Research update on physiological response of crab to OA

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2016 Alaska OA Network
King and Tanner crab lab research

Framework for assessment of climate change and OA: Organismal (individual tolerance), population, and ecosystem level response

Experiments: (2010-2016)

- Red king crab (*Paralithodes camtschaticus*) adult females
  - Red king crab embryos and larvae
  - Red king crab juveniles
- Southern Tanner crab (*Chionoecetes bairdi*) juveniles
- Golden king crab (*Lithodes aequispinus*) adults
- Snow crab (*Chionoecetes opilio*) adults

Response variables: Survival, fecundity, morphometrics (image analysis), growth (width and wet mass), calcification

Collaborations: Hemocyte function, genetics (protein expression), mechanics, population dynamics, bioeconomics
Chionoecetes bairdi multi-year lab experiment

Tanner crab

Experiments
- Morphology
  - Starvation-survival
  - C and N content
  - Ca and Mg content
  - Mass

Embryogenesis

Larvae
- Morphology
- Starvation-survival
- C and N content
- Ca and Mg content
- Mass

Oogenesis & Embryogenesis

Direct effects on
- Larvae
- None

Carryover effects from
- Embryogenesis
- None

2011
- Females wild-caught
  - None (wild brooded)

2012
- Females in treatments 1-year
  - Ambient
  - pH 7.8
  - pH 7.5

2013
- Females in treatments 2-years
  - Ambient
  - pH 7.8
  - pH 7.5

Ocean Acidification: is it the carbonate or the pH?

- pH and temperature measured daily (n=316 in year 1; n=412 in year 2)
- DIC, salinity, alkalinity measured weekly
- HCO₃⁻ and CO₃⁻ and omega calculated

<table>
<thead>
<tr>
<th>Treatment</th>
<th>pH</th>
<th>pCO₂ atm (μatm)</th>
<th>HCO₃⁻ mmol/kg</th>
<th>CO₃⁻² mmol/kg</th>
<th>ALK mmol/kg</th>
<th>ΩAr</th>
<th>ΩCa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient</td>
<td>8.09 (0.07)</td>
<td>391.90 (65.59)</td>
<td>1.90 (0.04)</td>
<td>0.09 (0.02)</td>
<td>2.01 (0.04)</td>
<td>1.44 (0.25)</td>
<td>2.31 (0.40)</td>
</tr>
<tr>
<td>pH 7.8</td>
<td>7.80 (0.03)</td>
<td>781.17 (31.13)</td>
<td>1.99 (0.04)</td>
<td>0.05 (0.00)</td>
<td>2.08 (0.04)</td>
<td>2.13 (0.06)</td>
<td>0.78 (0.05)</td>
</tr>
<tr>
<td>pH 7.5</td>
<td>7.50 (0.03)</td>
<td>1597.15 (62.76)</td>
<td>2.05 (0.04)</td>
<td>0.03 (0.00)</td>
<td>2.16 (0.04)</td>
<td>2.13 (0.04)</td>
<td>0.40 (0.02)</td>
</tr>
</tbody>
</table>

Do Tanner crab respond to lower pH or lower saturation state?
- relatively shallow & more variable environment
- can Tanner crab regulate pH?

Ca²⁺ + HCO₃⁻ ⇌ H⁺ + CaCO₃

Some corals, coccolithophores, and crustaceans can transport bicarbonate (organic carbonate) to site of mineralization

Future Research on hemolymph chemistry
Embryo response

- pH 7.5: 10% larger yolks and 6% smaller embryos (slower development)

Embryo → larvae carryover

- Year 1: no significant difference in # hatched
- Year 2: 48-83% fewer larvae hatched
- Year 2: 71% fewer viable larvae hatched at pH 7.5

Larval survival: starvation experiments

- Embryo treatment affected larval morphometrics
- However, minimal effect on survival
- In year 2
  - Larvae 10% smaller in pH 7.5
  - Larvae that survived lived longer in year 2 (acclimation?)
  - Decreased metabolism OR higher energy reserves
- Adaptation due to variable environment?
Juvenile crab mortality and growth

Juvenile stage is very susceptible to negative OA effects.

Adult condition and calcification

Energetic trade-off between condition and calcification?
Adult hemocytes (semi- and granular cells)

- Flow cytometer
- Total hemocyte count did not change
- More dead cells & phagocytosis increased at pH 7.5
  - Cells dying faster (turnover) than can be removed

- Internal pH no different among treatments
- Energetic costs to maintain pH and maintain defense mechanisms

Meseck et al. 2016
Fisheries population effects

Experimental results were used to inform pre-recruitment model
-Tanner crab oocyte, embryo, larval, and juvenile survival

Population dynamics model

Laboratory data

Bioeconomic model
**Population Effects: without acclimation**

- Proportion larvae hatching that survive to juvenile stage C8 could decline by 25% over 100 y.
- >50% decrease in catch and profits within 20 years
- Only significant when oocyte development is included in survival estimates
Evidence for phenotypic plasticity?

Effects at oocyte and embryo stage significant

Effects at larval stage minimal (no effect on mortality)
  • Decreased metabolism?
  • Larvae that survived may be acclimating?
  • Adaptation due to variable environmental conditions?

Effects at juvenile stage significant
  • Calcification vs condition tradeoff?

Adult crab maintain hemolymph pH
  • Energy spent maintaining cell pH and immunological function...effects development during oogenesis

Sustainability of commercial fisheries uncertain....but there is hope.
• Alaska Fisheries Science Center Kodiak Laboratory Research Staff
• NOAA Ocean Acidification Program
• North Pacific Research Board

http://www.afsc.noaa.gov/RACE/shellfish/oceanAcid/oceanAcidCurrent_HOME.php

Thank you!
Kodiak Lab approach to climate effects on commercial crab stocks

Climate Change
1. Range expansion
2. Change life history
   - Growth
   - Reproductive timing
   - Habitat availability
   - Species interactions
   - Larval drift

Ocean Acidification
1. Increased Mortality…
2. Growth change
3. Calcification
4. Behavioral changes

Framework to assess environmental effects

modified Koenigstein et al. 2016