Spatial and Temporal Variability in Fish Populations

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Goals for Talk

1) Case-study Example
   — Long-term monitoring data
   — Large-scale Ecological Change
   — Variance partitioning
   — Is variance structure responsive to perturbation?

2) Implications
   — Monitoring & Management
   — Climate Change
Using Variance Structure to Quantify Responses to Perturbation in Fish Catches

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Perturbation

“any deviation, or displacement, from the ‘nominal state’ in structure or function at any level of organization. The nominal state is the normal operating range, including expected variance.”

– Odum et al. 1979

“[I]t is not true that a species thus attacked comes back. The disturbed balance often gives a new species ascendancy and destroys forever the old relationships.”


(As cited in Roberts. 2007. The Unnatural History of the Sea.)
Fishery-independent Surveys

- Index of relative abundance
- Multiple visits
  - Sites
  - Years
- Variable over space and time
  - Catch
  - Effort

Credit: NOAA GLERL

MI Sea Grant
Case Study: Oneida Lake, NY

- Long-term gillnet surveys
  - 15 sites, >50 years

1958 → early 1990s → 2010
Depiction of variance Components

Spatial

Coherent temporal

Ephemeral temporal

Ecosystem response

(A) (B) (C)

Time

Modified from Irwin et al. 2013
\[ Y_{tj} \sim NB(\mu_{tj}, \kappa_p) \]

\[ \mu_{tj} = e^{\eta_{tj}} \]

\[ \eta_{tj} = \nu_p + \lambda(t) + a_{tp} + b_{jp} \]

\[ \text{Coherent} \quad a_{tp} \sim N(0, \sigma_{a\,p} \, \|^2) \]

\[ \text{Spatial} \quad b_{jp} \sim N(0, \sigma_{b\,p} \, \|^2) \]

\[ \text{var}_{tj} = \mu_{tj} + \mu_{tj}^2 / \kappa_p \]

\[ t = \text{year} \]

\[ j = \text{site} \]

\[ p = \text{period} \]

Vidal et al. 2017
Shift in Variance

Spatial

\[ \sigma_{\text{pre}}^2 = 0.35 \]
\[ \sigma_{\text{post}}^2 = 0.10 \]

Temporal

\[ \sigma_{\text{pre}}^2 = 0.10 \]
\[ \sigma_{\text{post}}^2 = 0.12 \]

Vidal et al. 2017
Summary (1 of 2)

- **Outputs / Results**
  - Capacity building via graduate education
  - Flexible & transferable modeling approach
    - Quantify population responses to large-scale change
    - More than just testing for mean response (e.g., spatial homogenization)

- **Collaborations & Stakeholders**
  - Partnerships: Universities (Cornell, UGA), State (NY DEC, GA DNR), and Federal (NECSC, USGS)
    - Question-driven monitoring, commitment to monitoring
    - Effective working relationships, discussions: questions, data usage & publication
Decision Making
— Spatial and temporal population structure has management & monitoring implications
  • e.g., priority locations (which sites to preserve?)
  • e.g., within year or among year changes?
  • e.g., eliminating sites or skipping years?

Gaps
— Confronting hypotheses with data
  • How do disturbances cause system instability?
  • “Other” species
  • “Exploration” monitoring