Trouble in Paradise: Paleoecology and extinction of island birds

Alison G. Boyer
Dept. Ecology and Evolutionary Biology
University of Tennessee
&
Climate Change Science Institute
Oak Ridge National Laboratory
Acknowledgements

Helen James (Smithsonian USNM)
Walter Jetz (Yale U.)
David Steadman (U. Florida)
Christophe Sand (IANCP, New Caledonia)
Jack Grant-Mackie (Auckland U, NZ)
Trevor Worthy (U New South Wales, Aus)
Richard Duncan (Lincoln U, NZ)
Endangered Pacific island birds
Barnosky et al. 2004, Science
Human colonization of Oceania

Based on Kirch 2002, On the Road of the Winds
Bird extinctions in Oceania
Bird extinctions in Oceania
Holocene paleorecord of Pacific islands

Fossil vertebrate localities:
archaeological sites

Makauwahi Cave, Kauai
Holocene paleorecord of Pacific islands

Fossil vertebrate localities:
- archaeological sites
- natural traps

Puu Makua Cave, Maui
Holocene paleorecord of Pacific islands

Fossil vertebrate localities:

- archaeological sites
- natural traps
- bone accumulations by predators

Me Aure Cave, New Caledonia
Extinction Mechanisms

- overexploitation of populations

- introduction of exotic predators and diseases

- habitat destruction
Extinction Mechanisms

- overexploitation of populations

- introduction of exotic predators and diseases

- habitat destruction

These processes remain primary drivers of modern extinctions
Island bird extinctions

• How many species were lost?
• Which species went extinct?
• How did they change ecological communities?
• How can they be prevented?
How many species were lost?

Islands differ in:

- collection effort
- number of sites
- taphonomy of sites
- traits and characteristics of species

Low collection rate means many extinct species may remain to be discovered.
Classic Mark–recapture estimates
Classic Mark–recapture estimates
Classic Mark–recapture estimates

\[ N = \frac{M \times T}{R} = \frac{3 \times 3}{1} = 9 \]
Mark–recapture for fossils

**Marked**
- Living species
- Historically observed

**Recaptured**
- Living species
- Historically observed
- Known only from fossils
Number of extinctions

Bayesian hierarchical mark–recapture model

Duncan, Boyer & Blackburn, 2013, PNAS
Number of extinctions

Bayesian hierarchical mark–recapture model

Duncan, Boyer & Blackburn, 2013, PNAS
Number of undiscovered species

Duncan, Boyer & Blackburn, 2013, PNAS
Island bird extinctions

• How many species were lost?
• Which species went extinct?
• How did they change ecological communities?
• How can they be prevented?
New Caledonia
Mé Auré Cave site

Me Aure Cave, New Caledonia
Mé Auré Cave record

- **Cal BP**
  - 2400: Human arrival
  - 1200: Arrival of Barn Owl
  - 200: European contact

- Depth (cm)
  - 5
  - 15
  - 45
  - 70
  - 80
Mé Auré Cave Birds

Turnix
3 Rails
2 Columbids
Parakeet & Lorikeet
2 Cuckoos
Barn Owl
2 Swiftlets
Sacred kingfisher
4 Honeyeaters *
** Fantail
2 Pachycephalids *
Shrikebill
New Cal. crow *
Long-tailed triller
Wood-swallow
Cuckoo-shrike
Island thrush
Glossy starling *
Pacific swallow
2 White-eyes *
Megalurus *
Parrot-finch *
Waxbill (i)

34

Artwork by Eric Barbour

Boyer et al. 2010, Biodivers Conserv
Mé Auré Cave Birds

Survey

- 1 Columbid
- Sacred kingfisher
- 2 Cuckoos
- 2 Swiftlets
- 1 Rail
- Lori collegiate
- Glossy starling *
- Wood-swallower
- Cuckoo-shrike
- New Cal. crow *
- Fantail
- Long-tailed triller
- Parrot-finch *
- 2 Honeyeaters *
- 2 Pachycephalids *
- 2 White-eyes *
- Waxbill (i)

Fossils

- Turnix
- 1 Columbid
- 2 Rails
- Parakeet
- Shrikebill
- Pacific swallow
- 2 Honeyeaters **
- Megalurus *
- Island thrush
- Barn Owl

8

13

22

Artwork by Eric Barbour

Boyer et al. 2010, Biodivers Conserv
New Caledonia's dry forest

“The most threatened tropical dry forest in the world.”
- Conservation International

Bouchet et al 1995
Boa Cave site

Fig. 1. — Limestone substrate in New Caledonia (adapted from Paris 1981).
Boa Cave excavations 2011
Boa Cave excavations 2011
A giant extinct bird

Sylviornis
Known extinctions in New Caledonia

- Sylviornis
- Megapodius
- Porphyrio
- Aegotheles
- Caloenas
- Tricholimnas
- Rhynochetos
- Meiolania
- Mekosuchus
Which species went extinct?

Me Aure Cave:
interior forest spp. declined and second-growth generalists increased

Boa Cave:
the largest vertebrate species disappeared

Forest remains intact only on steep ridges
The Hawaiian islands

Generalists

Nectarivores

Foragers among leaves

Seed and fruit eaters

Bark pickers

H. D. Pratt
The Hawaiian islands

Hawaiian bird

Hawaiian skull

Hawaiian map
The Hawaiian islands
Why are some species more likely to be threatened with extinction than others?

External threats

- hunting, predators, disease, habitat loss

Intrinsic susceptibility

- body size, endemism, flightlessness, trophic guild

Environmental correlates

- island area, isolation, climate

James & Olson 2003, Auk
Holocene paleorecord of Pacific islands

[Map showing distributions of islands such as Marianas, Solomon Is, Vanuatu, Fiji, New Caledonia, Tonga, Society Is, Marquesas, Cook Is, Hawaii, and Henderson, with symbols indicating quality of paleorecord: Poor, Fair, Good, Excellent]
Extinctions 3500 ybp – present

Random forest model

Relative Importance of Predictors

Boyer 2010, Conservation Biology
Extinctions 3500 ybp – present

Random forest model

- n = 1264
- Accuracy: 87%
- False-negatives: 5.1%
- False-positives: 31%

Boyer 2010, Conservation Biology

Relative Importance of Predictors

- Geographic range: 0.9
- Body mass: 0.9
- Diet: 0.8
- Isolation: 0.6
- Area: 0.5
- Human impact: 0.4
Extinction risk predictions

Relative Importance of Predictors:
- Geographic range: 0.9
- Body mass: 0.9
- Diet: 0.8
- Isolation: 0.6
- Area: 0.5
- Human impact: 0.4

Boyter 2010, Conservation Biology

Predicted Probability of Extinction

Red List Category:
- LC
- NT
- VU
- EN
- CR

Examples:
- Hawaiian thrush
- Henderson island rail
- Cloven-feathered dove
Which species went extinct?

Large species
Those found on only a few islands
Diet of vegetation and seeds

Island characteristics and deforestation were less important

Giant Moa (Dinornis robustus), by Paul Martinson
Island bird extinctions

- How many species were lost?
- Which species went extinct?
- How did extinctions change ecological communities?
- How can they be prevented?
Ecosystem services provided by birds

Functional Diversity
### Functional diversity of the bird community

<table>
<thead>
<tr>
<th>Trait</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass</td>
<td></td>
</tr>
<tr>
<td>Activity period</td>
<td></td>
</tr>
<tr>
<td>Diet</td>
<td>Vertebrate prey</td>
</tr>
<tr>
<td></td>
<td>Carrion</td>
</tr>
<tr>
<td></td>
<td>Invertebrates</td>
</tr>
<tr>
<td></td>
<td>Fleshy fruits</td>
</tr>
<tr>
<td></td>
<td>Nectar</td>
</tr>
<tr>
<td></td>
<td>Seeds</td>
</tr>
<tr>
<td></td>
<td>Plant material</td>
</tr>
<tr>
<td>Foraging niche</td>
<td>Water</td>
</tr>
<tr>
<td></td>
<td>Ground-level</td>
</tr>
<tr>
<td></td>
<td>Understory</td>
</tr>
<tr>
<td></td>
<td>Mid-canopy</td>
</tr>
<tr>
<td></td>
<td>Upper canopy</td>
</tr>
<tr>
<td></td>
<td>Aerial</td>
</tr>
</tbody>
</table>

![Functional diversity diagram](image)

- **Herbivores**
- **Frugivores**
- **Insectivores**
- **Predators**
Declining Functional Diversity with Extinctions

Guam:
Loss of birds led to dramatic increase in spiders (Rogers et al. 2012)

Boyer & Jetz, 2014, Global Ecology and Biogeography
Declining Functional Diversity with Extinctions

New Zealand: Loss of bird pollinators led to reduced fitness of trees (Anderson et al. 2011)

Boyer & Jetz, 2014, Global Ecology and Biogeography
Declining Functional Diversity with Extinctions

Fiji:
Loss of frugivorous birds led to decline in native trees (Meehan et al. 2002)

Boyer & Jetz, 2014, Global Ecology and Biogeography
Island bird extinctions

• How many species were lost?
• Which species went extinct?
• How did they change ecological communities?
• How can extinctions be prevented?
Modern biodiversity in crisis

Threatened with extinction

- 12% of birds
- 25% of mammals
- > 30% of amphibians

- Nearly half of all threatened bird species are found on oceanic islands
Eradicate invasive predators
Eradicate invasive predators
Rimatara Lorikeet reintroduced to Atiu, Cook Islands more than 200 years after
Lepredour island, New Caledonia:
- eradication of deer, goats, cats
- dry forest restoration
- reintroduction of native birds
Oceanic islands as global microcosms

• Islands are self-contained, replicated units with a long record of coupled human-environmental history

• We study past extinctions to understand:
  - baseline conditions
  - causes of biodiversity loss
  - predictability of extinctions
  - consequences of extinctions for societies & ecosystems