Effects of Temperature and Oxygen on Metabolic Parameters for Eucalanoid Copepods of the Eastern Tropical North Pacific: Implications for Biogeochemical Cycles

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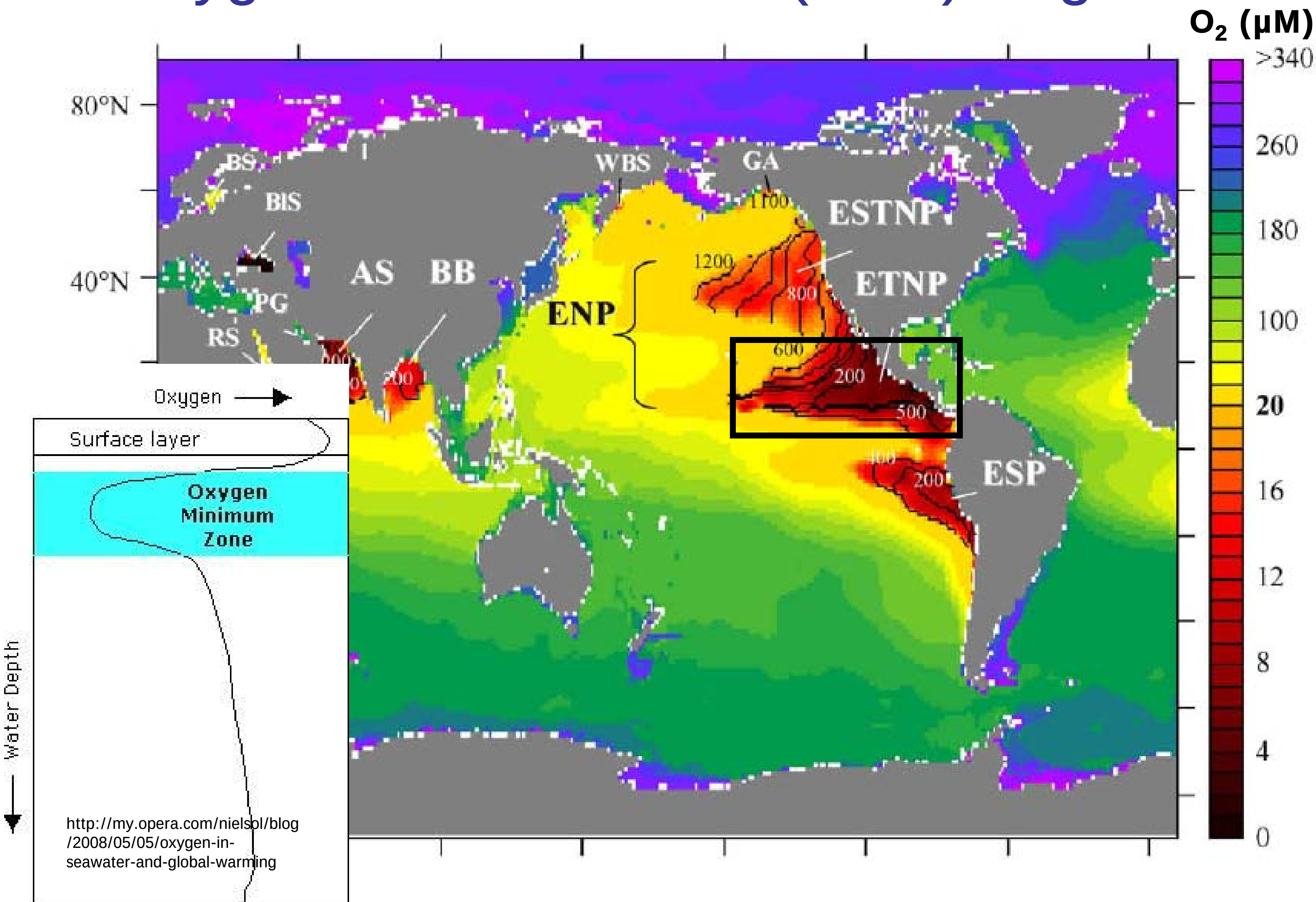
Population Connections, Community Dynamics, and Climate Variability

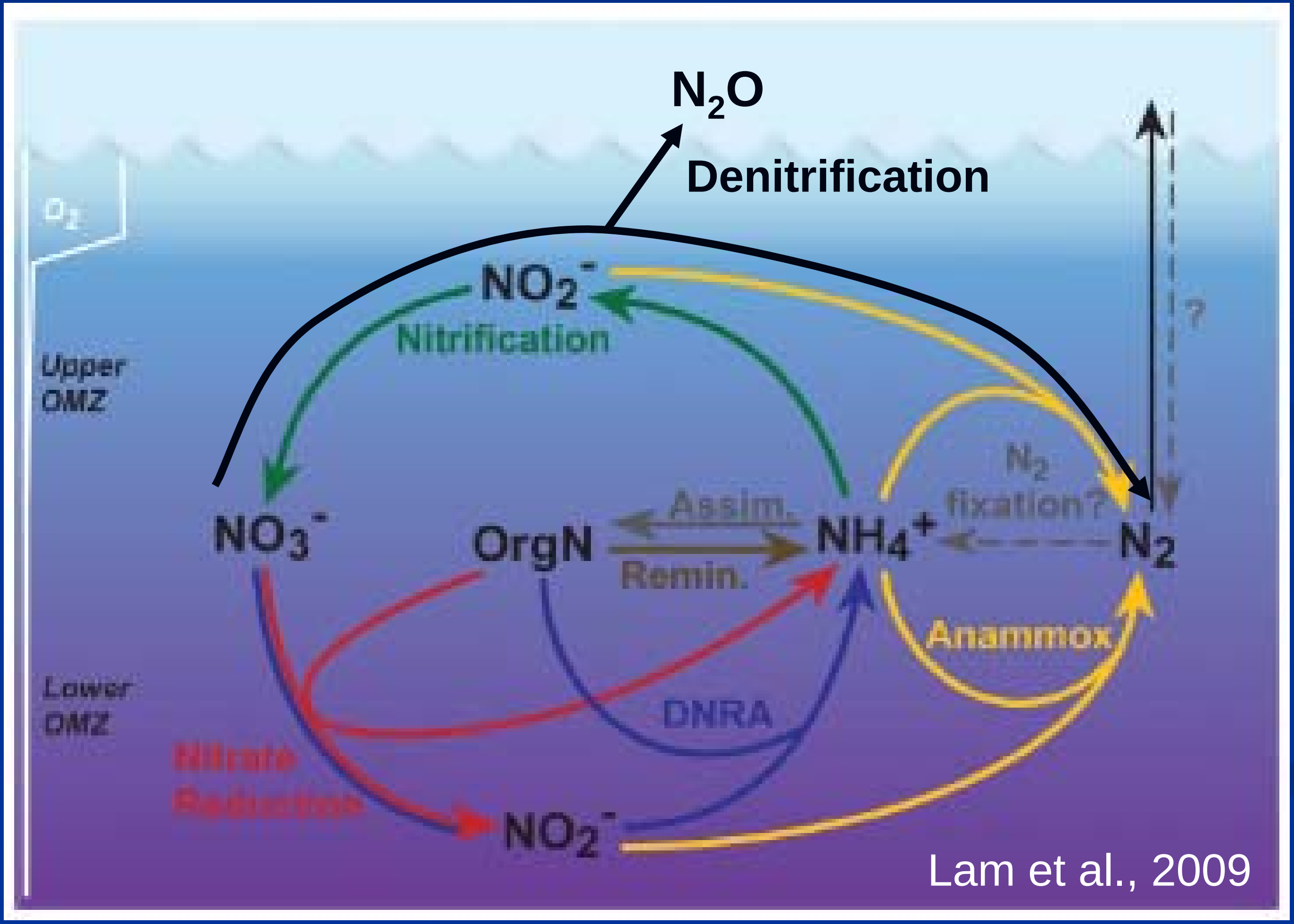
Oxygen Minimum Zone (OMZ) Regions



Paulmier & Ruiz-Pino (2009)

Why Study OMZs?

- Important regions for N cycling in oceans



Why Study OMZs?

- Oxygen gradients provide additional vertical habitat structure
  - Habitat compression
  - Refuge zone
- Long term stability
  - Organisms have adapted
- OMZ regions are expanding
  - Ocean warming
  - Increased stratification
- OMZs as models of past anoxic or suboxic oceans

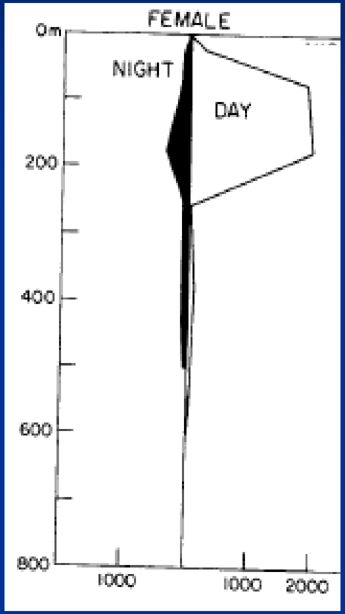
Metabolism and Oxygen Limitation

- Oxygen limitation can affect oxygen consumption rates, egg production, growth, development, activity, and survival
  - Well documented in benthic organisms exposed to coastal hypoxia
  - Not studied as extensively in pelagic organisms
- Effects of environmental oxygen concentration on excretion rates and product type are largely unknown
  - Explore how oxygen limitation alters biochemical processes
  - Understand the zooplankton contribution towards elemental cycling in ocean systems
    - Recall OMZ N cycling

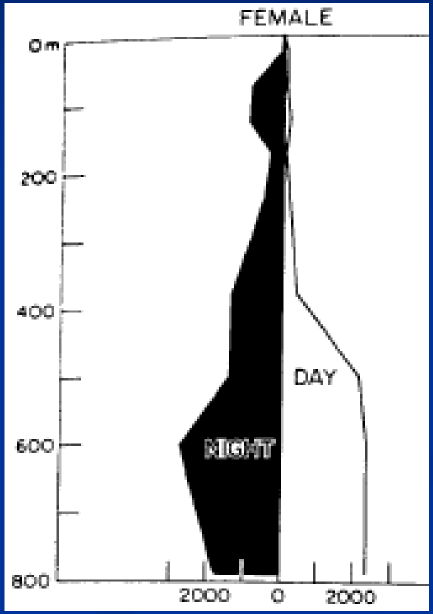
The Copepod Family Eucalanidae

- Abundant and diverse group
- Show varied vertical distributions
- Related to oxygen levels

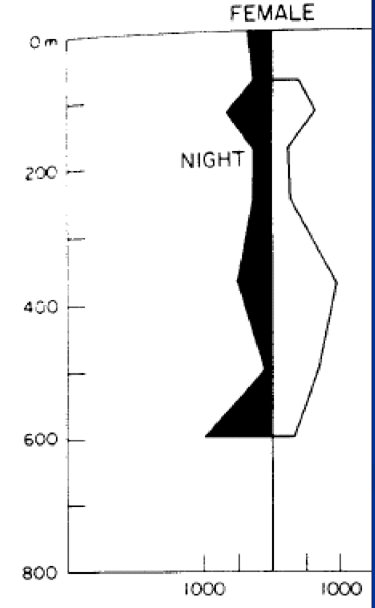
Subeucalanus subtenuis



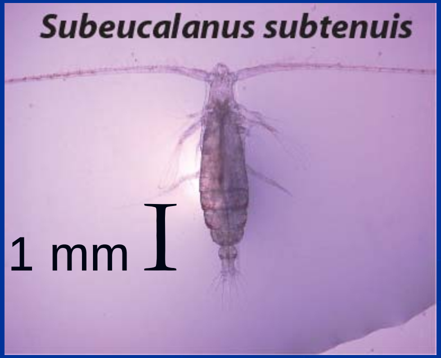
Eucalanus inermis

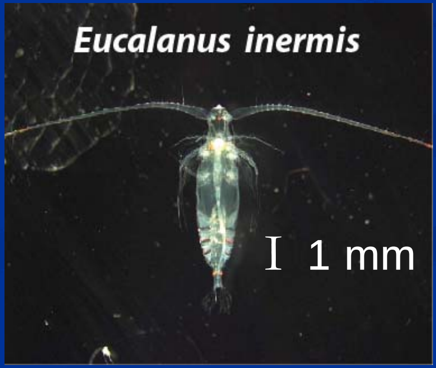


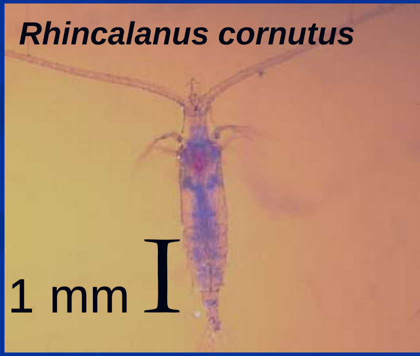
Rhincalanus rostrifrons



Individuals per 1000 m^3







Distributions from Chen, 1986

Goals

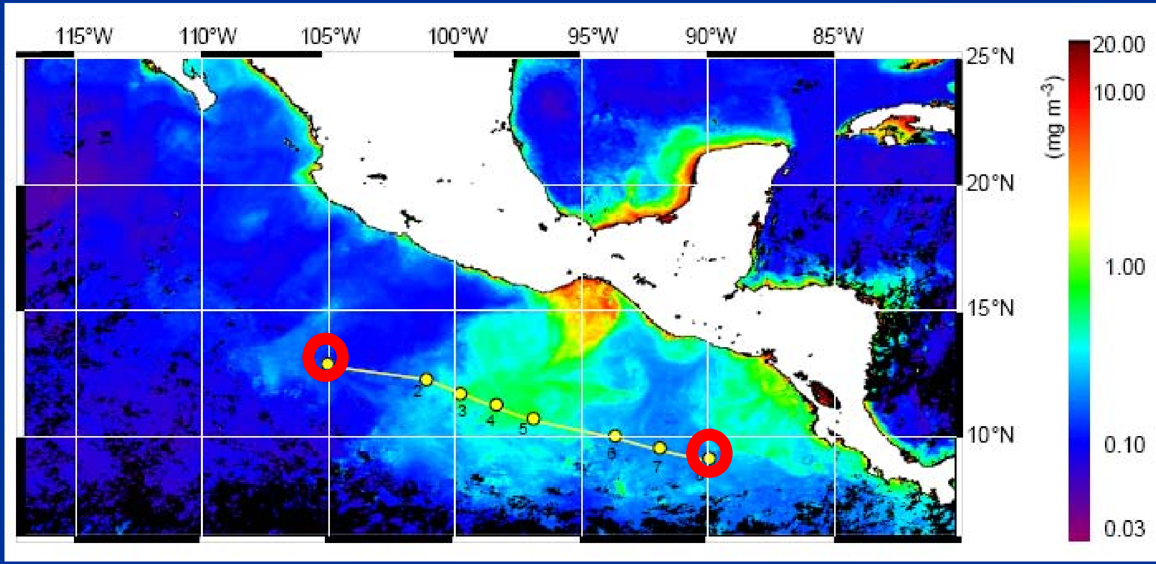
- Examine differences in oxygen consumption, urea, ammonium and phosphate excretion rates of three species of eucalanoid copepods under oxic and hypoxic conditions
  - Differences in metabolic demands
  - Differences in responses to oxygen limitation

- Use rates to extrapolate substrate utilization
  - O:N atomic ratio

Methods – Collection Sites

- Sample collection occurred on two cruises
  - Oct-Nov 2007 (R/V Seward Johnson)
  - Dec 2008-Jan 2009 (R/V Knorr)

- Two main stations



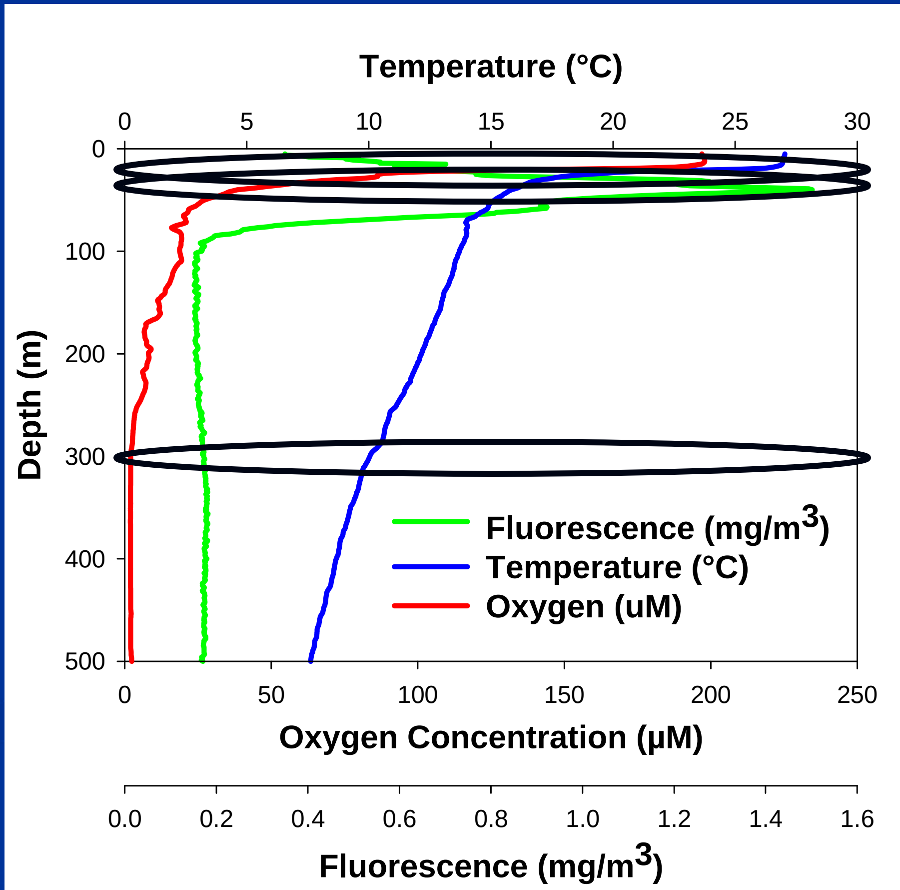
Methods – Copepod Collection

- Combination of Tucker trawls, Bongo and MOCNESS tows to collect live copepods
- Adult females were sorted and left to incubate for several hours at surface water temperatures to void gut material

Pictures courtesy of Paul Suprenand

Methods – Incubation Experiments

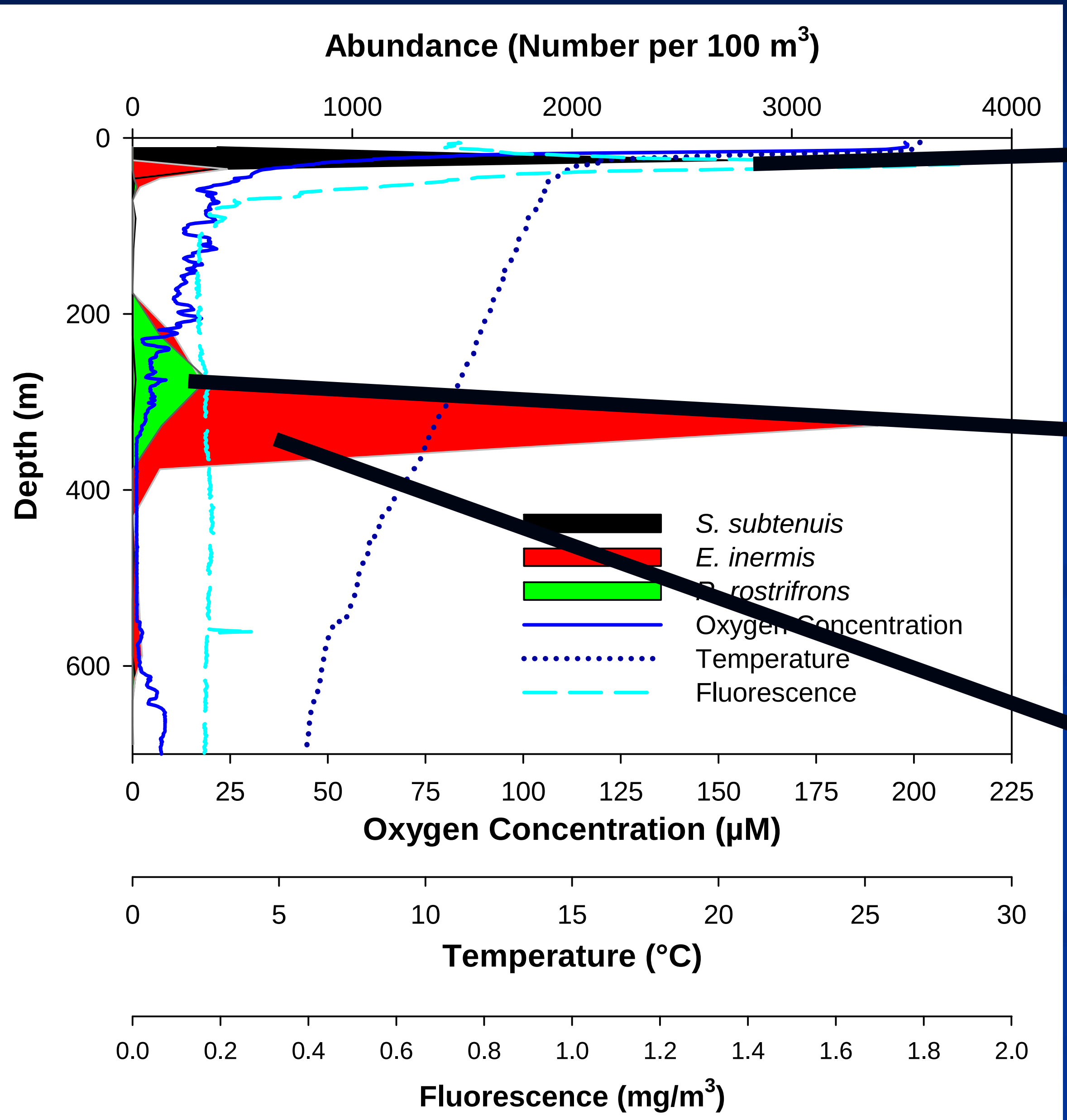
- End point experiments were used with BOD bottles (60 ml)
  - 2-15 individuals
  - 12-24 hours
  - Only used experiments with 100% survivorship
- Temperature: 10, 17, 23°C
  - Upper OMZ core, Chl max, Near-surface
- Oxygen Concentration: 15 (~50 μM), 100% (~200 μM) air saturation
  - Chl max, Near-surface

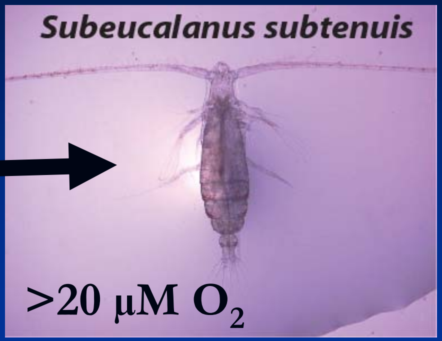


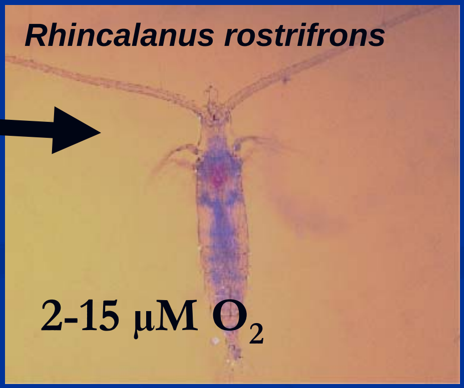
Summary of Experiments

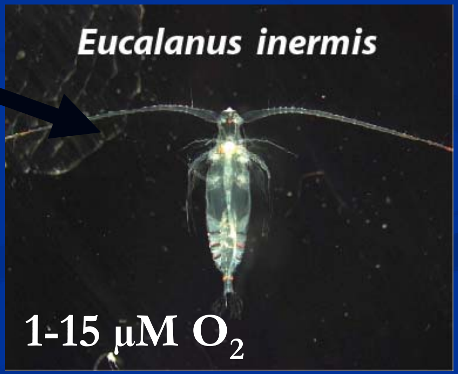
- Parameters examined
  - Oxygen consumption
  - Nitrogen excretion
    - Ammonium
    - Urea
  - Phosphate excretion
  - O:N atomic ratios
- Variables
  - Species
  - Temperature
  - Environmental oxygen concentration
  - Depth of collection
  - Interannual variability

Copepod Distributions



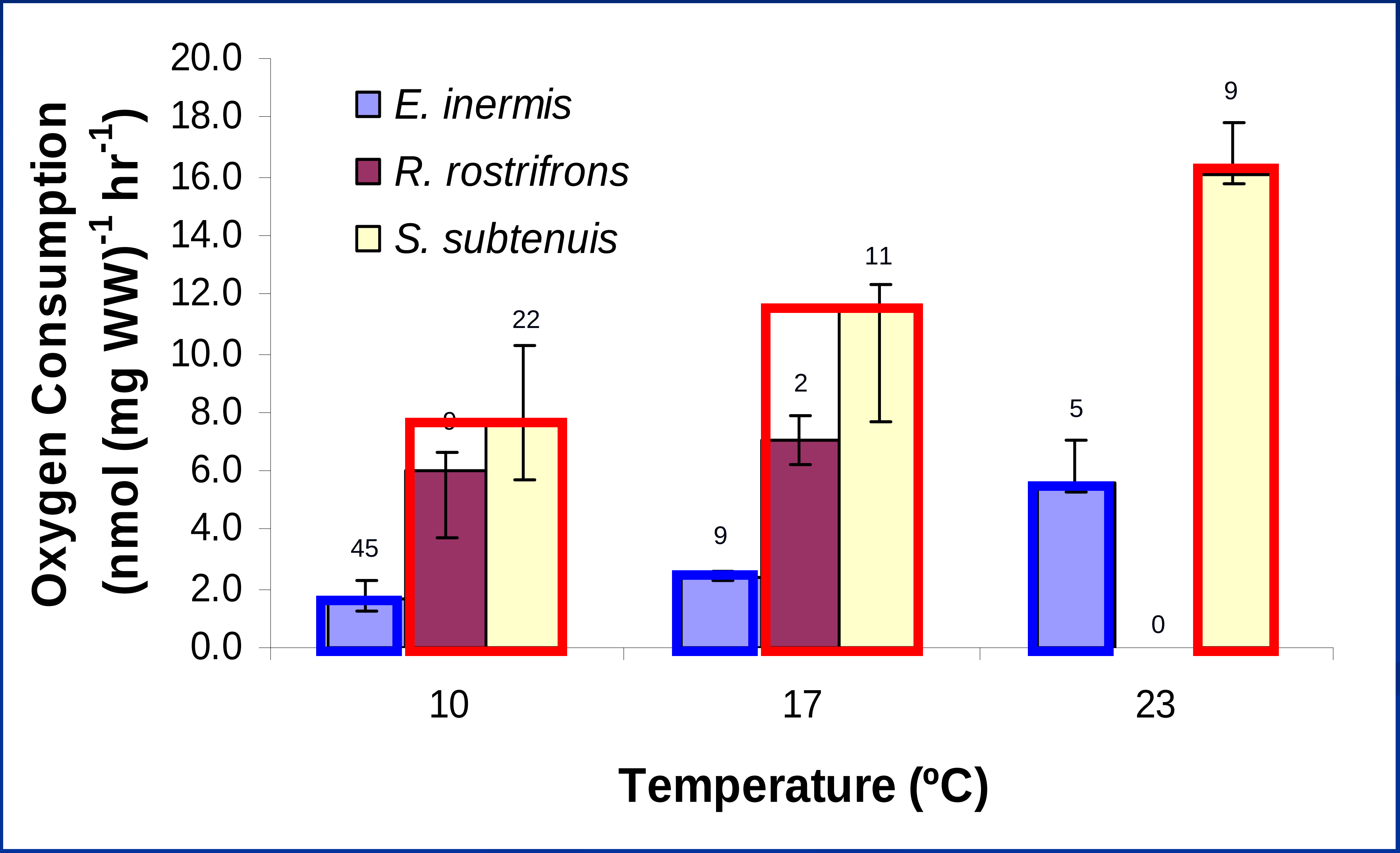




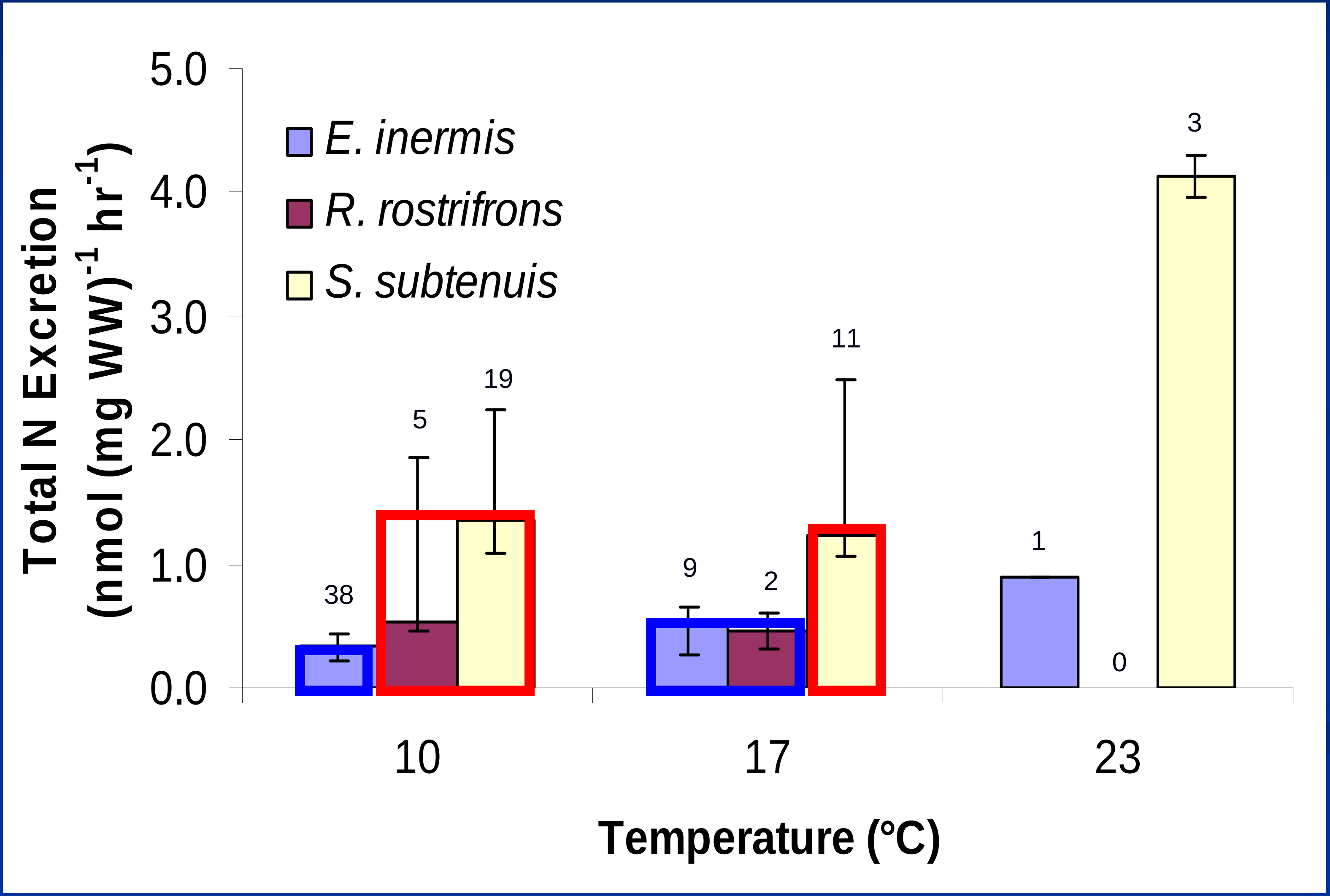


Distribution data courtesy of K. Wishner and D. Outram

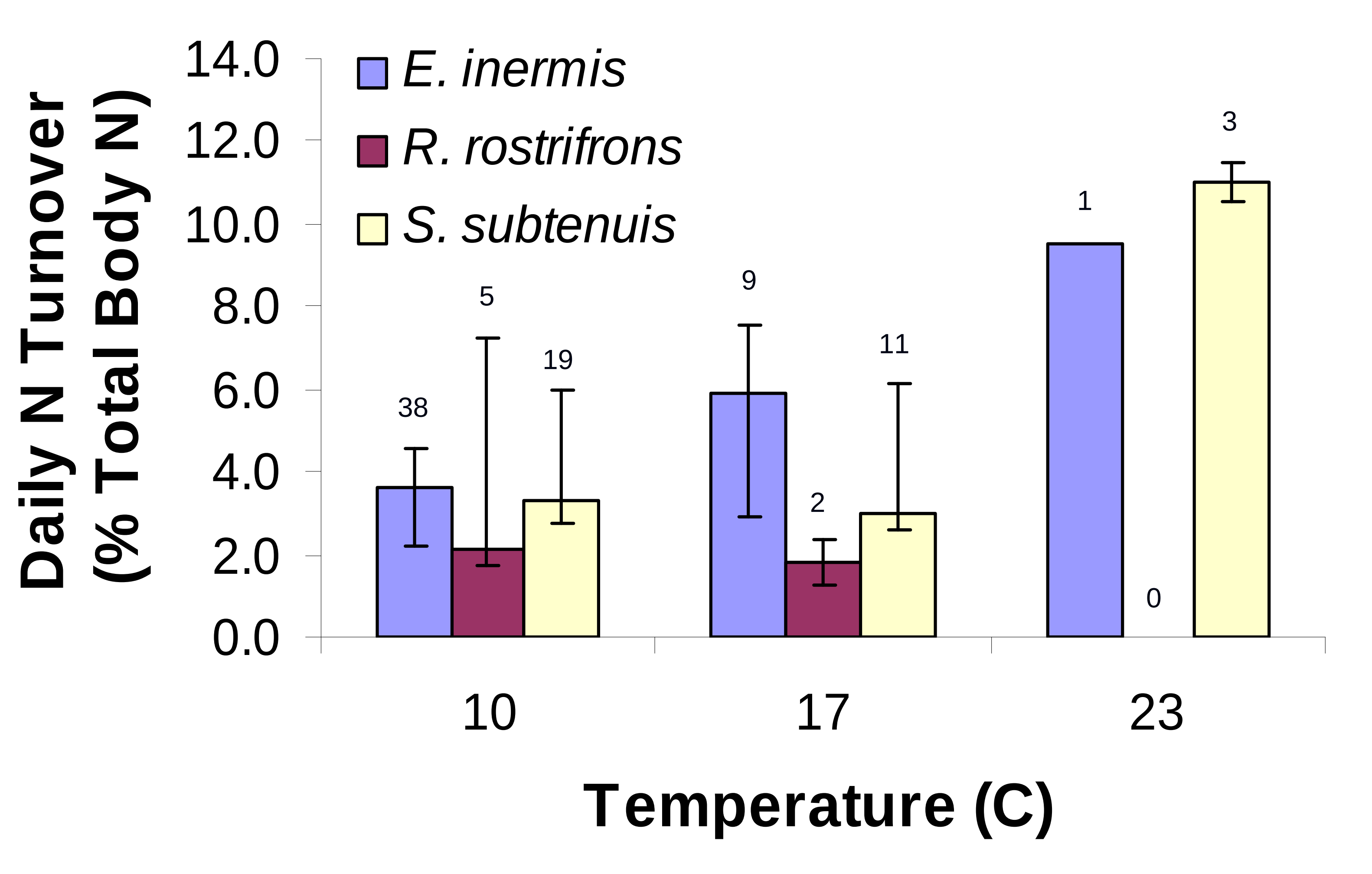
Species Differences - Oxygen Consumption



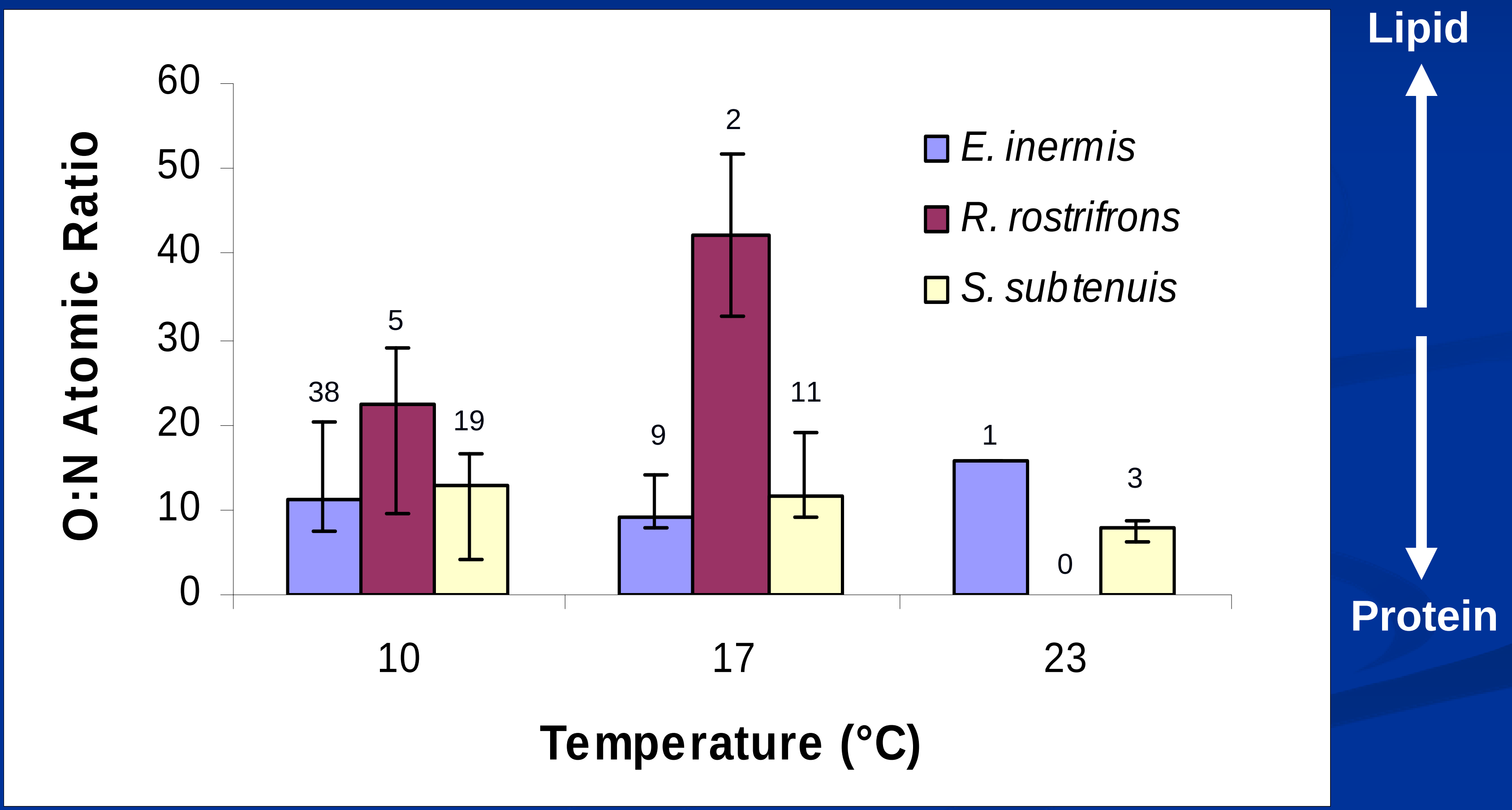
Species Differences - Total Nitrogen Excretion Rates



Species Differences - Daily Body Nitrogen Turnover



Species Differences – O:N Ratio



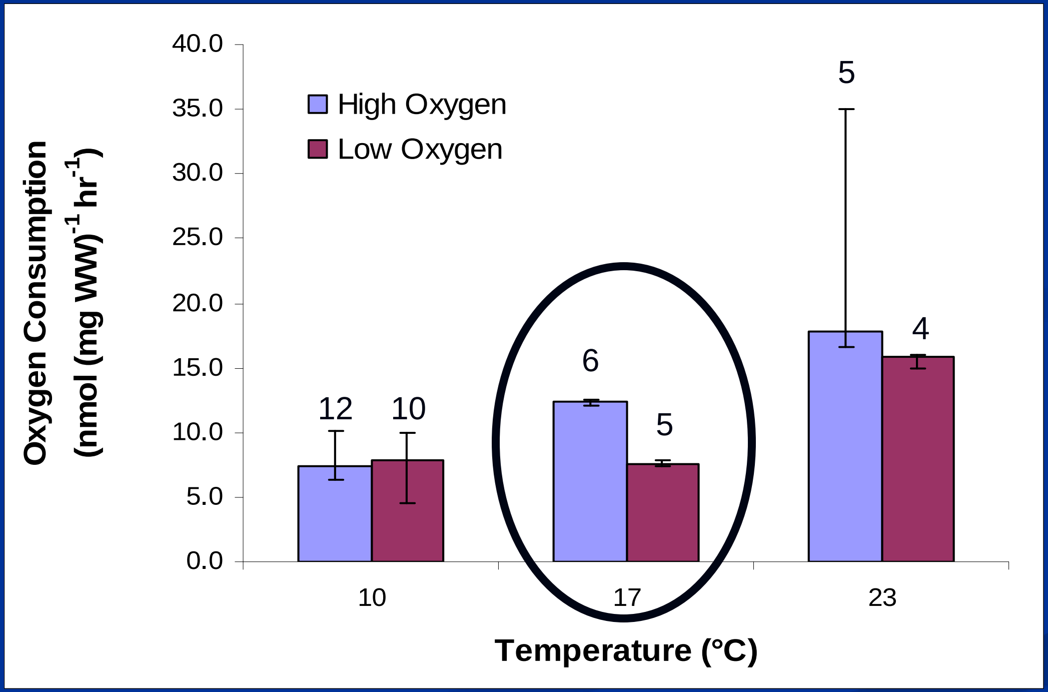
Species Differences – Summary

	E. inermis	*R. rostrifrons*	*S. subtenuis*
Environmental Oxygen (µM)	1-15	2-15	>20
Metabolic Rates	Low	Variable	High
Substrate Utilized	Protein	Protein-Lipid	Protein
Turnover Rates	Similar	Similar	Similar

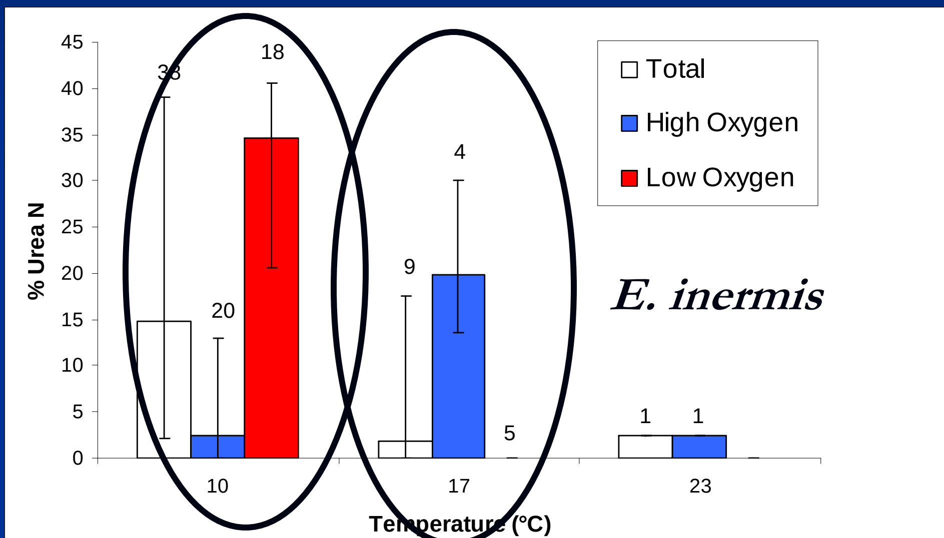
- Wet weight-specific rate measurements appear to correspond well with selected oxygen habitat
- Higher lipid utilization in *R. rostrifrons* not surprising, has large lipid stores (>10x)
- Elemental turnover rates are similar between species, indicating that while rates differ, biochemical mechanisms are likely similar

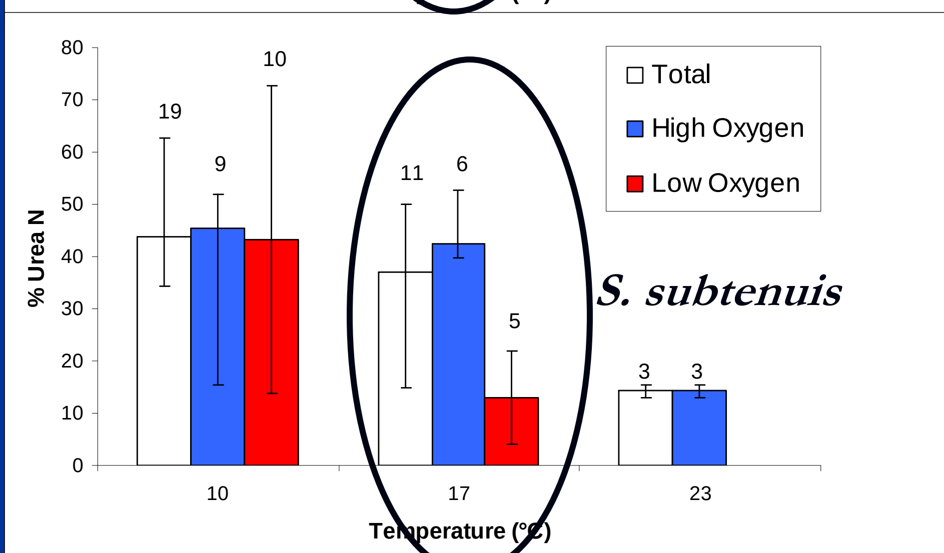
Oxygen Effects – Oxygen Consumption Rate

- Oxygen Consumption:
  - *Subeucalanus subtenuis*
  - Potential limitation in the chlorophyll max



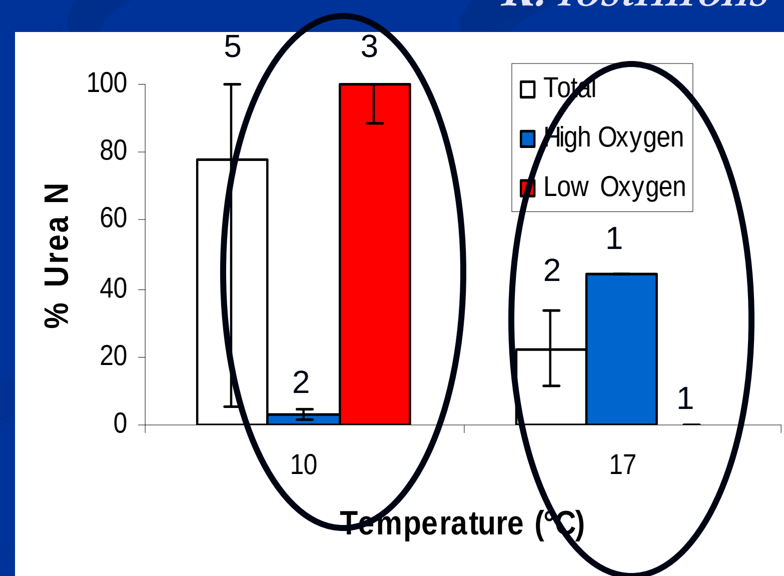
Oxygen Effects – Urea Excretion and Temperature





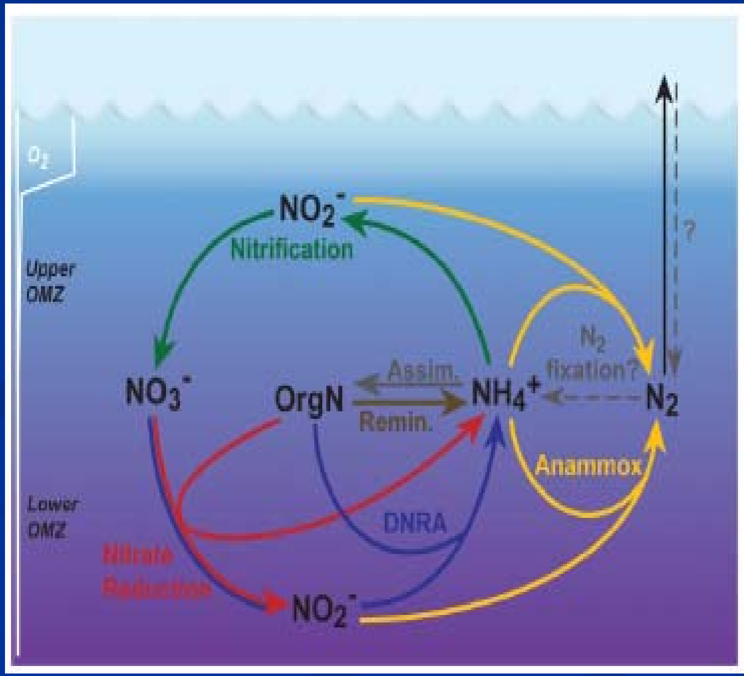
- At 10° C, low oxygen treatments had higher % urea-N
- At 17° C, low oxygen treatments had lower urea-N

R. rostrifrons



Why is this relationship important?

- In OMZ systems, knowledge of N cycling is particularly important
- Major differences in determining the contribution of zooplankton N excretion at the chlorophyll max
    - In the chl max, these three copepods produce 1,266 nmol N m^{-3} day^{-1}
    - Estimations using high oxygen concentrations: 35% is urea
    - Estimations using *in situ* oxygen concentrations: 9% is urea



Lam et al., 2009

Metabolic Parameters Summary

- Generally, *E. inermis* had the lowest weight specific metabolic rates while *S. subtenuis* had the highest
  - Consistent with observed oxygen environment
- Environmental oxygen concentration only affected oxygen consumption rates for *S. subtenuis* at higher temperatures
- Urea excretion rates and % urea-N showed an interesting combination effect of temperature and oxygen concentration
  - Implications for modeling N cycling in OMZ regions

Thanks to:

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- USF College of Marine Science

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- Captains and crews of the R/V Seward Johnson and R/V Knorr

- Advisor: Dr. Kendra Daly
- PhD Committee

- Seibel, Wishner, Fanning, Torres and Daly labs