Bayesian Data-Model Synthesis for Biological Conservation and Management in Antarctica

HEATHER J. LYNCH1 and MATHEW SCHWALLER2
1Department of Ecology & Evolution, Stony Brook University, NY USA 11794, 2NASA/Goddard Space Flight Center

The Problem—Management of Antarctic Living Resources
• Antarctica is a vast, inhospitable continent with large regions that remain unexplored.
• Current population abundance estimates are subject to under-reporting and sampling bias: estimates are typically confined to regions close to scientific research stations.
• Antarctica is changing in response to commercial fishing, a growing tourist industry, and the effects of climate change.
• Management decisions on fishing catch allocations, tourism, and designation of specially protected areas depend on the “best available” estimates of population abundance and dynamics.

Our Solution—Data Assimilation for Population Modeling
• A focus on the Adélie penguin: circum-Antarctic distribution and recognition as a key indicator of ecosystem health and status.
• Development of a physically-based algorithm to convert satellite remote sensing data to Adélie penguin colony location and spatial extent on a continuous basis.
• An ecologically-based Dynamic Bayesian Network (DBN) model assimilates remote sensing imagery from various sources with other sources of information such as field counts and predictions from state-space models of population change.
• A browser-based geospatial application custom designed to address the needs and concerns of the Antarctic research and management communities.

Expected Result: A data-to-knowledge pipeline that harnesses the power of remote sensing for effective resource management in the Antarctic.

Objective 1: Automated retrieval of Adélie penguin distribution & abundance

- There is a relatively constant “packing density” of nests per unit area within penguin colonies.
- A strong correlation was found between Adélie penguin population (measured by other studies) and colony area retrieved from Landsat data.
- A Poisson regression was used to model colony abundance as a function of guano stain area.
- Several new penguin colonies were identified in the Landsat ETM+ retrieval (unmatched yellow pushpins in this example from the Danger Islands). These are very likely to be comprised overwhelmingly of Adélie penguins.
- Brash Island (far left and near left in hi-res DigitalGlobe imagery [Copyright DigitalGlobe (2014)]) has a population estimated at 166,078 breeding pairs based on the Poisson regression model (and associated 95% percentile prediction envelope; gray-shaded envelope = continental Antarctica, orange-shaded envelope = Antarctic Peninsula).
- Phase-2 plans include multi-decadal retrieval using Landsat TM, ETM+ & OMI, plus ground validation to further reduce algorithm errors.

Objective 2: Develop an ecologically-motivated Dynamic Bayesian Network (DBN) model that combines satellite and ground based observations in a decision support tool

- Functional design document written for MAPPPD, which acts as a portal for data assimilation and Adélie population prediction.
- Prototype development planned as part of the NSF-funded National Socio-Environmental Synthesis Center (SESYNC) Summer Computational Institute.
- Phase-2 implementation: extensive use of new media for interactive, web-based geospatial visualization of Adélie penguin distribution and abundance, Phase-2 interface for DBN model.
- Crowd-sourcing: Citizen-scientist observations (photos, text) entered via an eBird interface, Phase-2 digital object identifier (doi) generation for field survey datasets (aerial photography, autonomous camera, field census) submitted by investigators and non-governmental organizations.
- Resource Management tool: Assimilation of a wide variety of data types; rapid interactive tools for iterative population estimation and hypothesis formulation; scalable in space from a single colony to the entire continent, in Phase-2 scalable over 4-decades of Landsat TM/ETM+OMI and hi-res Digital Globe observations.

Objective 3: Unrestricted, browser-based data products of Adélie penguin breeding distribution and abundance

- Functional design complete, designed for build/design charrette hosted by SESYNC July 7-11, 2014.

For more information: