Regionalizing seabirds as indicators of forage fish in Alaska

Sarah Ann Thompson, William J. Sydeman, Heather Renner, and John F. Piatt
Seabirds

• Conspicuous, highly mobile
• Monitored at sea and in colonies
Seabirds

• Conspicuous, highly mobile
• Monitored at sea and in colonies
• Indicators
  • population parameters track environmental variability and forage fish abundance
Seabird Parameters

• Reproductive/breeding success
  • = productivity
  • easily measured
  • relates well with prey abundance
Seabird Parameters

• Reproductive/breeding success
  • = productivity
  • easily measured
  • relates well with prey abundance
• Phenology (timing) of breeding
  • sensitive indicator of seasonal timing of local prey abundance
  • mean hatching date
Seabird Success Global Analysis

Cury et al. 2011 Science
Research Question

Can sites or taxa be combined to produce regional indicators in Alaska?
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- 4 piscivorous species
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• 4 piscivorous species
• 2 response variables
  • productivity and phenology
Research Question

Can sites or taxa be combined to produce regional indicators in Alaska?

- 4 piscivorous species
- 2 response variables
  - productivity and phenology
- 14 sites
Research Question

Can sites or taxa be combined to produce regional indicators in Alaska?

- 4 piscivorous species
- 2 response variables
  - productivity and phenology
- 14 sites
- principal component analysis (PCA)
Seabird Study Species

Diving birds: *Uria*

Common Murre
COMU

Thick-billed Murre
TBMU
Seabird Study Species

Surface feeders: *Rissa*

Black-legged Kittiwake
BLKI

Red-legged Kittiwake
RLKI
Seabird Colony Sampling Domain

Bering Sea

Gulf of Alaska

Alaska

Murres = 80 km
Kittiwakes = 50 km
Data Selection

Species-sites for each response
• not all species at each site
Data Selection

Species-sites for each response
- not all species at each site
- not all sites sampled each year
Data Selection

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1. select the most complete species-site time series
Data Selection

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1. select the most complete species-site time series
2. truncate time series
Data Selection

Species-sites for each response
• not all species at each site
• not all sites sampled each year

1. select the most complete species-site time series
2. truncate time series
3. fill in missing values
Selected Seabird Colonies

- Cape Lisburne (productivity only)
- Bluff (phenology only)
- Cape Peirce
- St. Paul
- St. George
- Buldir

Productivity: 1989-2012
Phenology: 1989-2008
Selected Seabird Colonies

Cape Lisburne (productivity only)
Bluff (phenology only)
Cape Peirce
St. Paul
St. George
Buldir

Productivity: 1989-2012
Phenology: 1989-2008
Multiple Imputation

• Produces values for missing data points by estimation
Multiple Imputation

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  • 5% productivity data (10% phenology)
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  • maximum 5 years/species-site, maximum 3 consecutive years
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  • 5% productivity data (10% phenology)
  • maximum 5 years/species-site, maximum 3 consecutive years
• Generated 10 imputations
Multiple Imputation

- Produces values for missing data points by estimation
  - 5% productivity data (10% phenology)
  - maximum 5 years/species-site, maximum 3 consecutive years
- Generated 10 imputations
- Averaged the 10 imputed values, used this average for the missing data point
  = full data matrix
Research Question

Can sites or taxa be combined to produce regional indicators in Alaska?

→ Do they co-vary?
Species-site covariation

Murres

Year

Standardized Breeding Success
-3
-2
-1
0
1
2

COMU St. Paul
COMU St. George
COMU C. Peirce
COMU Buldir
TBMU St. Paul
TBMU St. George
TBMU Buldir
Median

UCSC Natural Reserves
Research Question

Can sites or taxa be combined to produce regional indicators in Alaska?

→ Do they co-vary?
  • Spearman cross-correlation
# Productivity Cross-correlation

<table>
<thead>
<tr>
<th></th>
<th>COMU</th>
<th>TBMU</th>
<th>BLKI</th>
<th>RLKI</th>
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<td></td>
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Significance: $p < 0.1$; 97% correlations +
Research Question

Can sites or taxa be combined to produce regional indicators in Alaska?

→ Do they co-vary?
  
  Yes. Proceed with PCA
Principal Component Analysis

All species Productivity

Principal Component

Year

Principal Component

Component | Eigenvalue | Proportion | Cumulative
--- | --- | --- | ---
PC1 | 4.38 | 0.29 | 0.29
PC2 | 3.16 | 0.21 | 0.50

Variable | PC1 | PC2
--- | --- | ---
COMU St. Paul | 0.007 | 0.441
COMU St. George | 0.061 | 0.431
COMU C. Peirce | 0.216 | 0.328
COMU Buldir | -0.069 | 0.107
TBMU St. Paul | -0.075 | 0.452
TBMU St. George | 0.105 | 0.292
TBMU Buldir | 0.071 | 0.319
BLKI St. Paul | 0.415 | 0.021
BLKI St. George | 0.419 | 0.015
BLKI C. Peirce | 0.294 | 0.115
BLKI Buldir | 0.263 | -0.193
BLKI C. Lisburne | 0.157 | -0.179
RLKI St. Paul | 0.392 | -0.112
RLKI St. George | 0.300 | -0.011
RLKI Buldir | 0.286 | -0.121

Little co-variation across genera
### PCA Kittiwakes

#### Productivity

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<td>0.0</td>
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#### Eigenvalues and Proportions

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<tr>
<td>PC1</td>
<td>4.14</td>
<td>0.52</td>
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<tr>
<td>PC2</td>
<td>1.40</td>
<td>0.18</td>
<td>0.69</td>
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#### Variable Loadings

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<thead>
<tr>
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<tbody>
<tr>
<td>BLKI St. Paul</td>
<td>0.423</td>
<td>-0.231</td>
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<tr>
<td>BLKI St. George</td>
<td>0.423</td>
<td>-0.228</td>
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<tr>
<td>BLKI C. Peirce</td>
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<td>BLKI Buldir</td>
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<td>RLKI St. Paul</td>
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<td>0.322</td>
<td>0.602</td>
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PCA Kittiwakes

Productivity

First Principal Component

Year

Component | Eigenvalue | Proportion | Cumulative
---|---|---|---
PC1 | 4.14 | 0.52 | 0.52
PC2 | 1.40 | 0.18 | 0.69

Variable | PC1 | PC2
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BLKI St. Paul | 0.423 | -0.231
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### PCA Kittiwakes

#### Productivity

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#### First Principal Component

- PC1 All Species
- PC1 Kittiwakes

#### Component Table

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**PCA Murres**

**Productivity**

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<tr>
<td>PC1</td>
<td>2.98</td>
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<td>PC2</td>
<td>1.15</td>
<td>0.16</td>
<td>0.59</td>
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<td>COMU St. Paul</td>
<td>0.461</td>
<td>-0.271</td>
</tr>
<tr>
<td>COMU St. George</td>
<td>0.450</td>
<td>0.395</td>
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<td>COMU C. Peirce</td>
<td>0.341</td>
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<tr>
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<td>0.099</td>
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<tr>
<td>TBMU St. Paul</td>
<td>0.448</td>
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<td>TBMU St. George</td>
<td>0.347</td>
<td>0.636</td>
</tr>
<tr>
<td>TBMU Buldir</td>
<td>0.371</td>
<td>-0.400</td>
</tr>
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</table>

**Year**


**First Principal Component**

-6 -4 -2 0 2 4

**PC2 All Species**

**PC1 Murres**

*UCSC Natural Reserves*
PCA Murres

Productivity

First Principal Component

Year

Component | Eigenvalue | Proportion | Cumulative
---|---|---|---
PC1 | 2.98 | 0.43 | 0.43
PC2 | 1.15 | 0.16 | 0.59

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UCSC Natural Reserves
PCA Murres

Productivity

Year
First Principal Component
-6 -4 -2 0 2 4
PC2 All Species
PC1 Murres

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UCSC Natural Reserves
Seabird Interannual Variability

Loess Sampling Proportion = 0.3

Murres
Kittiwakes
Seabird Interannual Variability

Loess Sampling Proportion = 0.3

First Principal Component

Year

Murres
Kittiwakes
Seabird Interannual Variability

Loess Sampling Proportion = 0.3

Year
First Principal Component
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Murres
Kittiwakes
May be due to differing foraging ecology/prey base
Summary

- Seabird breeding success from multiple sites can be combined using PCA to regionalize
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  • Good representation of Eastern Bering Sea
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  • Across species but not across genera
• Temporal patterns in productivity may be explained by prey availability and environmental variability
• Murres (divers) and kittiwakes (surface) have differing foraging ecology and diet
Summary

- Seabird breeding success from multiple sites can be combined using PCA to regionalize
  - Good representation of Eastern Bering Sea
  - Across species but not across genera
- Temporal patterns in productivity may be explained by prey availability and environmental variability
- Murres (divers) and kittiwakes (surface) have differing foraging ecology and diet
  = indicate differences in forage fish communities by reverse inference
Thank you!

North Pacific Research Board
Alaska Maritime National Wildlife Refuge staff
Mike Litzow
Marcel Losekoot
Spencer Wood
Jarrod Santora