Statistical analyses to support guidelines for marine avian sampling

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USGS Patuxent Wildlife Research Center

Atlantic Marine Bird Conservation Cooperative
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Objectives

Develop a framework for assessing:

1) which lease blocks are hotspots and coldspots
2) survey effort required to have sufficient statistical power to detect hotspots and coldspots
What is a hot/coldspot?

Hot spot = A lease block with an average species specific abundance that is some multiple $> 1$ (e.g., 3x) the mean of the region.

Cold spot = A lease block with an average species specific abundance that is some multiple $< 1$ (e.g., 1/3x) the mean of the region.
Figure 1. Example summarized historical seabird survey data, illustrating the characteristic statistical noisiness of seabird data. Determining which of the apparent “hotspots” (or “coldspots”) are statistically significant is impossible without knowing the number of independent surveys that were conducted at each location. The purpose of this study is to develop guidelines for determining when a grid cell has been adequately sampled so that the relative abundance index (e.g., effort adjusted counts, as shown here) can be reliably compared to other well-sampled grid cells.
Figure 2a. Simulated seabird count maps with each of the candidate distributions (some distributions are shown with several possible parameter values, indicated in the panel title). To create each map, 2500 independent random draws were made from the indicated distribution and arranged on a 50x50 lattice. Note the apparent (false) hotspots and coldspots. All cells were drawn from a distribution with the same population mean value (\(\lambda=10\)) so all observed variation is purely due to statistical noise. Color scales are identical from panel to panel, and are scaled linearly.
Figure 2b. Same as figure 2a, but with each point representing the average of 3 simulated surveys. Both surveys were simulated at random (i.e. first survey does not match figure 2a)
Figure 2c. Same as figure 2a, but with each point representing the average of 10 simulated surveys. Both surveys were simulated at random (i.e. first surveys do not match figures 2a or 2b)
Figure 2d. Same as figure 2a, but with each point representing the average of 100 simulated surveys. Both surveys were simulated at random (i.e. first surveys do not match figures 2a,b,c)
How many surveys?

A. How many surveys needed to detect hotspot/coldspot of species A in grid cell X?

B. Region that contains this grid cell has been sampled before?

C. One of candidate distributions adequately describes data?

D. Data exist from nearby or similar region?

E. Power analysis inputs:
   1. Distribution type
   2. Distribution parameters
   3. Reference prevalence & abundance
   4. Effect sizes

F. Alternative Choices:
   1. Justify use of another distribution
   2. Implement more complex model
   3. Select defaults for this species or functional group or use worst-case, revisit after additional sampling
   4. Use best-fitting of candidates and apply precautionary multiplier; Revisit after additional sampling

G. Non-zero count power models
   - G1 Poisson Power Analysis Module
   - G2 Negative Binomial Power Analysis Module
   - G3 Geometric Power Analysis Module
   - G4 Lognormal Power Analysis Module
   - G5 Discretized Lognormal Power Analysis Module
   - G6 Zeta Power Analysis Module
   - G7 Zeta Exponential Power Analysis Module
   - G8 Yule Power Analysis Module

H. Occurrence probability power model

I. Number of additional surveys needed to achieve adequate power for species A in grid cell X
U.S. Bureau of Ocean and Energy Management (BOEM)

- 5km x 5km lease blocks
- Along the Outer Continental Shelf of the Atlantic Ocean
The Atlantic Seabird Compendium

- >250,000 seabird observations from U.S. Atlantic waters
- Collected from 1978 through 2011
- Data collected using a mix of methods including non-scientific approaches
The Atlantic Seabird Compendium

• >250,000 seabird observations from U.S. Atlantic waters
• Collected from 1978 through 2011
• Data collected using a mix of methods including non-scientific approaches

We used:

• 32 scientific data sets – 28 ship-based, 4 aerial
• Transects were standardized to 4.63km
• 44,176 survey transects representing 463 species
Two part approach

1) Determine the best statistical distribution to model the count data for each species in each season

2) Conduct power analysis and significance testing on the basis of this distribution
Two part approach

1) Determine the best statistical distribution to model the count data for each species in each season

2) Conduct power analysis and significance testing on the basis of this distribution
Model the data

Northern Gannet Spring Count Data

Test eight statistical distributions:

- Poisson
- Negative binomial
- Geometric
- Logarithmic
- Discretized lognormal
- Zeta-exponential
- Yule
- Zeta (power law)
Model the data

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Examples of the distributions

Positive Poisson (simulated)

Positive neg binomial (simulated)

Positive geometric (simulated)

Logarithmic (simulated)

Discretized lognormal (simulated)

Zeta (simulated)

Yule (simulated)
Model selection examples

Model fitting and selection example: maximum likelihood estimates of best-fitting parameters of each candidate distribution to non-zero counts for three example species, with AICc and log-likelihood values. For each species, the models are ranked from lowest to highest AICc.

<table>
<thead>
<tr>
<th>Model</th>
<th>Parameter estimates</th>
<th>AICc Rank</th>
<th>AICc</th>
<th>Log-Likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Herring Gull (Spring)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discretized lognormal</td>
<td>( \mu=0.138 )</td>
<td>1</td>
<td>20473.03</td>
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<tr>
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<td>20699.00</td>
<td>-10348.50</td>
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<td>20884.84</td>
<td>-10441.42</td>
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<tr>
<td>Logarithmic</td>
<td>( p=0.976 )</td>
<td>5</td>
<td>21214.83</td>
<td>-10606.19</td>
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<tr>
<td>Negative binomial</td>
<td>( \mu=0.206 )</td>
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<td>21231.33</td>
<td>-10613.67</td>
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<tr>
<td>Geometric</td>
<td>( p=0.091 )</td>
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<td>25628.78</td>
<td>-12813.39</td>
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<tr>
<td>Poisson</td>
<td>( \lambda=10.961 )</td>
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<td>157322.40</td>
<td>-78660.20</td>
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<tr>
<td><strong>Northern Gannet (Spring)</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Discretized lognormal</td>
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<td><strong>Wilson’s Storm-Petrel (Spring)</strong></td>
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<td>48571.69</td>
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</table>
Full Hurdle Model – Negative Binomial – $r=2$
Monte Carlo test – one tailed – alpha=0.05
Full Hurdle Model – Discretized Lognormal – $\sigma=1.6$
Monte Carlo test – one tailed – alpha=0.05

Reference mean = 2, Prevalence = 0.02

Reference mean = 10, Prevalence = 0.02

Reference mean = 50, Prevalence = 0.02

Reference mean = 2, Prevalence = 0.1

Reference mean = 10, Prevalence = 0.1

Reference mean = 50, Prevalence = 0.1

Reference mean = 2, Prevalence = 0.33

Reference mean = 10, Prevalence = 0.33

Reference mean = 50, Prevalence = 0.33
## Results-Model Fitting

<table>
<thead>
<tr>
<th></th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
<th>Winter</th>
<th>Total</th>
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<tbody>
<tr>
<td>Number species with &gt;500 observations</td>
<td>12</td>
<td>10</td>
<td>15</td>
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<td>48</td>
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<td>Discretized lognormal</td>
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<td>Yule</td>
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<td>Logarithmic</td>
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<tr>
<td>Zeta decay</td>
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<td>10</td>
<td>15</td>
<td>11</td>
<td>48</td>
</tr>
<tr>
<td>Discretized lognormal</td>
<td>7 (4*)</td>
<td>4 (3*)</td>
<td>8 (3*)</td>
<td>8 (2*)</td>
<td>27 (12*)</td>
</tr>
<tr>
<td>Yule</td>
<td>1*</td>
<td>3*</td>
<td>1*</td>
<td>1</td>
<td>1 (5*)</td>
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<tr>
<td>Negative binomial</td>
<td></td>
<td></td>
<td>3*</td>
<td></td>
<td>0 (3*)</td>
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<td>Logarithmic Zeta decay</td>
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</tbody>
</table>

*Not significantly better for α = 0.05*
Discretized Lognormal Distribution

• Criteria:
  • Positive
  • Non-zero values
  • Highly skewed
  • Multiplicative effects
Model fit → Power Analysis

Model selection

- Discretized lognormal
- Yule
- Zeta decay
- Zeta

Power curves

- Hot spot (3 x mean)
- Cold spot (0.33 x mean)

Power Maps & Significance tests
Products

- Interim report (Jan 2012)
- Mid-Term Technical Report (July 2012)
- Presented at 4th International Wildlife Management Conference in South Africa (July 2012)
Average hotspot power

All Species - All Seasons
Full Model (Zero & Non-zero Counts)

Average Power to Detect 3x Hotspots
- 0.000
- 0.001 - 0.100
- 0.101 - 0.250
- 0.251 - 0.500
- 0.501 - 0.650
- 0.651 - 1.000
Average coldspot power
Multi-species summary of power curves

(a) Conditional Model-Hotspot Power
(b) Conditional Model-Coldspot Power
(c) Full Model-Hotspot Power
(d) Full Model-Coldspot Power

- Power to detect a 3x hotspot vs. Number of non-zero surveys
- Power to detect a 1/3x coldspot vs. Number of surveys
Broad summary of results

• Useful technique

• Need to do additional focal work on key species of interest

• Most areas of the Atlantic need additional sampling to have adequate power to detect hotspots/coldspots

• Maps could be used to select well-studied areas where less additional sampling required

• Rare species a challenge
Characterizing Temporal Variability
Sea Surface Temperature

Variograms of de-seasoned SST in WEA areas
Surface Chlorophyll

Variograms of de-seasoned Log10(Chl) in WEA areas
Longer term variability – Interdecadal climate indices
Temporal variability in marine bird count data within BOEM lease blocks – LONG TERM
Temporal variability in marine bird count data within BOEM lease blocks – SHORT TERM
Discussion

• Overview of final report
  • General walk-through
  • Look at and discuss results for species of interest
• Discuss issues
  • Spatial scale
  • Temporal scale/environmental variability
  • Spatial and temporal trends
• Rare species/data poor situations
• Comparison to other approaches
• Detectability and other observer/platform issues
• Next steps/practical applications
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Jeffery Leirness (USFWS)

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Data :
Atlantic Seabird Survey Compendium

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