

# Changes in Copepod Size in Response to Warm and Cold Conditions During **Spring** in the Eastern Bering Sea

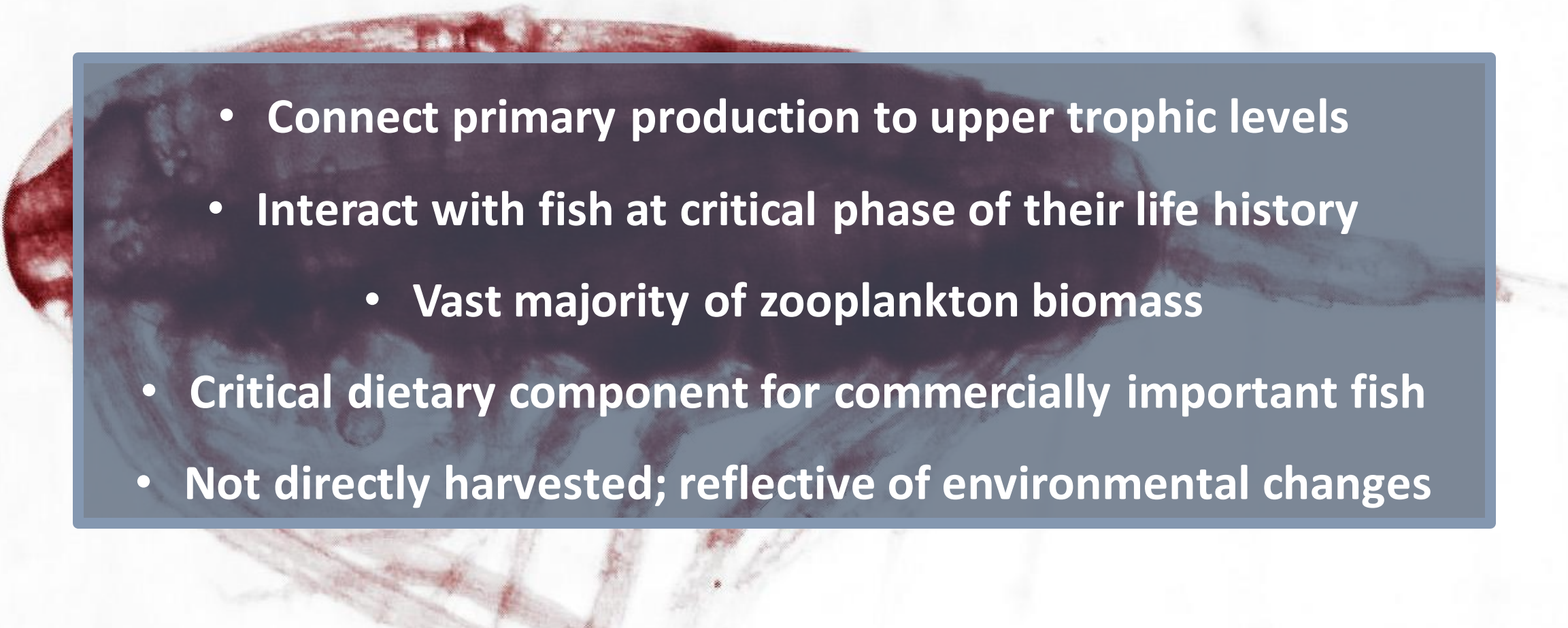
**Deana Crouser** – Lynker Technologies in support of Alaska Fisheries Science Center, NMFS, NOAA

**Jan Ohlberger** – School of Aquatic and Fishery Sciences, University of Washington; Washington Department of Fish and Wildlife

**Grant Woodard** – School of Aquatic and Fishery Sciences, University of Washington

**David Kimmel** – Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, NMFS, NOAA

# Fulcrum of the Food Web

- 
- **Connect primary production to upper trophic levels**
  - **Interact with fish at critical phase of their life history**
    - **Vast majority of zooplankton biomass**
  - **Critical dietary component for commercially important fish**
  - **Not directly harvested; reflective of environmental changes**

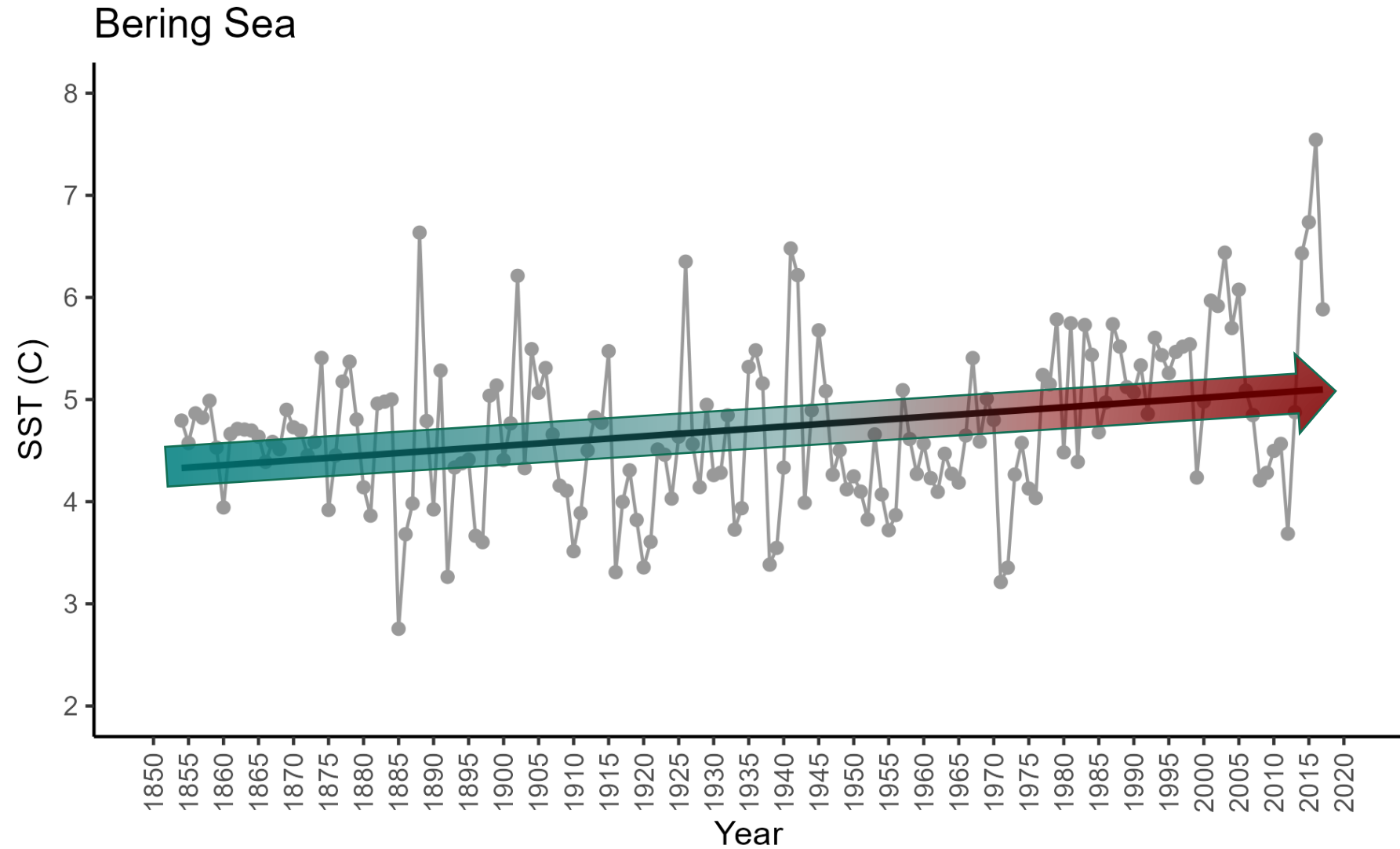
# Ecological Responses to Warming

**Change in  
Species  
Phenology**

**Shift in Species  
Distribution**

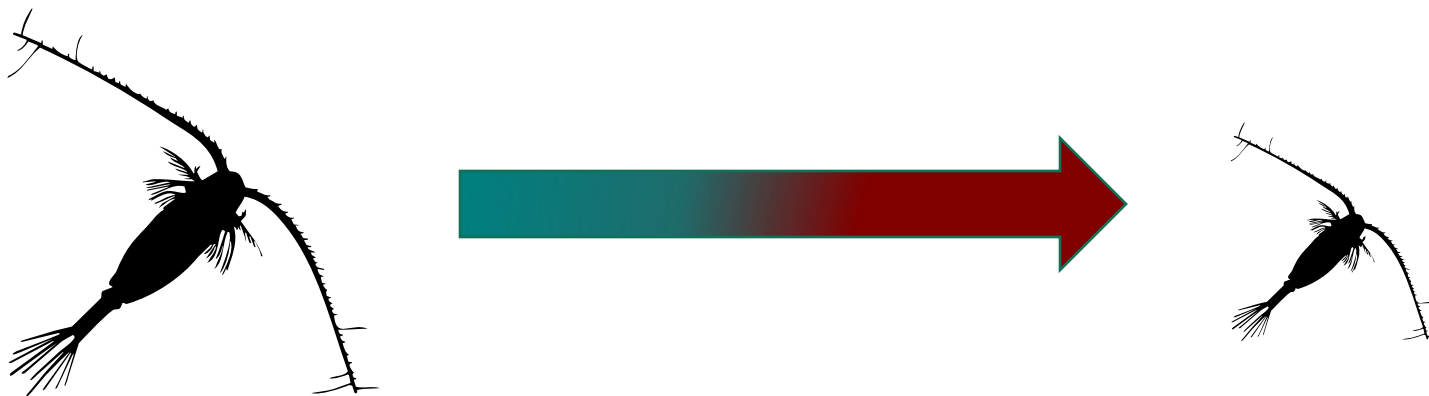
**Decline in  
Body Size**

# NOAA Extended, Reconstructed Sea Surface Temperature Plot



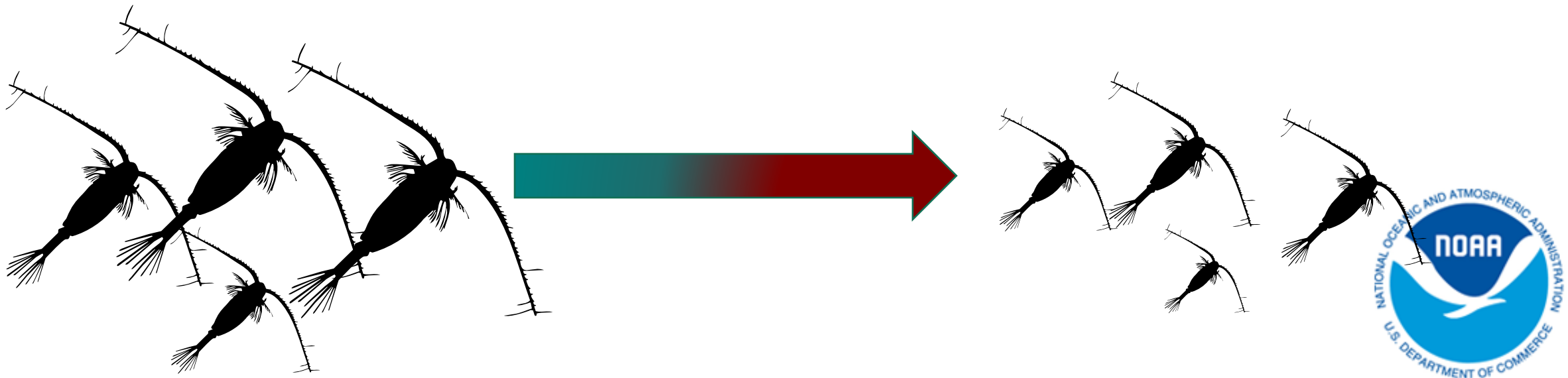
# HYPOTHESIS 1:

There has been an overall decrease in the mean INDIVIDUAL size of copepods



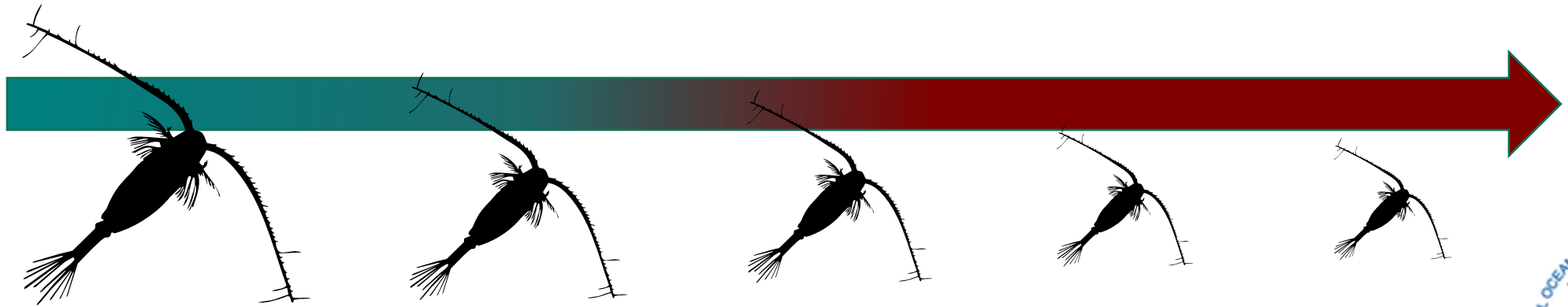
# HYPOTHESIS 2:

There has been an overall decrease in mean size for each POPULATION of copepod

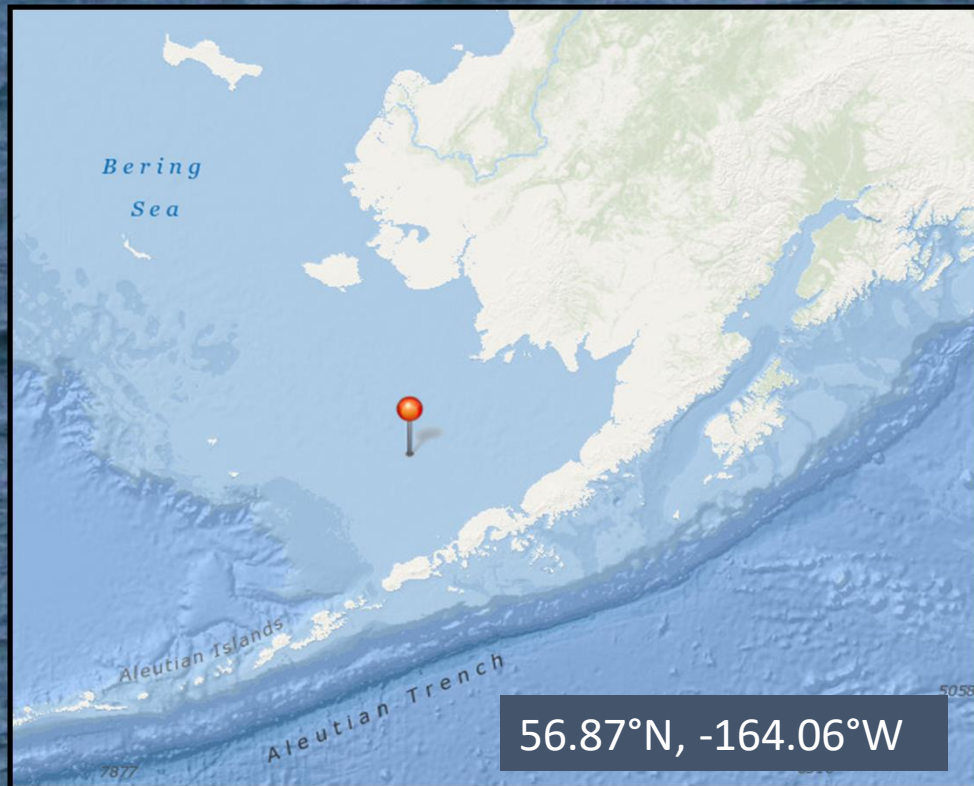


# HYPOTHESIS 3:

There is an overall trend in the mean copepod body size OVER TIME

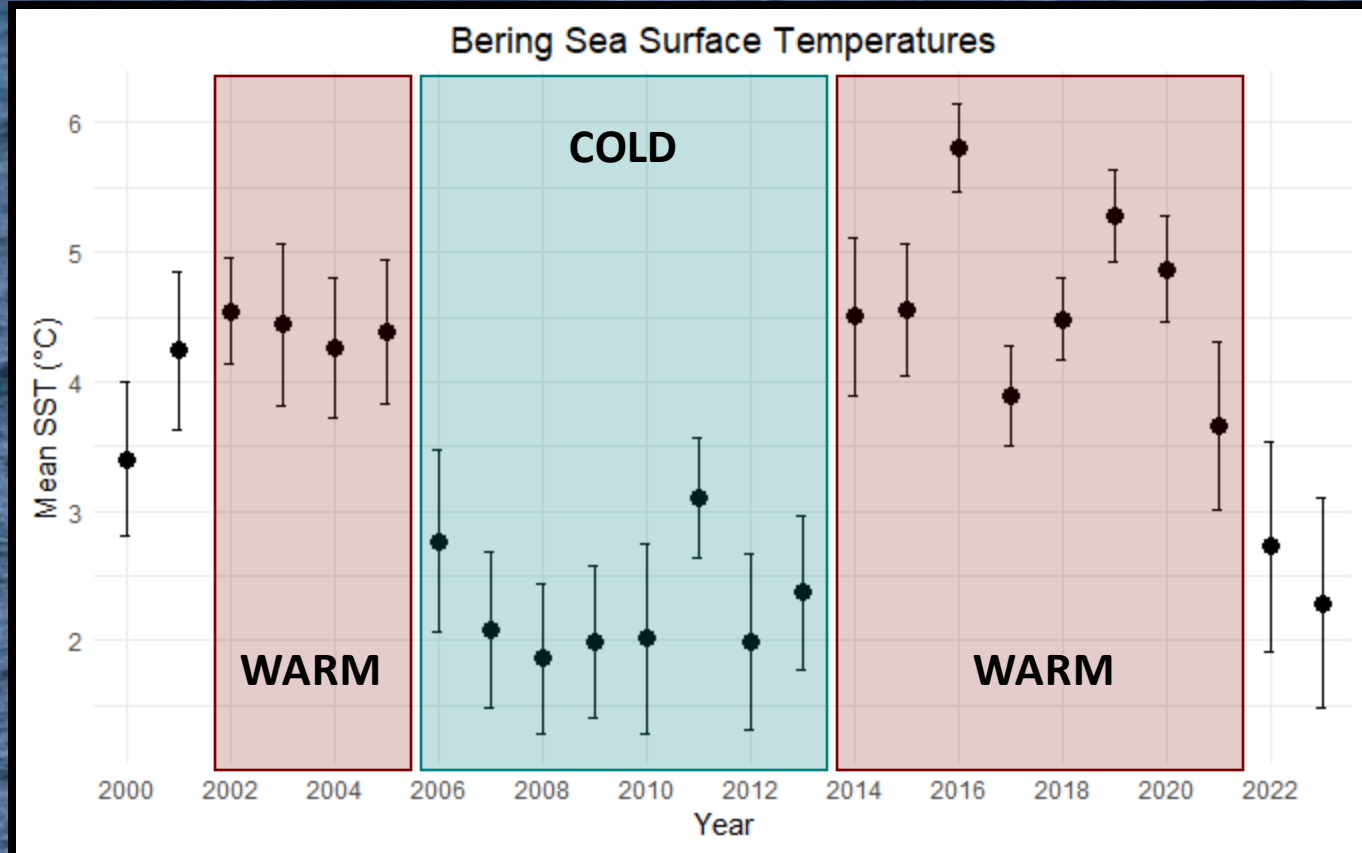


# NOAA's Pacific Marine Environmental Laboratory M2 Mooring



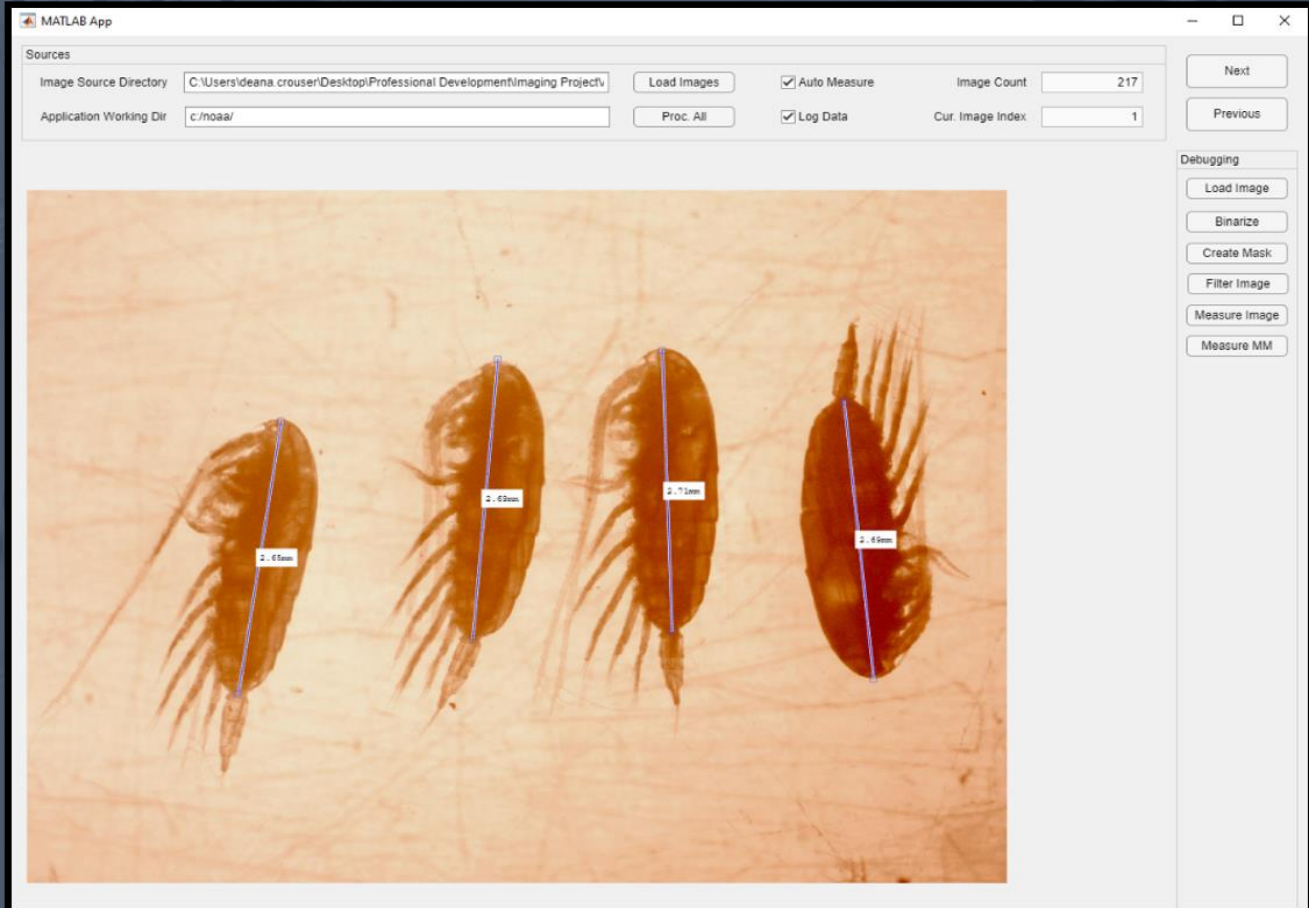
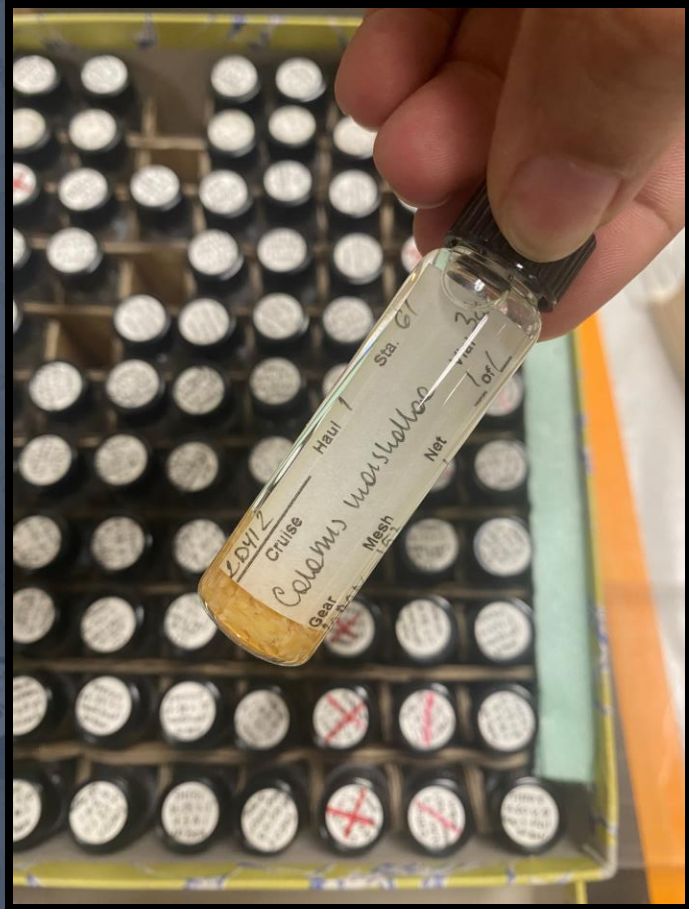


# NOAA's Pacific Marine Environmental Laboratory M2 Mooring



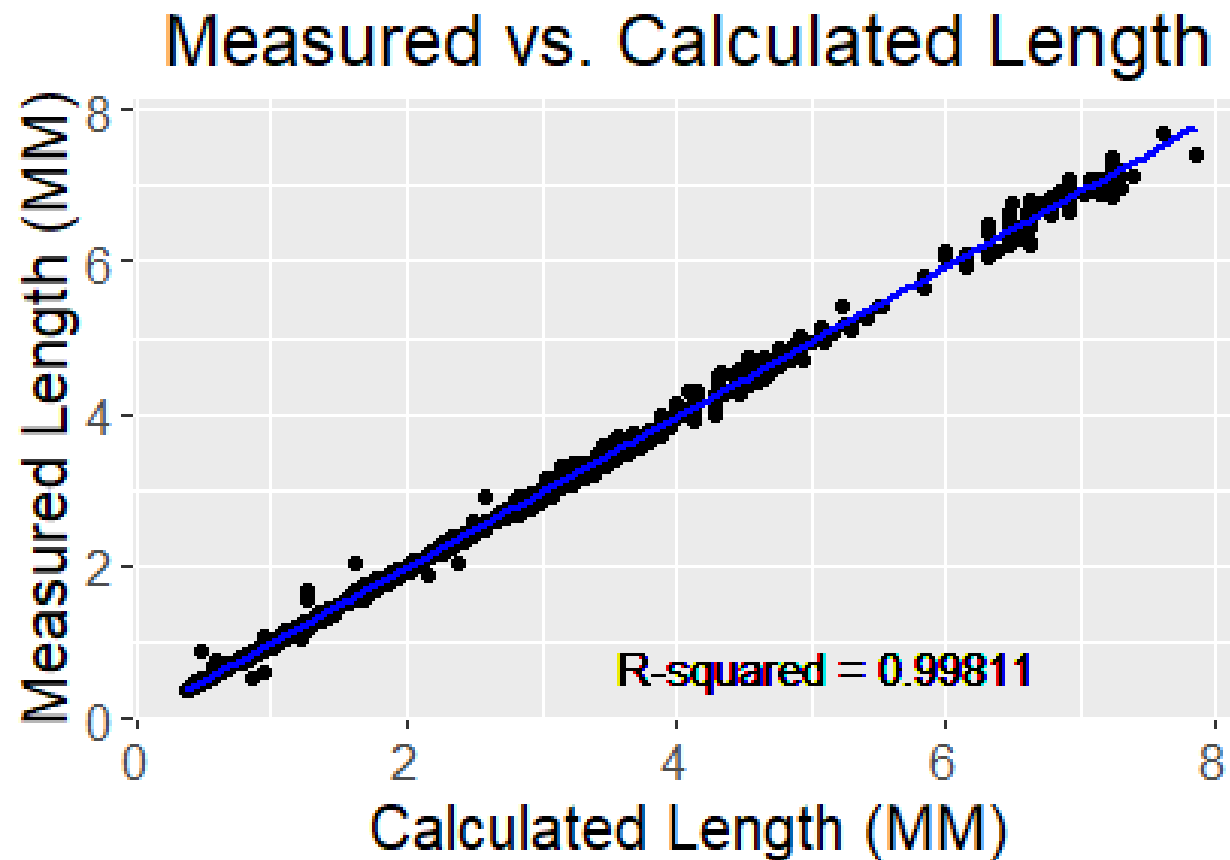
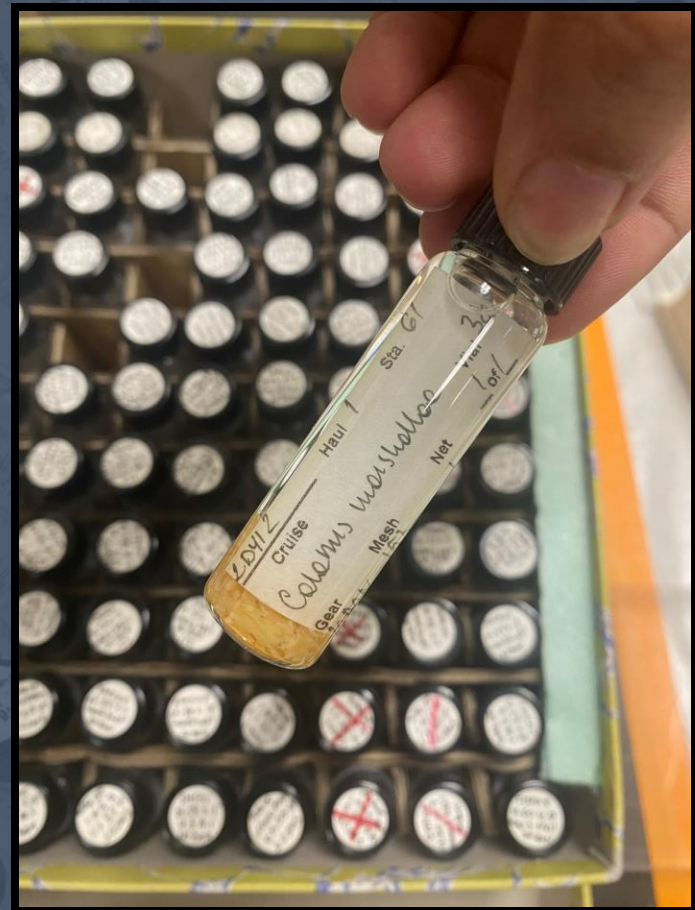
# Collecting Data from Archived Samples

## Times Series Range 2003 - 2018



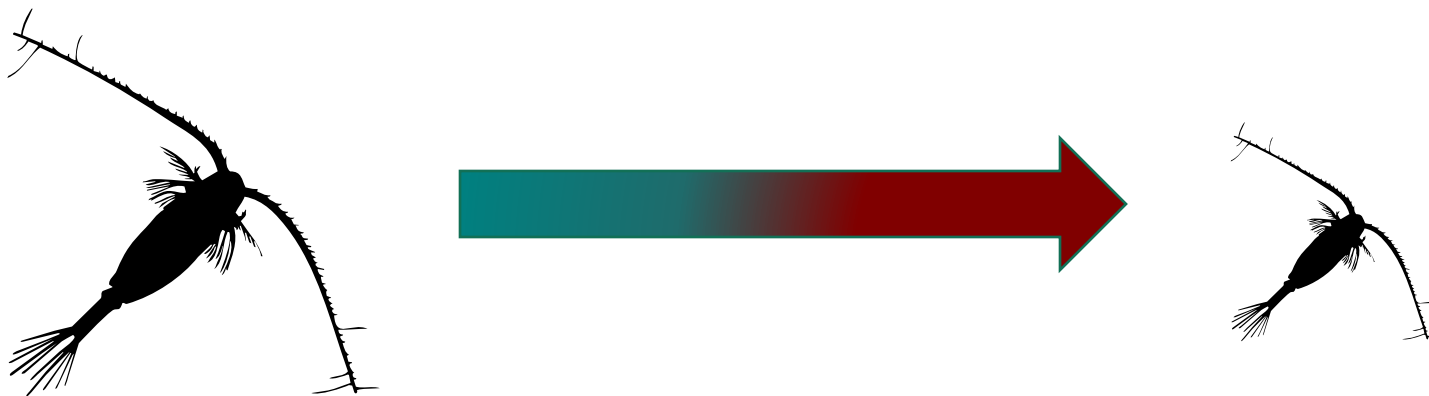
# Collecting Data from Archived Samples

Times Series Range 2003 - 2018



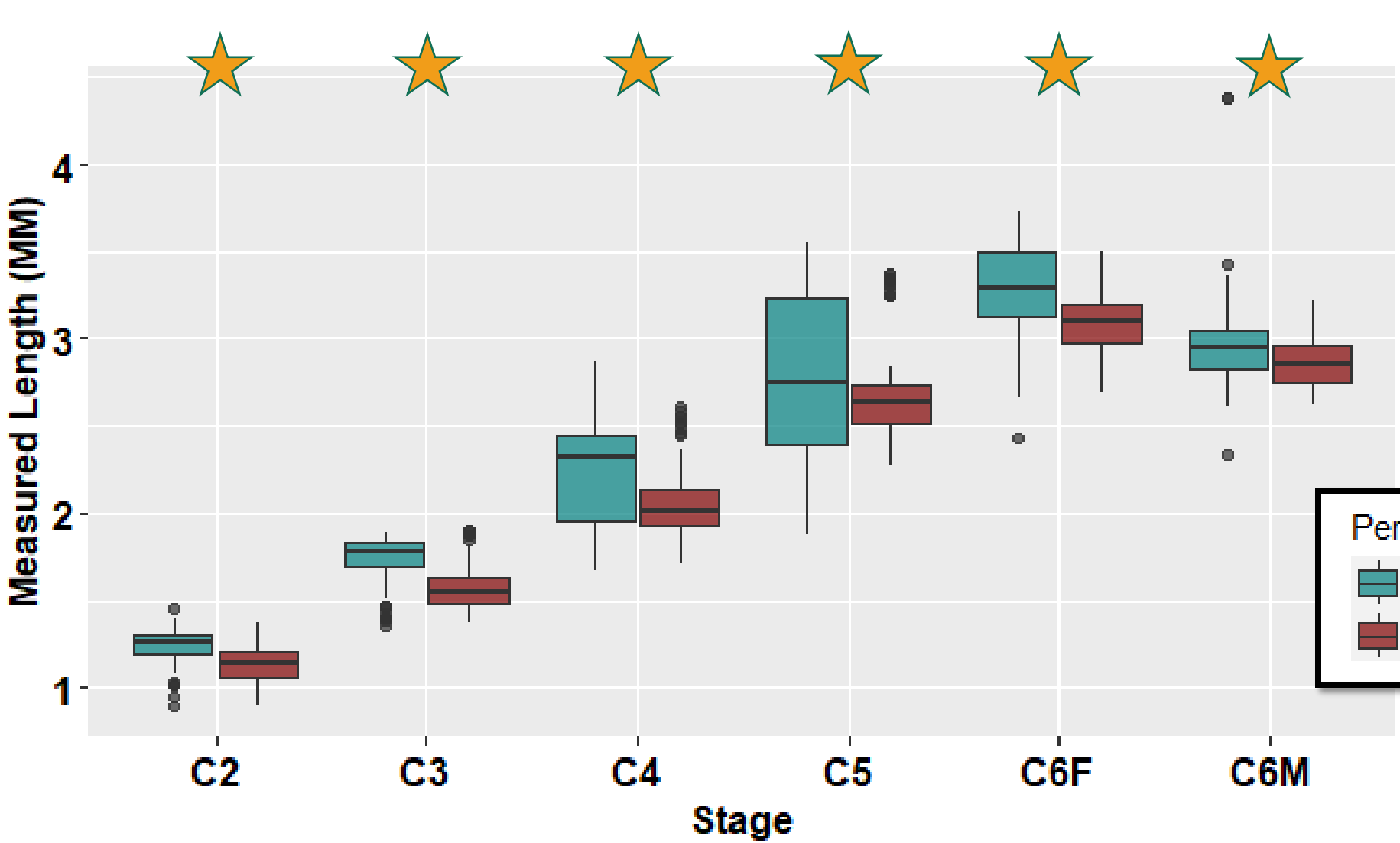
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# Mean Size During Spring

*Calanus marshallae*



Period

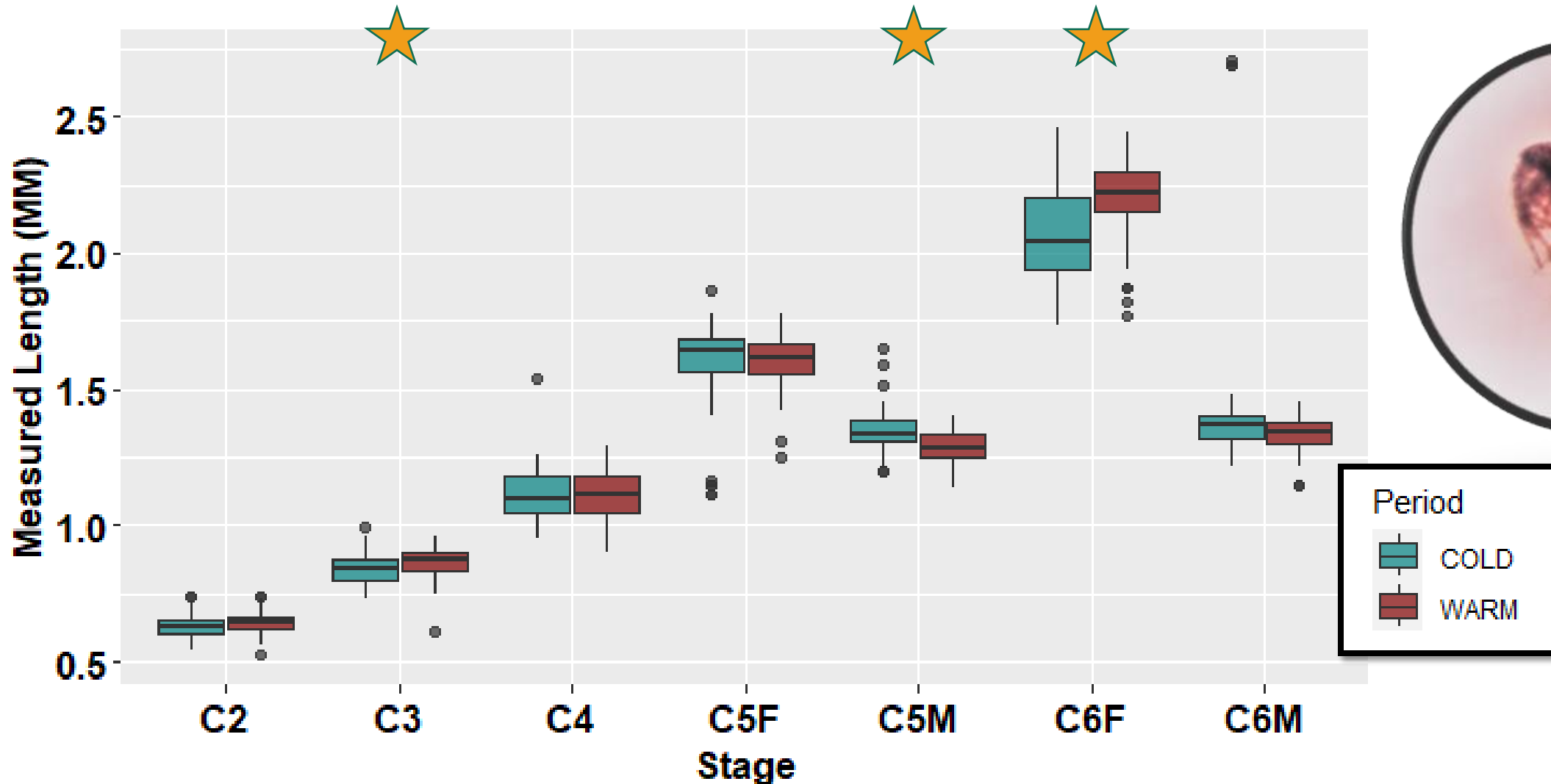
- COLD
- WARM

★ Statistical Significant Difference in Size between Warm and Cold Periods **FOR ALL STAGES**



# Mean Size During Spring

*Metridia pacifica*

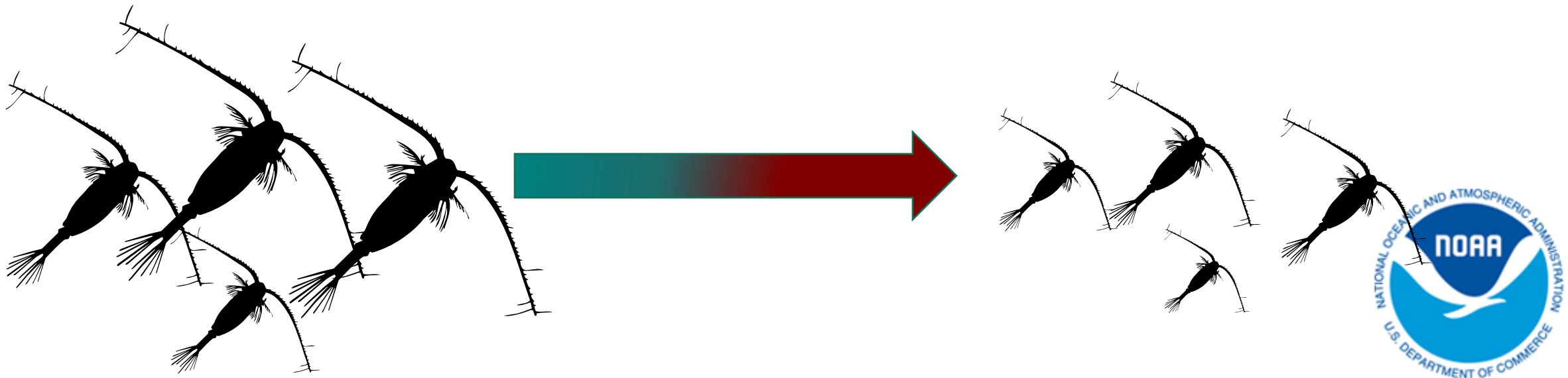


★ Statistical Significant Difference in Size between Warm and Cold Periods **FOR FEW STAGES**

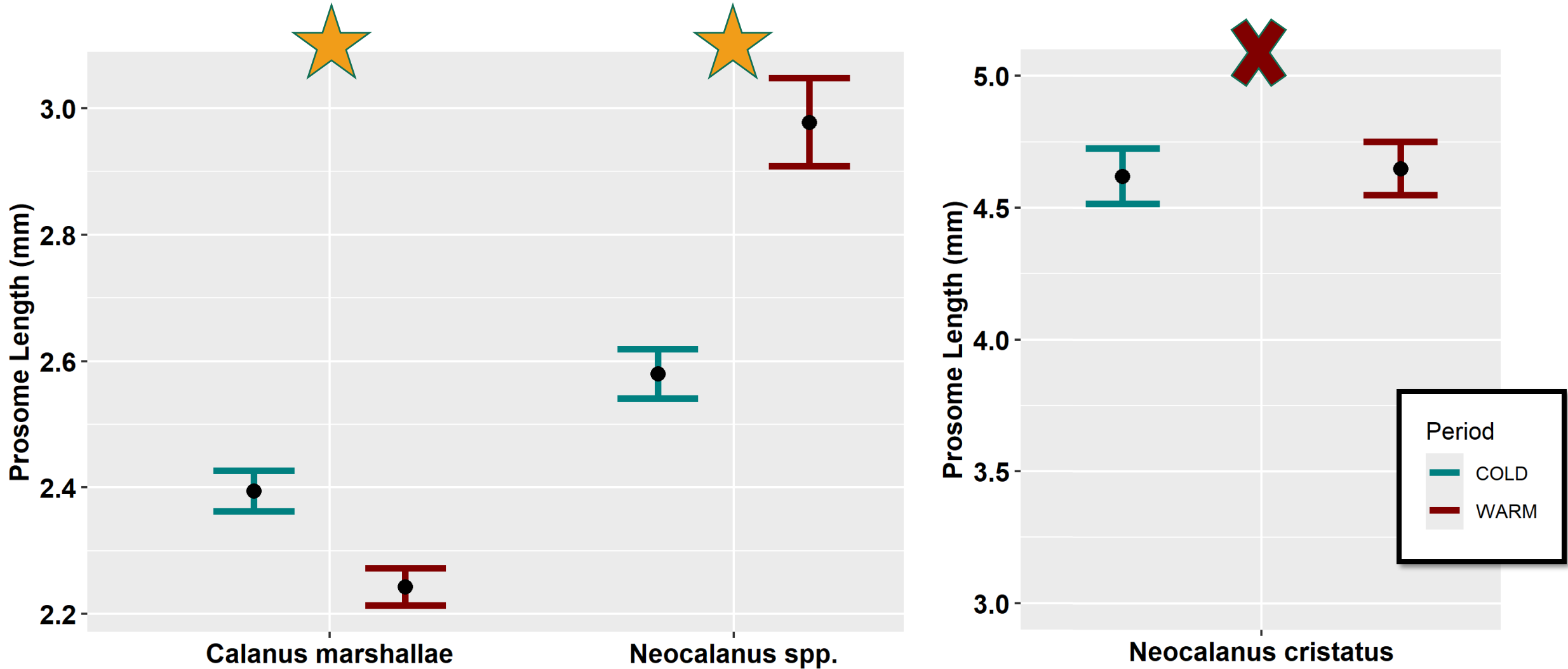


# HYPOTHESIS 2:

There has been an overall decrease in mean size for each POPULATION of copepod



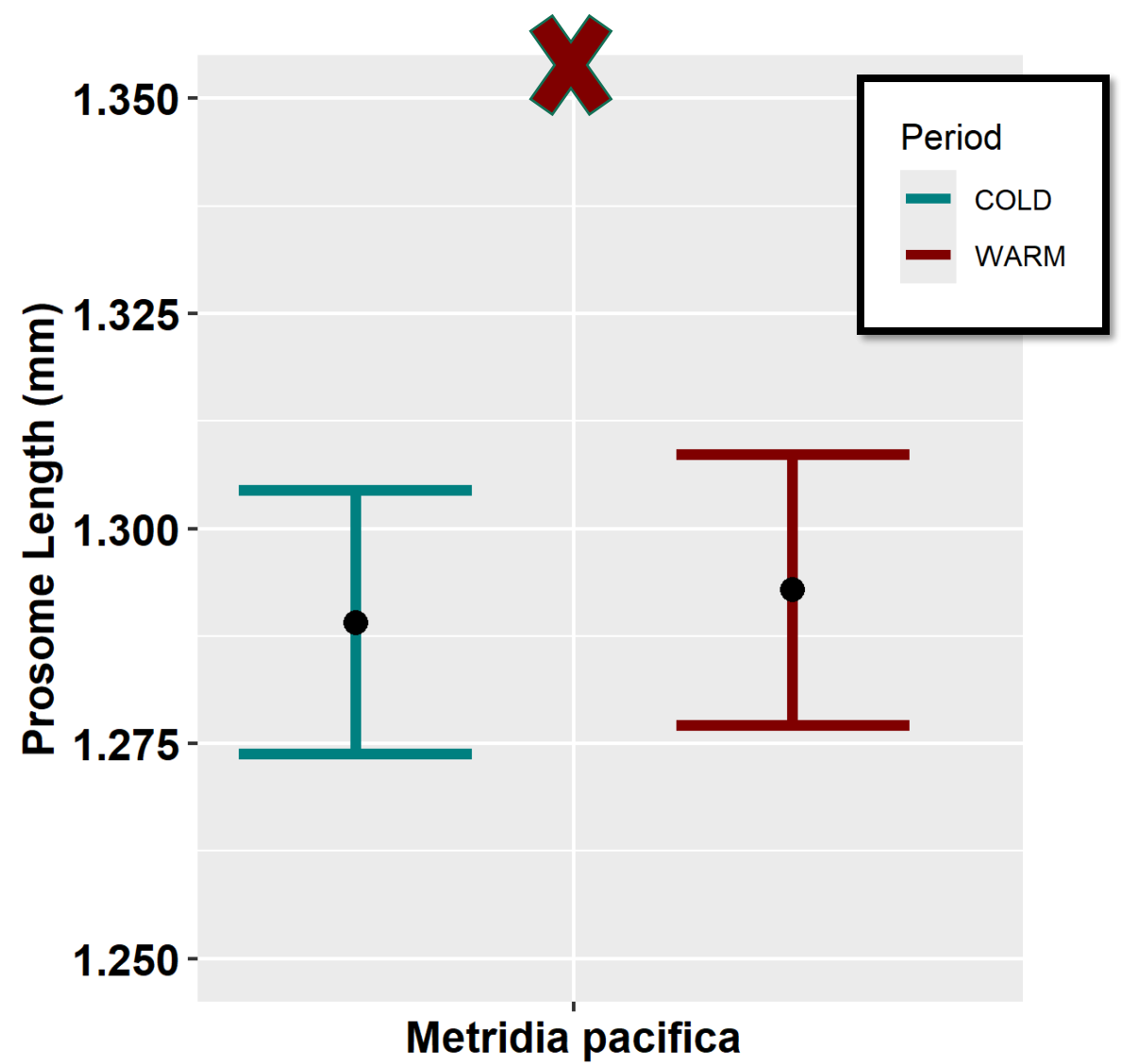
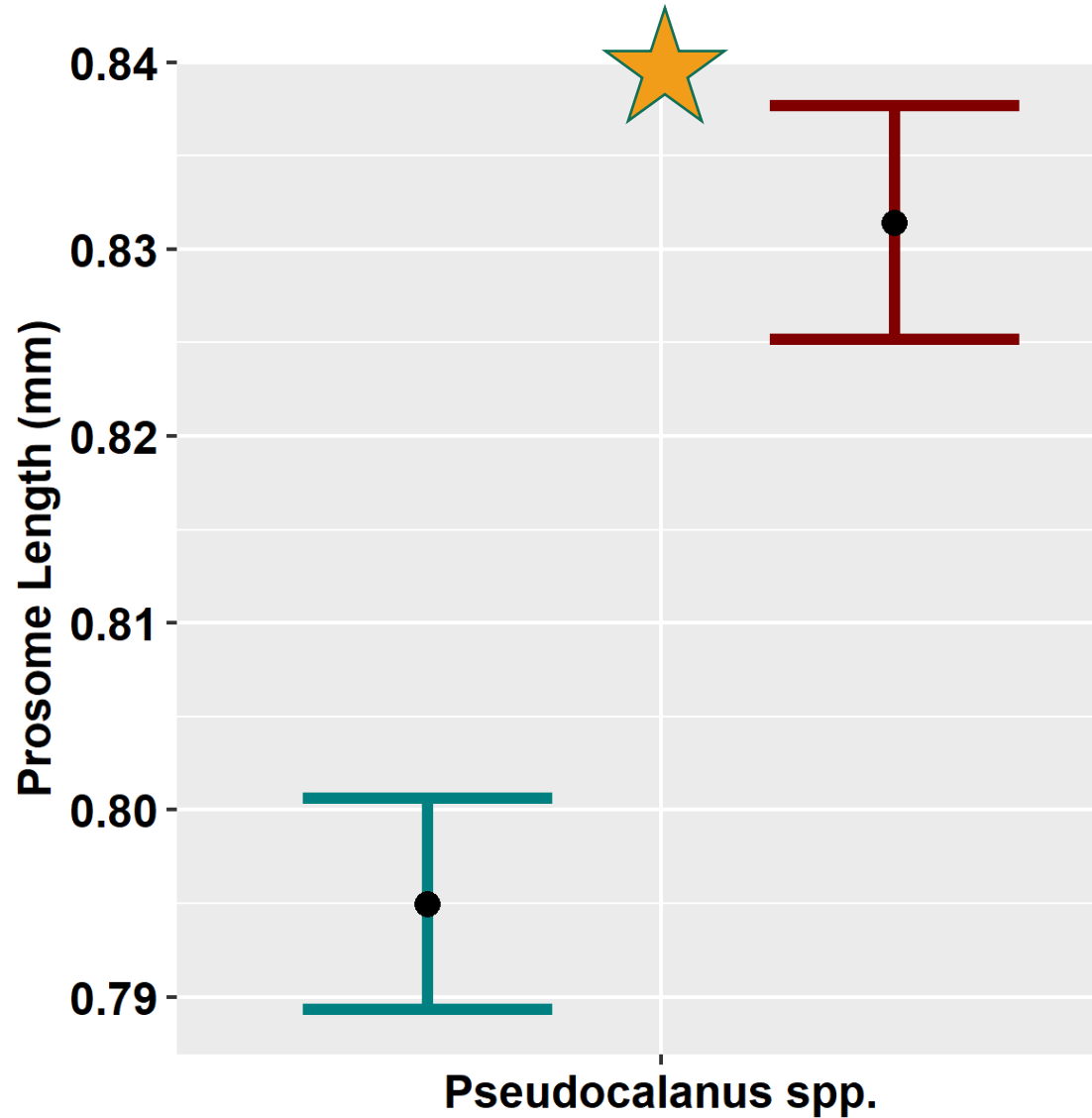
# Mean Spring Population Size: Large Copepods



 **Statistical Significant Difference in Size between Warm and Cold Periods**



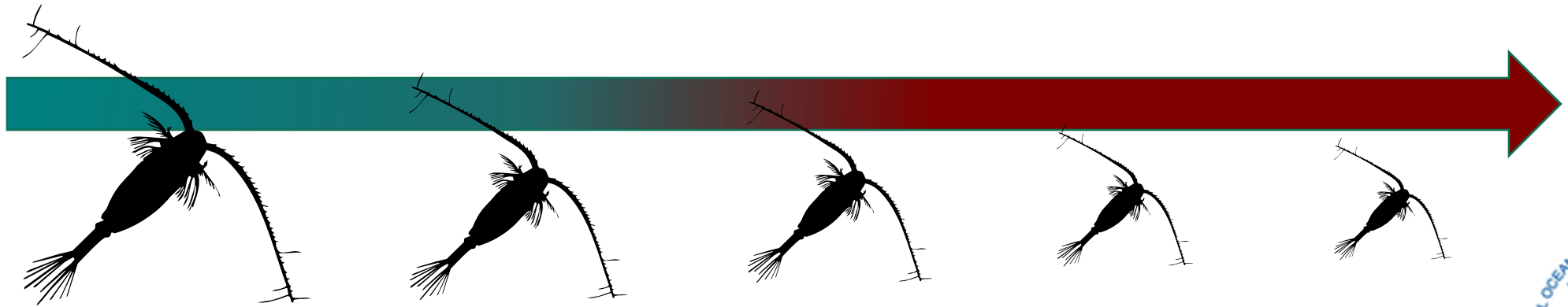
# Mean Spring Population Size: Small Copepods



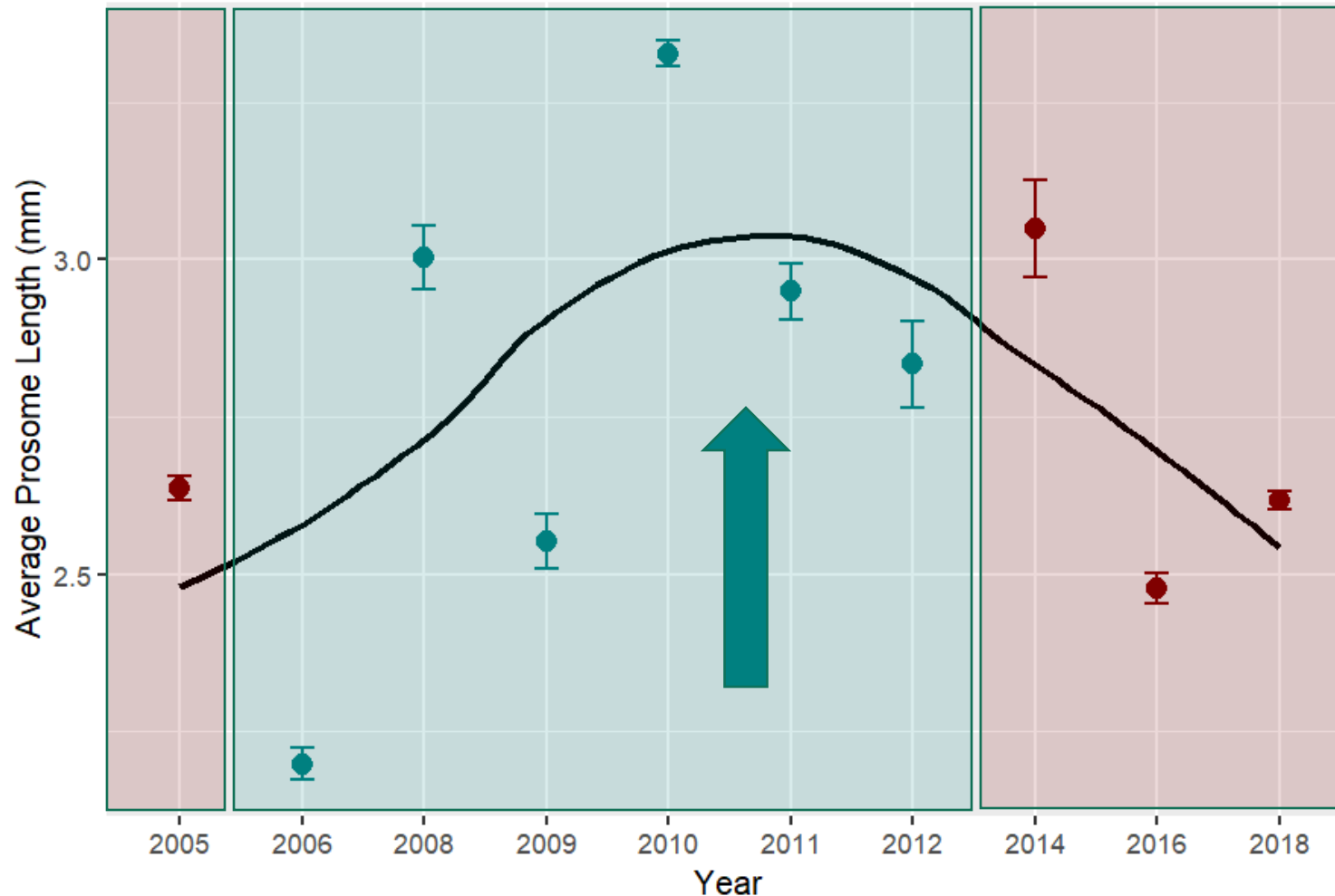
 Statistical Significant Difference in Size between Warm and Cold Periods

# HYPOTHESIS 3:

There is an overall trend in the mean copepod body size OVER TIME



# C5 Mean Size **Spring** Time Series

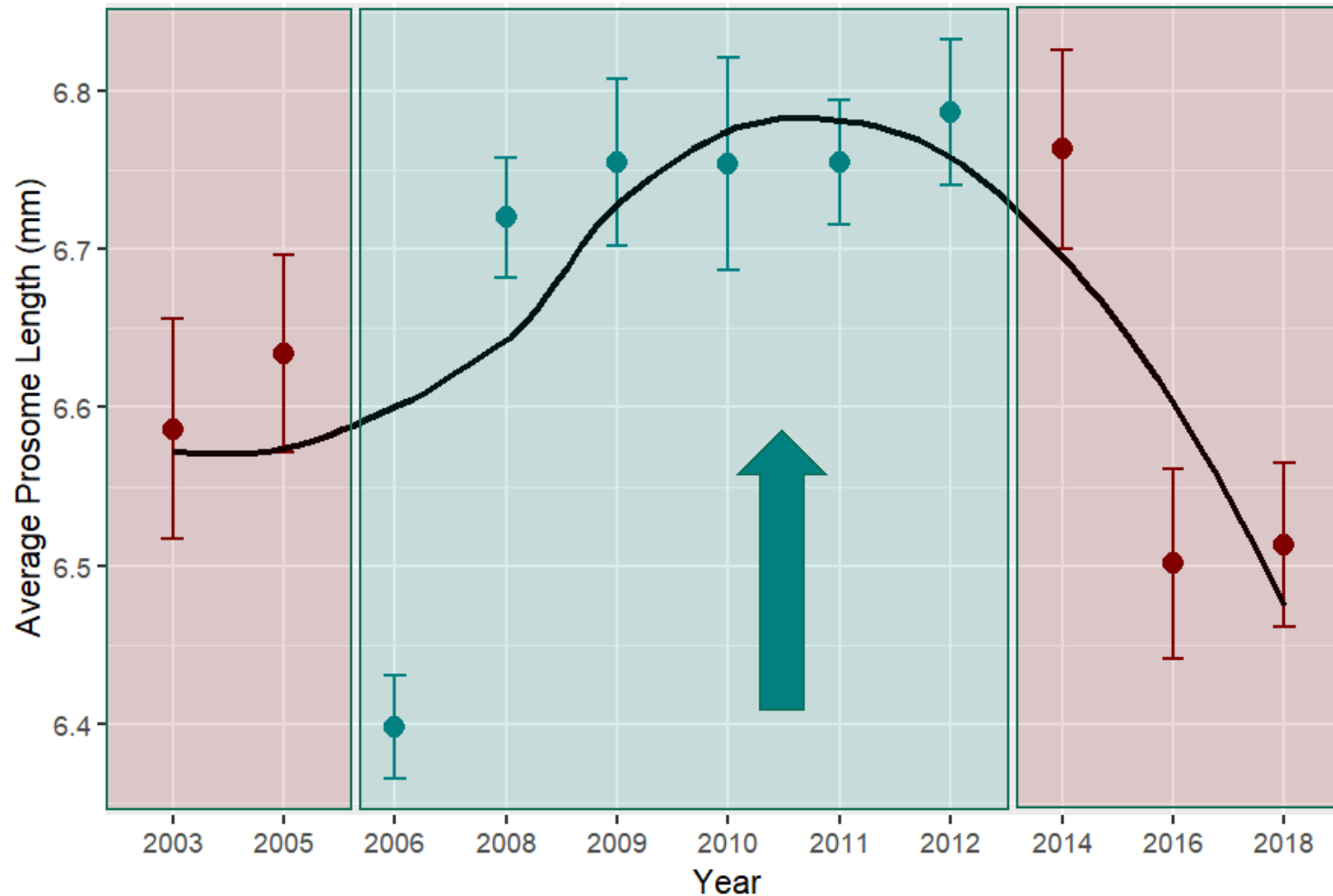


*Calanus marshallae*



★ Statistical Significant Difference in Size between Warm and Cold Periods

# C5 Mean Size **Spring** Time Series

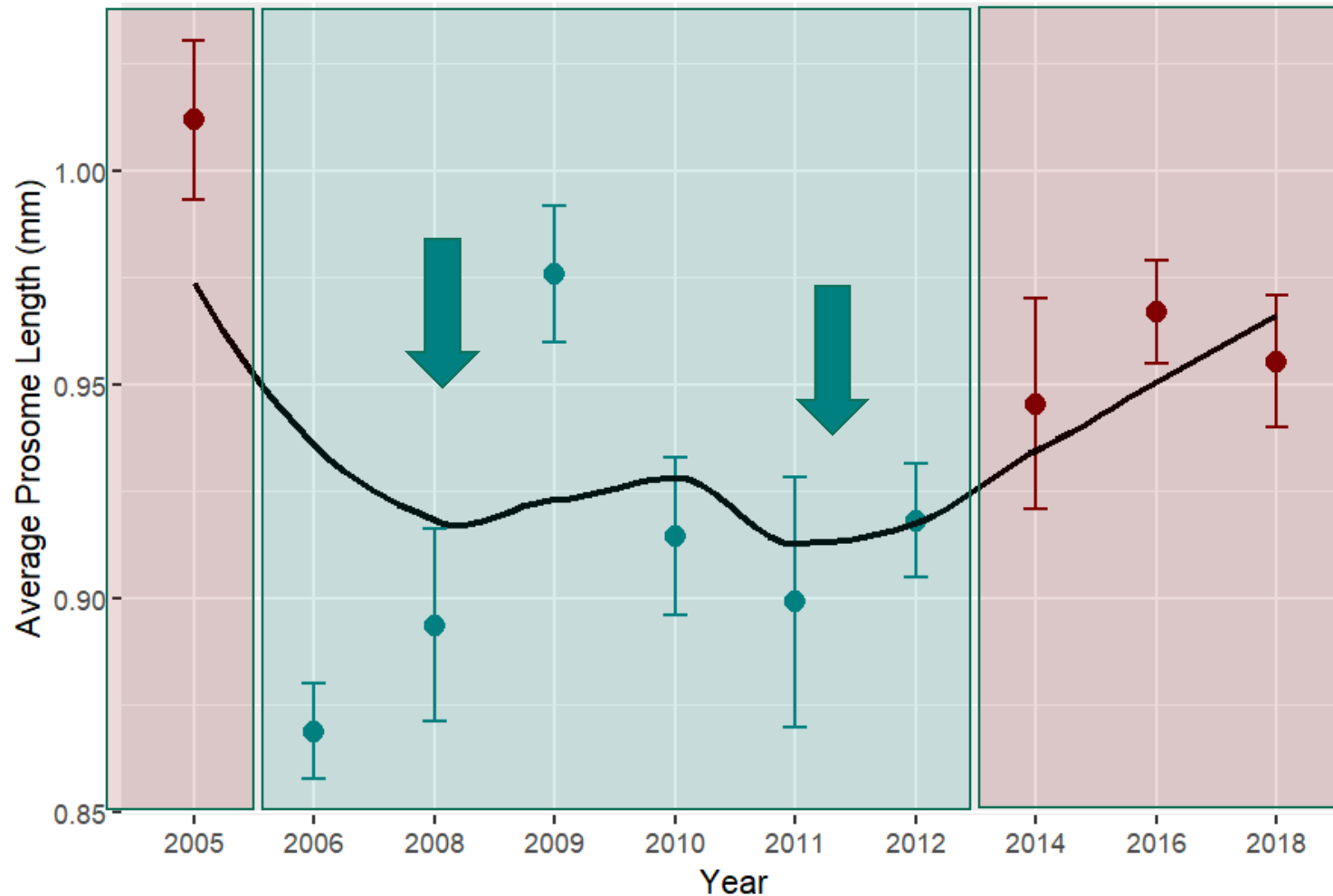


*Neocalanus cristatus*



**X** NO Statistical Significant Difference in Size between Warm and Cold Periods

# C5 Mean Size **Spring** Time Series

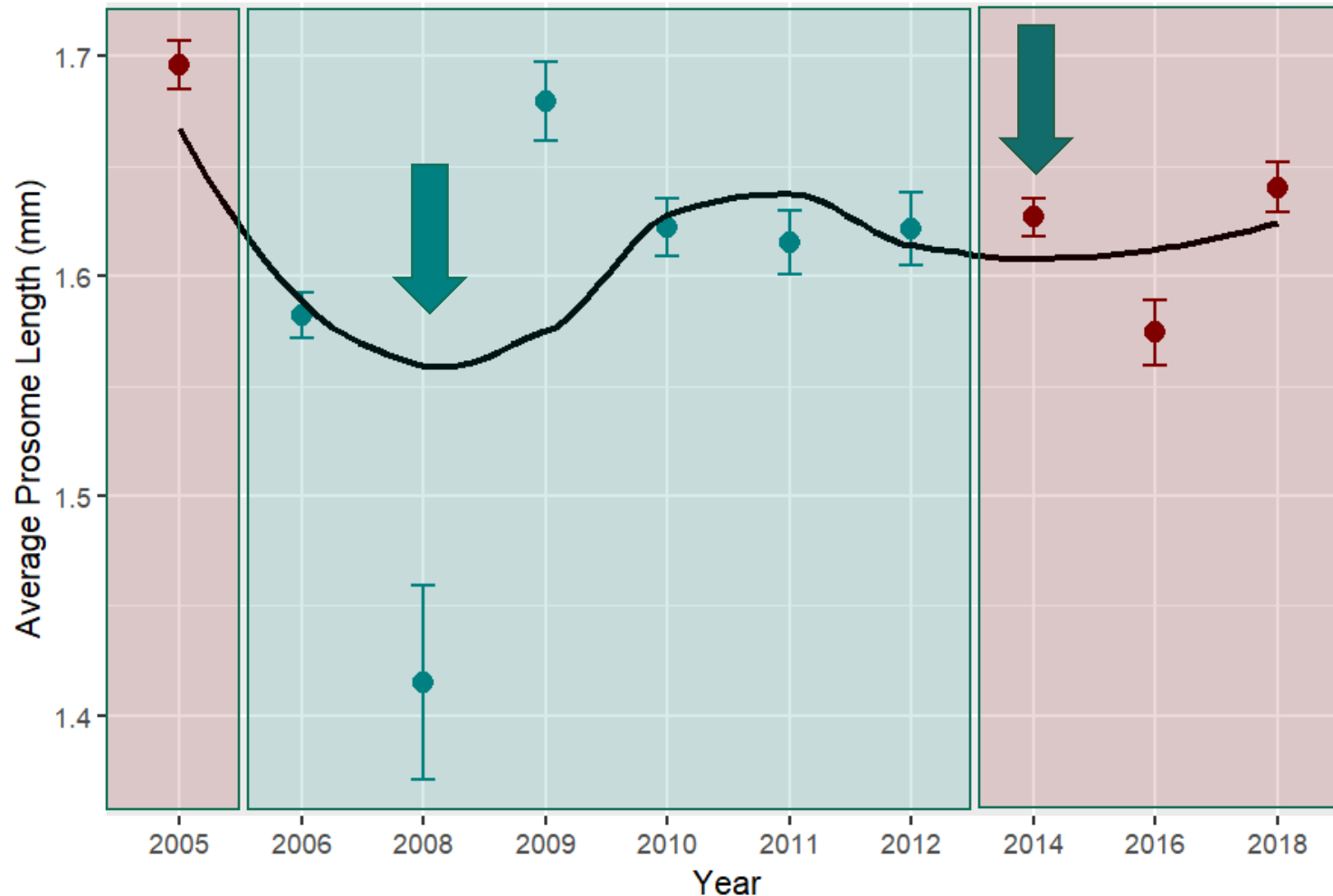


*Pseudocalanus* spp.



★ **Statistical Significant Difference in Size between Warm and Cold Periods**

# C5 Mean Size **Spring** Time Series



*Metridia pacifica*



**X** NO Statistical Significant Difference in Size between Warm and Cold Periods

# SUMMARY

## HYPOTHESIS 1:

There has been a decrease in the mean **INDIVIDUAL** size of copepods

## HYPOTHESIS 2:

There has been a decrease in the mean size for each **POPULATION** of copepod

## HYPOTHESIS 3:

There is an overall trend in the mean copepod body size **OVER TIME**

# SUMMARY

*Calanus marshallae*,  
smaller during warm  
periods

*Metridia pacifica*, lack  
difference in size

## HYPOTHESIS 2:

There has been a  
decrease in the  
mean size for each  
**POPULATION** of  
copepod

## HYPOTHESIS 3:

There is an overall  
trend in the mean  
copepod body size  
**OVER TIME**

- Supported for large copepod, *Calanus marshallae*
- Rejected for small copepod, *Metridia pacifica*



# SUMMARY

## HYPOTHESIS 1:

There has been a decrease in the mean **INDIVIDUAL** size of copepods

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There has been a decrease in the mean size for each **POPULATION** of copepod

## HYPOTHESIS 3:

There is an overall trend in the mean copepod body size **OVERTIME**

# SUMMARY

## HYPOTHESIS 1:

There has been a decrease in the mean **INDIVIDUAL** size of copepods

Multi-species classes showed significance

No significance expected for Metridia, and unexpected for *N. cristatus*

## HYPOTHESIS 3:

There is an overall trend in the mean copepod body size **OVER TIME**

- **Supported** for *Calanus marshallae*
- **Rejected** for *Neocalanus cristatus* & *Metridia pacifica*

# SUMMARY

## HYPOTHESIS 1:

There has been a decrease in the mean **INDIVIDUAL** size of copepods

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There has been a decrease in the mean size for each **POPULATION** of copepod

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There has been a decrease in the mean **INDIVIDUAL** size of copepods

## HYPOTHESIS 2:

There has been a decrease in the mean size for each **POPULATION** of copepod

Ecosystem response to warming

Need to regress against SST and remove natural variability

➤ **The potential of a trend...**

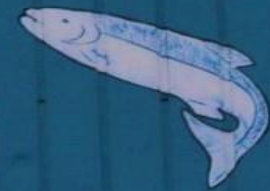
# IMPLICATIONS

WESTERN ALASKA

FISHERIES

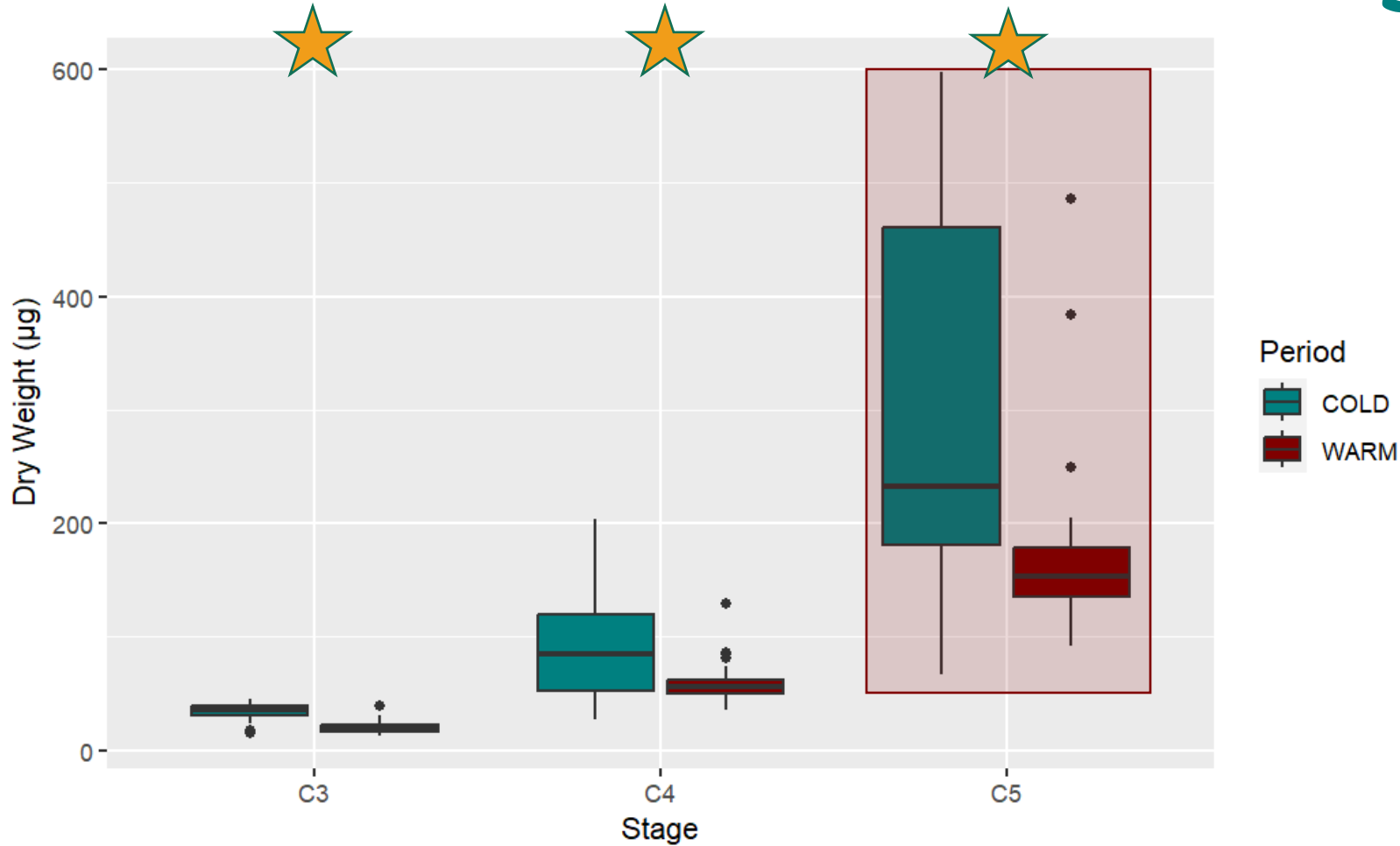


**KODIAK**



Where Fish Is King

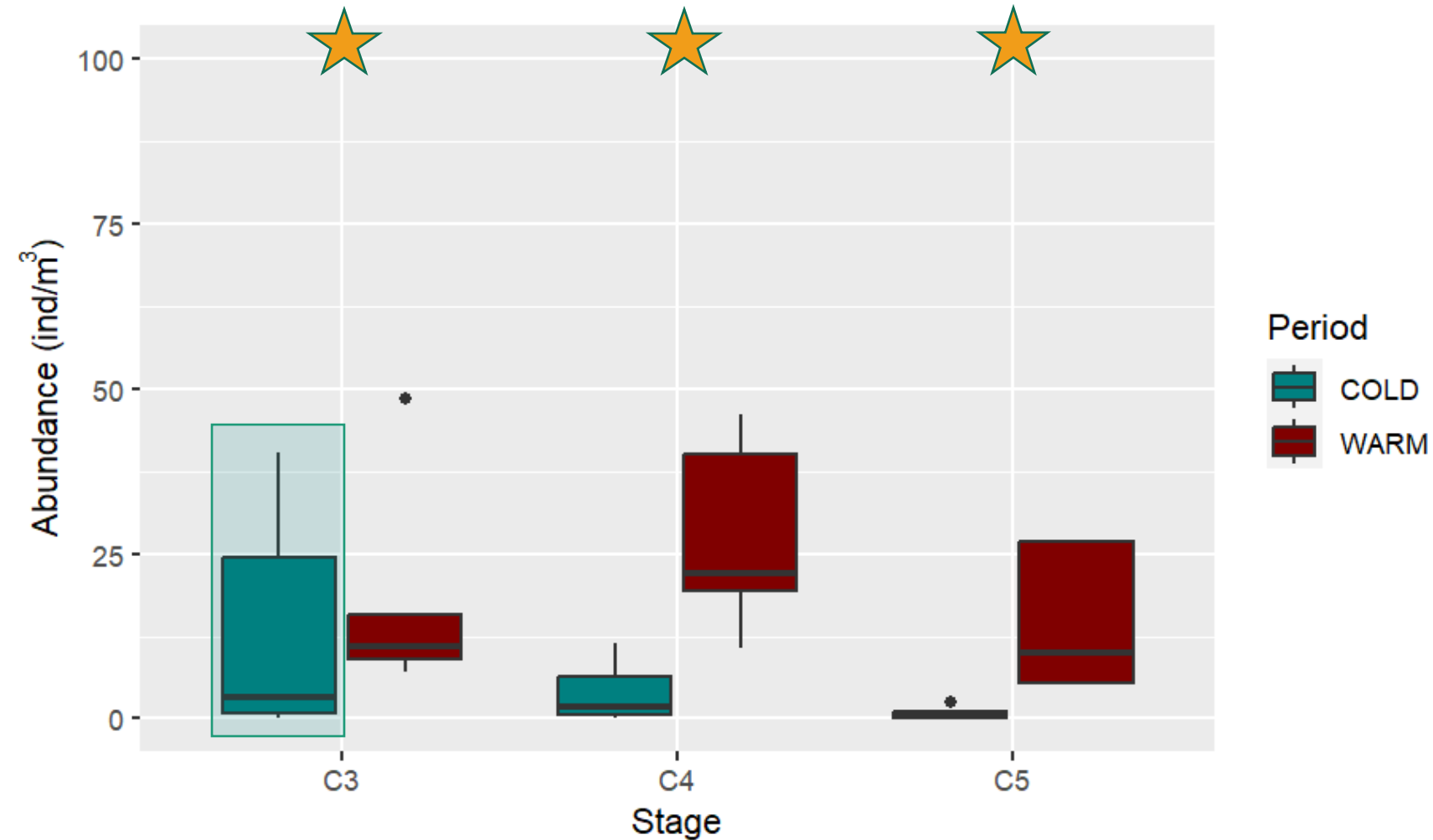
# Calanus marshallae: Average Dry Weight



- Average mass **DECREASES** during **WARM** periods
- Later **C5** stage most effected

★ Statistical Significant Difference in Size between Warm and Cold Periods

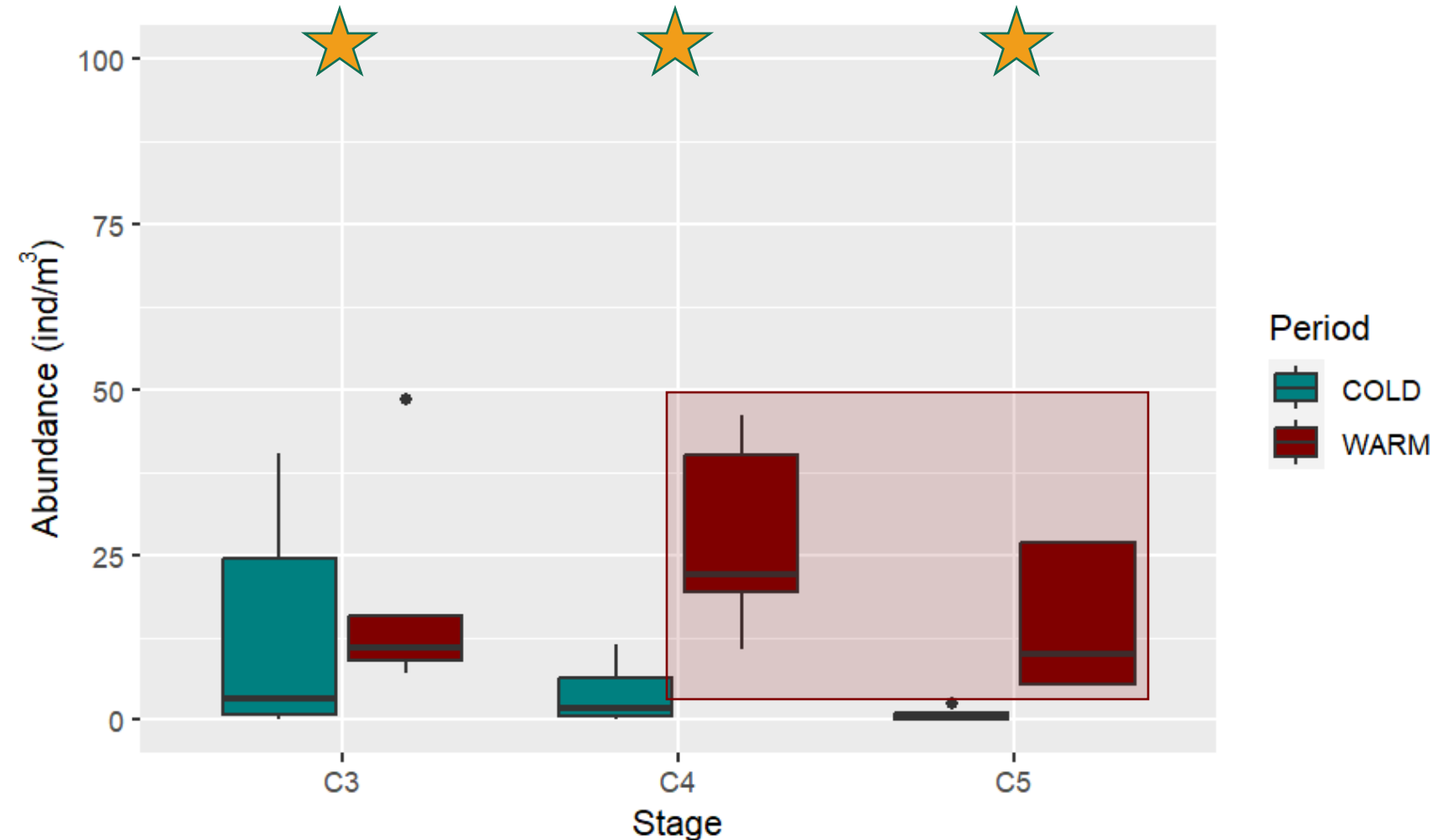
# *Calanus marshallae*: Average Abundance



- Later stages observed **EARLIER** in year
- Warming is **INCREASING** growth rates

★ Statistical Significant Difference in Size between Warm and Cold Periods

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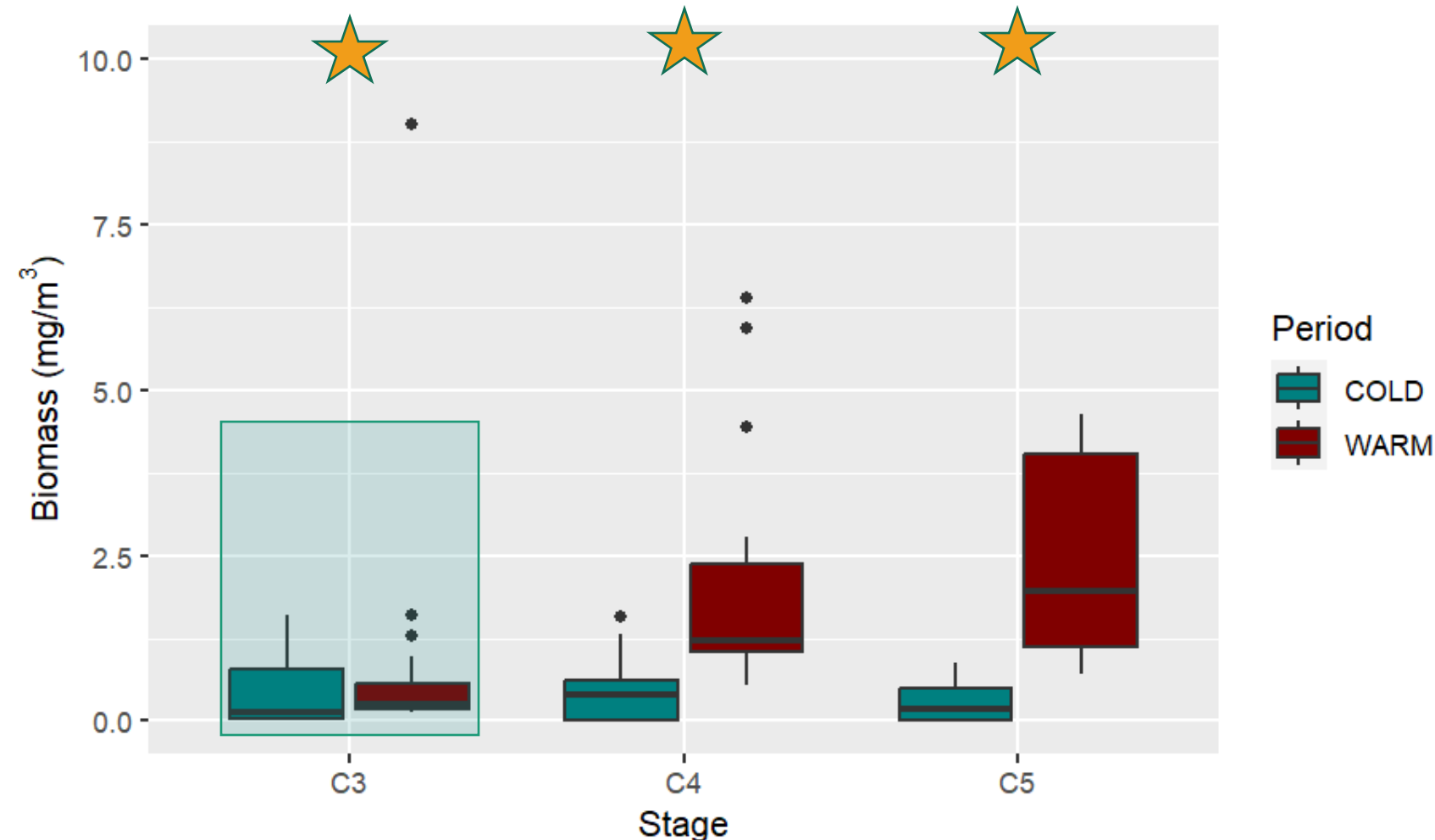


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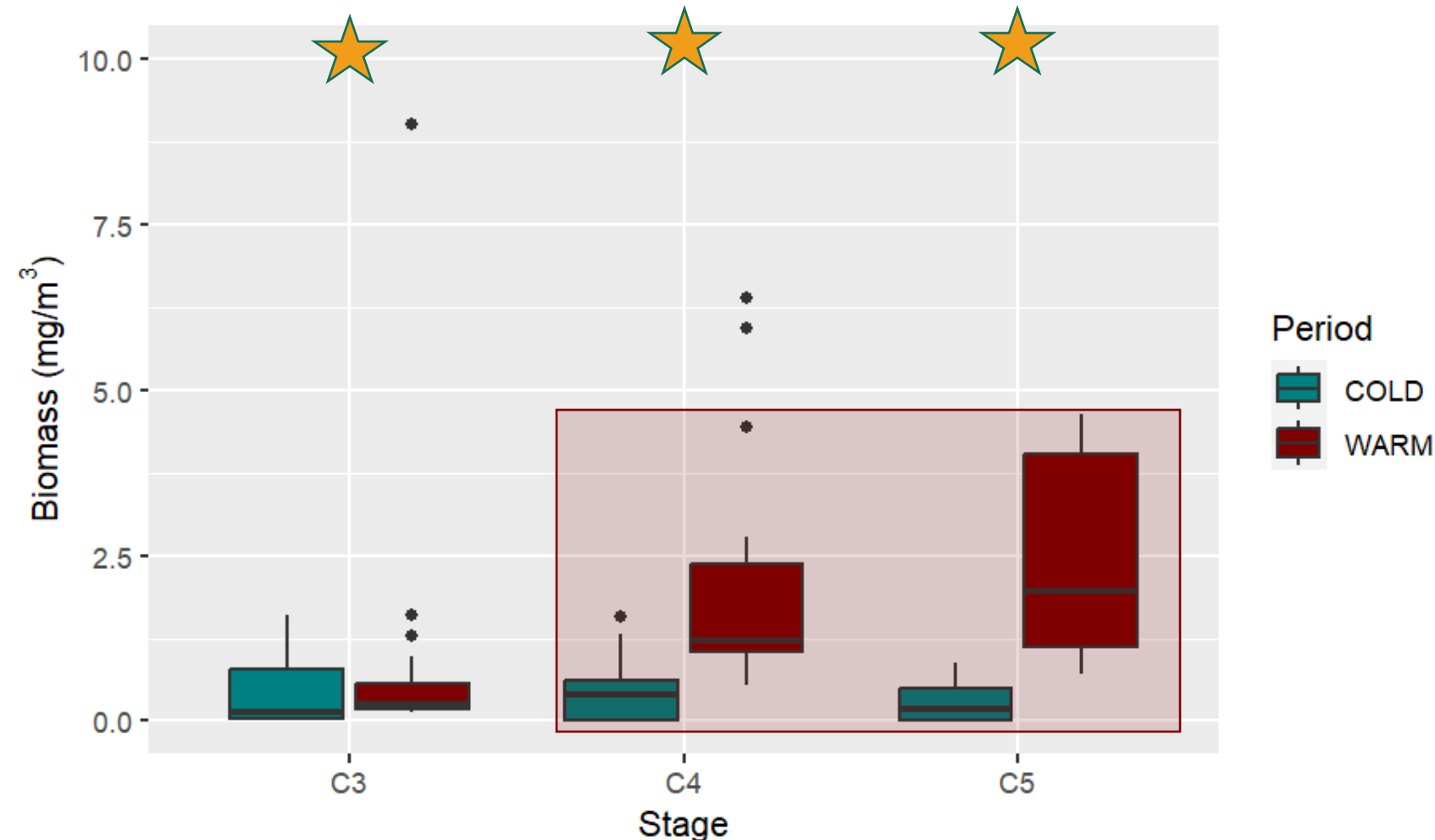
# *Calanus marshallae*: Average Biomass



- Increase in biomass for **WARM** periods
- Potential fall predator-prey **MISMATCH**

★ Statistical Significant Difference in Size between Warm and Cold Periods

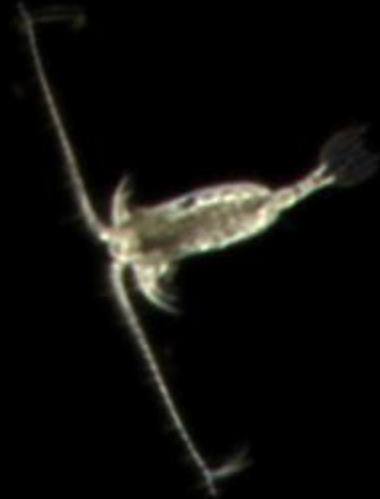
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# Take Home Messages



# Ecological Responses to Warming

**Change in  
Species  
Phenology**

**Shift in Species  
Distribution**

**Decline in  
Body Size**

# Ecological Responses to Warming

**Decline in  
Body Size**

**Calanus  
marshallae**

**Change in Species  
Phenology**

**predator-prey  
mismatch?**

**C5 most  
affected**

**Increased  
biomass**

**Increased  
growth  
rates**

# Acknowledgments

- North Pacific Research Board / NOAA's Alaska Fisheries Science Center / Lynker – For funding and support
  - NOAA's GPU Hackathon 2021 – for fostering connection and collaboration
    - Ryan Simpson, NVIDIA – for the development of our size application
  - Colleen Harpold, Jesse Lamb, and Brooke Snyder – for help with data collection and processing



# QUESTIONS?

