Tipping Points

How to Tip Your Wedding Vendors
Tipping Points, Seabird Indicators and Mid Trophic Level Fish in the North Pacific

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Mechanism(s) of change poorly understood
- How are changes in community structure related to changes in ecosystem functions?
Tipping Points in Trophic Interactions
Mid-Trophic Level Invertebrates & Fish

- Small pelagics
  (anchovy, sardine, herring, sand lance, smelts)
- Invertebrates (krill, squid)
- Juvenile stages of large predatory fish
  (e.g, age 0-1 gadids, rockfishes, hakes, hexagrammids, salmonids, etc.)

Hold key role in ecosystem functions, important to upper trophic level species, including fish, seabirds, mammals/humans
Forage Fish “Interaction Nodes”

- Meso-Predators* May Be Most Responsive To Forage Fish Community Variability - Serve as Indicators Of Variability in Ecosystem Functions

*medium-sized predators
Key North Pacific Forage Fish

Pacific sand lance

Pacific herring

Capelin
Different parameters may show variable numerical responses with changes in forage fish biomass.

E.g., changes in breeding success may be “more sensitive”-provides widest threshold response.

From Cairns 1987
Global Analysis of Threshold Model for Forage Fish and Seabirds (Cury et al. 2011 Science) (tipping point just below zero where 0 = mean MTL fish abundance)
How appropriate is Cury et al.’s result (threshold at mean biomass) for North Pacific marine ecosystems?

Is there variability in the threshold numerical response between forage fish abundance and seabirds by:

i. predator species?
ii. prey species?
iii. parameter examined?
Conceptual Threshold Relationship

Forage fish biomass

Seabird trait

\[ y = c + a (1 - e^{-bx}) \]

threshold range

High

Low

High

Forage fish biomass

Low
Seabird Threshold Indicators and Variation in MTL Biomass

2 examples: breeding success & survival
## North Pacific Threshold Modeling
*(seabirds and forage fish biomass/abundance/CPUE)*

<table>
<thead>
<tr>
<th>Ecosystem</th>
<th>Demographic Response</th>
<th># Models</th>
<th># (%) Significant (p &lt; 0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA Current</td>
<td>Survival</td>
<td>24</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>CA Current</td>
<td>Breeding Success</td>
<td>30</td>
<td>15 (50%)</td>
</tr>
<tr>
<td>Alaska – GoA</td>
<td>Survival</td>
<td>2</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Alaska – GoA</td>
<td>Breeding Success</td>
<td>2</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Benguela</td>
<td>Survival</td>
<td>4</td>
<td>2 (50%)</td>
</tr>
<tr>
<td>Benguela</td>
<td>Breeding Success</td>
<td>4</td>
<td>3 (75%)</td>
</tr>
<tr>
<td>Japan</td>
<td>Breeding Success</td>
<td>3</td>
<td>2 (67%)</td>
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<tr>
<td><strong>Total Models</strong></td>
<td></td>
<td><strong>69</strong></td>
<td><strong>22 (32%)</strong></td>
</tr>
</tbody>
</table>
Japan Sea – Japanese Anchovy
Do threshold responses vary by predator?

- Threshold just below mean biomass (corroborates Cury)
- Visually identical threshold between predators
California Current – Sanddab (flatfish) CPUE

Standardized sanddabs abundance vs. breeding success.

- **Standardized COMU**
- **Standardized RHAIU**
- **Standardized CAAU**
- **Standardized PIGU**

- **No threshold**
- **Lower threshold**
California Current – Juvenile (Age-0) Rockfish (Sebastes spp.) CPUE

- Standardized RHAU breeding success
- Standardized CAAU breeding success
- Standardized PIGU breeding success
North Pacific seabird threshold similar to global (Cury et al.), despite variation by prey and predators examined.
Last, what about if we change the predator parameter investigated?

- Survival of adult birds = the probability of an adult surviving from one year to the next year (mark-recapture statistics).

No models were successful for the North Pacific, so we provide an example from the Benguela (South African) ecosystem.
**Benguela Current – Survivorship**

- **Standardized Robben Island survival**
  - Y-axis: -2.0 to 2.0
  - X-axis: Standardized west sardine abundance

- **Standardized Dassen Island survival**
  - Y-axis: -2.0 to 1.5
  - X-axis: Standardized west sardine abundance

- **Standardized AFPE survival**
  - Y-axis: -2.0 to 2.0
  - X-axis: Standardized sardine abundance

Arrows indicating trends or significant points are visible in the plots.
Summary

- variation by predator? Yes, some variation, but overall thresholds similar

- variation by predator parameter? No, but highly uncertain (limited data)

- variation by prey species? Yes, but general pattern supports threshold at roughly mean forage fish biomass
Conclusions

- Seabirds appear adapted to long-term mean biomass of forage fish (is this threshold appropriate for other taxa?).

- Predator-prey threshold relationships may provide insight to ecosystem state shifts. Need to work out time lags to population-level responses.

- Next step: multi-species predator-prey numerical response threshold models.

- Seabirds provide unique data for this approach, possible for other taxa (pinnipeds and some fish)
Diet Composition

Common Murre
Thank you for listening!

Questions?

Thanks to: NPRB 1213, National Fish and Wildlife Foundation, Pew Charitable Trusts, Alaska Maritime National Wildlife Refuge
Forage fish are critical to the transfer of energy from primary producers to top consumers in North Pacific marine ecosystems. Information on seabird food habits and demographic parameters (breeding success and survival) may provide a valuable complement to traditional forage nekton sampling methods as well as reveal important benchmarks for ecosystem regime shifts and fisheries. In this paper, we investigate and compare “tipping points” in seabirds relative to forage fish availability in the California Current, Aleutian Island/Bering Sea, and Japan Sea. To establish tipping points, we modeled non-linear functional responses using extensive datasets on breeding success, survival and diet composition. Cury et al. (2011) showed that 1/3 of maximum biomass (~mean biomass) is a key benchmark below which seabird breeding success consistently declined across ecosystems. Our models indicate that this benchmark varies little by parameter, predator or prey species in the North Pacific, supporting this benchmark for use in management and predator-prey studies relevant to ecosystem state shifts. Multi-species models of predator numerical responses are a next step to more accurately model and predict pelagic ecosystem shifts. Seabirds provide a unique perspective on North Pacific forage fish “tipping points” which are unlikely to be reproduced in studies of other upper trophic level predators due to a dearth of data on individual-based reproductive success, recruitment and survival.