Ecosystem-based management in Alaska: The role of seabirds as indicators of ecosystem change

Seabirds

Forage fish

Zooplankton

Climate

Widespread Reproductive Failure
Goals

- Ecosystem-based (fishery) management in Alaska
- Ecosystem indicators
- Future directions for ecosystem indicators
Definitions

- Ecosystem indicators
  - Time-series of data that measures an ecosystem component

- Groundfish
  - Pollock, cod, flatfish, rockfish
  - 2012 value: $1.05 billion
Alaska marine ecosystems

- Arctic
- Eastern Bering Sea
- Aleutian Islands
- Gulf of Alaska
Fishery management plan GOALS for Alaska groundfish

There are many:

1. Prevent overfishing
2. Promote sustainable fisheries & fishing communities
3. Preserve the food web
4. Manage incidental catch & reduce bycatch & waste
5. Avoid impacts to **seabirds** & marine mammals
6. Reduce and avoid impacts to habitat
7. Promote equitable & efficient use of fishery resources
8. Increase Alaskan native consultation
9. Improve data quality monitoring & assessment
Ecosystem-Based Fishery Management in Alaska

**Current**
- Closures, forage fish ban, gear modification, bycatch reduction, stock assessments, ecosystem assessments, fishery ecosystem plans, 2 MT cap

**Future**
- Integrated ecosystem assessments (IEA), stock assessments, ecosystem models, climate change
Ecosystem Indicators for Fisheries Managers

- NOAA follows 100’s of ecosystem indicators that are evaluated annually to inform fisheries managers
- Developed by NOAA and other researchers
- Trends monitored for early signs of ecosystem change that may have management implications
- Ecosystem-based fisheries management
Why a Suite of Indicators?

Synthesis – more than the sum of its parts

1. Provide stronger links between ecosystem research and management
2. Spur new understanding of connections between ecosystem components
What makes a good indicator?

- What do the indicators indicate??
  - Functional responses
  - Species interactions

- Need to be useful
  - Requires understanding the management system
  - Frequent dialogue, adaptive
The annual Council process

Aug-Sept
- Stock assessments
- Ecosystem considerations

Sept, Nov
- Regional Plan Teams

Dec
- Science and Statistical Committee
- Public input

Advisory Panel

100+ Ecosystem Indicators

Ecosystem information added at each level

Fishery quotas set
From Council minutes, December 2006:

• “The [eastern Bering Sea walleye pollock] stock remains above the MSY level, having declined … at a rate of about 19% per year. . . .

  **Result from stock assessment**

• Other issues raised … suggest a need for further caution.
  – a northward shift … with some portion of the population into Russian waters.

  **Assessment + ecosystem indicators**

  – a large decline in zooplankton, which is important in providing forage for juvenile pollock.

  **Ecosystem indicators**

  – increasing predation by arrowtooth flounder on juvenile pollock.

Consequently, … a reduction in … catch … is justified.”
Seabirds as indicators

Seabirds as Indicators of Marine Food Supplies

D. K. CAIRNS*
Newfoundland Institute for Cold Ocean Science and Psychology Department
Memorial University of Newfoundland

Seabirds as indicators of marine ecosystems

Idea: John F. Platt, William J. Sydeman
Coordination: William J. Sydeman, John F. Platt, Howard I. Brownman

Seabirds as indicators of the marine environment

Matt Parsons, Ian Mitchell, Adam Butler, Norman Ratcliffe, Morten Frederiksen, Simon Foster, and James B. Reid
How seabirds fit into Alaska fisheries management

- Seabirds are becoming increasingly important indicators:
  - of fisheries interactions (bycatch)
  - of the ecosystem (colony-based)
Indicators: from qualitative to quantitative

- 4 case studies:
  - Qualitative synthesis
    1. Red flags in the Gulf of Alaska
  - Indicator selection
    2. Report cards for the Aleutians and the eastern Bering Sea
  - Developing multivariate indicators
    3. Combined Pribilof seabird indicators
    4. Ecosystem reference point for the eastern Bering Sea
Case Study #1

Qualitative Indicator Synthesis: Red Flags
Ecosystem indicators that cumulatively suggest anomalous conditions occurred in 2011.

Gulf of Alaska
Red Flag #1: Seabirds

- Aiktak:
  - Fail: Common murre
  - Fail: Thick-billed murre
  - Ok: Tufted puffin

- Chowiet:
  - Fail: Black-legged kittiwake
  - Fail: Tufted puffin
  - Fail: Parakeet auklet
  - Poor: Common murre
  - Poor: Thick-billed murre

- Barrens:
  - Fail: Black-legged kittiwake

- Middleton:
  - Fail: Tufted puffin
  - Ok: Black-legged kittiwake
  - Ok: Rhinoceros auklet

- St. Lazaria:
  - Ok: Common murre
  - Ok: Thick-billed murre

Gulf of Alaska
Red Flag #2: Halibut

Reoccurrence of “Mushy” Halibut Syndrome

- First detected in GOA in 1998
- Also seen 2005 and 2012
- Hypothesized nutritional deficiency
- Stomachs contain crab rather than forage fish
What Do They Indicate?

- Seabirds: Widespread Reproductive Failure
- Halibut: Mushy Flesh Prevalent

- Both are attributed to poor foraging conditions

Forage Fish?
Below average forage fish catch rates in small mesh surveys (Urban et al. 2012)

- Winter age-1 pollock (2011 year class) survey estimates low
- Juvenile pink salmon catch rates 2nd lowest in 15 years (Orsi et al. 2012)
Zooplankton

Very low zooplankton biomass sampled by Continuous Plankton Recorders (Batten 2012)

- Also, high abundance of salps in eastern GOA
Climate

- PAPA Trajectory Index unusually east and southernmost since 1993 (Stockhausen and Ingraham 2012)

- Decline in poleward branch of the Alaska Current (Bond 2012, Freeland)
Synthesis of indicators’ status across multiple trophic levels can reveal broad-scale changes.

Upper trophic organisms can provide near-real time cues of environmental state.

Changes in bottom-up forcing factors may have negatively influenced productivity during 2011.

Thus, 2011 may be a poor year class for forage fish and forage-fish eating predators.

- Prediction holding true for pollock
How do we turn myriad indicators into something more useful for managers?
Case Study #2

Indicator Selection: Developing Report Cards
Goal: to create short Ecosystem summaries

“Team-based Synthesis Approach”

• Created Ecosystem Assessment Synthesis teams: regional scientific experts, fisheries managers, others

• Met 1-2 times

• Chose structuring themes to guide indicator selection

• Developed list of 8-10 indicators:
  • “vital signs”
  • updatable
# Ecosystem comparison

<table>
<thead>
<tr>
<th></th>
<th>Eastern Bering Sea</th>
<th>Aleutian Islands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat</td>
<td>Broad, flat, muddy shelf. Valuable fisheries. Fish-related research.</td>
<td></td>
</tr>
<tr>
<td>Team members:</td>
<td><strong>NOAA</strong> 17</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Academia</strong> 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Management</strong> 1 (3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Commercial</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Other Fed</strong></td>
<td></td>
</tr>
<tr>
<td>Structuring theme</td>
<td>Production</td>
<td></td>
</tr>
<tr>
<td>Indicator focus</td>
<td>Broad, community-level, indicators of ecosystem-wide productivity, and those most</td>
<td></td>
</tr>
<tr>
<td></td>
<td>informative for managers</td>
<td></td>
</tr>
</tbody>
</table>

[Map of the Eastern Bering Sea]
## Results

<table>
<thead>
<tr>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate</td>
</tr>
<tr>
<td>Zooplankton</td>
</tr>
<tr>
<td>Forage fish</td>
</tr>
<tr>
<td>Fish biomass</td>
</tr>
<tr>
<td>Marine Mammals</td>
</tr>
<tr>
<td>Seabirds</td>
</tr>
<tr>
<td>Humans</td>
</tr>
</tbody>
</table>
## Results

**EASTERN BERING SEA**

- North Pacific Index
- Ice Retreat Index
- Euphausiids/Copepods
- Motile epifauna biomass
- Benthic foragers biomass
- Pelagic foragers biomass
- Fish apex predator biomass
- St Paul fur seal pups
- **St George thick-billed murre reproductive success**
- Area trawled

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Climate</th>
<th>Zooplankton</th>
<th>Forage fish</th>
<th>Fish biomass</th>
<th>Marine Mammals</th>
<th>Seabirds</th>
<th>Humans</th>
</tr>
</thead>
</table>
1. **Report Card particularly useful**

2. **Establish Teams for all regions**

3. **Increase diversity on Teams**

- A strong La Niña has formed on the eastern coast of North America in the recent dow. The prediction for the Bering Sea is above average sea-surface temperature in spring 2011. This would result in a fifth year of expanded plankton bloom.

- The euphausiid biomass index increased more than 6-fold from 2004 to 2010, in 2010 by ca. 30%. Large copepod biomass increased 40 fold from very low 2002-2005 warm period to 2009. This suggests that overall food availability species is high. Age-0 pollock and other planktivorous species may be dependent on sufficient prey to generate enough depot foods to survive their first winter. An increase in the proportion of forage fish, particularly schooling species, has been apparent in recent years.

- Current (2005-2010) mean biomass, catch, and exploitation rates of major benthic foraging fish have increased with a standard deviation of 197-201 apparent in recent years for these foraging guilds.

- There is a concern with two of the commercial crab stocks in the mobil which are overfished. However, this trend appears stable because the guild is depc fish and invertebrate biomass.

- There are no apparent trends in benthic foraging guilds, and the depc fish foragers guild appears stable and may not require further management.

- Pelagic foragers have biomass below mean and exploitation rate above mean, biomass and decreasing trends in catch and exploitation rate. In the last 5 years, has been at a historic low, which has been a concern for the recovery of the fishery. The recovery within the guild, as well as increased forage, positive physical recovery. Continued caution with the management of species in this guild and may be necessary, but the outlook is improved for recovery.

- The recent increasing trend in the apex predator guild biomass is due in Pacific cod biomass being offset by an increase in arrowtooth flounder. The predators guild appears stable and may not require additional management.

- Thick-billed murre reproductive success has increased in the past five years colder Bering Sea, later ice retreat, and increased biomass of zooplankton on the cold conditions the Bering Sea will likely lead to favorable conditions for nesting on St. George Island and a continued trend of higher reproductive success.

- Northern fur seal pup production on St. Paul Island has been declining since it has been relatively stable on St. George since 2002. Estimated pup prod Islands in 2008 was similar to the level observed in 1916; however, the population in 1916, the northern fur seal population was increasing at approximately 85% cessation of extensive pelagic sealing, while currently (1968 through 2008), product on both Pribilof Islands is decreasing at approximately 90%.

- The northern fur seal pup production on St. Paul Island has been declining since it has been relatively stable on St. George since 2002. Estimated pup production in 2008 was similar to the level observed in 1916; however, the population in 1916, the northern fur seal population was increasing at approximately 85% cessation of extensive pelagic sealing, while currently (1968 through 2008), production on both Pribilof Islands is decreasing at approximately 90%.
Aleutian Islands

Eastern Bering Sea
## Ecosystem comparison

<table>
<thead>
<tr>
<th></th>
<th><strong>Eastern Bering Sea</strong></th>
<th><strong>Aleutian Islands</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Habitat</strong></td>
<td>Broad, flat, muddy shelf. Valuable fisheries -&gt; Lots of fish-related research.</td>
<td>Extensive rocky island chain, deep trenches, oceanic basins. Smaller-scale fisheries (and research)</td>
</tr>
</tbody>
</table>
| **Team members:** | 17  
NOAA  
Academia  
Management  
Commercial  
Other Fed  
Non Profit  
Research sponsor | 10  
4  
1  
1  
2  
1  
1 |
| **Structuring theme** | Production | Variability |
| **Indicator focus** | Broad, community-level, indicators of ecosystem-wide productivity, and those most informative for managers | Characterize global attributes with local behavior |
“Top” Indicators for Ecosystem Assessments Now Include Seabirds

**EASTERN BERING SEA**
- North Pacific Index
- Ice Retreat Index
- Euphausiids/Copepods
- Motile epifauna biomass
- Benthic foragers biomass
- Pelagic foragers biomass
- Fish apex predator biomass
- St Paul fur seal pups
- St George thick-billed murre reproductive success
- Area trawled

<table>
<thead>
<tr>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate</td>
</tr>
<tr>
<td>Zooplankton</td>
</tr>
<tr>
<td>Forage fish</td>
</tr>
<tr>
<td>Fish biomass</td>
</tr>
<tr>
<td>Marine Mammals</td>
</tr>
<tr>
<td>Seabirds</td>
</tr>
<tr>
<td>Humans</td>
</tr>
</tbody>
</table>

**ALEUTIAN ISLANDS**
- North Pacific Index
- Auklet reproductive success
- Tufted puffin chick diets
- Pelagic foragers biomass
- Fish apex predator biomass
- Sea otters
- Steller sea lion non-pups
- Area trawled
- K-12 enrollment
1. Indicator selection influenced by:
   - Physical and biological nature of ecosystem
   - Extent of regional scientific knowledge
   - Expertise and interests of Team members

2. Assessment development should be iterative process with frequent review by managers
Multivariate indicators: quantitative method to reduce datasets

- Previously, selecting and interpreting indicators ‘as is’
- How to create useful indicators?

I. Reducing multiple time series – creating combined seabird indicators

II. Reducing an ecosystem to one indicator – creating an ecosystem reference point
Case Study #3

Reducing multiple time series: creating combined seabird indicators
Reducing multiple time series: creating combined seabird indicators

- The Pribilof Islands, eastern Bering Sea
Study Species

- Same species breed on each island
  - Black-legged kittiwakes (BLKI)
  - Red-legged kittiwakes (RLKI)
  - Thick-billed murres (TBMU)
  - Common murres (COMU)
  - Red-faced cormorants (RFCO)

Classifications:
- Surface-feeders
- Divers
- Near-shore foragers
Methods

- **17 productivity and phenology datasets**
  - 1996-2013

- **Reducing multiple time series: Principal Components Analysis (PCA)**

- **What do the indicators indicate? Time series analysis**
  - Leading PC scores against local environmental variables
  - Cross correlations with lags ≤3 yr
Results: Two strong and distinct trends

- Explanatory value: PC1 = 42.7% and PC2 = 23.5%

PC1 - “The phenology and divers productivity index”

PC2 - “The kittiwake productivity index”
The New Indicators: Temporal trends

- Higher murre and cormorant productivity.
- Earlier seabird hatch dates
- Higher kittiwake productivity

- Reduces 17 time series to 2!
- Together explain 66.2% of variance
What do these 2 seabird trends indicate?

**PC1: the phenology and divers productivity index**
- The warmer in year $x$, the later and less productive in year $x+1$, $x+2$

**PC2: the kittiwake productivity index**
- The more age-1 pollock in survey, the higher kittiwake productivity the following year

Zador et al., 2013 MEPS
• Multivariate indices simplify multiple seabird reproductive trends.

• Time series analysis reveals lagged effects of ecosystem
Case Study #4

Reducing an ecosystem to one indicator: creating an ecosystem reference point
Ocean Health Index

Global
- Natural products: 40
- Carbon storage: 75
- Coastal protection: 73
- Livelihoods: 84
- Economies: 67
- Iconic species: 70
- Lasting special places: 41
- Clean waters: 78
- Sense of place
- Artisanal fishing opportunity: 87
- Mariculture: 10
- Fisheries: 25
- Species: 79
- Habitats: 88
- Biodiversity
- Food provision

Australia: 67
China: 53
Germany: 73
Micronesia: 53
Poland: 42
Russia: 67
Singapore: 48
Suriname: 69
United Kingdom: 61
Ocean Health Index

www.oceanhealthindex.org/

OHI = sum (Goal Score * Weight)

Goal Score = (Present Status + Likely Future Status) / 2

Likely Future Status = 1 + 2/3 * Trend + 1/3 * (Resilience - Pressure)
Can we use the Eastern Bering Sea Report Card indicators to create an ecosystem reference point?
Eastern Bering Sea Ecosystem Reference Point

Annual trend
Eastern Bering Sea Ecosystem Reference Point

Within year indicator influences

1993

1) Non-trawled area
2) Fur seal pups
3) Thick-billed murre success
4) Apex predator B
5) Pelagic forager B
6) Benthic forager B
7) Motile epifauna B
8) EBS Zooplankton B
9) Ice Retreat Index
10) NPI (Nov-Mar average)
11) Calanus copepods
12) Euphausiids
13) Seabird phenology & success
14) Kittiwake success (PC2)
Eastern Bering Sea Ecosystem Reference Point

2008

1) Non-trawled area
2) N fur seal pups
3) Thick Billed Murre success
4) Apex predator B
5) Pelagic forager B
6) Benthic forager B
7) Motile epifauna B
8) EBS Zooplankton B
9) Ice Retreat Index
10) NPI (Nov–Mar average)
11) Calanus copepods
12) Euphausiids
13) Seabird phenology & success
14) Kittiwake success (PC2)
Eastern Bering Sea Ecosystem Reference Point

2011

1) Non–trawled area
2) N fur seal pups
3) Thick Billed Murre success
4) Apex predator B
5) Pelagic forager B
6) Benthic forager B
7) Motile epifauna B
8) EBS Zooplankton B
9) Ice Retreat Index
10) NPI (Nov–Mar average)
11) Calanus copepods
12) Euphausiids
13) Seabird phenology & success
14) Kittiwake success (PC2)
Next Steps

Will this allow us to:

- Evaluate risk under various management actions?
- Detect effects of management actions on ecosystem indices?
Final Comments
Final comments

- What do the indicators indicate?
- Change management system or work with system?
- Increase dialogue
- Qualitative to quantitative
- Seabird opportunities
Acknowledgements

Kerim Aydin, Kirstin Holsman, Sarah Gaichas, George Hunt, Ivonne Ortiz, Andy Whitehouse, Geoff Lang, Shannon Fitzgerald, Heather Renner, John Piatt, Yumi Arimitsu, Rebecca White

Data: Heather Renner, Scott Hatch, Sonia Batten, Nick Bond, Joe Orsi, Jamal Moss, Dan Urban, Olav Ormseth, Howard Freeland, John Piatt, Alaska Maritime National Wildlife Refuge biologists

FATE (Fisheries and the Environment)