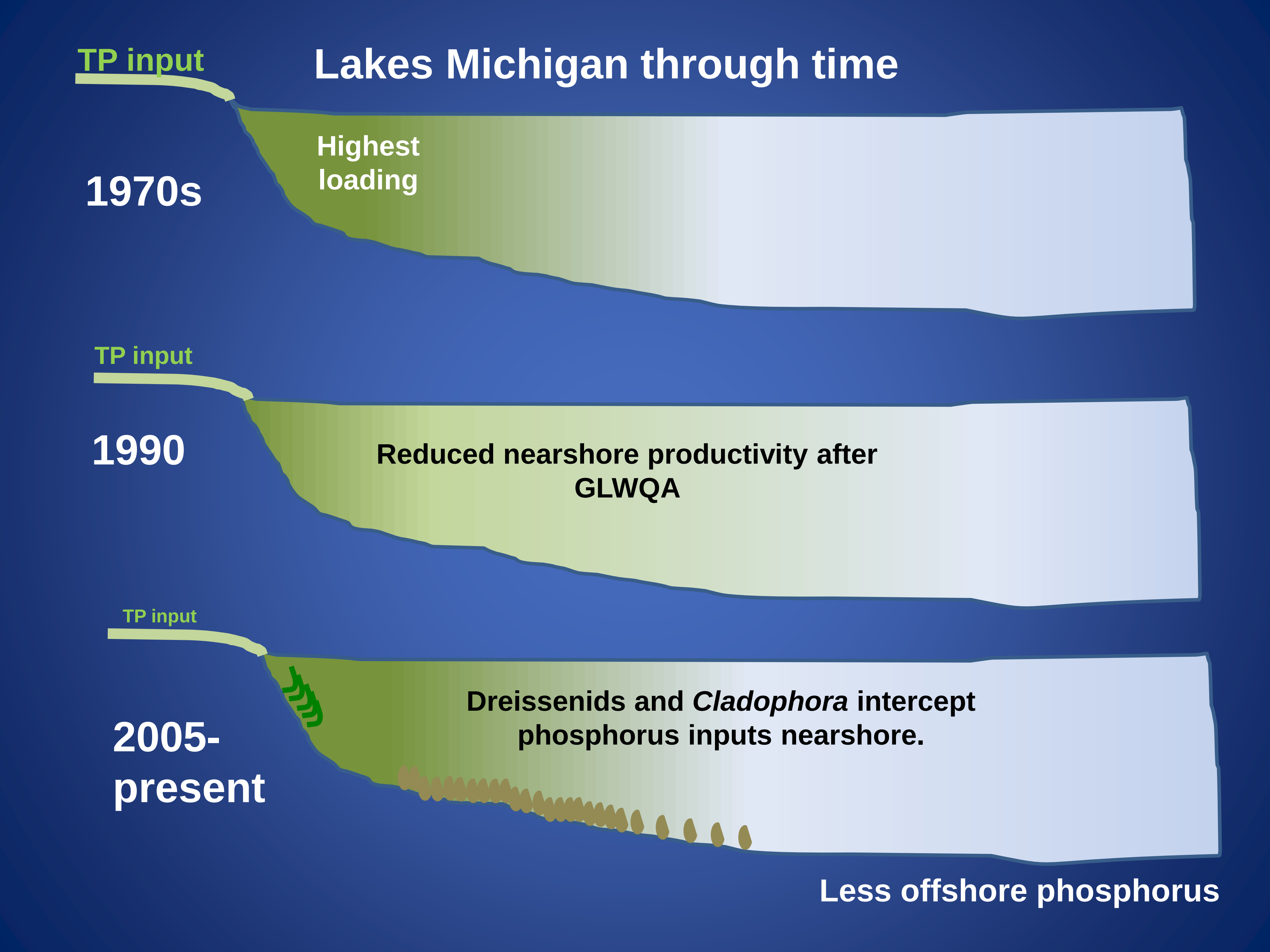
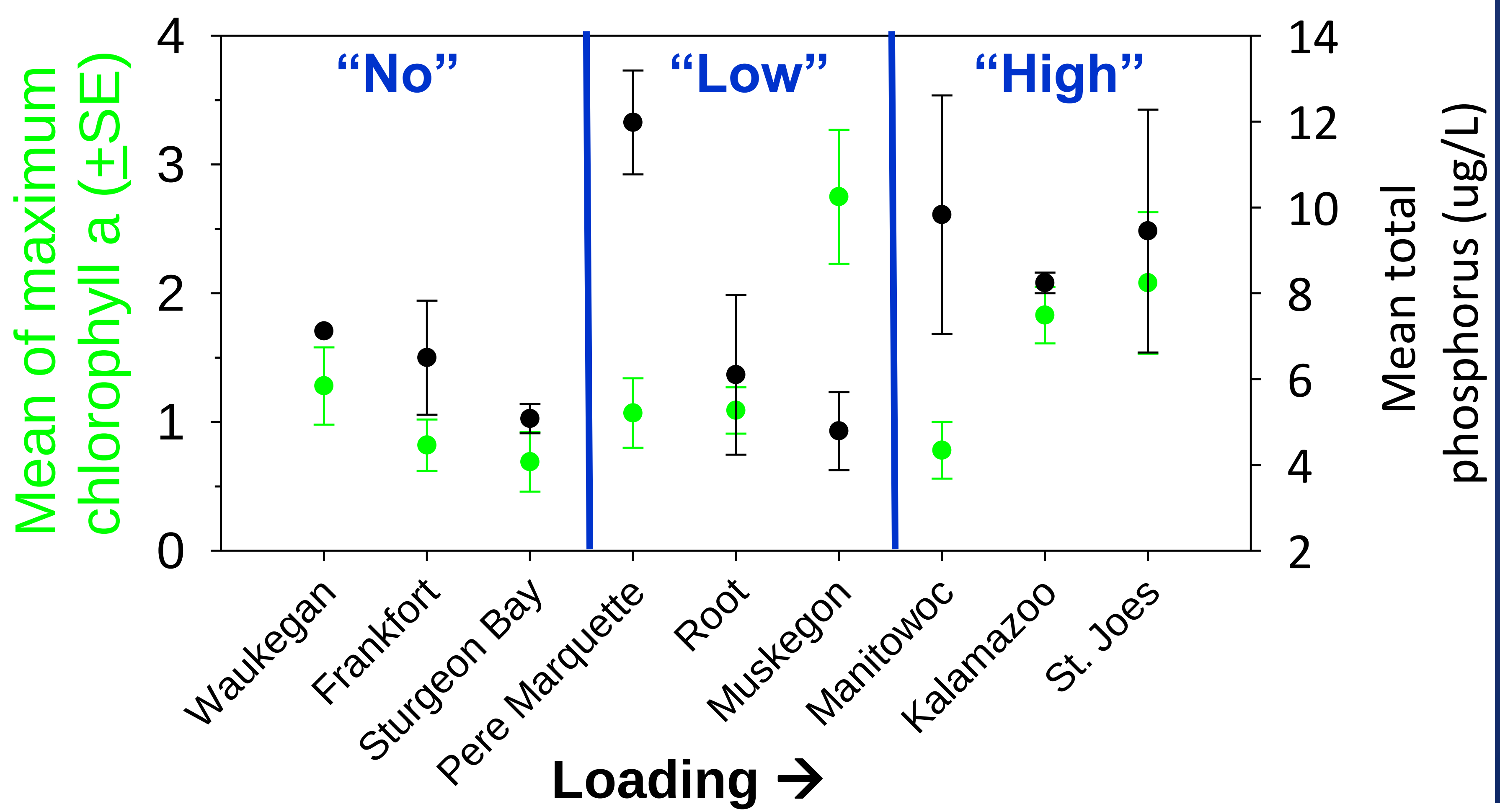



Lakes Michigan through time
TP input
1970s
Highest loading
TP input
1990
Reduced nearshore productivity after GLWQA
TP input
2005-present
Dreissenids and *Cladophora* intercept phosphorus inputs nearshore.
Less offshore phosphorus

Nearshore (18 m) sites near "high" TP loading tribs weren't always most productive



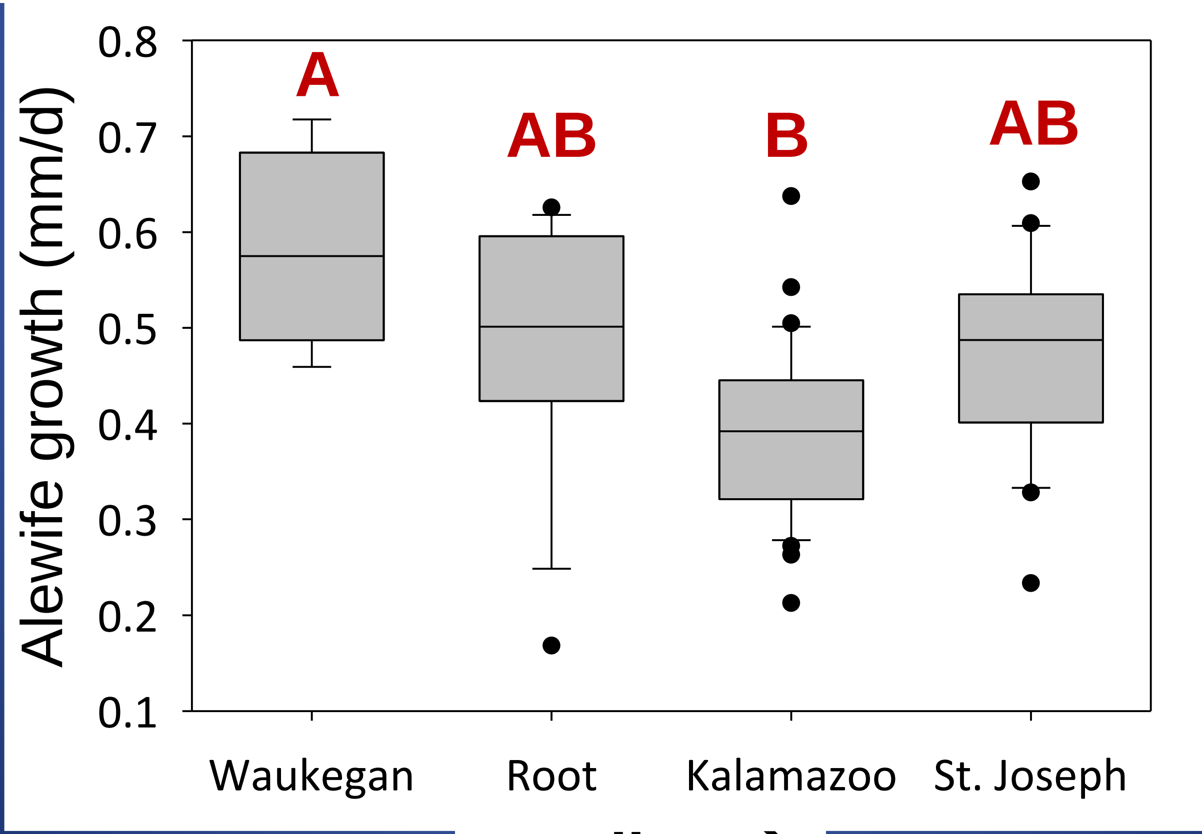
Data: EPA, USGS, NOAA

Hypothesis 1:

Among nearshore sites, larval alewife growth should be greatest at sites near tributaries with high TP loading.

No Support.

Growth rates of alewife < 21 d old



Loading →

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