Bayesian data-model synthesis for biological conservation and management in Antarctica

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Remote sensing provides perhaps the only method to study the largest and most remote penguin colonies.

Photo: Tom Hart
Remote sensing of penguins by satellites: A paradigm shift

**Why Antarctica?** Antarctica remains one of the planet’s most challenging environments for biological survey. Recent developments in remote sensing have radically expanded the opportunities for regular, high-quality biological surveys at the continental scale. As a result, Antarctica has become a model system for the use of remote sensing for biological conservation.

*Drawings from del Hoyo et al. 1992*
Why now? With the support of the Southern Ocean Observing System, we have the opportunity to help develop a regional biodiversity observing network (BON) in the Antarctic. Additionally, there is currently an effort to assess how we can meet the 2020 Aichi biodiversity targets for Antarctica. **Our decision-support tool is a critical component to these important international efforts.**
Remote sensing of penguins by satellites: A paradigm shift

**Big questions**
1. Can we detect penguins?
2. Can we differentiate different species of penguins?
3. Can we estimate abundance?
4. Can we assess changes in abundance?
5. Can we start doing global/regional censuses?
6. Can we learn something new about penguin biology?
7. **Can we improve the decision-making process for conserving Antarctic marine living resources?**

*Drawings from del Hoyo et al. 1992*
The mission: To create a publicly-accessible, easy-to-use, browser-based application that provides Antarctic biodiversity data at any user-defined spatial and temporal scale.

Chinstrap penguin colony in Quickbird imagery

**NASA**
- Landsat-4
  - 30m multispectral
- Landsat-5
  - 30m multispectral
- Landsat-7
  - 15m panchromatic
  - 30m multispectral
- Landsat-8
  - 15m panchromatic
  - 30m multispectral

**Commercial**
- Quickbird
  - 2.4m multispectral
  - 0.6m panchromatic
- Worldview-1
  - 0.5m panchromatic
- Worldview-2
  - 1.6m multispectral
  - 0.4m panchromatic
- Geoeye
  - 1.6m multispectral
  - 0.4m panchromatic
- IKONOS
  - 4m multispectral
  - 1m panchromatic
- Worldview-3
  - 1.24m multispectral
  - 0.31m panchromatic

Merger of commercial and NASA satellite imagery products

“Data-to-knowledge pipeline”
Danger Islands

Map 1: Important Bird Areas in Antarctica - Qualifying sites - Overview

- Confirmed IBA location
- Permanent IBA location
- Ice shelf
- Sea

BirdLife International

Harris et al. 2015
A large number of Adélie Penguins breed in the Danger Islands group, with between 285,115 and 305,165 Adélie Penguin nests estimated in 1996 (Naveen & Lynch 2011). Breeding occurs on slopes and ridges across most of the islands in the group (Elliott et al. 1978; Naveen & Lynch 2011; Lynch & LaRue 2014; Lynch & Schwaller 2014). Brash and Earle islands possess breeding colonies of Pygoscelid penguins of sufficient size and distance from each other and the other islands to warrant qualification as IBAs in their own right, and these are described in IBAs ANTO63 and ANTO64. Numbers of breeding pairs of Pygoscelid penguins on the remaining islands were estimated by Lynch & LaRue (2014) and Lynch & Schwaller (2014) (Table 062.1).

Table 062.1: Estimates of the number of breeding pairs of Pygoscelid penguins on northeastern Danger Islands

<table>
<thead>
<tr>
<th>Island</th>
<th>Species</th>
<th>Breeding Pairs</th>
<th>95% CI</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heroina</td>
<td>Pygoscelis adeliae</td>
<td>51 358</td>
<td>31 184, 83 938</td>
<td>Lynch &amp; LaRue 2014</td>
</tr>
<tr>
<td>Beagle</td>
<td>Pygoscelis adeliae</td>
<td>96 892</td>
<td>59 507, 158 260</td>
<td>Lynch &amp; LaRue 2014</td>
</tr>
<tr>
<td>Comb (Peine)</td>
<td>Pygoscelis adeliae</td>
<td>3 311</td>
<td>1805, 5564</td>
<td>Lynch &amp; LaRue 2014</td>
</tr>
<tr>
<td>Platter (Plato)</td>
<td>Pygoscelis adeliae</td>
<td>27 902</td>
<td>16 876, 45 600</td>
<td>Lynch &amp; LaRue 2014</td>
</tr>
<tr>
<td>Darwin</td>
<td>Pygoscelis sp.</td>
<td>7 419</td>
<td>5384, 9931</td>
<td>Lynch &amp; Schwaller 2014</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>186 882</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Geographical name used in Lynch & LaRue 2014.

Gentoo Penguins (Pygoscelis papua) also breed on the Danger Islands in small numbers, with 215 pairs present on Heroïna Island in 1996 and 173 chicks counted in late Jan 2009, reported by the Antarctic Site Inventory (Naveen & Lynch 2011; Lynch et al. 2013).

Other birds thought to breed at the site include the Cape Petrel (Daption capense), Snowy Sheathbill (Chionis albus), Kelp Gull (Larus dominicanus), Brown Skua (Catharacta antarctica), Wilson’s Storm-petrel (Oceanites oceanicus) and Antarctic Tern (Sterna vittata). Occasional visitors include Chinstrap Penguin (Pygoscelis antarctica), Southern Giant Petrel (Macronectes giganteus), Snow Petrel (Pagodroma nivea), Imperial Shag (Phalacrocorax atriceps transfieldensis) and South Polar Skua (Catharacta maccormicki) (Naveen & Lynch 2011).
Some populations known only from helicopter survey – the rest recently discovered by Landsat imagery.
Need to automate image interpretation, but both medium- and high-resolution imagery presents challenges.

- medium-resolution sensors (e.g., Landat)
- high-resolution sensors (e.g., Worldview-3)

Need algorithms to automate the interpretation of both medium and high-resolution imagery.
Lots of streaming data on environmental drivers but almost no comparable streaming datasets on wildlife abundance and distribution.
Mapping Application for Penguin Populations and Projected Dynamics (MAPPPD)

Satellite imagery & Field counts

Map-based search engine for current abundance and predicted dynamics

“Data-to-knowledge” pipeline

Dynamic Naive Bayesian Network Modelling
MAPPPD (Mapping Application for Penguin Populations and Projected Dynamics) is an open access decision support tool designed for managers, scientists and the general public. Scientists from all corners of the Antarctic have collaborated to create a database of penguin population counts with data from four charismatic Sphenisciformes. Our tool takes penguin populations a step further by integrating advanced modeling techniques to detect and count penguin colonies from remote sensing data. MAPPPD also calculates occupancy probabilities and presents graphical output which projects how penguin populations will change in the future.

Become a contributor

If you have data you would like to contribute to the database:
1. Read our Terms of Use
2. Download the contributor's form
3. Read the instructions
4. Submit your data to: info@penguinmap.com

Instructions  Contributor form
MAPPPD allows for easy analysis of entire regions.
MAPPPD allows for easy analysis of entire regions.
What we’ve completed to date:

- Underlying PostgreSQL database for all four Antarctic penguins
- 80-90% of the front end application GUI complete (MAPPPD “works” but lacks some features still in development)
- Underlying population dynamics model for Adélie penguins is complete
- Archival Landsat survey (L4,L5,L7,L8) complete
- Characterization of ground targets with field spectrometer complete
- Occupancy model for non-penguin Antarctic seabirds complete (but checklists not yet in MAPPPD)
- Initial beta-testing by community members underway

What we will do in the next year:

- Complete all remaining features of MAPPPD GUI (adding occupancy species checklists)
- Add tools for data input by the community
- Integrate Landsat retrievals
- Complete beta-testing

MAPPPD premier at the Scientific Committee for Antarctic Research Open Science Conference Kuala Lumpur, Malaysia September 2016
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