# How do ocean acidification and increased temperatures affect juvenile red king crab survival, growth and morphology?

Katherine M. Swiney

W. Christopher Long

Robert J. Foy

NOAA FISHERIES

Alaska Fisheries Science Center

# Ocean Acidification and Increased Temps



- Uptake of anthropogenic $CO_2$ reduces oceanic pH
- Oceans warming due to climate change

- High-latitude waters predicted to have increased OA and temps compared to other areas
- Multi-stressors studies needed
  - effects often not simply additive

# Why Red King Crab, *Paralithodes camtschaticus?*

- Important fishery species
- Sensitive to OA
  - Juvenile mortality increased with decreasing pH
    - 100% mortality 95 d pH 7.5 (Long et al., 2013 PlosOne)
  - Juvenile growth decreased pH 7.8 (Long et al., 2013 PlosOne)
  - Embryo and larval morphology altered pH 7.7 (Long et al., 2013 Marine Pollution Bulletin)
  - Decrease in larval starvation survival time pH 7.7 (Long et al. 2013 Marine Pollution Bulletin)
- Populations and fisheries likely negatively affected by the end of the century (Punt et al., 2014)
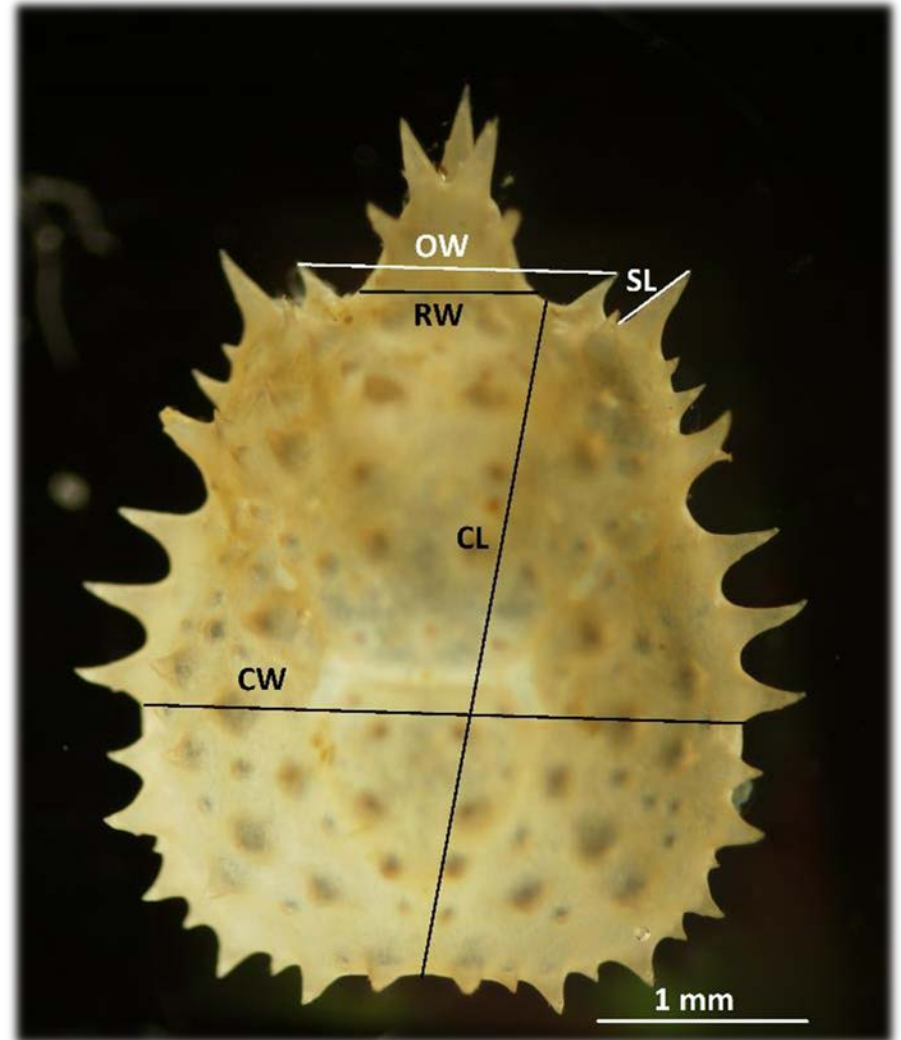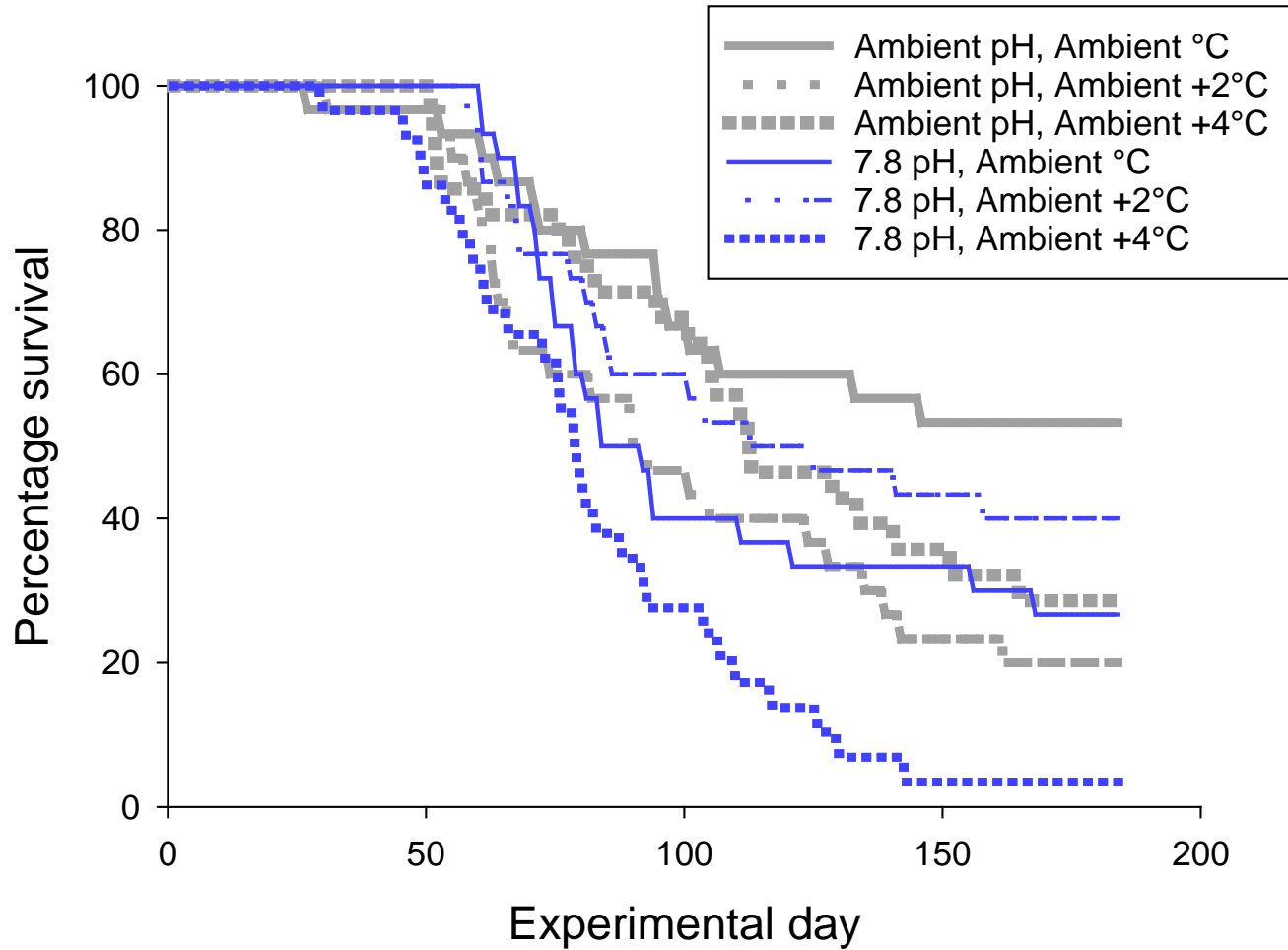
# Project Questions



- How will OA and increased temps affect juvenile
  - survival?
  - growth?
  - morphology?
  - cuticle mechanics, structure, and composition? (G. H. Dickinson lead)
  - gene regulation? (J. H. Stillman lead)

# Methods

- Fully crossed design
  - pH Treatments: Ambient (~8.0), 7.8
  - Temp Treatment: ambient °C, ambient +2°C, ambient +4°C
- Juveniles reared in individual inserts
- Checked daily for molts and mortalities
  - Photographed for growth and morphometric analysis
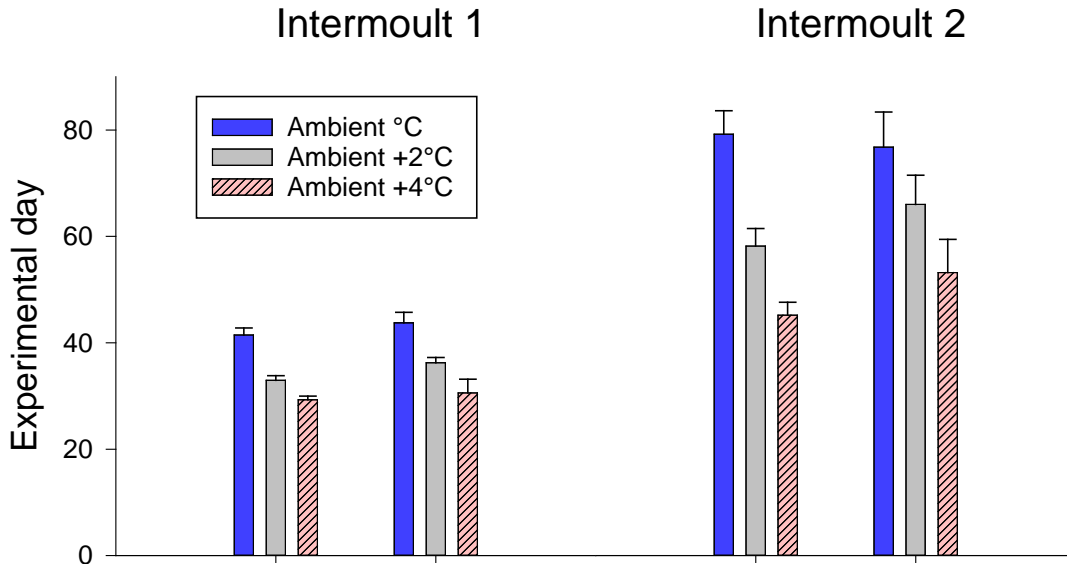- Duration 184 days
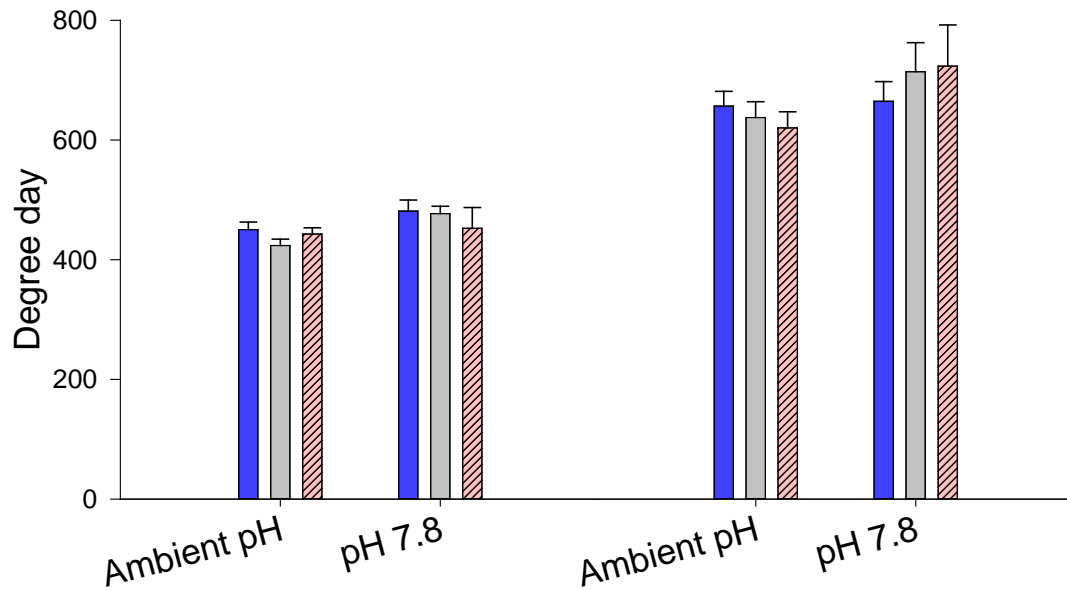
# Results: Survival



- Mortality rate increased 82% w/ low pH, 49% to 107% w/ higher temps

- Interactive effects varied
  - Synergetic pH 7.8, ambient +4°C
  - Antagonistic pH 7.8, ambient +2°C

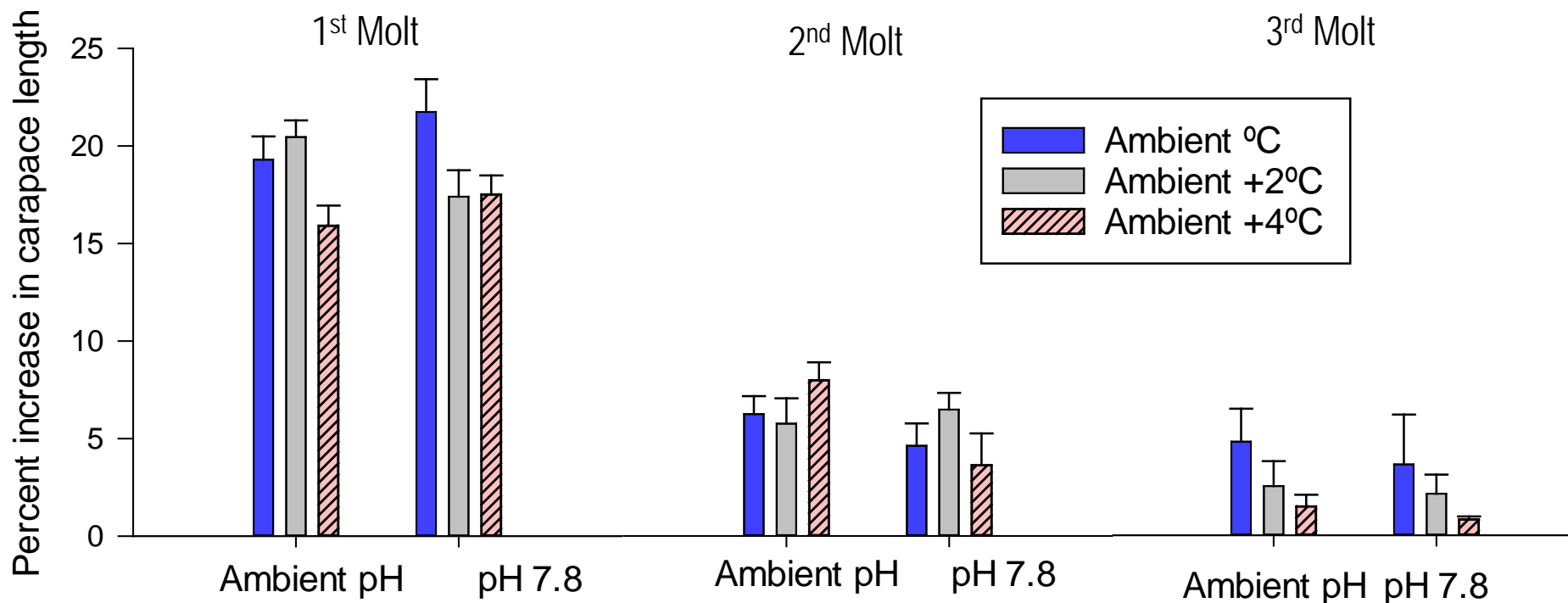# Results: Growth-Intermoult Duration



- 8-22 d shorter with increasing temp
- 5 d longer pH 7.8
- 1st IM 29 d shorter

- Did not vary w/ temp
- 64 DD longer pH 7.8
- 1st IM 232 DD shorter

# Results: Growth-Percent Increase



- Did not vary with pH
- 2.5% less in ambient +4°C vs ambient °C
- Decreased with consecutive periods of growth
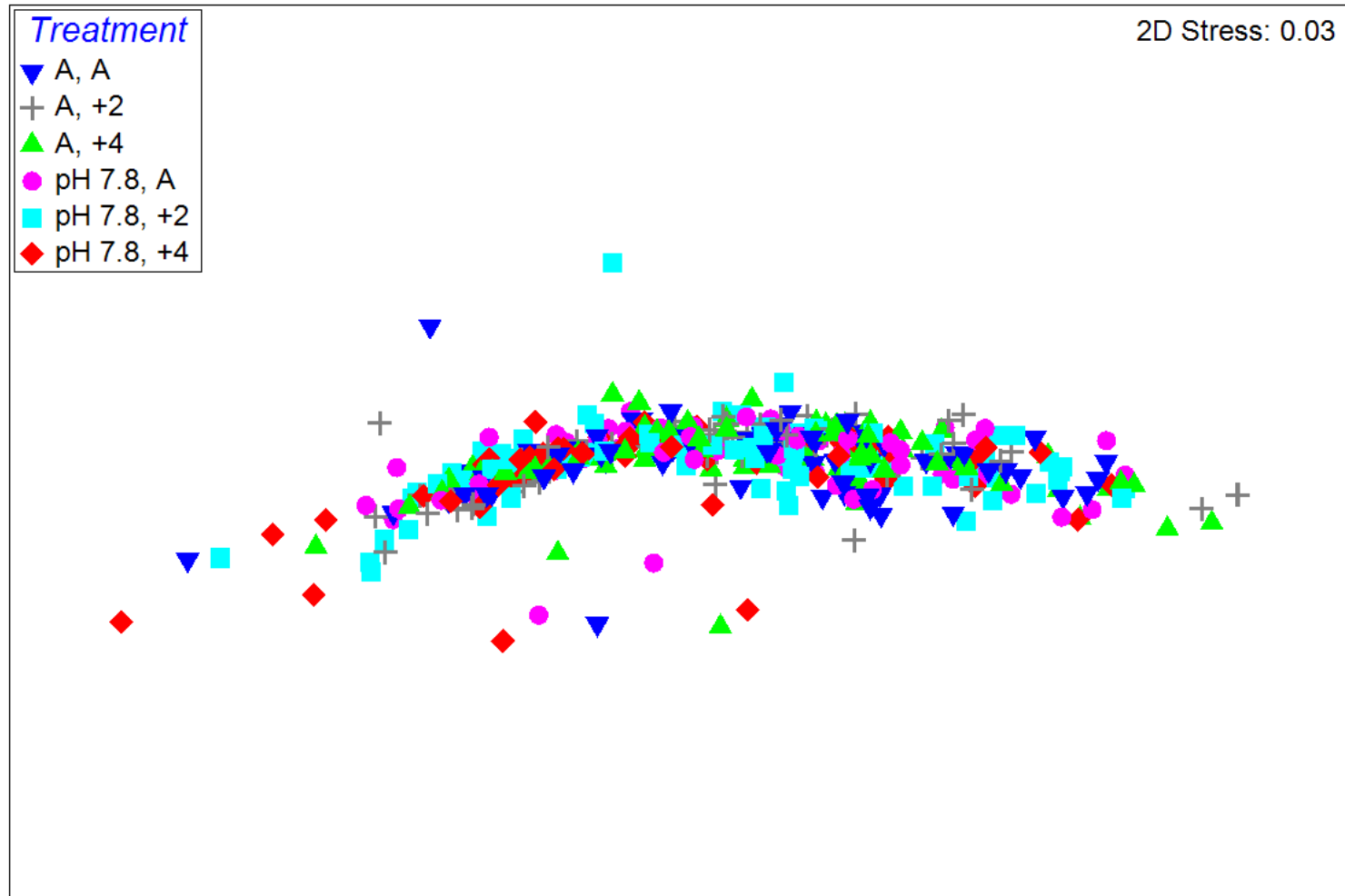
NOAA FISHERIES

# Results: Growth

- CL did not vary with pH or temp
  - after each molt
  - at the end of the experiment
- After a few more molts differences would have likely been observed because of IM and % increase in size results
- Juvenile RKC study reduced growth in pH 7.8 (Long et al. 2013)
  - Younger juveniles which may be more sensitive to OA



- Porcelain crab brood-specific responses to OA (Carter et al. 2013, Ceballos-Osuna et al. 2013, Stillman and Paganini, 2015)
  - genetic variation?
  - environmental factors?
  - maternal condition during egg production?
- RKC juveniles came from different mothers from different micro-environments

# Results: Morphology



- Morphology did not vary with pH or temp
- Juvenile RKC morphology did not differ with pH (Long et al., 2013)

# Conclusions

- Mortality increased with reduced pH and higher temps
- Intermolt duration
  - decreased with higher temps
  - increased with low pH
- Percent increase in size
  - not affected by pH
  - decreased in warmest temp treatment
- Carapace length and morphology not affected

**NOAA FISHERIES**

# Population and Fisheries Implications

- Of the stages and parameters studied, most potential harmful effects are low survival rates of juveniles
  - 3% survival pH 7.8, ambient +4°C
  - 0% survival pH 7.5 after 95 days (Long et al., 2013)
- If these rates occur *in situ* under predicted conditions, recruitment to fishery will likely not be sufficient to allow current harvest levels or potentially any harvest unless RKC are able to quickly adapt or acclimate to changing conditions
- Stock assessment and management will likely be improved if effects of OA on populations are considered

NOAA FISHERIES

# Acknowledgements

Special thanks to:
    Karen Barnard
    Ben Daly
    Nikki Gabriel
    Jan Haaga
    Lacey Harver
    Jane Murawski
    Scott Van Sant

**NOAA FISHERIES**