Ecophysiological/energetics consequences of secondary colonization of aquatic ecosystems by birds.

Warren Porter and David Gremillet

(Bird and microclimate model field tests)
Current great cormorant distributions

Q: What are the great cormorant’s monthly food requirements and migration times for the west coast of Greenland?
Colder water = shorter dive times (when more food needed)
Colder weather = higher energy costs

Great cormorant food requirements in Greenland
3.2 kg, 0.5 cm body fat, 19.7% reflectivity
Summer site: 69° 30' N. 54° 5' W.
Winter site: 68° 15' N. 52° 50' W.

No fog
Local microclimates (fog) can reduce energy costs

3.24 kg adult male great cormorant
west coast of Greenland
North site: 69° 30' N., 54° 5' W.
South site: 68° 15' N., 52° 50' W.

![Graph showing metabolic rate (kJ/d) vs. month of year for two sites, one with fog in winter and the other with snow in winter.](image)
Higher rate of food intake required in cold weather

3.24 kg adult male great cormorant
0.5 cm body fat, 1.5 x resting metabolism
19.7% reflectivity, west coast of Greenland

North site: 69° 30' N., 54° 5' W.
South site: 68° 15' N., 52° 50' W.
Tests of the models – amphibians with Paul Bartelt

• What governs a species’ use of the landscape?
• How good are our estimates of habitat utilization/location on the landscape?
Environmental Biophysical Approach

Weather Model

Topography

Veg Layers

Mechanistic Model
- Warren P. Porter

Indices of Habitat Suitability
Evaluation of Terrestrial Habitat Model

Targhee National Forest, Idaho
Building a Composite Index

Western toad

Component

1) Energy required to travel through pixel
2) Window of time for movements
3) # hours to forage \((T_b \text{ 8 – 25°C})\)
4) # hours to maintain \(T_b > 27°C\)
5) Constraint of evaporation rate on \(T_b\)

Variables

slope & dnrg
nite hrs \(T_c >8°C\)
hrs \(T_c 8 - 25°C\)
hrs \(T_c >27°C\)
evap
Stamp Meadows Landscape Suitability

Composite Index

SMLANDSUITE93

<VALUE>

-5.309 - 2.133
-2.133 - 1.100
-1.100 - 0.120
-0.120 - 1.134
1.134 - 5.823
Least-cost Path & Corridor
Toad #78 - Stamp Meadows
Least-cost Path & Corridor
Toad #31 - Stamp Meadows

Toad Locations
Least-cost Path & Corridor 31
<p>VALUE>
- 5%
- 10%
- 15%
- 20%
- >20%
- pond

Legend:
- Blue dots indicate toad locations.
- Black line represents the least-cost path.
- Color gradient indicates different percentage values.

Scale:
- 0 250 500 1,000 1,500 2,000 Meters
Least-cost Path & Corridor
Toad #31 - Stamp Meadows
Modeling Animal Landscapes on PCs: tests and applications

- Nature of the models: overview, organisms in general/data requirements, landscapes on PCs
- Tests of the models: mammals, birds, reptiles, amphibians, insects, early hominids
- Model applications: vertebrate and invertebrate rare and endangered species
What pollination services can wild bee communities provide in the Central Valley of California?

$Q_{\text{met}}$ fixed in flight, $T_{\text{core}}$, evaporation must vary
Pollination efficiency & bird migration implications
Digital elevation map (DEM)
Central valley of California:
Remote sensing needed: plant phenology, distribution, blossoming in time, space
Central Valley, California
Courtesy of Sam Batzli, U.W. Environmental Remote Sensing Center
Modeling Animal Landscapes on PCs: tests and applications

- Nature of the models: overview, organisms in general/data requirements, landscapes on PCs
- Tests of the models: mammals, birds, reptiles, amphibians, insects, early hominids
- Model applications: vertebrate and invertebrate rare and endangered species
Micro-Climate 24-Hour Energy Balance Equation

\[ Q_{\text{in}} = Q_{\text{out}} + Q_{\text{stored}} \]

\[ Q_{\text{in}} = \text{Solar \& Infrared Radiation from Sky \& Vegetation} \]

\[ Q_{\text{out}} = \text{Infrared Radiative Energy Loss + Convective Energy Loss + Evaporative Energy Loss from the Surface} \]

\[ Q_{\text{stored}} = \text{Soil Energy Exchange at the Surface by Radiation, Convection and Conduction} \]

Graphics courtesy W. Klousie

(Photo Courtesy J. Altmann)
Early hominid energetics on early landscapes with Bill Klousie
Question

• What might be the bounds on mass and energy costs to early hominids coming out of Africa 500,000 – 450,000 years ago of
  – climate variation
  – fur quality, wearing ‘clothes’
  – building shelters?
Climate variation

Mean Temperature of the Earth

- 15.3°C
- 10.3°C

Today

- CAVES
- SHELTERS/HUTS
- TENTS
- HOUSES
- NEANDERTHALS
- HOMO SAPIENS/CROMAGNON
- HOMO ERECTUS/HOMO HABILIS

Present: 1000 AD 0 BCE 20 Kya 50 Kya 0.5 Mya 1.0 1.5 7.5
Getting climate estimates
Limiting the choices for the first estimates and tests
Niche-based approaches using GIS: b) Mechanistic approach

<table>
<thead>
<tr>
<th>Microclimate model input</th>
<th>Microclimate model output</th>
</tr>
</thead>
<tbody>
<tr>
<td>• air temperatures</td>
<td>• hourly estimates for average day of each month for:</td>
</tr>
<tr>
<td>• wind speeds</td>
<td>➢ radiation</td>
</tr>
<tr>
<td>• humidities</td>
<td>➢ air temperatures at different heights</td>
</tr>
<tr>
<td>• cloud cover</td>
<td>➢ wind speeds at different heights</td>
</tr>
<tr>
<td>• latitude/longitude</td>
<td>➢ soil temperatures at different depths</td>
</tr>
<tr>
<td>• slope</td>
<td>➢ relative humidity</td>
</tr>
<tr>
<td>• aspect</td>
<td></td>
</tr>
<tr>
<td>• elevation</td>
<td></td>
</tr>
<tr>
<td>• soil properties</td>
<td></td>
</tr>
</tbody>
</table>
Niche-based approaches using GIS: b) Mechanistic approach

Animal model input
- body size, shape
- solar reflectivity
- behaviour (e.g. nocturnal, arboreal, crepuscular, shelter use)
- core temperature
- fur properties
- diet composition (e.g. protein, carbohydrates, fats, water content)

Animal model output
- hourly estimates for average day of each month for:
  - hours of activity
  - growth, reproductive potential
  - metabolic rates
  - water loss rates

Model development, lab and field tests
Porter et al, 1994; 2000; 2002;
Kearney & Porter, 2004
AUSTRALOPITHICINE SILHOUETTE MODELS

90 Degree Zenith Angle

60 Degree Zenith Angle

30 Degree Zenith Angle

0 Degree Zenith Angle

What is the difference between a silhouette and a shadow?

Also, why isn't the 60 Degree Silhouette proportionately shorter, when compared to the full size vs the 30 degree drawing?
Homo ergaster silhouette areas
180 cm tall, 63 kg
0 azimuth angle = side view
Terra Amata, Nice, FR
Mindel Glaciation
450,000 – 380,000 ybp
Assumed 11 m x 3.5 m size,
3 cm thick wood walls, insulated floor
Chimpanzee fur, shelter, no shelter
Added elk ‘robes’ as clothing; shelter, no shelter
3 focal sites for preliminary analysis: 608 m, 164 m, 12 m
An example of hourly results – 680 m elevation

Homo ergaster, chimpanzee fur, Torrejon, Spain
January, 500kbp, no shelter

Metabolism (W)

Hour of day

Clear sky
90% shade
Monthly example, 164 m Chateauroux, FR
Some annual results

*Homo ergaster* in Europe

180 cm tall, 63 kg

Spain site 680 m, French site 164 m, Italy site 12 m

Spain, 500 kbp
Spain, 450 kbp
France, 500 kbp
France, 450 kbp
Italy, 500 kbp
Italy, 450 kbp

Ave. annual metabolism (W)

Chimp fur (1), Elk 'clothes' (2), Elk 'clothes' + Shelter(3)

- Thermoneutral
- resting modern *Homo*

Some annual results
Correlative approach:
known distribution ⇒ “environmental niche” ⇒ predicted distribution

• good for identifying suitable habitat
• substantial animal location data requirements
• conservative predictions - extrapolation risky?

Mechanistic approach:
organismal properties ⇒ “fundamental niche” ⇒ predicted distribution

• greater explanatory power
• requires physical/physiological/behavioral animal data
• extrapolations can identify ‘hidden’ key variables - more difficult!