Citizen science and estimation of species abundances in a habitat-structured space

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ISEC
Montpellier
July 2nd, 2014
1. Context

Aim

- Joint work with Clément Calenge (ONCFS), Christophe Giraud (U. of Orsay) and Romain Julliard (MNHN).
- Estimate relative species abundances in habitat-structured spaces.
- Estimate species and observers preferences for different habitats.
Data

Observations of common birds in Aquitaine (23 species), 2 databases:
- STOC: "standardized" data, 48 sites visited, precise instructions.
- LPO: "non-standardized" data, 440496 observations in 2086 municipalities.

Figure: In black: positions of the non-standardized data, in red: positions of the standardized data.
2. Model

Model: distribution of birds

- Space is divided into large squares indexed by $j \in [1, J]$.
- We consider several species indexed by $i \in [1, I]$: $A_{ij}$ is the abundance of species $i$ in square $j$.

- Space is divided into several habitats, indexed by $h \in [1, H]$.
- $V_{hj}$ is the area (volume) of square $j$ occupied by habitat $h$.
- Probability that an individual of species $i$ in square $j$ is in habitat $h$:

$$\frac{S_{ih}V_{hj}}{\sum_{h'} S_{ih'}V_{h'j}}.$$
Model: distribution of observers

- 2 datasets indexed by $k \in \{1, 2\}$.
- Sites (1st dataset) and municipalities (2nd dataset) are indexed by $c \in \{1, C\}$.
- An observer in the cell $c$ is in habitat $h$ with probability:
  \[ \frac{q_{hk}}{\sum_{h' \in c} q_{h'k}}. \]
- An individual of species $i$ is observable in habitat $h$ with probability:
  \[ \alpha_h P_{ik}. \]
- An individual of species $i$ is reported with probability:
  \[ R_{ik}. \]
Model

We observe:

\[ X_{iv} \sim \text{Bernoulli}(p_{iv}), \]

with

\[ p_{iv} = R_{ik} \left( 1 - (1 - \alpha_{Hv} P_{ik})^{A_{iv}} \right), \]

where

\[ A_{iv} \sim \mathcal{B} \left( A_{ij}, \frac{S_{iHv} V_{Hv c}}{\sum_{h'} S_{ih'} V_{h'c}} \right) \]

and

\[ \mathbb{P}(H_v = h) = \frac{q_{hk}}{\sum_{h' \in c} q_{h'k}}. \]

Finally we observe:

\[ X_{ick} \sim \mathcal{P} \left( A_{ij} E_{kc} P_{ik} \sum_{h \in c} \frac{q_{hk}}{\sum_{h' \in c} q_{h'k}} \frac{\alpha_h S_{ih} V_{hc}}{\sum_{h'} S_{ih'} V_{h'j}} \right). \]
3. Numerical results

**JAGS: test with generated data**

Real value: $A_{62}/A_{61} = 4.8$

Figure: In red: Expected density. In black: estimated density.

$mean = 4.818536$, $sd = 0.07182255$. 

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Species distributions in a habitat-structured space
Impact of habitat structure

Real value: \( \frac{A_{62}}{A_{61}} = 4.8 \).

**Figure:** Estimation of the relative abundance \( \frac{A_{62}}{A_{61}} \). In black: with habitat structure. In blue: without habitat structure.
3. Numerical results

**JAGS: real data**

![Graph showing relative abundance A_{62}/A_{61}.](image)

**Figure:** Estimation of the relative abundance $A_{62}/A_{61}$. In black: with habitat structure. In blue: without habitat structure.

"Real" value: $A_{62}/A_{61} = 2.783838$. 
Outlook

- Quantify the advantages of spatial structure integration.
- Consider more types of habitats.
- Distinguish two types of non-standardized data: form data and opportunistic data.