working owls methods

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# Methods

load("../data/output\_data/richness\_species\_accounts\_byRt.Rdata")  
library(pander)  
pander(species.accounts.byRt)

Table continues below

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Mottd | PacSc | FerPy | Specd | Barn | Unk | Styg | Whisk | GrHor | Fulvous |
| 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |

|  |  |  |
| --- | --- | --- |
| Year | Route | Region |
| 2003-2013 | EI1 | El Imposible |
| 2003-2013 | EI2 | El Imposible |
| 2003-2013 | N1 | Nancuchiname |
| 2003-2013 | N2 | Nancuchiname |
| 2009-2012 | M2 | Montecristo |
| 2004-2012 | M1 | Montecristo |

## Occupancy Model Framework

Let

We assumed that survey occupancy () was the outcome of Bernoulli trials with probability , which we allowed to vary by year and route:

with hyperpriors for and such that the expected value of :

We assumed that detecting an owl depended on an owl being present during that survey () and the probability of detection, which was related to the species of owl played for broadcast ():

where, generally, , or more specifically:

This model provides a consistent probability of detection for all surveys in the first two minutes of each survey before the broadcast owl recording was played (). Then, the probability of detection for each post-broadcast time period would depend on the species of broadcast owl. This allowed species-specific behavior in response to the different broadcast owl species (Baumgardt et al. 2019). We used means parameterization such that the coefficients were interpretable as the effect of that specific broadcast species (including the pre-broadcast time frame). The priors for every logistic model coefficient were chosen to be near uniform as recommended in Gelman et al. (2008). Specifically, we used the Cauchy prior as such: .

The broadcast species were consistent at each station across years, but varied by route. For stations at El Imposible and Nancachaname, the following broadcast species were used, respectively: Pacific, Mottled, Crested, Black and White, Spectacled, Mottled, Crested, Black and White, and Spectacled. At Montecristo, the following species were called at stations , respectively: Whiskered, Mottled, Gaut Barred, Stygian, Great Horned, Whiskered, Mottled, Gaut Barred, Stygian, and Great Horned. Thus, the effective sample sizes of the different broadcast species varied.

### Occupany Model Implementation

We used the R2jags package in R (R Development Core Team 2014,Plummer (2013)) to implement the occupancy model for three owl species: Mottled, Spectacled, and FerPy owls. These owls had enough positive detections to analyze occupancy, as Mottled, Spectacled, and FerPy owls had 542, 137, and 187 positive detections over the 11 year period, respectively. Based on our understanding of owl ecology, we assumed that Spectacled and FerPy owls would not occupy route M1 in Montecristo, so we removed that route from those occupancy models.

For all three species' occupancy models, we ran 3 chains for 10,000 iterations and 1000 iterations discarded as burn-in, for a total of 27,000 iterations comprising the posterior distributions for each model parameter. Initial values for were equivalent to one if an owl was detected in that survey and otherwise zero. We visually inspected traceplots to verify that chains mixed well (Supplemental information S1-3xx).

## Richness Model Framework

To model species richness at each route in each year, we assumed that there were 14 possible species present in El Salvador. This included the 10 species observed during our surveys (including unknown owl species) and an additional 4 unidentified species. This limit to species richness relates directly to the 13 species known to inhabit El Salvador (cite Owls of El Salvador here) plus one species we identified (Stygian owl), which was previously undocumented in El Salvador. We augmented our owl detection data with 4 additional potential species with all-zero detection (Royle 2007). For each species (where ), is a binary indicator of that owl species being present in each route and year:

where is the probability of species presence in each route . Now, the presence of an owl species in any route, year, and survey, , is conditional on the probability of occupancy for that route, year, and species *and* that species belong to that route's community ():

Richness is conditional on each species presence and was estimated as the sum of owl species present in each route and year:

To share information about occupancy amongst species, we incorporated random effects into the parameterization of :

This parameterization allowed us to borrow strength across species in determining the mean probability of occupancy () for each route and year (Guillera-Arroita et al. 2019).

Consistent with our approach for the occupancy models, we assumed that detecting an owl depended on an owl of that species being present during that survey () and the probability of detection , which was related to the broadcast species:

where generally for each broadcast species as described above. The coefficients of the detection model were thus assumed to be consistent for all owl species, which allowed us to borrow information about the detection process for undetected owls from those that were detected.

### Richness Model Implementation

We used the R2jags package in R (R Development Core Team 2014,Plummer (2013)) to implement the richness model. We ran 3 chains for 20,000 iterations and 2000 iterations discarded as burn-in and a thinning rate of 2, for a total of 27,000 iterations comprising the posterior distributions for each model parameter. Initial values for were equivalent to one if that species of owl was detected in that survey and otherwise zero. Similarly, initial values for were equivalent to one if that species of owl was detected in that route and year. We visually inspected traceplots to verify that chains mixed well (Supplemental information S4xx).

# Results

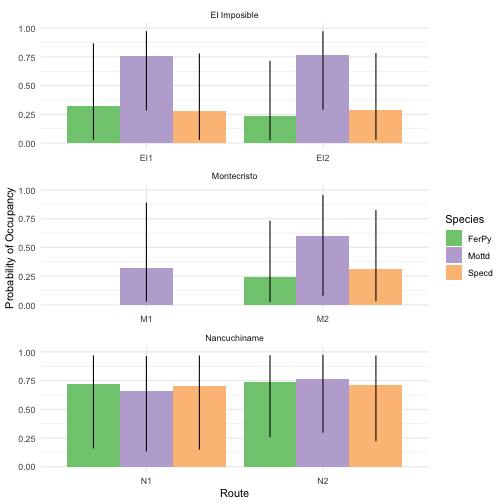
## Occupany Model Results

Averaged across years, we found that the probability of occupancy was somewhat higher for Mottled owls than for FerPy or Spectacled owls in both routes of El Imposible and in M2 route of Montecristo (Fig. 1X). The probability of occupancy across all three species and both routes of Nancuchiname were relatively high (Fig. 1XX). We found that the probability of occupancy for Mottled owls was relatively consistent across time in El Imposible and in N2 route (Fig. 2XX), but that it seemed to increase in the last 6 or so years of the surveys in M2 and N1 routes (Fig. 2XX). The probability of occupancy in M1 seemed to have decreased through time for Mottled owls (Fig. 2XX).

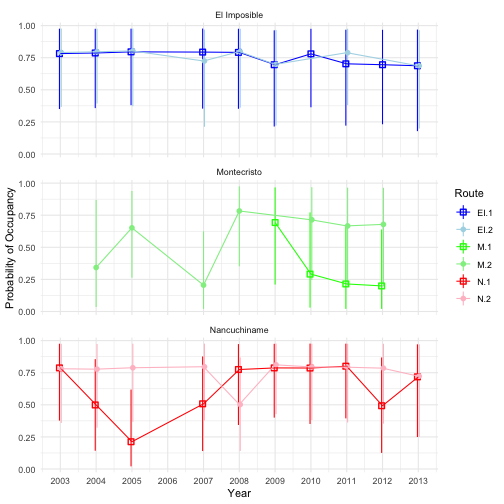
The probability of occupancy for FerPy and Spectacled stayed relatively consistently low across time in routes EI1, EI2, and M2 other than a higher probability of occupancy for FerPy in EI1 in the early years of the surveys (Figs. 3XX and 4XX). FerPy probability of occupancy was relatively high in both routes of Nancuchaname except in 2008 and 2009 (Fig. 3XX), and the probability of occupany for the Spectacled owl slightly fluctuated year to year in the Nancuchaname routes (Fig. 4XX).

The probability of detecting these three owls varied little during the timeframe before broadcast recordings were played (Pre-broadcast); however, the probability of detecting owls after broadcast species were called varied by broadcast species and between Mottled, FerPy, and Spectacled owls (Fig. 5XX). The probability of detecting Mottled Owls increased after broadcasting Mottled, Pacific, Crested, Black and White, or Spectacled owls. The probability of detecting FerPy owls increased after broadcasting Mottled and Pacific owl calls, and the probability of detecting Spectacled owls increased after broadcasting Pacific, Black and White, and Spectacled owls (Fig. 5XX).

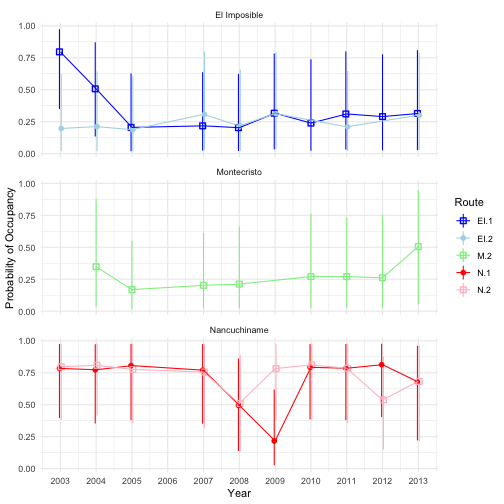
# Figures



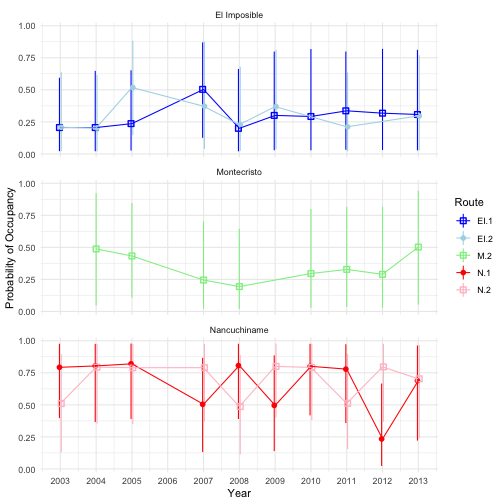
1XX. Probability of occupancy () averaged by route for Mottled, FerPy, and Spectacled Owls. Owl surveys were conducted from 2003 to 2013 in three different protected areas within El Salvador. Posteriors were summarized with median 90% credible intervals.



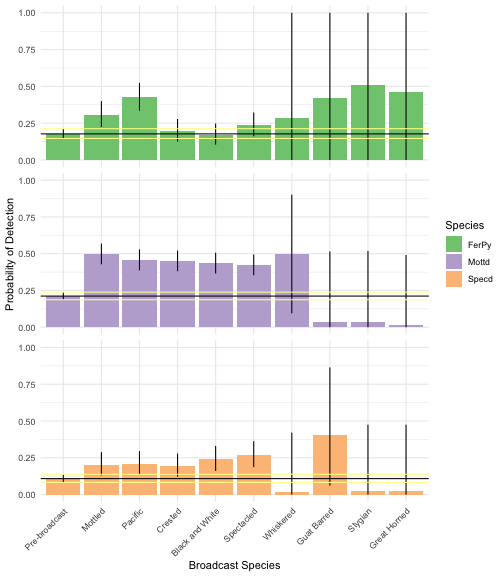
2XX. Probability of occupancy () by route and year for Mottled Owl. Owl surveys were conducted from 2003 to 2013 in three different protected areas within El Salvador. Posteriors were summarized with median 90% credible intervals.



3XX. Probability of occupancy () by route and year for FerPy Owl. Owl surveys were conducted from 2003 to 2013 in three different protected areas within El Salvador. Posteriors were summarized with median 90% credible intervals.



4XX. Probability of occupancy () by route and year for Spectacled Owl. Owl surveys were conducted from 2003 to 2013 in three different protected areas within El Salvador. Posteriors were summarized with median 90% credible intervals.



5XX. The logistic regression parameters that related the probability of detecting owls ($\p\_{t,h,i,j,k}$) to the broadcast timeframe (pre-broadcast) or speccies. Owl surveys were conducted from 2003 to 2013 in three different protected areas within El Salvador. Posteriors were summarized with median 90% credible intervals.

# References

Baumgardt, J. A., M. L. Morrison, L. A. Brennan, and T. A. Campbell. 2019. Effects of broadcasting calls on detection probability in occupancy analyses of multiple raptor species. Western North American Naturalist 79:185–194.

Gelman, A., A. Jakulin, M. G. Pittau, and Y.-S. Su. 2008. A weakly informative default prior distribution for logistic and other regression models. The Annals of Applied Statistics 2:1360–1383.

Guillera-Arroita, G., M. Kéry, and J. J. Lohoz-Monfort. 2019. Inferring species richness using multispecies occupancy modeling: Estimation performance and interpretation. Ecology and Evolution 9:780–792.

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