Climate vulnerability analysis of Eastern Bering Sea fish and invertebrate stocks

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Assessing Vulnerability

Vulnerability to climate change is defined as a function of sensitivity to climate change and exposure to climate change (i.e., “exposure factors”)

Goals:
1. Determine which stocks are vulnerable and why
2. Identify data gaps and research priorities

Eastern Bering Sea
A diversity of stocks and analysts for EBS study

36 stocks
- 4 elasmobranchs
- 9 flatfish
- 5 salmon
- 4 crab stocks
- 3 cephalopods
- 2 forage species
- 4 rockfish
- 5 other ‘roundfish’

34 analysts for sensitivity scores
- 19 NOAA-Fisheries
- 4 Other management agencies (ADFG, IPHC)
- 11 Academia (U. of Alaska, Oregon State U., UC-Santa Barbara, U. of Washington)
Methodology – Framework

Species Vulnerability

Exposure
- Sea surface temperature
- Bottom temperature
- Air temperature
- Salinity
- Ocean acidification (pH)
- Precipitation
- Currents
- Sea surface height
- Large zooplankton biomass
- Phytoplankton biomass and bloom timing
- Mixed layer depth

Sensitivity
- Habitat Specificity
- Prey Specificity
- Sensitivity to Ocean Acidification
- Sensitivity to Temperature
- Stock Size/Status
- Other Stressors
- Adult Mobility
- Spawning Cycle
- Complexity in Reproductive Strategy
- Early Life History Survival and Settlement Requirements
- Population Growth Rate
- Dispersal of Early Life Stages

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Example Sensitivity Attribute – Spawning cycle

Does the duration of the spawning cycle (within a year) limit the ability of the stock to successfully reproduce if necessary conditions are disrupted by climate change?

**Rationale** – Spawning throughout the year may allow adaption to a changing environment

**Evaluation criteria**

Low sensitivity – Spawning throughout the year

Moderate sensitivity – Several spawning events within a year

High sensitivity – Several spawning events within a confined period.

Very High sensitivity – One spawning event per year
Example Sensitivity Attribute – Population growth rate

What is the relative productivity of the stock?

**Rationale** – More productive stocks are, in general, more resilient to changes in the environment

**Evaluation criteria**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum growth rate ($r_{max}$)</td>
<td>&gt; 0.50</td>
<td>0.16 - 0.50</td>
<td>0.05 - 0.15</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>von Bertalanffy K</td>
<td>&gt; 0.25</td>
<td>0.16 - 0.25</td>
<td>0.11 - 0.15</td>
<td>&lt;= 0.10</td>
</tr>
<tr>
<td>Age at maturity</td>
<td>&lt; 2 yrs</td>
<td>2 - 3 yrs</td>
<td>4 - 5 yrs</td>
<td>&gt; 5 yrs</td>
</tr>
<tr>
<td>Maximum age</td>
<td>&lt; 10 yrs</td>
<td>11 - 15 yrs</td>
<td>15 - 25 yrs</td>
<td>&gt; 25 yrs</td>
</tr>
<tr>
<td>Natural mortality (M)</td>
<td>&gt; 0.50</td>
<td>0.31 - 0.50</td>
<td>0.21 - 0.30</td>
<td>&lt; 0.2</td>
</tr>
<tr>
<td>Maximum length</td>
<td>&lt; 55 cm</td>
<td>55 – 85 cm</td>
<td>85 – 150 cm</td>
<td>&gt; 150cm</td>
</tr>
</tbody>
</table>
Example of how EBS species are sensitive to environmental conditions

Winter-spawning flatfish

Wilderbuer et al. (2002)

Walleye pollock

Mueter et al. (2011)
Sensitivity scores

- Low
- Moderate
- High
- Very high

Number of stocks

- Very High: no stocks
- High: 5 flatfish, 1 forage fish, 4 rockfish, 5 salmon, 4 crab
- Moderate: 1 groundfish, 3 flatfish, 1 cephalopod, 3 elasmobranchs, 1 forage fish
- Low: 4 groundfish, 1 flatfish, 2 cephalopods, 1 elasmobranch
Most important attributes for high sensitivity stocks

Flatfish -- population growth rate, spawning cycle
Rockfish -- population growth rate, spawning cycle
Crab -- population growth rate, spawning cycle, ocean acidification
Salmon -- spawning cycle, dispersal of early life history stages, complexity in reproductive strategy
Herring -- spawning cycle, complexity in reproductive strategy, early life history survival and settlement requirements
Assessing exposure to climate change
Assessing a change in the mean of an environment variable

Changes in the mean of a variable are evaluated relative to its variability.

\[ Z = \frac{\mu_{Future} - \mu_{current}}{\sigma_{current}} \]

**Future: 2030 – 2039**
**Current: 2003 - 2012**

High variation
Low variation
Assessing a change in the variance of an environment variable

The increased (or decreased) frequency of unusual events may be important for some stocks.
Vulnerability Assessment Methodology
Climate Exposure

*Example – spring sea surface temperature*

- **Current SST**
- **Future - Current**
- **Current Sd. Dev.**
- **Z-score**

- **Z-score** is \((\text{Future} - \text{Current}) / (\text{Current SD})\) \([\text{i.e., column2 / column 3}]\)
- For each stock, we will compare the overlap of the current species distribution and the expected change in the exposure factor.

- Spatial domain of ROMS model (from Hermann et al 2013)
Vulnerability Assessment Methodology

Climate Exposure

- Projected future conditions (for most variables) were obtained from 3 downscaled Global Climate models (Al Hermann)
  - CCCma – high degree of warming
  - MIROC – intermediate warming
  - ECHO-G – least warming
- For each stock, we will need to consider which environmental variables affect the stock dynamics
EBS climate vulnerability

(Preliminary – do not cite)
Why are the exposure scores low?

1) Future period is 2030-2039 - looking further into the future would likely result in greater exposure.

2) Finer scale resolution of downscaled climate models
Summary and Conclusions

1) Eastern Bering Sea stocks show a wide range of sensitivities to climate change

2) Global climate models were downscaled to project future conditions in the eastern Bering Sea

3) Preliminary scores for exposure have been produced, and indicate low to moderate exposure to climate change for 2030-2039.

4) Final review of exposure and vulnerability scores, evaluation of uncertainty and data quality, and writing manuscripts/reports is expected to occur winter/spring 2017.