# Effects of Hypoxia, Temperature, and Mycobacteriosis on Striped Bass

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# Acknowledgments


- Technical support
  - Peter Bushnell (Indiana Univ) – physiology
  - Jim Brister (VIMS) – seawater lab
  - Katie Blackshear (VIMS) – histology
- Equipment:
  - Roger Mann (VIMS)
- Experimental assistance:
  - Oliver Foulds, Carol Hopper-Brill, Ryan Schloesser, Lauren Nys, Leonard Machut, Jennifer Greaney, Alicia Norris, Josef Seiler (VIMS), and Cyrille Lapointe
- Funding:
  - NOAA-Chesapeake Bay Office
  - Virginia Sea Grant

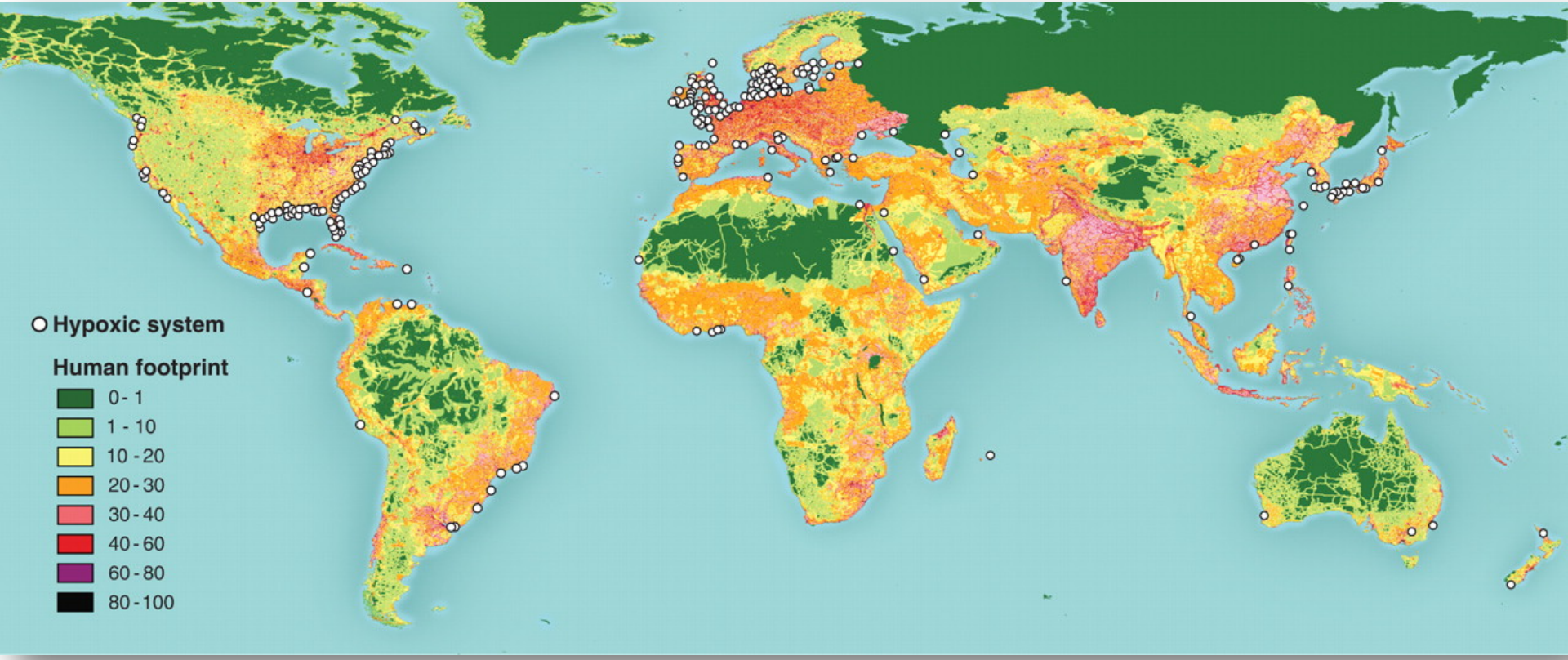


# Effects of Hypoxia, Temperature and Mycobacteriosis on Striped Bass

- In warm hypoxic waters, the scope for activity of diseased striped bass is greatly compromised
  - experience fatigue more rapidly
  - are restricted in their ability to elude predators or secure prey
  - likely have lower growth rates
  - exhibit reduced immune function and reproductive performance

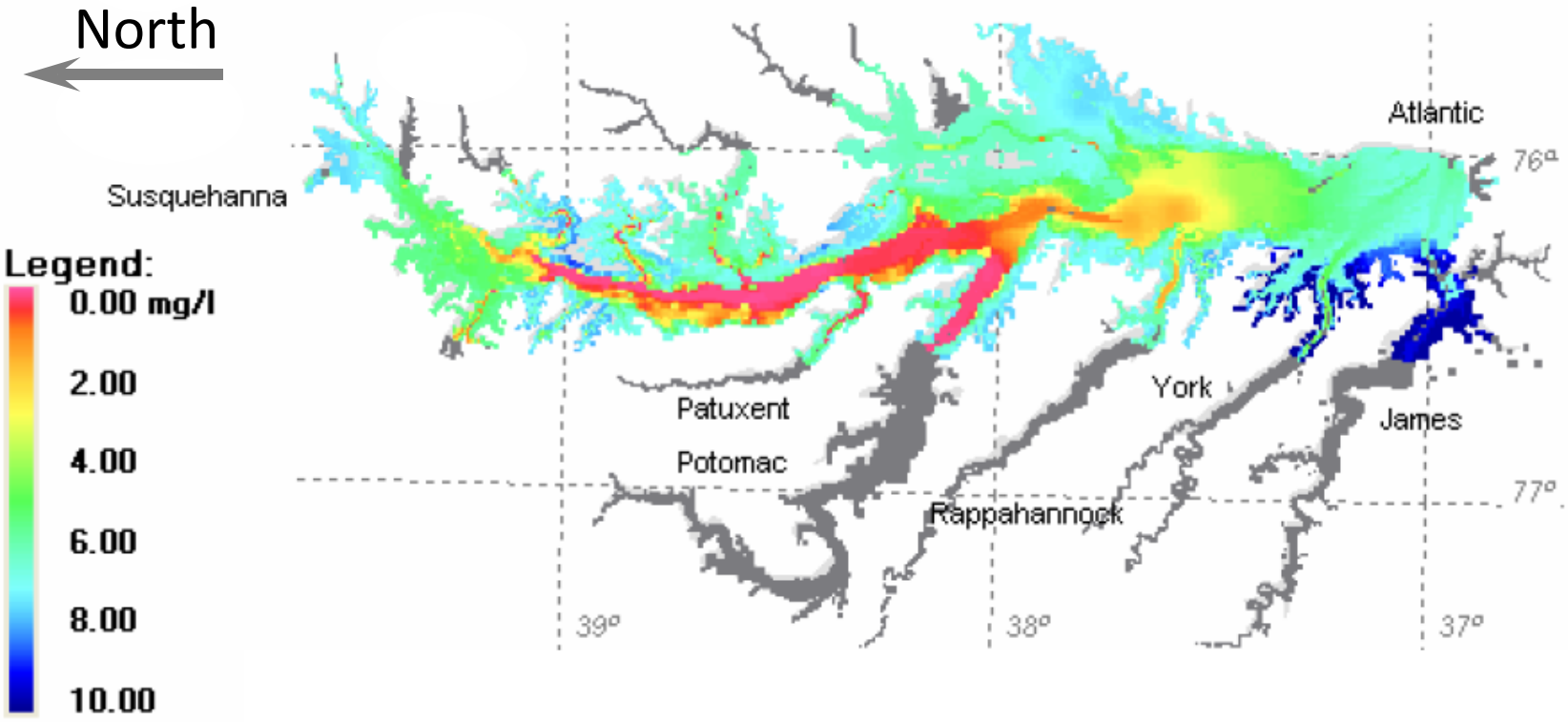
LAPOINTE, D, W. K. VOGELBEIN, M. C. FABRIZIO, D. T. GAUTHIER, AND R. W. BRILL. 2014. Temperature, hypoxia, and mycobacteriosis: effects on adult striped bass metabolic performance. *Diseases of Aquatic Organisms* 108: 113-127.

# Hypoxia: A Global Threat to Aquatic Resources




Diaz and Rosenberg 2008

# $dO_2$ in Chesapeake Bay
## Late July 2012



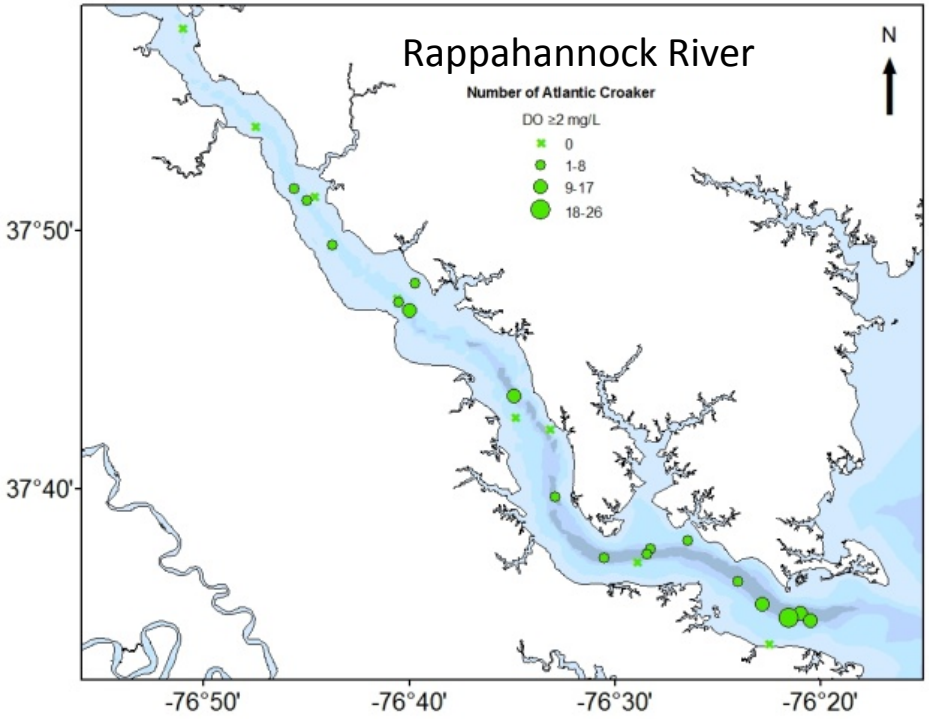

- Hypoxia affects fish at the population and individual-fish levels

Image: NOAA Chesapeake Bay Office

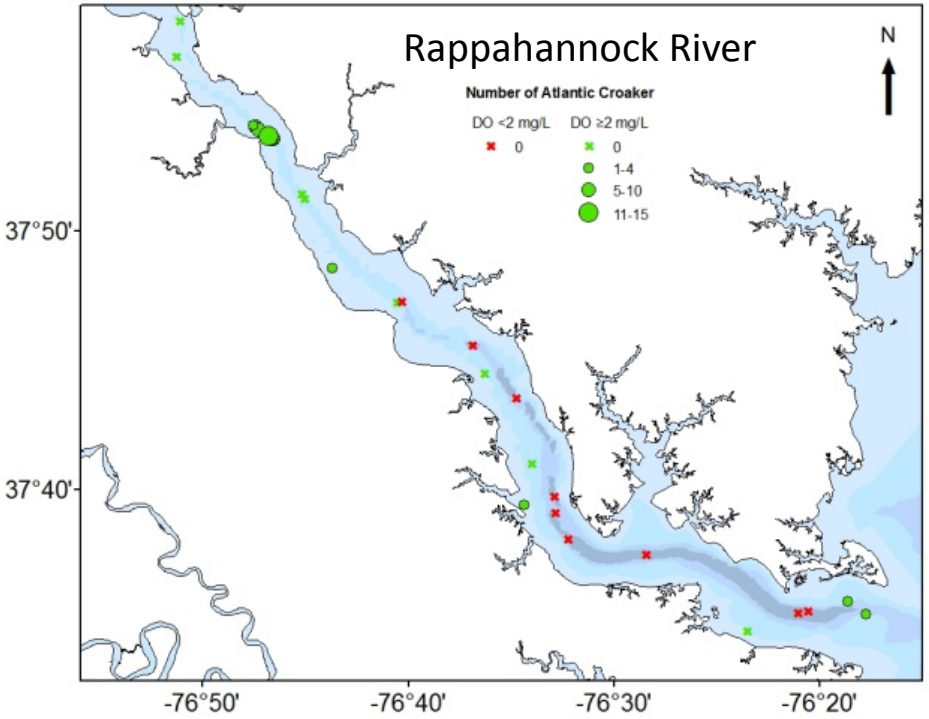
# Hypoxia Affects Fish Distribution

- Behavioral avoidance

May 2011



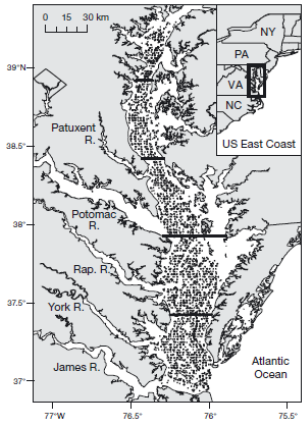

July 2011

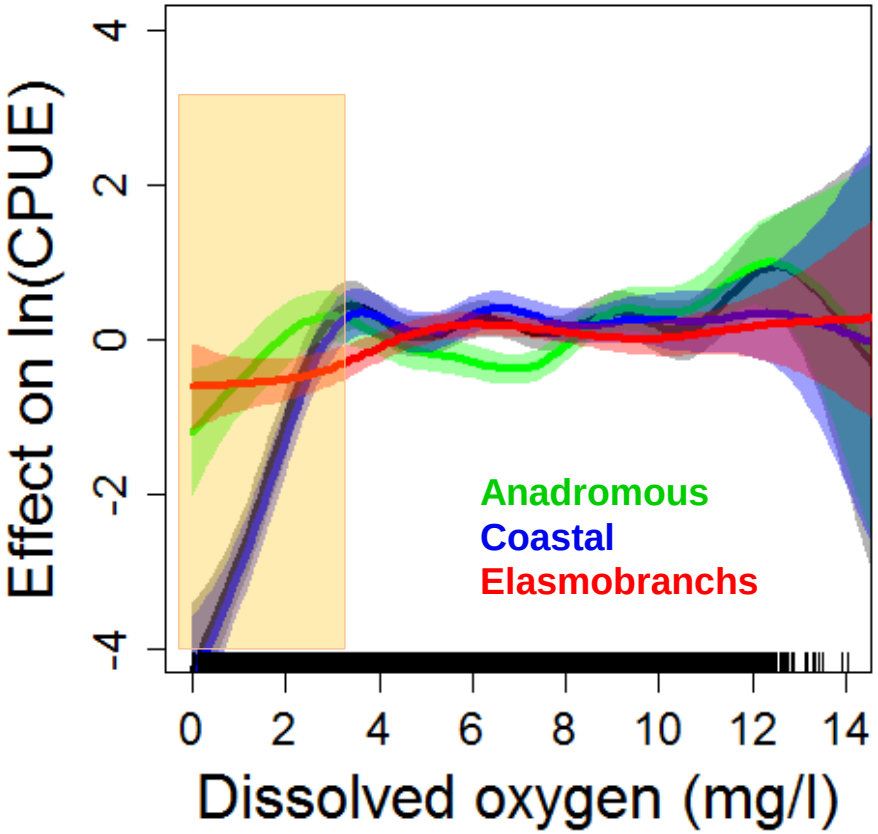


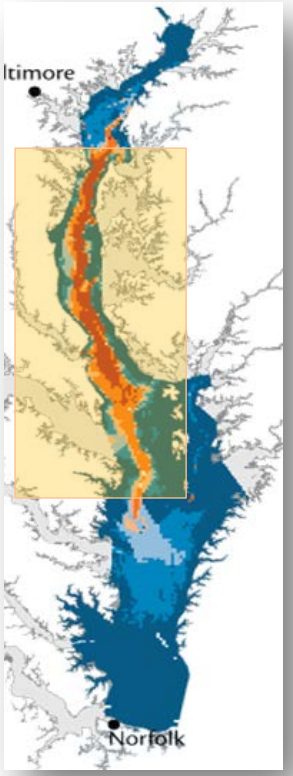

Craig & Crowder 2005; Switzer et al. 2009; Zhang et al. 2009; Craig et al. 2013; Tuckey & Fabrizio, *in review*

# Hypoxia Affects **Abundance** of Demersal Fishes in Chesapeake Bay

2002-2011



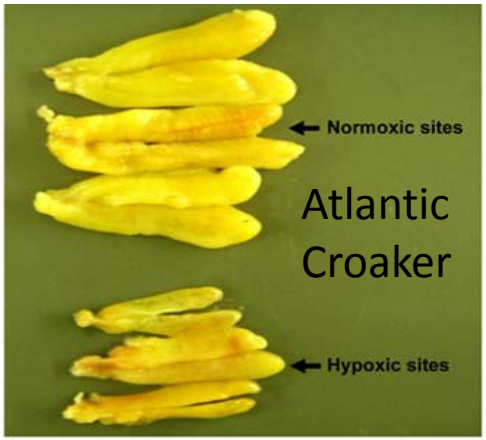



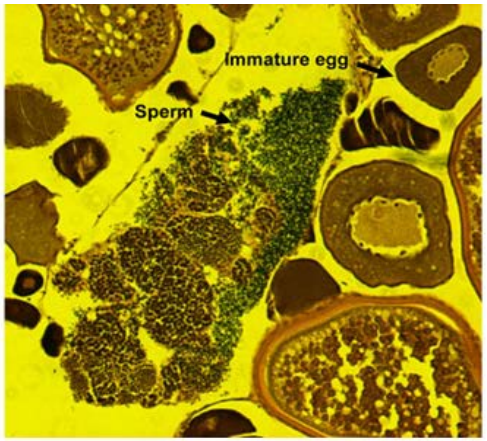

- Strong effect of low DO (<3.5 mg/l) on Chesapeake Bay fishes

Buchheister et al. 2013

# Hypoxia Affects Growth and Reproduction of Fishes

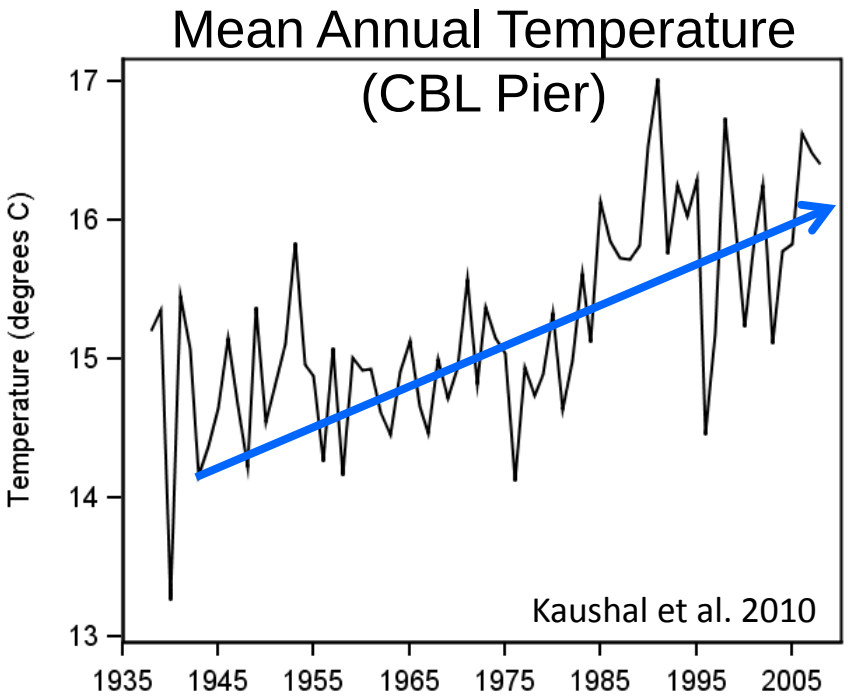
- Growth
  - Alteration of food web dynamics (Pihl et al. 1992; Eby et al. 2005; Powers et al. 2005; Long & Seitz 2008; Stierhoff et al. 2009; Brandt et al. 2009)
- Reproduction
  - Endocrine disruption
    - Reduced gonadal development (Wu et al. 2003; Thomas et al. 2006; Thomas & Rahman 2009)
    - Lower lipid concentrations in ovaries (Tuckey and Fabrizio, *in review*)




Thomas & Rahman 2011

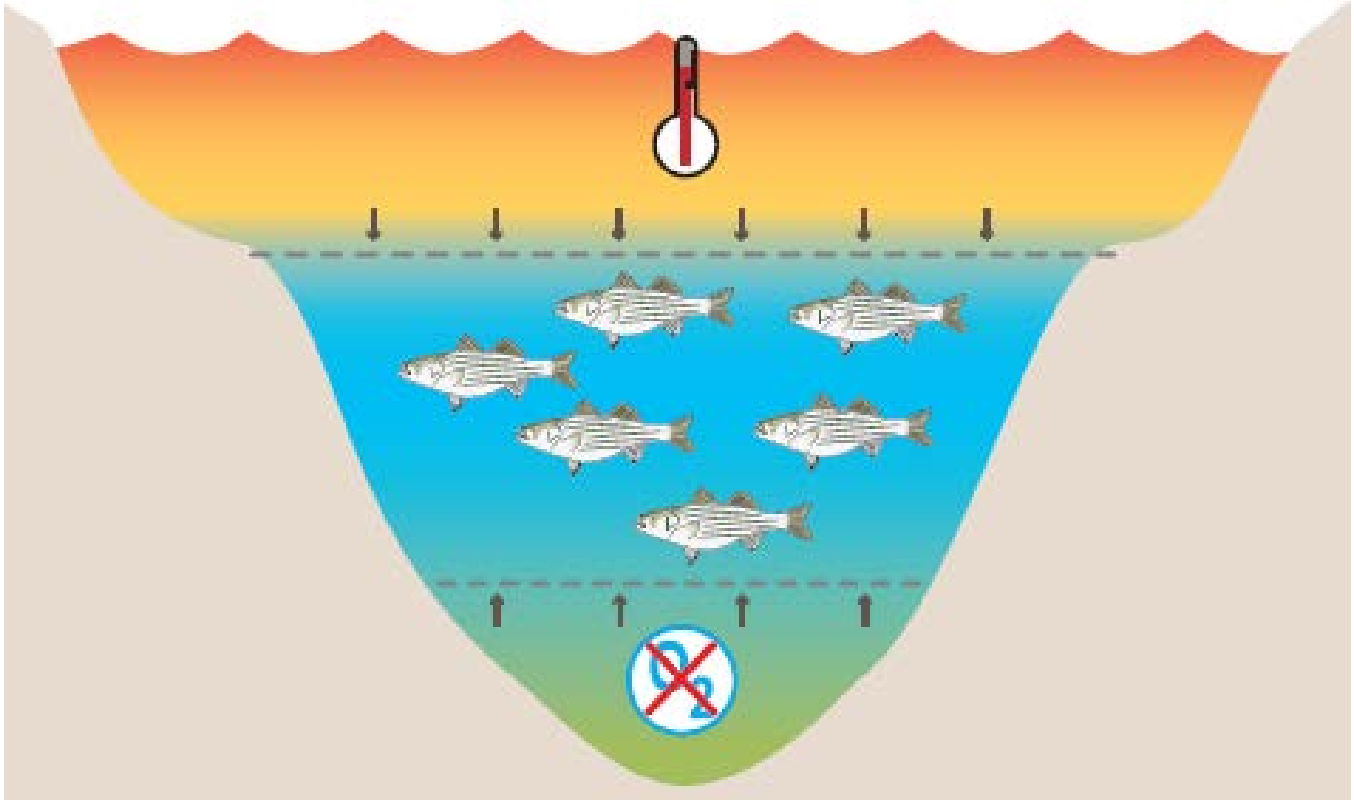
# Hypoxia and Other Stressors?




Increased water temperature →

- Decreased solubility of $O_2$ in water
- Increased metabolism of fish
- Increased $O_2$ requirements

# Hypoxia Leads to Shifts In Distribution of Fishes to Unfavorable Habitats



High surface temperatures and low $dO_2$ levels in deep waters lead to a habitat squeeze for striped bass (Coutant 1985)

# Mycobacteriosis in Striped Bass

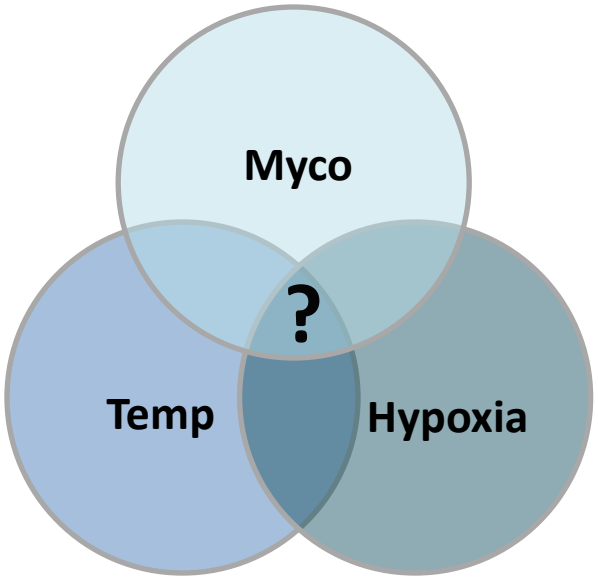
- First observed in VA in 1997
- Bacterial disease (*Mycobacterium* spp.)
  - Granulomatous inflammation
    - Viscera (spleen & kidney)
  - Dermal lesions & emaciation
- Prevalence > 75%
- Associated with increased natural mortality and lower growth rates


W.K. Vogelbein

D. Lapointe

Vogelbein et al. 1998; Overton et al. 2003; Jiang et al. 2007; Gauthier et al. 2008; Latour et al. 2012

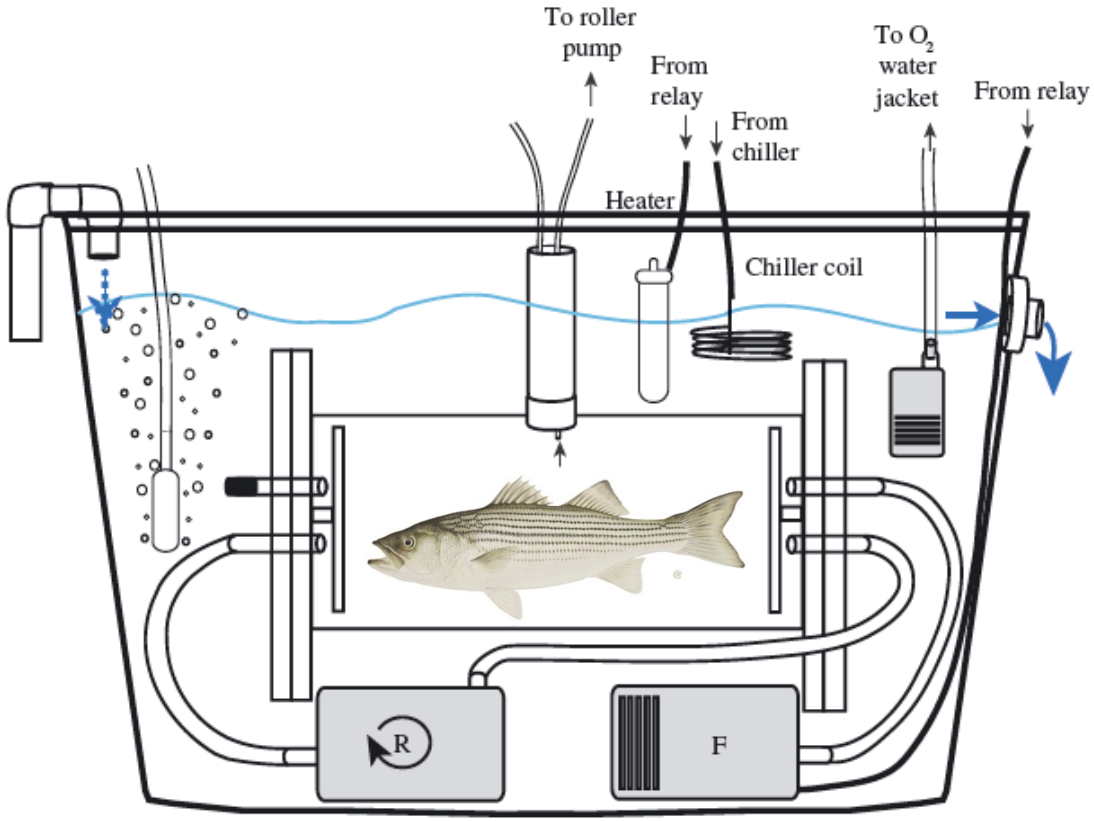
# What are the Interactive Effects of Hypoxia, Elevated Temperature, and Disease on Striped Bass?




- Collected healthy & diseased striped bass from the Rappahannock and Great Wicomico rivers, VA
  - Mean size (mm FL):
    - 464 (healthy)
    - 489 (moderate)
    - 510 (heavy)
- Measured metabolic performance

# Metabolic Performance

- Standard metabolic rate **SMR** **mg $O_2$ $kg^{-1}$ $h^{-1}$**
  - Oxygen consumption rate at rest




**Stop-flow respirometry**

# Other Performance Measures

- Critical oxygen saturation **$S_{crit}$** **%**
  - A measure of hypoxia tolerance
  - measured as the $O_2$ level at which SMR can no longer be sustained

- Maximum metabolic rate **MMR** **mg $O_2$ $kg^{-1}$ $h^{-1}$**
  - maximum short-term energy output for demanding activities
  - measured as the $O_2$ consumption rate following exhaustive exercise – 'chase' protocol

- Metabolic scope **MS** **mg $O_2$ $kg^{-1}$ $h^{-1}$**
  - represents the limits within which all aerobic activities must be undertaken
    - swimming, growth, reproduction, regulation, diseases & other stressors
  - calculated as difference between MMR and SMR

# Experimental Design


Day 1 — Day 5

20°C

| • Chase<br>• $MMR_N$ | • SMR | • $S_{crit}$ | • Rest<br>• Chase | • $MMR_H$ |
|---|---|---|---|---|

Normoxia | Hypoxia*

Day 8 — Day 12

28°C

| • Chase<br>• $MMR_N$ | • SMR | • $S_{crit}$ | • Rest<br>• Chase | • $MMR_H$<br>• Sampling |
|---|---|---|---|---|

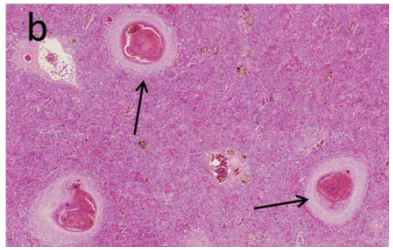
Normoxia | Hypoxia*

*3 mg $O_2$ $l^{-1}$

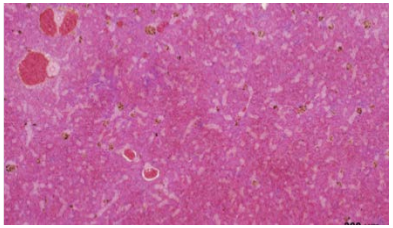
# Classification of Disease State

- Density of granulomas in spleen
  - Histological determination
- Classified into 3 states:


**Heavy** N=10




**Moderate** N=6



**Healthy + Mild** N=16

# Analysis

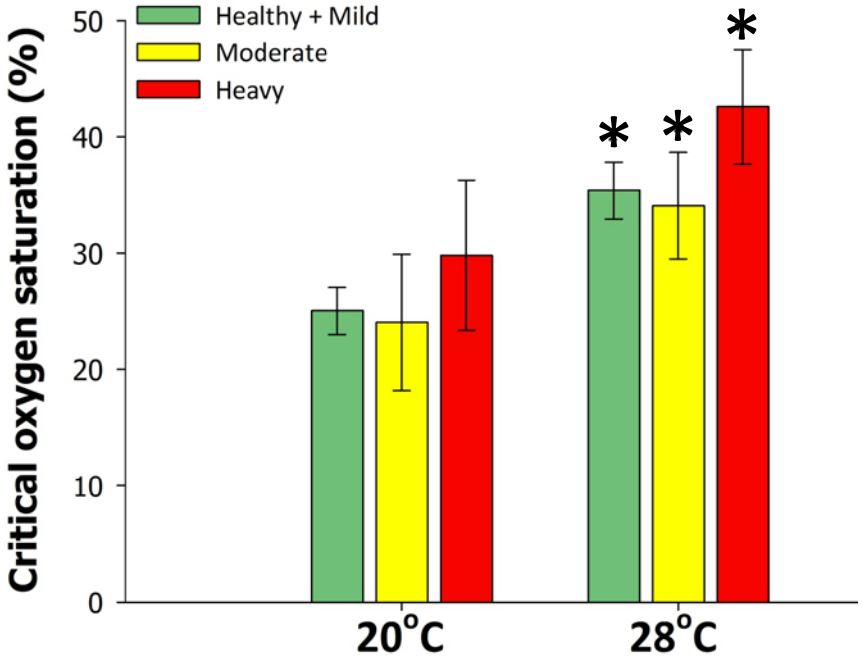
- Responses
  - Standard metabolic rate
  - Critical oxygen saturation
  - Maximum metabolic rate
  - Metabolic scope

  } Measured from each fish

- Predictors
  - Disease state — mild, moderate, severe
  - $O_2$ concentration — normoxia / hypoxia (3 mg $O_2$ $l^{-1}$)
  - Temperature — 20, 28° C
  - Interactions
- MV repeated measures model with heterogeneous errors: $Y_{1ijkm}, Y_{2ijkm}, Y_{3ijkm}, Y_{4ijkm} = \mu + \delta_i + o_j + \tau_k + int + \varepsilon_i + \varepsilon_{jkm}$

# Elevated Temperature

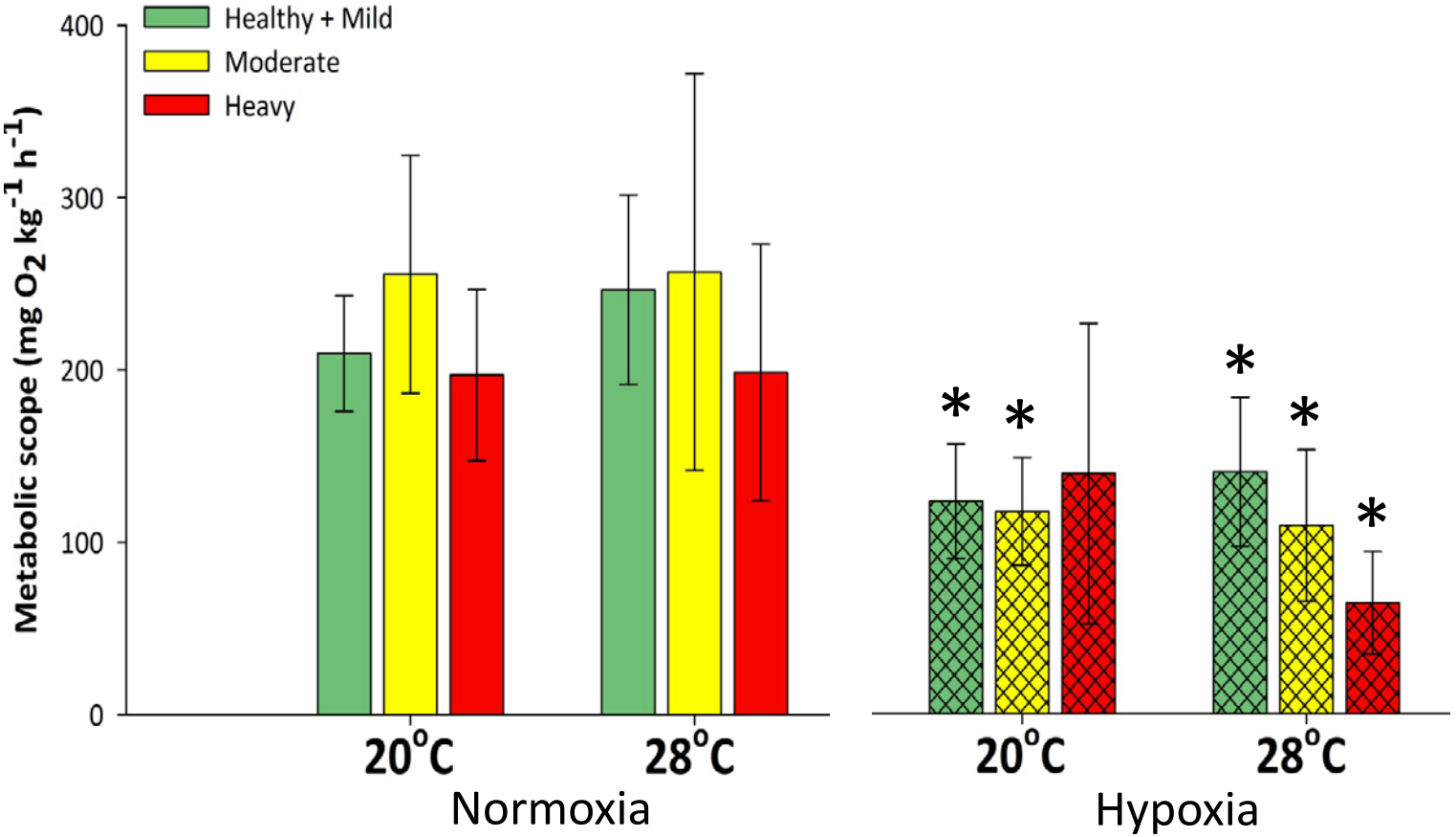
- Increases standard metabolic rate
- Increases maximum metabolic rate (healthy/mild)
- Decreases hypoxia tolerance (increases $S_{crit}$)




| T (°C) | $S_{crit}$ (%) | $C_{crit}$ (mg/l) |
|---|---|---|
| 20 | 25.0 ± 2.0 | 2.0 ± 0.1 |
| 28 | 35.4 ± 2.4 | 2.5 ± 0.2 |

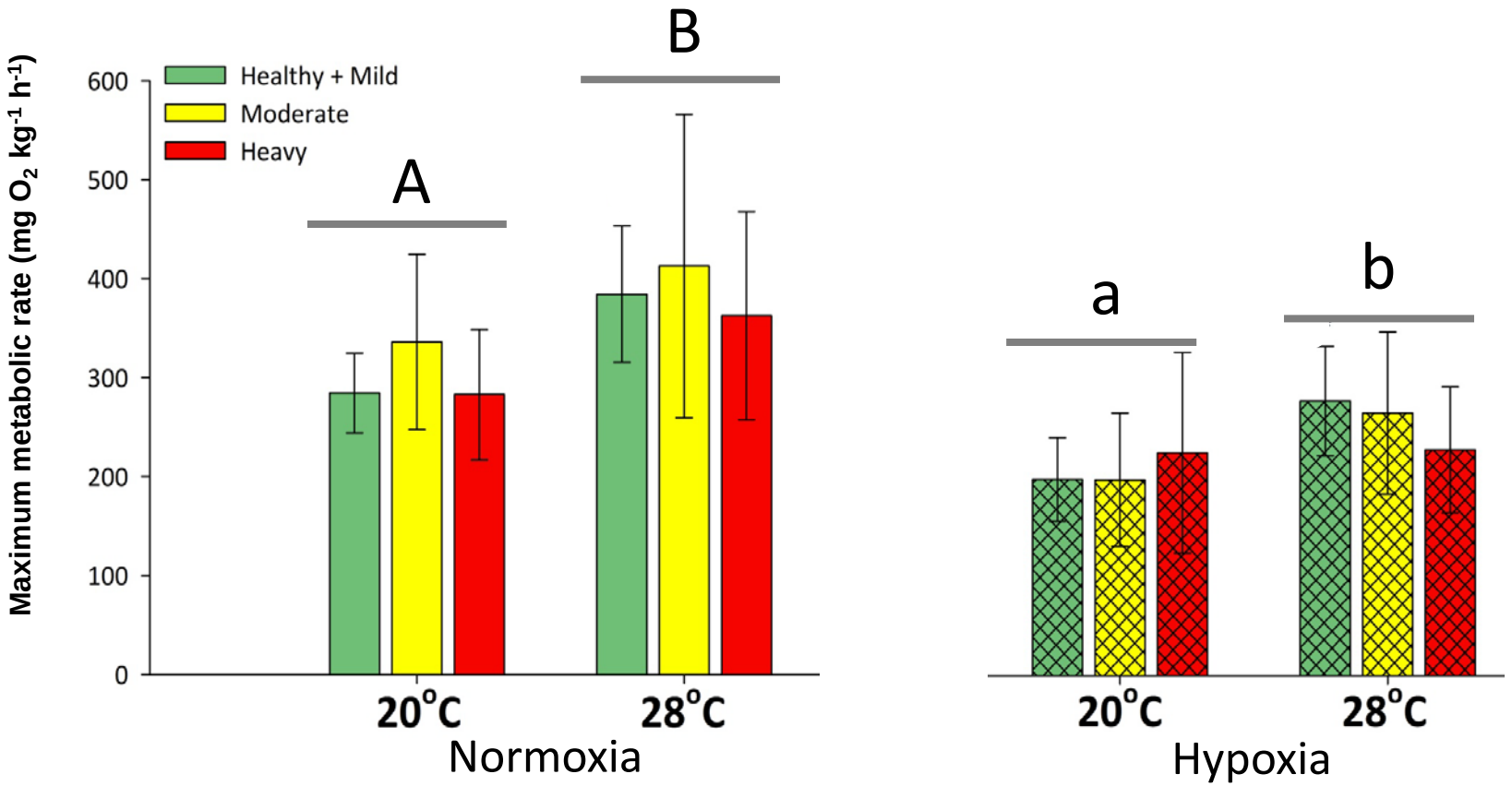
# Hypoxia

- Reduces MMR and metabolic scope
  - Lower ability to undertake aerobic activities in hypoxic conditions



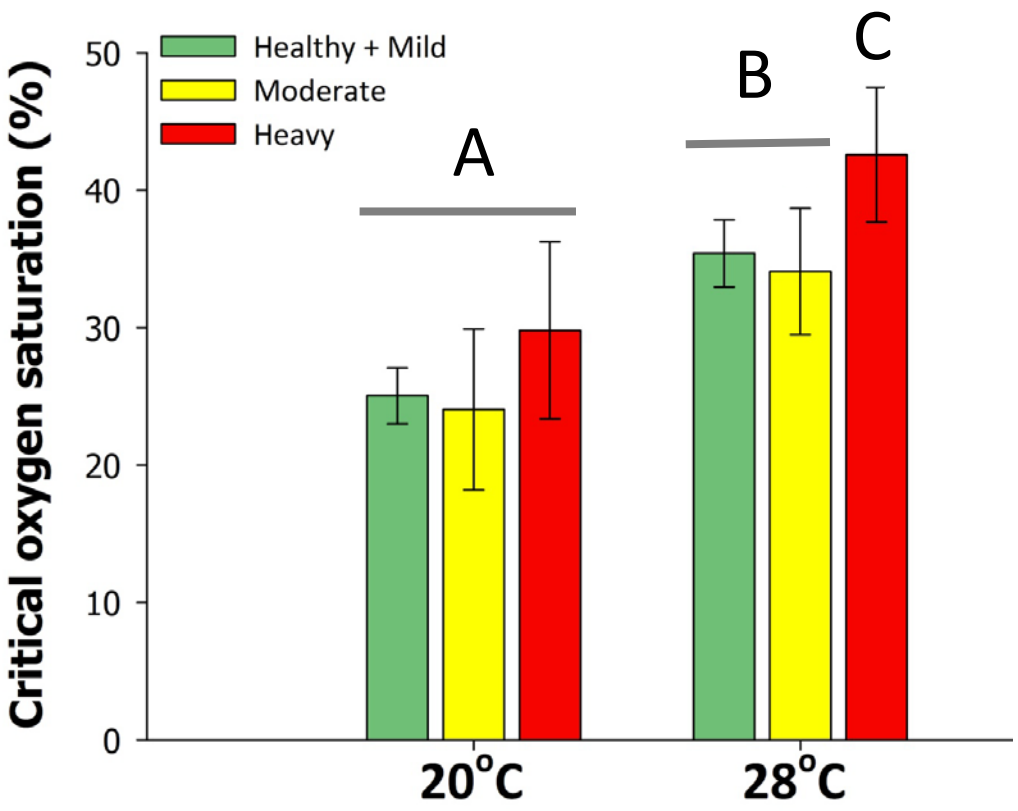
# Disease Severity

- Has no effect on SMR or MMR
  - Limits on aerobic activity not affected by disease



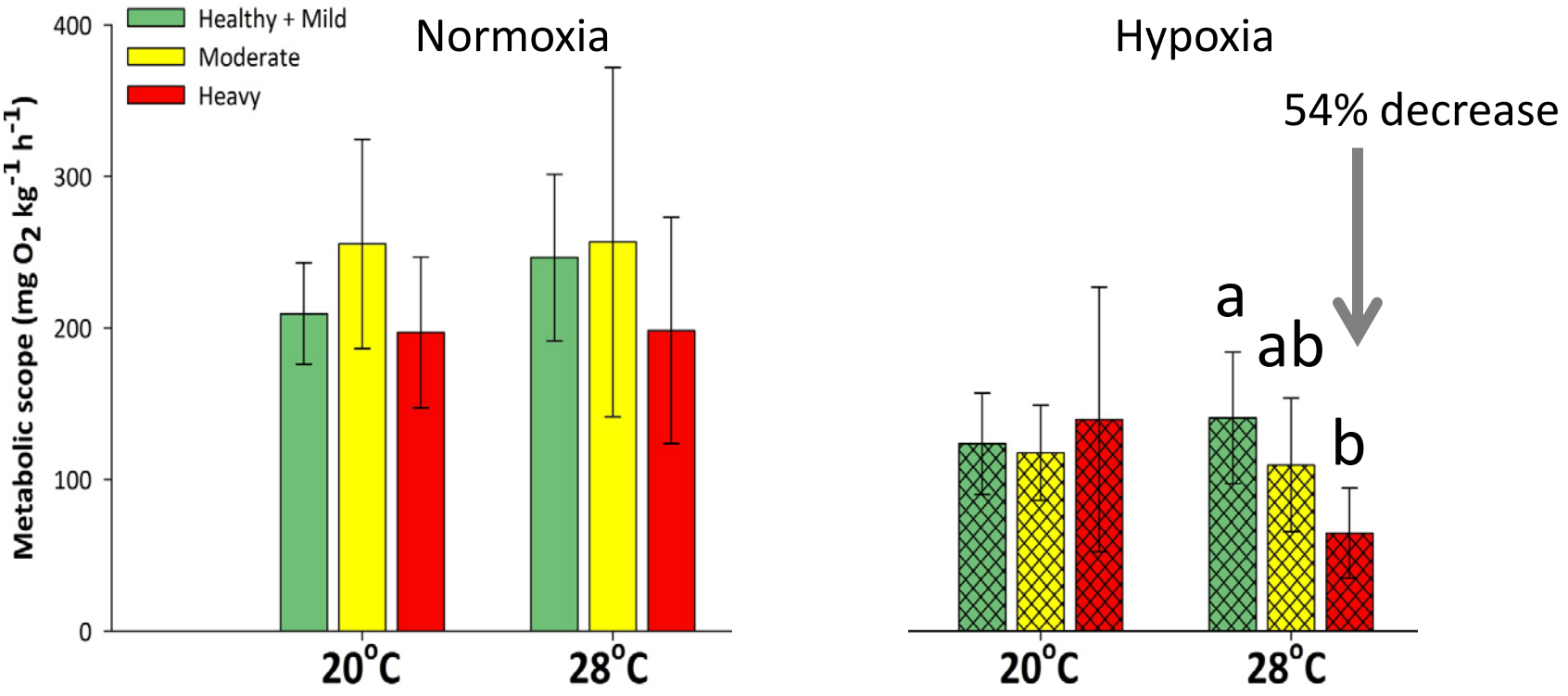
# Disease Severity

- Decreases hypoxia tolerance ($S_{crit}$ increases)
- For heavily infected fish, hypoxia tolerance at elevated T is reduced by a factor of 1.2



# Interactive Effects

- A significant interactive effect of hypoxia, elevated temperature, and disease severity



# Triple Whammy for Striped Bass

- Scope for activity of diseased striped bass in warm hypoxic waters is greatly compromised
  - experience fatigue more rapidly
  - are restricted in their ability to elude predators or secure prey
  - likely have lower growth rates
  - exhibit reduced immune function and reproductive performance

# Concluding Remarks

- Anthropogenic impacts on environmental quality, possible changes in forage abundance, the recent decline in striped bass condition, and the emergence of mycobacteriosis are **interlinked processes**
- Striped bass may be fairly tolerant of hypoxia, but tolerance declines with elevated temperatures
- Furthermore, summer temperature-oxygen conditions increase the prevalence of disease, and in turn, the disease reduces the tolerance of fish to elevated temperature & hypoxia
  - Multiple positive feedback loops → observed high prevalence of disease, reduced growth rates, and elevated rates of natural mortality
- Interactive effects of stressors and individual variation should be considered in population models
  - Individual-based responses

# Thank You