Estimating Migration Resistance: a Case Study on Greenlandic Arctic Terns

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“Migration species, by traveling large distances, being subject to a wide range of environmental influences and relying on a wide range of natural resources, are particularly likely to be affected by climate change at some point in their life cycles.”
(CMS/UNEP Secretariat, 2006)

Introduction
Many researchers have employed cost-distance models using geographic information systems (GIS) in order to identify migration corridors of migratory species. Cost-distances use a friction or cost layer that estimates areas of high and low permeability. Most cost-surfaces are generated using a priori justifications and later verified. The availability of tracking data enables more data driven models of migration resistance.

This study focuses on the migration pathways of the Arctic Tern (Sterna paradisaea). The Arctic Tern is an arctic seabird with a circumpolar breeding distribution. This species migrates annually to wintering areas in the south Atlantic Ocean near Antarctica. This impressive migration behavior is ideal to study the effect of environment on migratory behavior.

Because large-scale migrations are energetically expensive, we expect that individual migrants would only deviate from the optimal, shortest distance paths in the event of some kind of resistance in space. In order to test this hypothesis, we measured the environments along the travel path of the Arctic Tern to see where travel deviates from optimal direction.

Methods
This study measured the environments along travel routes of the Arctic Tern using the following data:

- Light-logging geolocator data for 8 Arctic Terns. This data provided latitude and longitude coordinates once every 12 hours.
- Environmental raster layers for ocean winds, mean daytime sea surface temperature (SST), and net primary productivity (NPP).
- GIS polygons delimiting breeding destination (Greenland/Iceland) and wintering destination (Antarctica).

Using the migration point data, we calculated azimuth values for optimal pathways and actual pathways for each point. We also calculated distance to next migration point and estimated velocity for each point.

Using these measurements, we created wedge-shaped zones to extract the mean environment values in the region of actual travel and the region of optimal travel.

Analysis
Data was analyzed for the southern and northern migrations using generalized linear models with the following parameters:

- The response variable was a cosine transformation of the deviation angle, θ.
- The sampled values for NPP were log transformed to make the distribution of values more normal.
- Wind values were transformed into scalar projections upon a unit vector in the direction of travel.
- The list of predictor variables included: Bird ID, and for both actual and optimal paths, Wind, SST, and NPP.

Discussion
Individual Arctic Terns preferred flight paths with strong tailwinds. This result is troubling because some climate models predict the calm and shifting of ocean winds in the future. These changes may adversely affect the future migration success of Arctic Terns.

There was a measurable difference between the migration choices on the southern and northern migrations. The southern migration was slower (97 day average) and more prone to deviations than the northern route (40 day average).

This method of measuring migration resistance may be useful to conservation planners and biodiversity policy-makers interested in other migratory species. It can be completely generalized for usage with any migratory species that has sufficient tracking data.

For references or further questions, please contact me at: hensz@ku.edu