Marine Top Predators as Climate and Ecosystem Sentinels

Elliott L. Hazen, Briana Abrahms, Stephanie Brodie, Gemma Carroll, Michael Jacox, Matthew S. Savoca, Kylie L. Scales, William J. Sydeman, Steven J. Bograd

elliott.hazen@noaa.gov; SWFSC - ERD
New conditions, new risks

Whale species entangled on the West Coast

CSI: CRIME SCENE INVESTIGATION
2015-16 Whale Entanglements

Key ecosystem ingredients:

Persistent marine heat wave

Jacox et al. 2016 GRL
2015-16 Whale Entanglements

Key ecosystem ingredients:

- Persistent marine heat wave
- Record HAB + domoic acid delayed Dungeness crab fishery

McCabe et al. (2016)
2015-16 Whale Entanglements

Key ecosystem ingredients:

- Persistent marine heat wave
- Record HAB + domoic acid delayed Dungeness crab fishery
- Low krill off shelf break & high concentration of anchovies on shelf

Santora et al. in review *Nature Communications*

May-June Anchovy CPUE from trawls
2015-16 Whale Entanglements

Key ecosystem ingredients:

- Persistent marine heat wave
- Record HAB + domoic acid delayed Dungeness crab fishery
- Low krill off shelf break & high concentration of anchovies on shelf
- Recovering whale populations
- Humpback whale prey switching

End result: unusual time-space overlap between foraging humpback whales and crab pots

Santora et al. in review Nature Communications

May-June Anchovy CPUE from trawls
What is an ecosystem sentinel?

- Global Ocean Observing System
- What can animals measure and tell us about the environment?
- Direct measurements are useful, but what about ecosystem thresholds

Harcourt et al. 2019 F Mar Sci
What is an ecosystem sentinel?

“A sentinel species provides the perspectives and methodologies to tease apart the complexity of marine ecosystems.” - Tabor and Aguirre 2004 *EcoHealth*

“…where do we look for signals of how climate change influences ecosystems? Lakes and reservoirs are an important part of the answer.” - Williamson et al. 2009 *Science*

“Species dependent on sea ice, such as the polar bear (*Ursus maritimus*) and the ringed seal (*Phoca hispida*), provide the clearest examples of sensitivity to climate change.” - Moore 2008 *J. Mammology*
Identifying and monitoring sentinels

An ecosystem sentinel as a species that responds to ecosystem variability and/or change in a timely, measurable, and interpretable way, and can indicate an otherwise unobserved change in ecosystem structure or function.
Identifying and monitoring sentinels

An ecosystem sentinel as a species that responds to ecosystem variability and/or change in a timely, measurable, and interpretable way, and can indicate an otherwise unobserved change in ecosystem structure or function.
Identifying and monitoring sentinels

An ecosystem sentinel as a species that responds to ecosystem variability and/or change in a timely, measurable, and interpretable way, and can indicate an otherwise unobserved change in ecosystem structure or function.

Hazen et al. 2019 Frontiers in Ecology and the Environment
Identifying and monitoring sentinels

An ecosystem sentinel as a species that responds to ecosystem variability and/or change in a timely, measurable, and interpretable way, and can indicate an otherwise unobserved change in ecosystem structure or function.
What is an ecosystem sentinel?

An ecosystem sentinel as a species that responds to ecosystem variability and/or change in a timely, measurable, and interpretable way, and can indicate an otherwise unobserved change in ecosystem structure or function.
What is an ecosystem sentinel?

An ecosystem sentinel as a species that responds to ecosystem variability and/or change in a timely, measurable, and interpretable way, and can indicate an otherwise unobserved change in ecosystem structure or function.
What is an ecosystem sentinel?

An ecosystem sentinel as a species that responds to ecosystem variability and/or change in a timely, measurable, and interpretable way, and can indicate an otherwise unobserved change in ecosystem structure or function.

Hazen et al. 2019 *Frontiers in Ecology and the Environment*
What is an ecosystem sentinel?

An ecosystem sentinel as a species that responds to ecosystem variability and/or change in a timely, measurable, and interpretable way, and can indicate an otherwise unobserved change in ecosystem structure or function.

Hazen et al. 2019 Frontiers in Ecology and the Environment
2005 in the Northeast Pacific

Weise et al. 2006, GRL
What is an ecosystem sentinel?

An ecosystem sentinel as a species that responds to ecosystem variability and/or change in a timely, measurable, and interpretable way, and can indicate an otherwise unobserved change in ecosystem structure or function.
What is an ecosystem sentinel?

An ecosystem sentinel as a species that responds to ecosystem variability and/or change in a timely, measurable, and interpretable way, and can indicate an otherwise unobserved change in ecosystem structure or function.

Hazen et al. 2019 Frontiers in Ecology and the Environment
2005 in the Northeast Pacific

Sydeman et al. 2006, GRL
Upwelling

What delay in upwelling leads to an ecosystem response?

Schwing et al. 2006, GRL
### California Herring EBFM

#### Timeseries of SFB herring SSB, observed (solid black line with triangles) vs. predicted (dashed gray line with circles)

#### Table: Herring predators and diet percentages

<table>
<thead>
<tr>
<th>Herring predator</th>
<th>CCS summer diet</th>
<th>Summer California diet</th>
<th>Winter California diet</th>
<th>GOF (Sep-Dec) diet</th>
<th>GOF (Oct-Mar) diet</th>
<th>GOF-MB (Dec-Mar) diet</th>
<th>GOF (Mar-Apr) diet</th>
<th>Source - Winter diet central California (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinook salmon</td>
<td>9%</td>
<td>4%</td>
<td>27%</td>
<td>3% (1-5%)</td>
<td>16% (5-27%)</td>
<td>29% (10-49%)</td>
<td>24% (9-39%)</td>
<td>1955 GOF [28]; 1980-86 GOF [29]</td>
</tr>
</tbody>
</table>
| humpback whale          | ~13%
            | x²               | ~19%                   | ~5%                   | ~33% (26-40%)     |                   |                      | 1920, 1922 MB [66]; 1988, 1990 GOF [67]      |
| common murre            | 7%              | 0%                     | 6%                     | 20% (12-28%)      |                   |                      | 28%                                           |
| harbor seal             | 6%              | 8%                     | 1%                     |                   |                   |                      |                                               |
| Pacific hake            | 11%             | 7%                     |                         |                   |                   |                      |                                               |
| rhinoceros auklet       | 6%              | 1%                     | 1%                     |                   |                   |                      |                                               |
| California sea lion     | 4%              | 1%                     | <1%                    |                   |                   |                      |                                               |

83 predators eat CC herring

Thayer et al. in review Mar Policy
Top predators in forage fish EBFM

SST+ model for Herring

California Herring

Sydeman et al. 2018 Fish Res; Thayer et al. in review Mar Policy
Top predators in forage fish EBFM

SST+ model for Herring

What is the state of alternative forage?

California Herring

Sydeman et al. 2018 *Fish Res*; Thayer et al. in review *Mar Policy*
Top predators in forage fish EBFM

**SST+ model for Herring**

What is the state of alternative forage?

Population / pup counts of marine mammals and seabirds

California Herring

Sydeman et al. 2018 *Fish Res*; Thayer et al. in review *Mar Policy*
Top predators in forage fish EBFM

Harvest Control Framework Proposal

- Harvest Control Rule is applied prior to ecosystem decision matrix.
- Harvest may be increased when ecosystem conditions are good.
- Moderate reductions in harvest may occur when ecosystem conditions warrant precaution.
- Large reductions in harvest may be necessary when extreme ecosystem conditions are detected.
- Between 15K and 20K a fishery closure may be warranted under extreme circumstances.
- Above 40K no further ecosystem-based reductions are necessary.

Sydeman et al. 2018 Fish Res; Thayer et al. in review Mar Policy
Conclusions

• Marine top predators offer a unique perspective into ocean processes, making them ideal sentinels.
Conclusions

- Marine top predators offer a unique perspective into ocean processes, making them ideal sentinels.
- Choosing appropriate sentinels can aid management in rapidly changing ecosystems.
Conclusions

• Marine top predators offer a unique perspective into ocean processes, making them ideal sentinels.
• Choosing appropriate sentinels can aid management in rapidly changing ecosystems
• As such, marine sentinels should be explicitly considered as a tool to support Ecosystem Based Fisheries Management
Acknowledgements

Yutaka Watanuki, Takashi Yamamoto, Rob Suryan, Marisol Garcia Reyes, Kevin Weng, Chandra Goetsch, Briana Wittiveen, Barb Muhling