University of St Andrews

Is that bird extinct?

And other difficult statistical questions

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NCSE 2025 | 18 December 2025, St Andrews

Himalayan Quail (***Ophrysia superciliosa***)
Critically Endangered | Last Seen: 1876
Artwork: J. Gould

Introduction: lost and extinct species

- Knowing **which species are extinct** is a key question in conservation biology
- Extinction is rarely observed
- How do we know if a species is simply **lost** or truly **extinct?**



Streaked Reed Warbler (Acrocephalus sorghophilus)
Not documented since 2008, possible sightings still ongoing

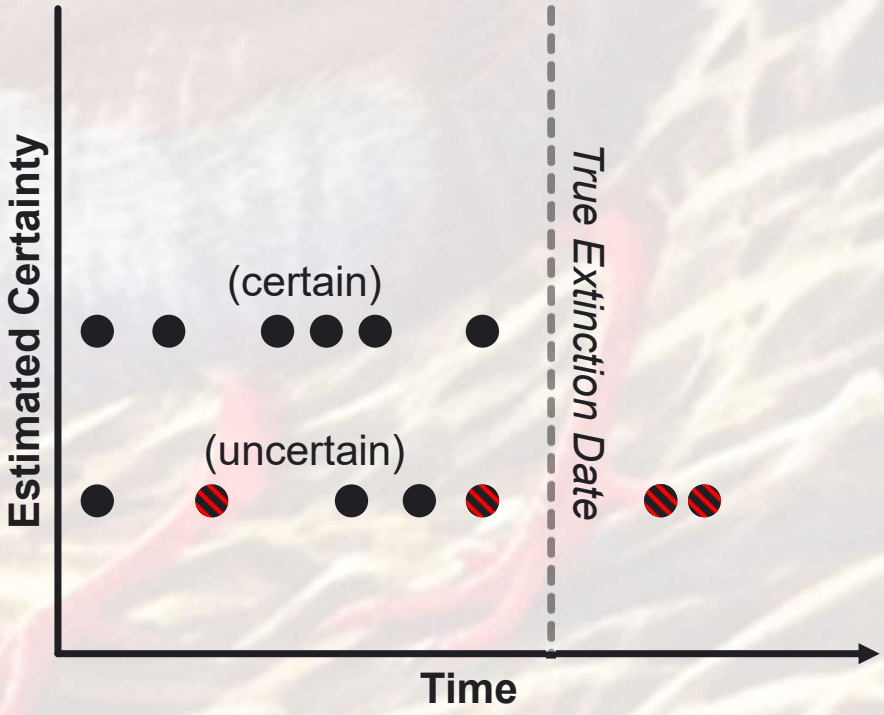
Introduction: extinction models

- We can answer extinction questions via statistical models:
  1. Threats-based
  2. **Sightings-based**
- Use the **temporal pattern of species sightings** to make inferences about the **likelihood of extinction**
  - First models developed by palaeontologists, later by ecologists

Ivory-billed Woodpecker (*Campephilus principalis*)
Critically Endangered | Last Seen: 1956
Artwork: J. J. Audubon

Introduction: data structure

- **Presence only** sighting times
  - Most models have no explicit non-detections
- Sightings may be **certain** …
  - … or **uncertain**
  - Possible false positives!
- "Certainty" can be continuous



Zapata Rail (*Mustelirallus cerverai*)
Critically Endangered | Last Seen: 1934
Artwork: A. Brooks

Worked Example: Solow 1993a

Caribbean Monk Seal (not a bird)

- Certain sightings: **1915, 1922, 1932, 1948, 1952**
  - Omit first record (use as t_0)
- Number of records $\rightarrow \boldsymbol{n = 4}$
- Time of the last record $\rightarrow \boldsymbol{t_n = 37}$
- Test time (1992 in paper) $\rightarrow \boldsymbol{T = 77}$

Calculate **p-value, point estimate,** and **95% CI**

Worked Example: Solow 1993a

- P-value
  - $p = \left(\frac{t_n}{T}\right)^n = \left(\frac{37}{77}\right)^4 = \mathbf{0.053}$
- Point Estimate
  - $\widehat{T_E} = \frac{n+1}{n} t_n = \frac{4+1}{4} \cdot 37 = 46.25 \rightarrow \mathbf{1961.25}$
- Confidence Interval
  - $T_E^{upper} = \frac{t_n}{\alpha^{1/n}} = \frac{37}{0.05^{0.25}} = 78 \rightarrow \mathbf{1993}$
- **Extinct by 1962 (95% CI: [1952; 1993])**

Number of records $\rightarrow \boldsymbol{n = 4}$
Time of the last record $\rightarrow \boldsymbol{t_n = 37}$
Test time $\rightarrow \boldsymbol{T = 77}$

Model Review: overview

- **How many** models are out there, and **how do they differ?**
- Review models which satisfy the following criteria:
  1. Model must explore **present-day** extinction dynamics via inference about ***whether*** extinction has occurred or ***when*** extinction occurred
  2. Model must use **sighting records** (information about when the species was observed – this can come in many forms)
  3. Model must explore extinction dynamics for **single species**
  4. Model **must not require additional data** beyond (1) sighting uncertainty or (2) sampling effort

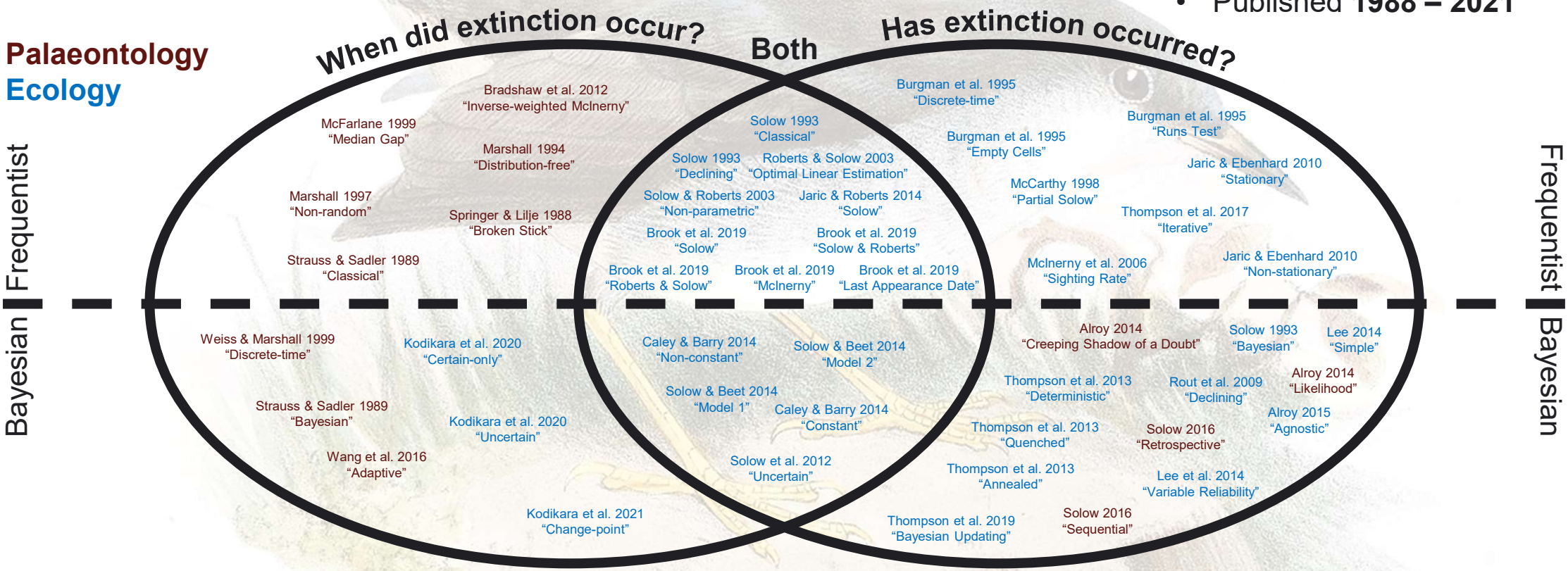
Robust White-eye (*Zosterops strenuus*)
Extinct | Last Seen: 1908
Artwork: H. Richter

Model Review: the models

Quick Facts:

- **48** models in **32** papers
  - **23** Frequentist
  - **24** Bayesian
  - **1** Neither? (Iterative)
- Published **1988 – 2021**

Palaeontology
Ecology

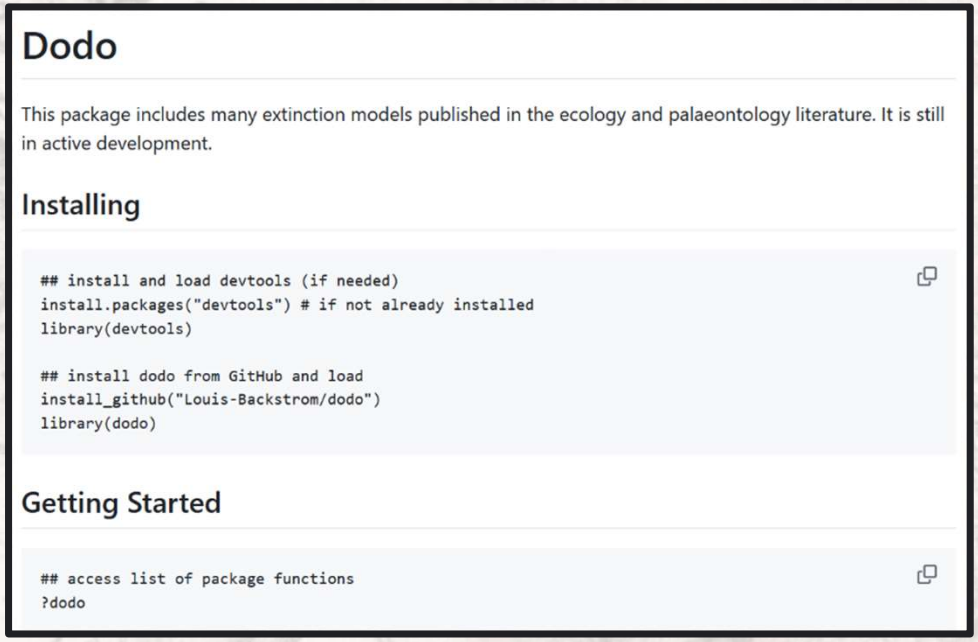


Model Review: R package

- R package called **dodo**
  - **Just finished!**
  - 47* models implemented
- Making an R package is **hard**

Is that bird extinct?

Let's find out!



Dodo

This package includes many extinction models published in the ecology and palaeontology literature. It is still in active development.

Installing

```
## install and load devtools (if needed)
install.packages("devtools") # if not already installed
library(devtools)

## install dodo from GitHub and load
install_github("Louis-Backstrom/dodo")
library(dodo)
```

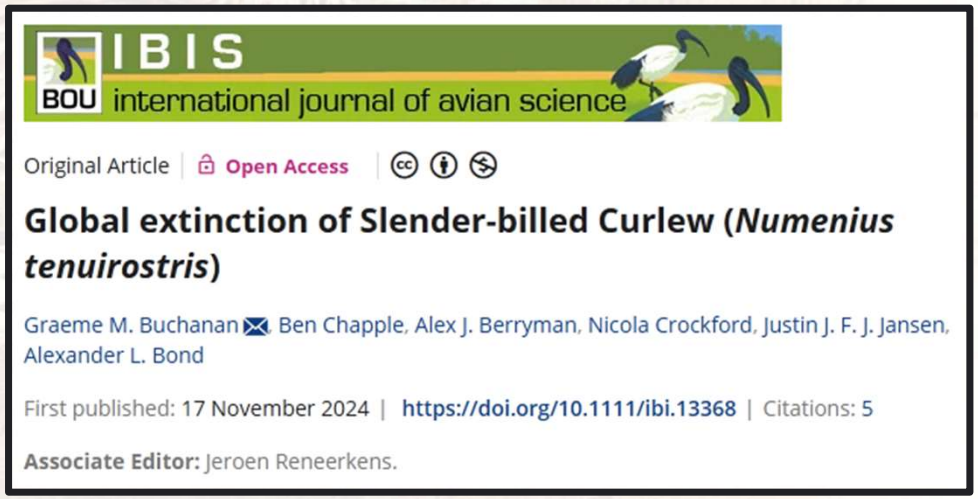
Getting Started

```
## access list of package functions
?dodo
```

```
remotes::install_github("Louis-Backstrom/dodo")
```

Case Study: Slender-billed Curlew

- **Recently declared extinct**
  - We “know the truth”
  - Extinction shortly after the last photograph in 1995
- Detailed dataset provided
  - More than 1000 records
  - Survey effort and sighting uncertainty data also included



IBIS BOU international journal of avian science

Original Article | Open Access

Global extinction of Slender-billed Curlew (*Numenius tenuirostris*)

Graeme M. Buchanan, Ben Chapple, Alex J. Berryman, Nicola Crockford, Justin J. F. J. Jansen, Alexander L. Bond

First published: 17 November 2024 | https://doi.org/10.1111/ibi.13368 | Citations: 5

Associate Editor: Jeroen Reneerkens.

Case Study: Slender-billed Curlew

- **45/47** models fit
- **42/45 agree the curlew is extinct** (as of 2022)
- Median estimated extinction time (21 models): **1998**



Preliminary results only!

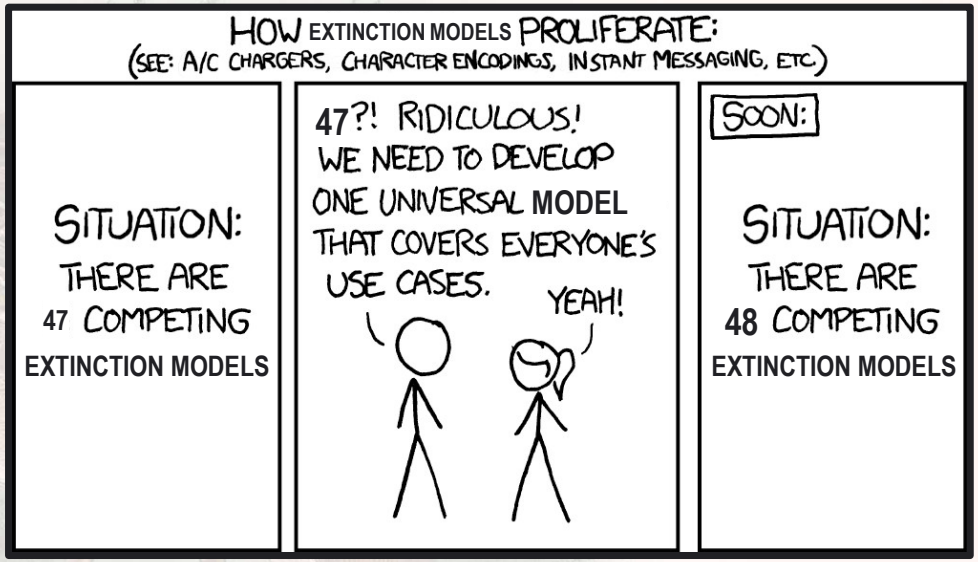
Conclusions: challenges

- **Conceptual**
  - Different **approaches** (Bayesian vs Frequentist, assumptions about data, etc.)
  - Different kinds of **data** (certain vs uncertain sightings, discrete vs continuous time, etc.)
  - Different **outputs** (CIs vs Point Estimates vs “p-values” vs “probabilities” vs …)
- **Practical**
  - Many models **break** when applying them to novel datasets
  - What constitutes an **independent** sighting?
  - Current implementation of some models is rather **slow**

Great Auk (*Pinguinus impennis*)
Extinct | Last Seen: 1852
Artwork: J. J. Audubon

Conclusions: where to from here?

1. Statistical **review** of models
   - Real and simulated data
2. Development of **new** model
   - Use best bits of each model
   - Incorporate spatial information?
   - Citizen science?
   - Make non-detections explicit?
3. **Apply** models to real species!



With apologies to Randall Munroe…

Is that bird extinct?

- **Probably? Maybe.**
  - **It's complicated!**
  - More to come… **please chat!**
- Thanks to:
  - Ali Johnston & Hannah Worthington (CREEM)
  - Alex Berryman (Birdlife)
  - Ben Sheldon (Oxford)
  - Many authors of published models (code, advice, etc.)

See my package dodo on GitHub

```
remotes::install_github(
  "Louis-Backstrom/dodo")
```

Download these slides

Email: ljb38@st-andrews.ac.uk

Kinglet Calyptura (***Calyptura cristata***)
Critically Endangered | Last Seen: 1860
Artwork: W. Swainson



Himalayan Quail
Ophrysia superciliosa
Critically Endangered
Last Seen: 1876
Artwork: J. Gould



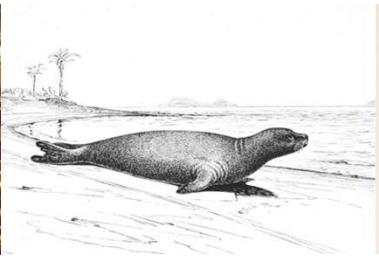
Bachman's Warbler
Vermivora bachmanii
Critically Endangered (PE)
Last Seen: 1959
Artwork: L. A. Fuertes



Ivory-billed Woodpecker
Campephilus principalis
Critically Endangered
Last Seen: 1956
Artwork: J. J. Audubon



Zapata Rail
Mustelirallus cerverai
Critically Endangered
Last Seen: 1934
Artwork: A. Brooks



Caribbean Monk Seal
Neomonachus tropicalis
Extinct
Last Seen: 1952
Artwork: G. B. Goode



Robust White-eye
Zosterops strenuus
Extinct
Last Seen: 1908
Artwork: H. Richter



Semper's Warbler
Leucopeza semperi
Critically Endangered
Last Seen: 1934
Artwork: J. Smit



Dodo
Raphus cucullatus
Extinct
Last Seen: 1662
Artwork: J. & R. Savery



Slender-billed Curlew
Numenius tenuirostris
Extinct
Last Seen: 1995
Artwork: H. Grønvold



Great Auk
Pinguinus impennis
Extinct
Last Seen: 1852
Artwork: J. J. Audubon



Buff-breasted Buttonquail
Turnix olivii
Critically Endangered
Last Seen: 1924
Artwork: J. Keulemans



Kinglet Calyptura
Calyptura cristata
Critically Endangered
Last Seen: 1860
Artwork: W. Swainson

Additional Slender-billed Curlew Results

- **Point Estimate**: 21 models
  - Range: [1995.4, 2011.0]
  - Mean: 2001.6 / Median: 1997.7
- **Upper Conf. Int.**: 18 models
  - Range: [1995.0, 2204.0]
  - Mean: 2017.5 / Median: 2010.8
  - 16 < 2022 (RS03F1, SR03F1)
- **Upper Cred. Int.**: 9 models
  - Range: [1996.5, 2009.0]
  - Mean: 2001.7 / Median: 2000.0
- **P-Value**: 13 models
  - Range: [0.00, 0.29]
  - 11 < 0.05 (RS03F1, SR03F1)
- **P(Extant)**: 23 models
  - Range: [0.00, 1.00]
  - Mean: 0.04 / Median: 0.0
  - 22 < 0.05 (TH19B1)
- **Bayes Factor**: 5 models
  - 4 > 1 (TH19B1)