Assessing impacts of climate stressors on near-coastal species at a regional scale (Gulf of California through Beaufort Sea)

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Project objective

- Identify species most vulnerable to climate change
- Predict how vulnerability changes geographically
- Identify major climate stressors for vulnerable species

Insufficient information to develop statistical, physiological, or mechanistic models for 98% to 99% of coastal species.
APPROACH – Risk assessment, cuts through the complexity of many species & many locations

Risk assessments based on environmental thresholds and biotic traits as a practical solution to assess vulnerability in hundreds to thousands of species over large regional scales.

Comparable to health questionnaires in resolution:

- Use existing data about the species
- Relatively inexpensive to conduct
- Generate relative risks for multiple species
- Generate risk patterns across geographic regions
METHODS - Scale, Scope & Taxa

MEOW Ecoregions (Marine Ecoregions of the World)

Gulf of California to Beaufort Sea

Crabs (Brachyuran & Lithodid) & Rockfish (ca. 450 Species)

Bivalves, Amphipods, Polychaetes & Echinoderms (ca. 2500 Species)
Climate Risk Assessments Implemented as a Web-Based Tool
‘Coastal Biodiversity Risk Analysis Tool’- (www.cbrat.org)

≤ 2016: CBRAT functions as a powerful ecoinformatics platform synthesizing biotic & environmental information on Pacific crabs & rockfish

2017: Risk assessments implemented for crabs & rockfish and updated analysis of regional climate risks, including bivalves

Preliminary Results
**METHODS - Phases of Implementation**

Phase I: Synthesize biotic and environmental data at a species level

Phase II: Generate rules and climate thresholds based on literature & workshops

Phase III: Implement an algorithm-based risk assessment - uses biotic & environmental data-based rules instead of expert opinion

**Advantages of Algorithm-Based Risk Assessments:**
- Reduce biases
- Increase transparency
- Reproducible
- Model different climate scenarios
METHODS – Algorithm Considers 2 Types of Risk

**Baseline Risks:** Species traits related to population viability but not readily linked to specific climate drivers (e.g., endemic, habitat specialists).

**Climate-Related Risks:** Ecoregion-specific projections, thresholds compared directly to climate driver.

- Sea Level Rise
- Ocean Acidification
- Temperature
## Baseline climate rules derived from biogeographic and life history traits.

Rules are classified as a Risk or a Resilient depending upon whether the trait results in increased or reduced risk to climate change. Risk is scored from -3 (high risk) to 3 (high resiliency).

<table>
<thead>
<tr>
<th>Trait</th>
<th>Risk / Resilient</th>
<th>Type</th>
<th>Global or Ecoregion Specific</th>
<th>Baseline Rule</th>
<th>Risk</th>
<th>Comments &amp; Exceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Endemic</strong></td>
<td>Risk</td>
<td>Distribution</td>
<td>Ecoregion</td>
<td>If species present in only one ecoregion AND not Abundant</td>
<td>-3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>If species present in only one ecoregion AND Abundant</td>
<td>-2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>If species present in more than one ecoregion</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Restricted Distribution</strong></td>
<td>Risk</td>
<td>Distribution</td>
<td>Ecoregion</td>
<td>If species present in only two ecoregions AND Hyper-rare in one or both</td>
<td>-3</td>
<td>Do not include ecoregions where the species is Transient or Hyper-rare.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>If species present in only two ecoregions AND Rare in both</td>
<td>-2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>If species present in only two ecoregions AND Present or Moderate or Abundant in one or both</td>
<td>-1</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>If species present in more than two ecoregions</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Wide Distribution</strong></td>
<td>Resilient</td>
<td>Distribution</td>
<td>Global</td>
<td>If species occurs in Arctic &amp; Cold Temperate &amp; Warm Temperate Provinces</td>
<td>2</td>
<td>Do not include ecoregions where the species is Transient or Hyper-rare.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>If species occurs in Cold Temperate &amp; Warm Temperate &amp; Tropical Provinces</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>If species does not occur in three Provinces with different temperature regimes</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Nonindigenous Species (NIS)</strong></td>
<td>Resilient</td>
<td>Distribution</td>
<td>Global</td>
<td>If species is classified with a Master NIS anywhere globally WITH a Master Established value</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>If species has a Master NIS classification but Establishment is Not Established OR only Stocked</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Habitat Specialization</strong></td>
<td>Risk</td>
<td>Life History</td>
<td>Global</td>
<td>If no Specialized Habitats -&gt; 0</td>
<td>0</td>
<td>If multiple specialized habitats, take the greatest risk</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Obligate &amp; Preferred Habitat -&gt; -3</td>
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<td></td>
<td></td>
<td>Facultative &amp; Preferred Habitat -&gt; -2</td>
<td>-2</td>
<td></td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>Facultative &amp; Observed Habitat -&gt; -1</td>
<td>-1</td>
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</tr>
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<td></td>
<td></td>
<td></td>
<td>Incidental &amp; Observed Habitat -&gt; 0</td>
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<td></td>
<td></td>
<td>Obligate &amp; Preferred Habitat -&gt; -2</td>
<td>-2</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>Facultative &amp; Preferred Habitat -&gt; -1</td>
<td>-1</td>
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<td></td>
<td></td>
<td>Facultative &amp; Observed Habitat -&gt; 1</td>
<td>-1</td>
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<tr>
<td><strong>Trophic Specialization</strong></td>
<td>Risk</td>
<td>Life History</td>
<td>Global</td>
<td>If Moderate Trophic Specialization -&gt; -1</td>
<td>-3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>If Specialist Trophic Specialization -&gt; -3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>If Generalist Trophic Specialization -&gt; 0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
**METHODS - Overview**

- **Historical Enviro. Conditions**
  - pH or Ω
  - Temperature
  - What habitats
  - Depth within those habitats

- **Projected Enviro. Conditions**
  - pH or Ω
  - Temperatures
  - SLR rates

- **Habitat Thresholds**
  - Establish taxa or habitat specific tolerances to stressors.

- **Biotic Modifiers**
  - Natural history traits, distributions, etc. modify climate risk

- **Relative Risk at ecoregion scale**
<table>
<thead>
<tr>
<th>Habitat / Threshold Class</th>
<th>Increase/Minor (Increase to -10% loss)</th>
<th>Low (-11 to -29% loss)</th>
<th>Moderate (-30 to -49% loss)</th>
<th>High (&gt;50% loss)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Constrained</td>
<td>Unconstrained</td>
<td>Constrained</td>
<td>Unconstrained</td>
</tr>
<tr>
<td>Rocky Intertidal</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Low Marsh</td>
<td>360</td>
<td>270</td>
<td>630</td>
<td>450</td>
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<tr>
<td>Mangroves</td>
<td>750</td>
<td></td>
<td>1150</td>
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<tr>
<td>Submerged Aquatic Vegetation</td>
<td>540</td>
<td>1080</td>
<td>720</td>
<td>1440</td>
</tr>
<tr>
<td>Tide Flats</td>
<td>180</td>
<td>360</td>
<td>630</td>
<td>990</td>
</tr>
<tr>
<td>Coastal Beaches</td>
<td>550</td>
<td>650</td>
<td>600</td>
<td>800</td>
</tr>
</tbody>
</table>

Unconstrained = Inland migration of habitat not artificially limited  Constrained = Inland migration of habitat limited by structures; coastal squeeze

Net SLR (mm) by 2110 associated with different % habitat loss at a regional scale
SLR - RESULTS

Geographical Pattern of Sea Level Rise Risk
Across Ecoregions – using 8 mm/yr eustatic SLR

Alaskan & Arctic Ecoregions:
• Few or no crabs are ‘primarily’ intertidal in Arctic ecoregions
• High potential for habitats to migrate inland
• Isostatic uplift high in several ecoregions

# of Crabs with High or Mod. SLR Risk / Total Crabs

0/7 Chukchi Sea
0/14 Eastern Bering Sea
0/17 Aleutian Islands
0/25 Gulf of Alaska
0/3 Beaufort Sea
0/35 North American Pacific Fiordland
8/29 Puget Trough/Georgia Basin
9/44 OR, WA, Vancouver Coast and Shelf
14/65 Northern California
49/135 Southern California Bight
37/138 Magdalena Transition
80/285 Cortezian
OA METHODS - Developing Taxa Thresholds

34 Studies
25 Species
177 Sig. Tests

Response variables:
• Behavior
• Calcification
• Development
• Genetics
• Mortality
• Physiological

Sensitive Species
• *Paralithodes camtschaticus*, Alaska King crab
• *Chionoecetes bairdi*, Tanner crab

Cumulative Percent effects experimental results - Decapods

Taxon / Risk Class | Standard Decapods | Sensitive Decapods |
--- | --- | --- |
High Risk | <7.76 | <7.85 |
Moderate Risk | 7.77 – 7.82 | 7.86 – 7.90 |
Low Risk | 7.81 – 7.85 | 7.87 – 7.8 |
Trivial Risk | >7.85 | >7.8 |

OA METHODS – Developing Taxa Thresholds

Cumulative Percent effects experimental results - Decapods
Regional Patterns of Risk to pH
Decapods – RCP 8.5

- Decapods with ‘standard’ tolerances
  - Mod. Risk
  - Low Risk
  - Trivial Risk

- Decapods sensitive to pH
  - High Risk
  - Mod. Risk

PH data CMIP5 downloaded from NOAA’s Climate Web Portal
**Temperature METHODS**

**BERING SEA:** Predicted SST  
3.75° + 3.56° = 7.31°C

**NORTHERN CALIFORNIA:** 28 year mean in Warmest Occupied Ecoregion

- Minor Risk: 13.55-14.16 °C  
(<1 SD from mean)
- Low Risk: 14.17-14.78° C  
(>1 SD from mean)
- Mod. Risk: 14.79-15.40° C  
(>2 SD’s from mean)
- High Risk: >15.41° C  
(>3 SD’s from mean)

**Ecoregional Thermal Window Approach**

- Tanner Crab, Yearly SST, IPCC RCP 8.5, 2099
  - Compare Predicted SST to Ranges in Warmest Occupied Ecoregion
  - Assessment can be run for yearly, just summer, or just winter temperature increases – user defined
Chionoecetes bairdi (Tanner Crab)

Summer SST, RCP 8.5
Risk in 2099

- High Risk: N. California
- Low Risk: Pacific Fjords & Puget
- Moderate Risk: Oregonian
- No/Trivial Risk: Moderate Risk: No/Trivial Risk

Legend:
- Green = No/Trivial Risk
- Orange = Low Risk
- Yellow = Moderate Risk
- Red = High Risk
Temperature Risk Analysis Yearly
SST - RCP 8.5

- Risk largely limited to southern most occupied ecoregions
- Best case scenario for northern ecoregions
- In U.S., 47 of 152 crabs (31%) are classified at risk in at least one ecoregion.

# of Crabs with High or Mod. SLR Risk / Total Crabs

- 5 / 43
- 6 / 63
- 36 / 133
- 7 / 139
- 65 / 296
Overarching Conclusions:

• Climate change associated with an RCP 8.5 emission scenario will result in moderate to high risk in over half the crabs in U.S. Pacific waters in at least one ecoregion.

• Algorithm risk assessments are a practical and rigorous approach to assessing relative risk for large number of species at a regional scale.

• Strong geographical and taxonomic patterns to risk evident.

• Distribution and migration rates of warm genotypes may be key for the potential of species to adapt to increased temperatures in the northern limit of their range.
Climate Change is Likely to Have Multiple Impacts on Near-Coastal Species & Ecosystem Services.....

Thank You