Evidence of climate-driven ecosystem reorganization in the Gulf of Mexico

NOAA Southeast Integrated Ecosystem Assessment Team

AOML/SEFSC collaboration workshop
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and many others....
Indicator selection process

Responsive – Does the indicator respond to or drive changes in the ecosystem?

Integrative – Does the indicator describe overall ecosystem status?

Understandable – Is the indicator understood by a non-scientific audience?

1. Please indicate your area of expertise.
   - Fisheries - Management
   - Marine Resource Management

2. What is your affiliation?
   - NOAA Sea Grant

3. Please rate the following indicators according to the criteria listed, with respect to the potential utility of the indicator for the management of the Gulf of Mexico Large Marine Ecosystem. ‘Ecosystem’ in this context refers to the entire extent of the Gulf of Mexico, and includes coastal human communities dependent on the Gulf.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Does the indicator respond to changes in the state of the ecosystem?</th>
<th>Does the indicator status reflect OVERALL ecosystem health? (i.e., is the indicator integrative?)</th>
<th>Is the indicator understood by managers and the public?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average trophic level in the catch</td>
<td>Definitely yes</td>
<td>Definitely yes</td>
<td>Maybe</td>
</tr>
<tr>
<td>Average trophic level in fishery-independent survey</td>
<td>Definitely yes</td>
<td>Definitely yes</td>
<td>Maybe</td>
</tr>
<tr>
<td>Mean length in the catch (by species)</td>
<td>Probably yes</td>
<td>Probably yes</td>
<td>Probably yes</td>
</tr>
<tr>
<td>Mean length in the catch (all species pooled)</td>
<td>Probably yes</td>
<td>Maybe</td>
<td>Maybe</td>
</tr>
<tr>
<td>Condition factor of individual species in the catch</td>
<td>Probably yes</td>
<td>Probably yes</td>
<td>Maybe</td>
</tr>
<tr>
<td>Size at maturity in the catch (by species)</td>
<td>Probably yes</td>
<td>Maybe</td>
<td>Probably yes</td>
</tr>
<tr>
<td>Pelagic demersal fish ratios in catch vs. demersal fish ratios in fishery-independent survey</td>
<td>Don't know</td>
<td>Don't know</td>
<td>Don't know</td>
</tr>
<tr>
<td>Proportion of predatory fishes in catch</td>
<td>Definitely yes</td>
<td>Maybe</td>
<td>Maybe</td>
</tr>
<tr>
<td>Proportion of moderately exploited species in catch</td>
<td>Definitely yes</td>
<td>Maybe</td>
<td>Maybe</td>
</tr>
<tr>
<td>Proportion of moderately exploited species in fishery-independent survey</td>
<td>Definitely yes</td>
<td>Maybe</td>
<td>Maybe</td>
</tr>
</tbody>
</table>
DPSIR Indicator Framework

**PRESSURE**
- Atlantic Multidecadal Oscillation
- Sea surface temperature
- Loop current intrusion
- Precipitation
- Area of hypoxia
- # of oil spills

**STATE**
- Extent of benthic habitats
- Chlorophyll concentrations
- Species abundances

**IMPACT / ECO SERVICES**
- Trophic level of the catch
- Landings
- Species diversity

**RESPONSE**
- Fishing effort
- Fishing revenues
- Human population

**DRIVER**
- Species abundances
- Trophic level of the catch
- Landings
- Species diversity
Ordination techniques

<table>
<thead>
<tr>
<th>time</th>
<th>Indicator 1</th>
<th>Indicator 2</th>
<th>Indicator 3</th>
</tr>
</thead>
</table>

**Principal components analysis**
Represents complex data sets with a smaller number of axes which represent covariance structure

**Chronological clustering**
Similarities between ordered times steps calculated based on distance matrix
Ordination by indicator group
Atlantic Multidecadal Oscillation?

AMO warm phase:
- Increased SST in GoM
- Decreased precipitation in U.S.
- Shallower mixed layer in GoM

Expect to see an ecosystem shift in ~1965?

Nye et al. 2013
NMDS of landings data to 1950
Chronological clustering of landings

Magnuson–Stevens Act

AMO
Effects of AMO on GoM

Atlantic Warm Pool area

SST mean

SST max

AMO cool phase
AMO warm phase
P < 0.05

climate drivers

MS River watershed fertilizer use MS River precipitation MS River TN load

physical drivers

area hypoxic zone dissolved oxygen Louisiana summer dissolved oxygen Louisiana fall

dissolved oxygen Texas summer dissolved oxygen Texas fall

hurricane activity Hg concentration central GoM

lower trophic states

zooplankton fall benthic ichthyoplankton 1 benthic ichthyoplankton 2

zooplankton spring mesopelagic ichthyoplankton 1 mesopelagic ichthyoplankton 2
Conclusions

• Different ecosystem states appear to be associated with warm and cool phases of the Atlantic Multidecadal Oscillation

• Changes in GoM likely due to both climatic and anthropogenic forces – and the interactions between the two
Questions?

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EXTRAS
Ecosystem stability – Changes in indicator trends

Short-term vs. long-term

- / +

+ / +

- / -

+ / -
Indicators of drivers and pressures becoming increasingly positive.
Populations may show patterns of increasing variance before collapse occurs.

(Litzow et al, 2013, Boettiger and Hastings 2013)
Major pressures are becoming increasingly variable from year to year.