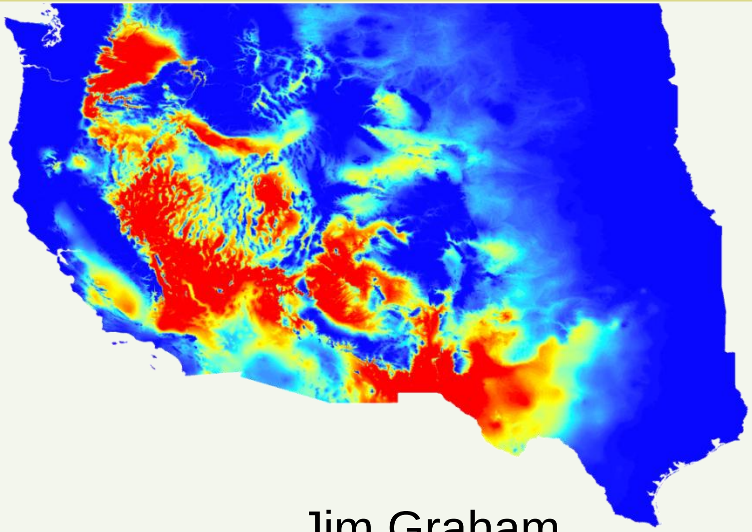
IBIS
International Biological Information System

Modeling Potential Distributions of Species at Large Spatial Extents



Jim Graham

Greg Newman, Nick Young, Catherine Jarnevich

Natural Resource Ecology Laboratory

Oregon State University / Colorado State University

Colorado State University
Knowledge to Go Places

Natural Resource Ecology Laboratory

Jim Graham

- BS CS and Math from California State University at Chico
- 15 Years Image Processing at HP
- 3 Years a CEO for GIS web corp.
- PhD in GIS from Colorado State University, Fort Collins
- 4 Years as Research Scientist at the Natural Resource Ecology Laboratory
- Visiting Professor at OSU

Jim's Research

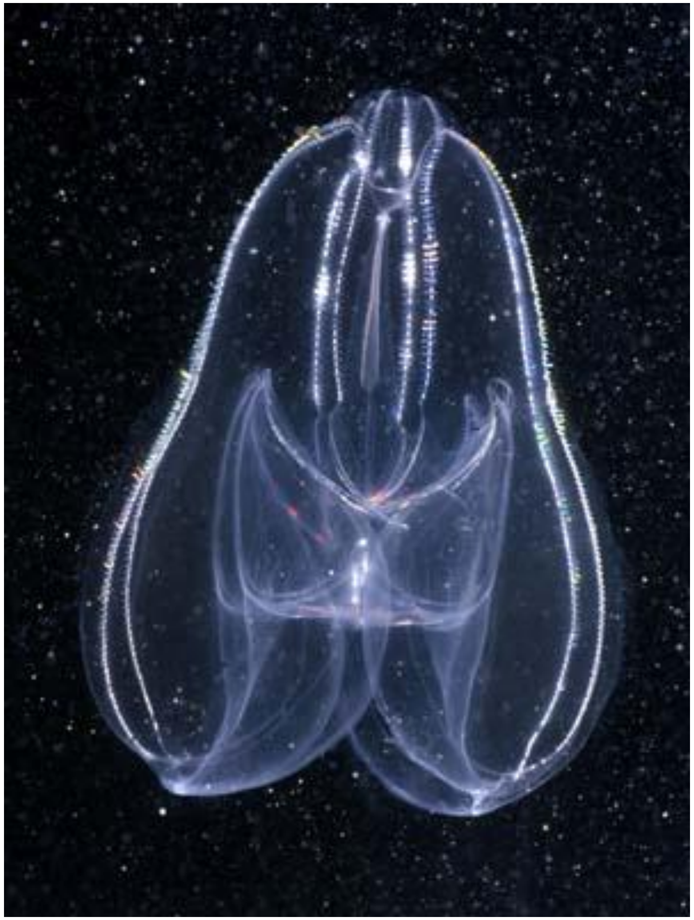
- Engaging citizen scientists
- Web-based GIS
- Integrating eco-informatics databases
- Global species occurrence databases
- Optimal data access for large spatial databases
- Habitat suitability modeling at large extents
- Risks and impacts of energy production

Invasive Species

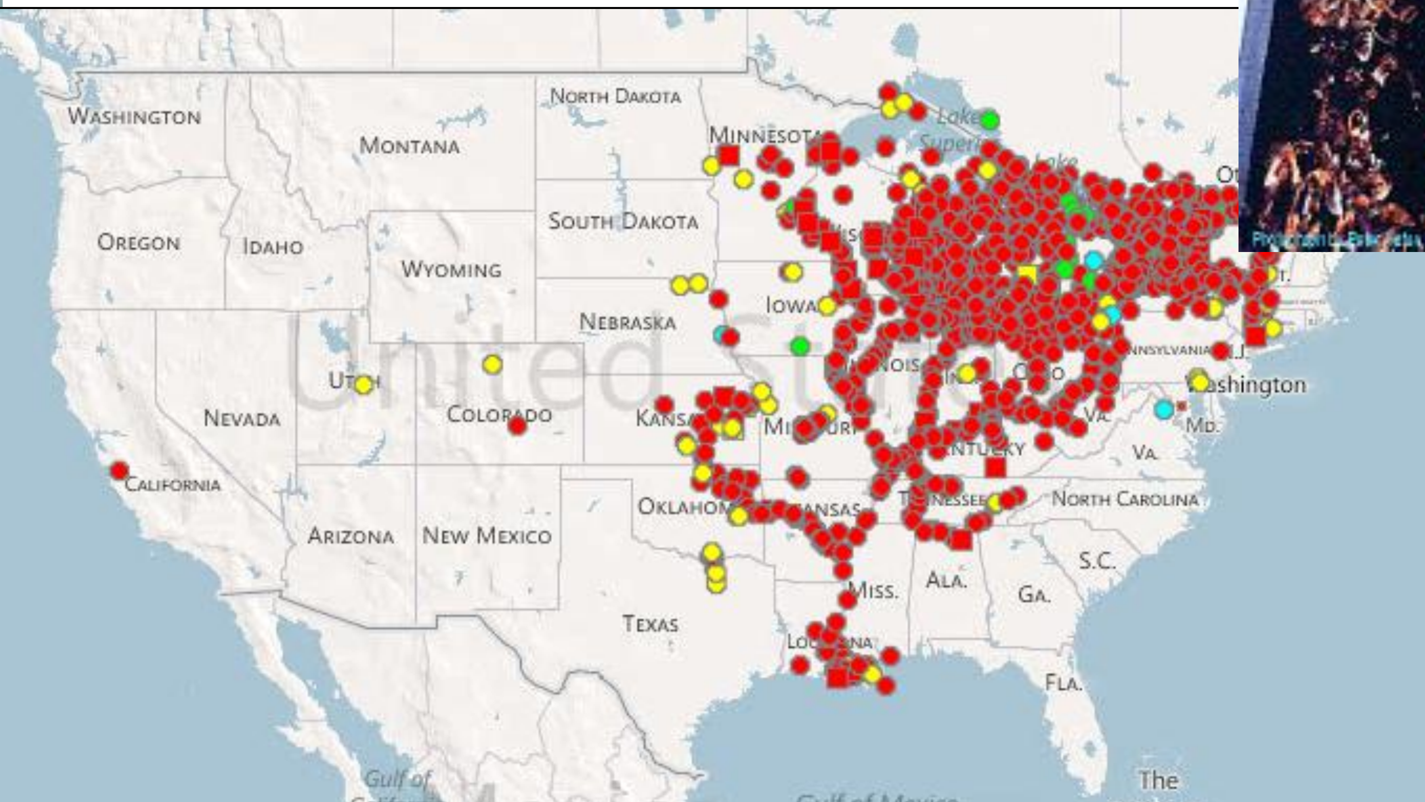
Rat attacking New Zealand fantail

Photo: David Mudge

Mnemiopsis leidyi (comb jelly)



Zebra Mussel Distribution

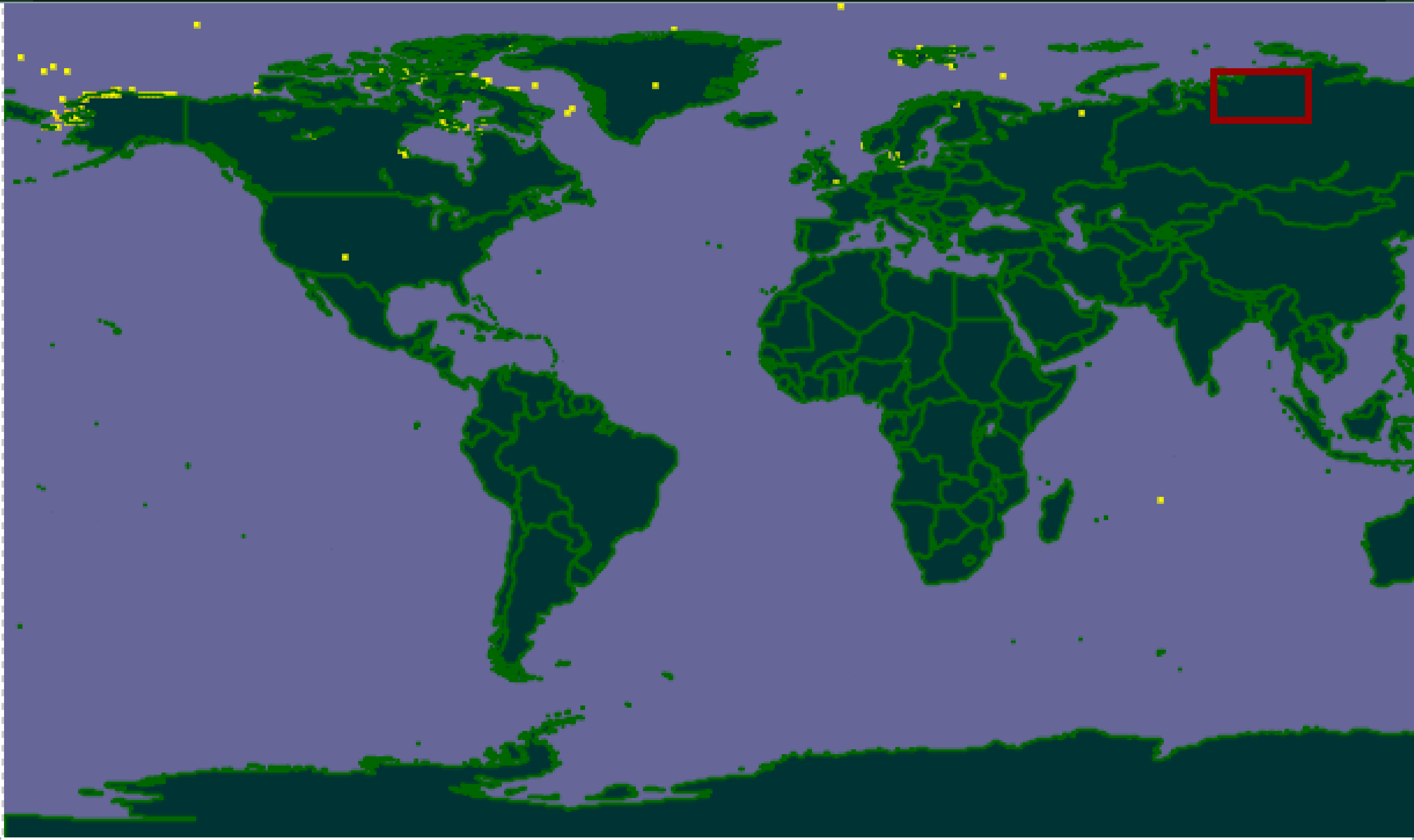


Non-indigenous Aquatic Species Database (USGS), Oct 4th, 2011

Predicting Distributions

- Predicting potential species distributions at large spatial and temporal extents
- Given:
  - Limited data
    - Most have unknown uncertainty
    - Most biased/not randomly sampled
    - >90% just “occurrences” or “observations”
  - Lots of species
  - Climate change and other scenarios

Occurrences of Polar Bears



From The Global Biodiversity Information Facility (www.gbif.org, 2011)

Uncertainty in Data

- Experts more accurate in correctly identifying species than volunteers
  - 88% vs. 72%
  - Volunteers: 28% false negative identifications and 1% false positive identifications
  - Experts: 12% false negative identifications and <1% false positive identifications
- Conspicuous vs. Inconspicuous
  - Volunteers correctly identified “easy” species 82% of the time vs. 65% for “difficult” species
  - 62% of false ids for GB were CB

GISIN Organizations

GBIF

SERC

Nonindigenous Aquatic Species

Convention on Biological Diversity

Biodiversity Information Standards TDWG

NASA

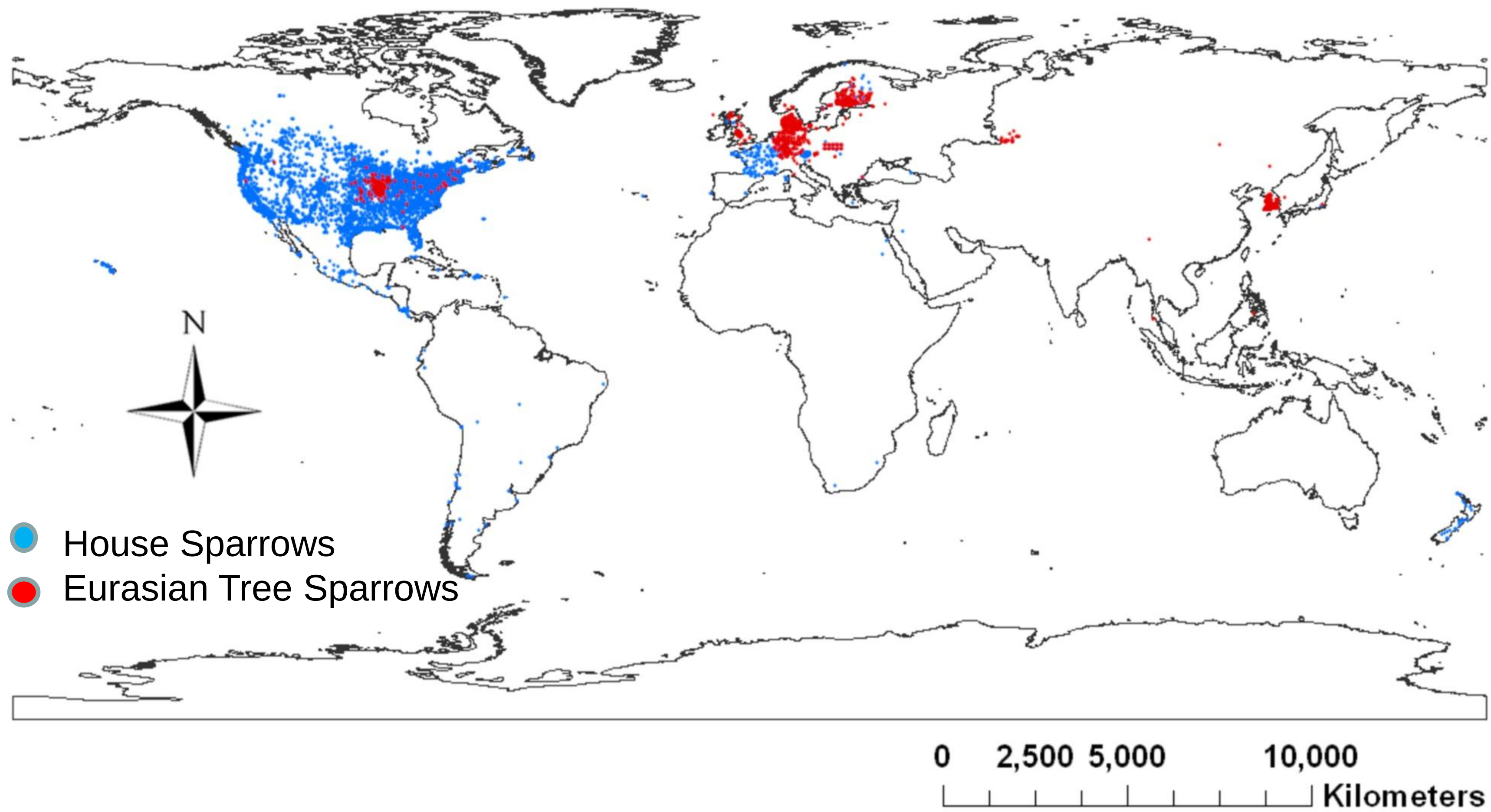
NISbase

iabin Inter-American Biodiversity Information Network

Discover Life

USGS science for a changing world

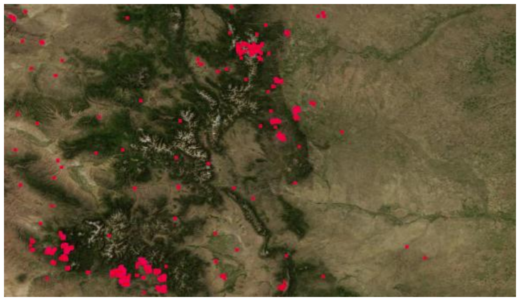
Tree Sparrow Occurrences



Graham, J., C. Jarnevich, N. Young, G. Newman, T. Stohlgren, How will climate change affect the potential distribution of Eurasian Tree Sparrows (Passer montanus)? Current Zoology, 2011.

Modeling Process

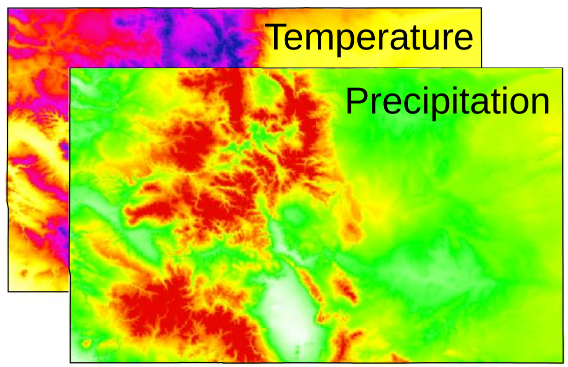
Occurrences



Spreadsheets

Lat	Lon	Temp	Precip
-105.504	40.35819	5.32	58.4
-107.472	40.498	6.31	47.6

Environmental Layers



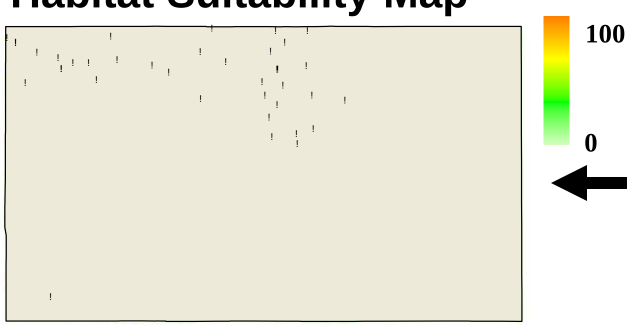
Modeling Algorithm

Model Parameters

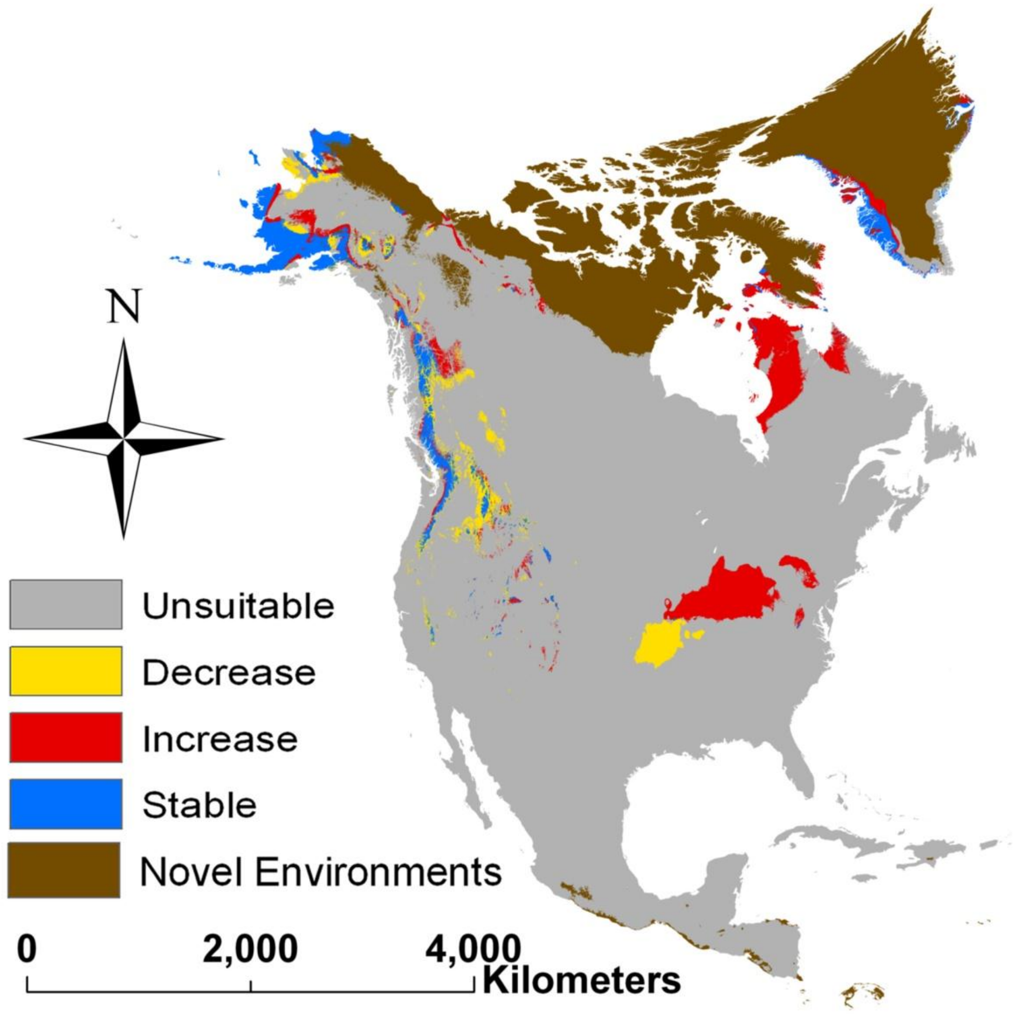
Variable	Coefficient	P-Value
Intercept	-1.52	0.064
Annual Precip	-0.05	0.0
Annual Temp.	0.61	0.0

Map Generation

Habitat Suitability Map



Tree Sparrow Model - 2050

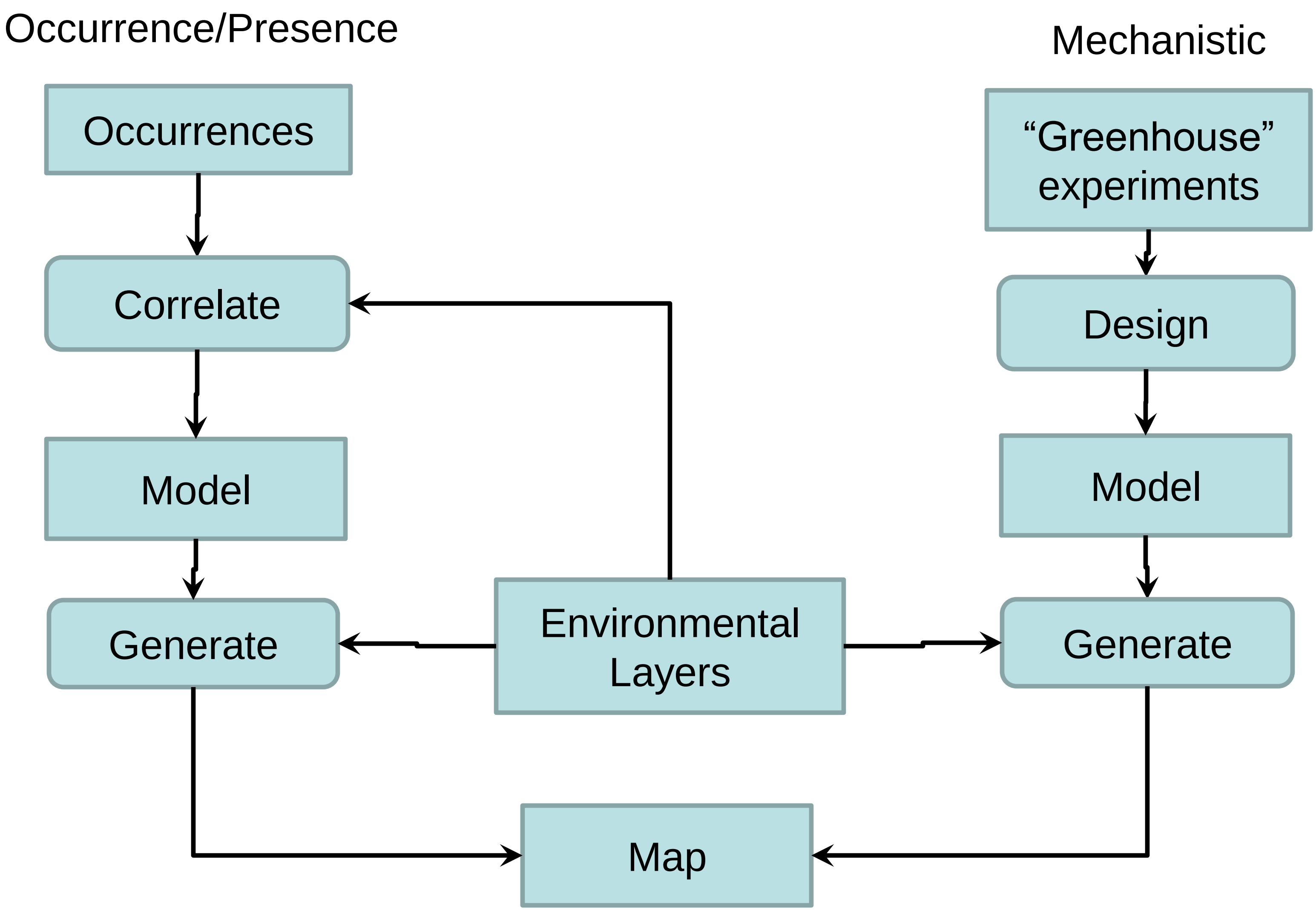


Graham, J., C. Jarnevich, N. Young, G. Newman, T. Stohlgren, How will climate change affect the potential distribution of Eurasian Tree Sparrows (Passer montanus)? Current Zoology, 2011

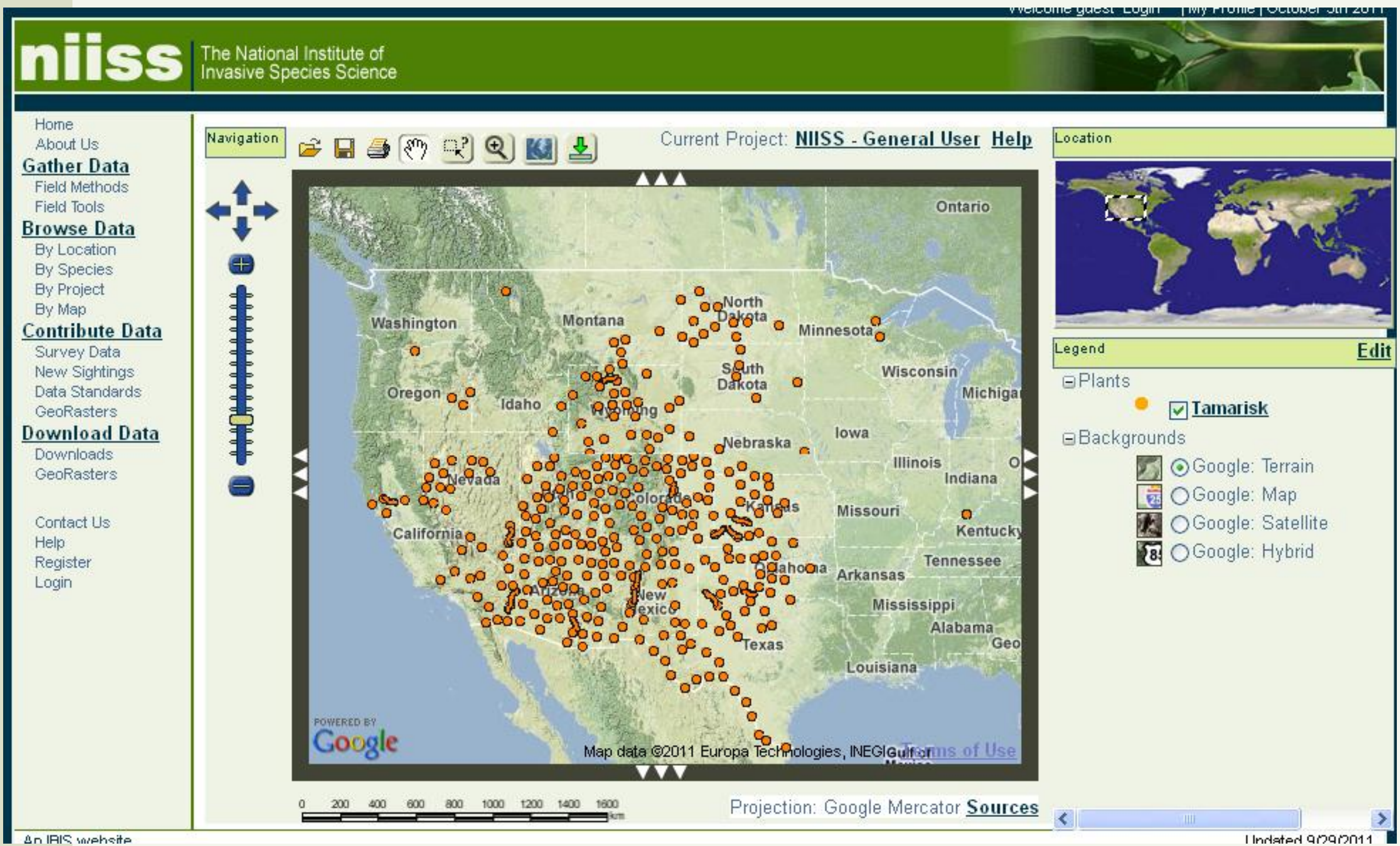
Spatial Modeling Concerns

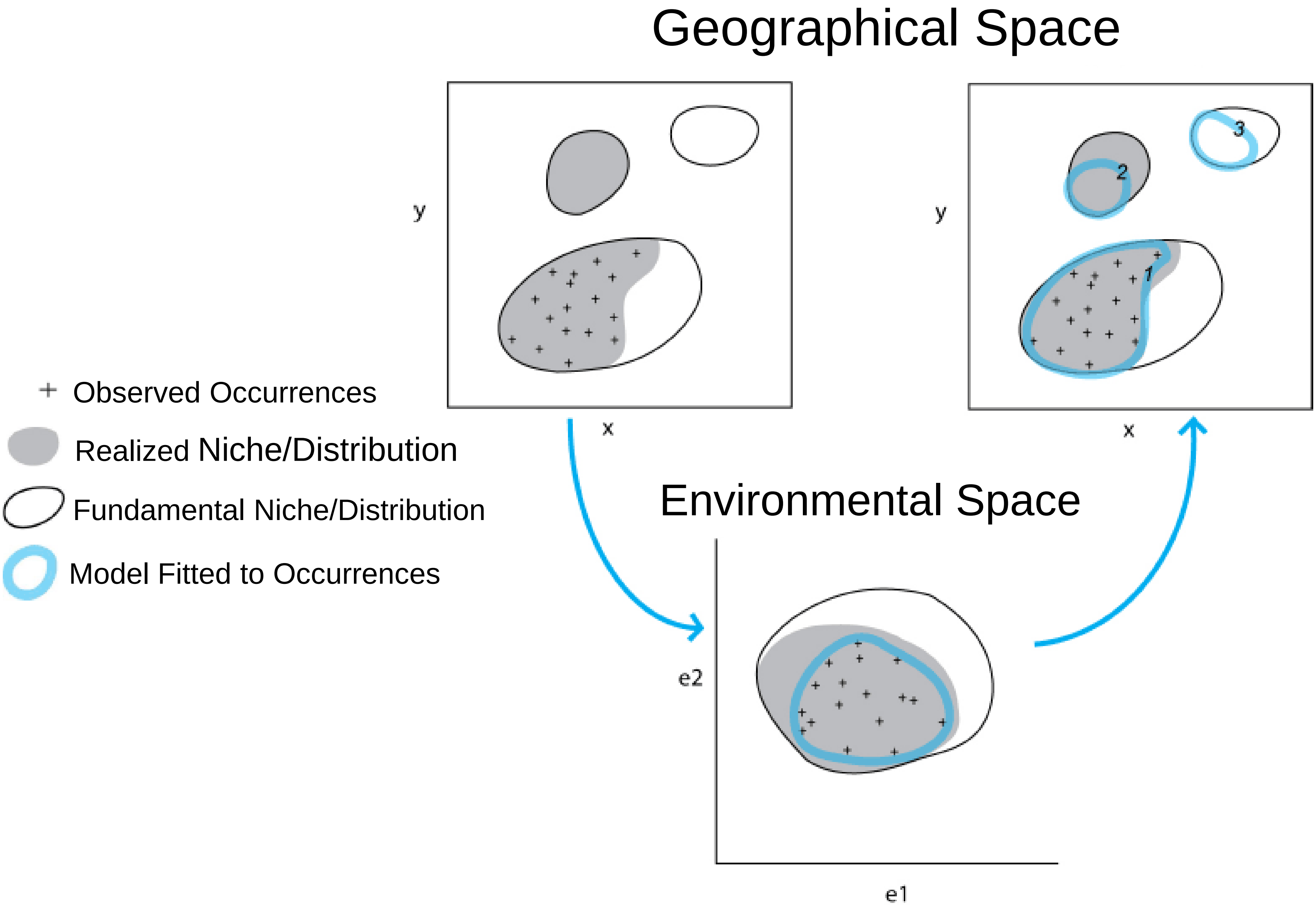
- Over fitting the data
  - Are we modeling biological/ecological theory?
- What does the model look like?
  - In environmental space vs. geographic space
- Absence points?
  - What do they mean?
- Analysis and representation of uncertainty?
- Can we really model the potential distribution of a species from a sub-sample?

Two Approaches



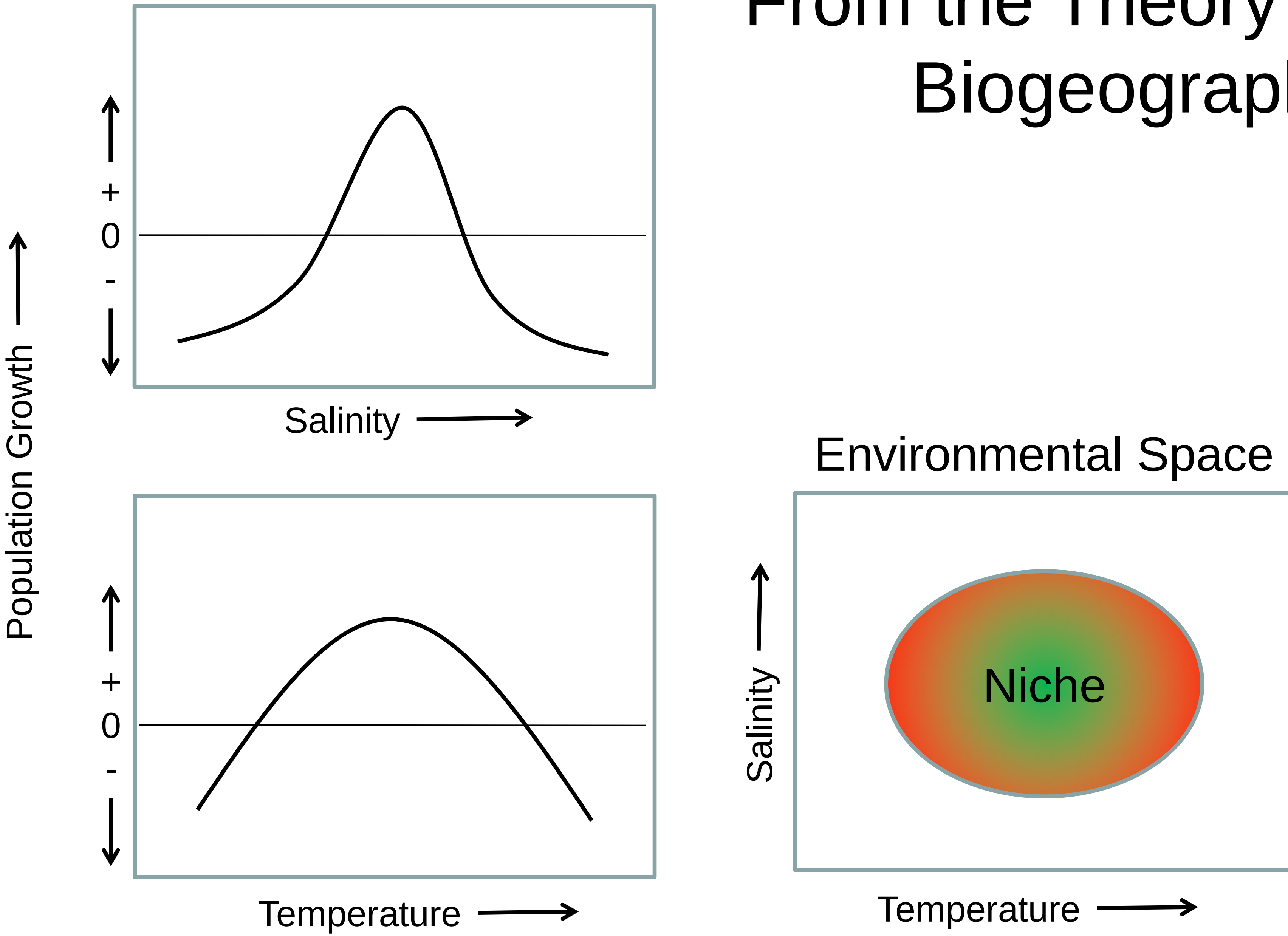
Tamarisk Data





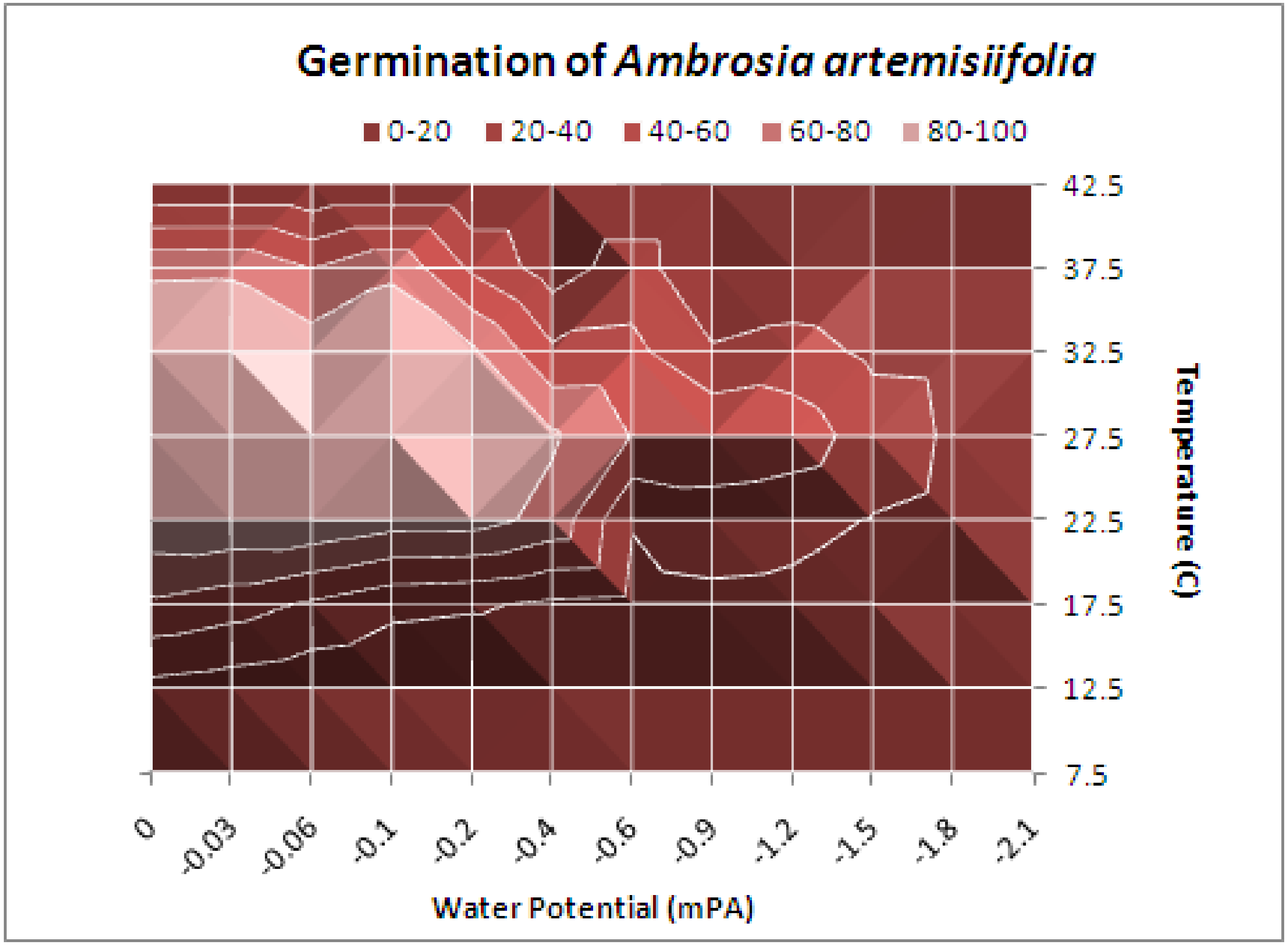
Adapted from Richard Pearson, Center for Biodiversity and Conservation at the American Museum of Natural History

From the Theory of Biogeography

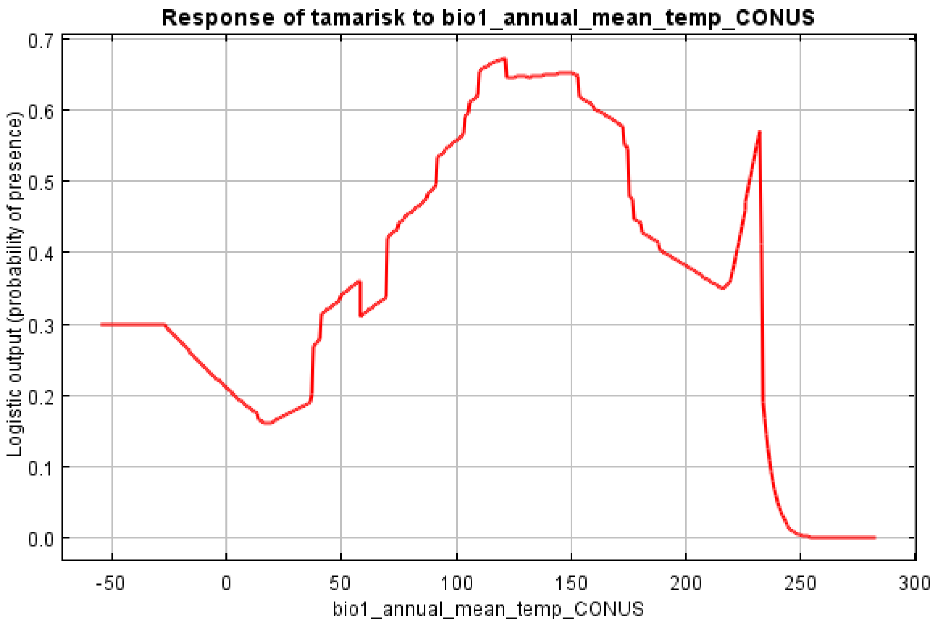


Brown, J.H., Lomolino, M.V. 1998, Biogeography: Second Edition. Sinauer Associates, Sinauer Massachusetts

Germination Percentage



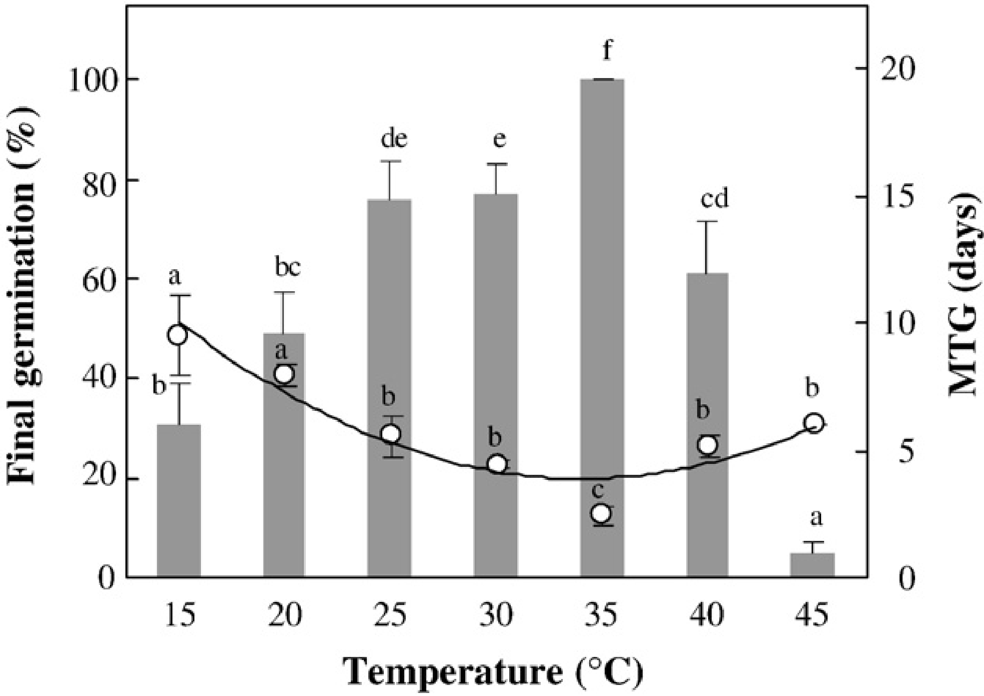
Shrestha, A., E. S. Roman, A. G. Thomas, and C. J. Swanton. 1999. Modeling germination and shoot-radicle elongation of Ambrosia artemisiifolia. Weed Science 47:557-562.



Over-fitting The Data?

Maxent model for *Tamarix* in the US: response to temperature when modeled with temperature and precipitation

What should the model look like?



Maraghni, M., M. Gorai, and M. Neffati. 2010. Seed germination at different temperatures and water stress levels, and seedling emergence from different depths of Ziziphus lotus. South African Journal of Botany 76:453-459.

Maxent Model Parameters

- bio12_annual_percip_CONUS, -4.946359908378759, 52.0, 3269.0
- bio1_annual_mean_temp_CONUS, 0.0, -27.0, 255.0
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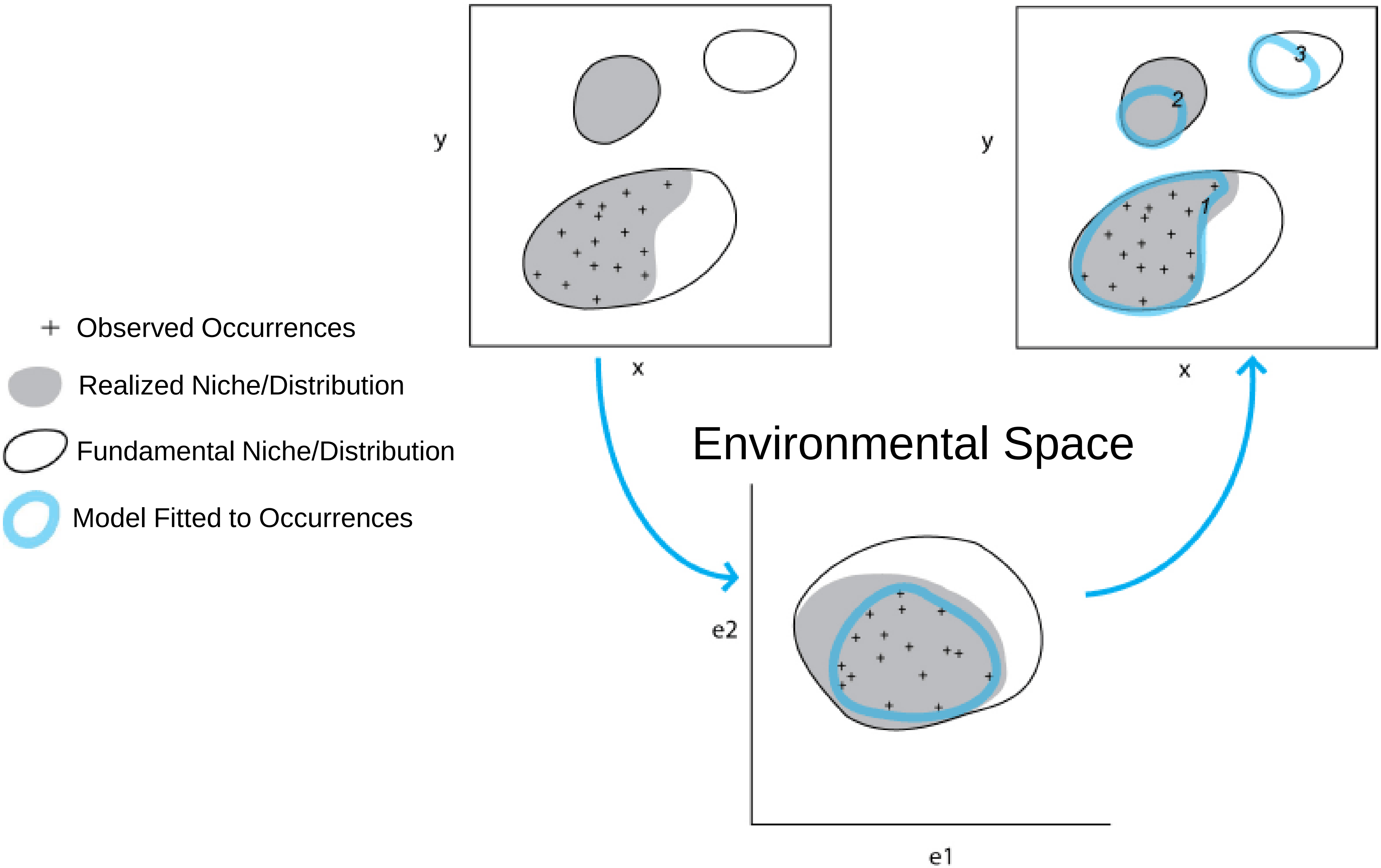
- densityNormalizer, 1311.2581836276431
- numBackgroundPoints, 10000
- entropy, 8.358957722359722

162 Parameters

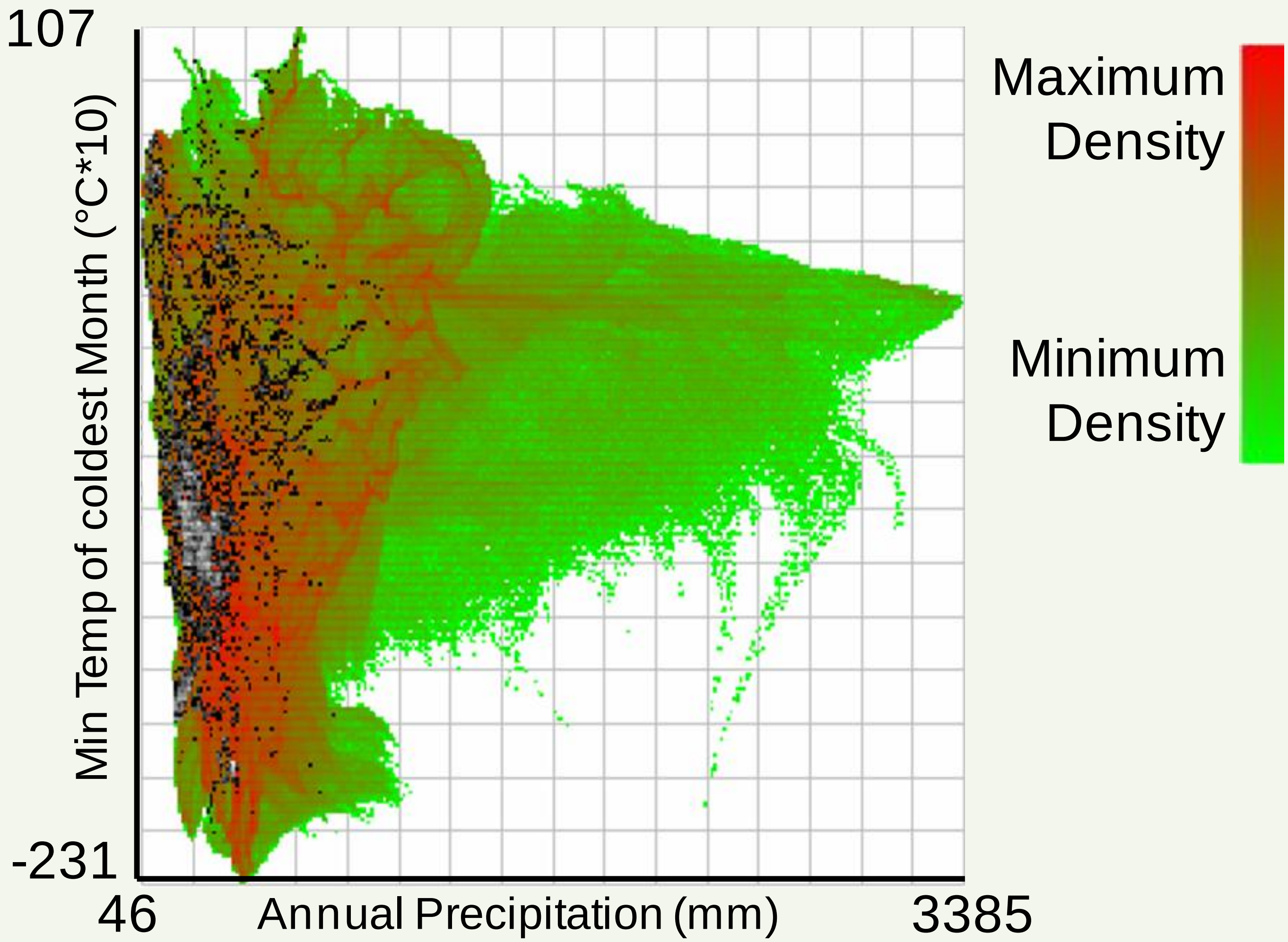
Maxent model from Tamarix model of western US using precipitation and temperature.

Geographical Space



Adapted from Richard Pearson, Center for Biodiversity and Conservation at the American Museum of Natural History

Tamarisk Occurrences



Can we?

- Create a species distribution modeling method that:
  - More closely matches ecological theory?
  - Allows visualization of the model in environmental space?
  - Does not use absence points?
  - Allows integration of physiological knowledge and occurrence data?
  - Allows editing the model to try scenarios?
  - Represents uncertainty?

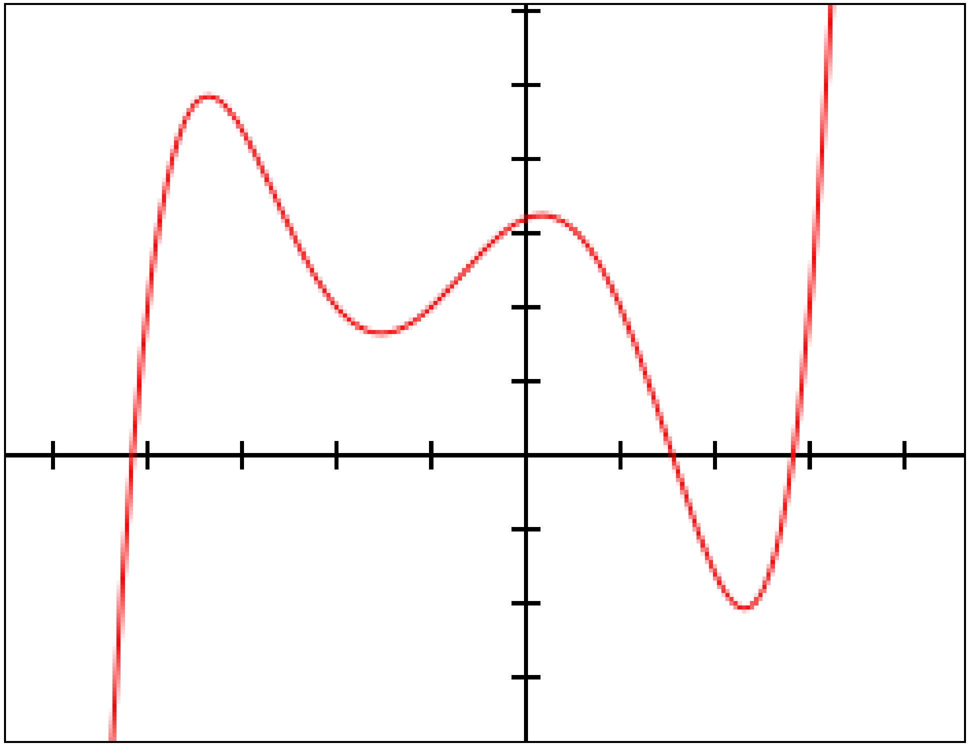
Some Caveats

- We are modeling “observations”
  A. Modeling occurrences with some uncertainty
  B. Modeling the realized niche if the data is a complete sample for the environmental space the species currently occupies
  C. Modeling the fundamental niche if B is true and the species is covering it’s full possible range of habitats
- Habitat Suitability Modeling
  - Predicting the potential species distribution

Problems with Polynomials

$f(x) = a_0 + a_1x + a_2x^2 + ... + a_nx^n$, where $a_n \neq 0$ and $n \geq 2$

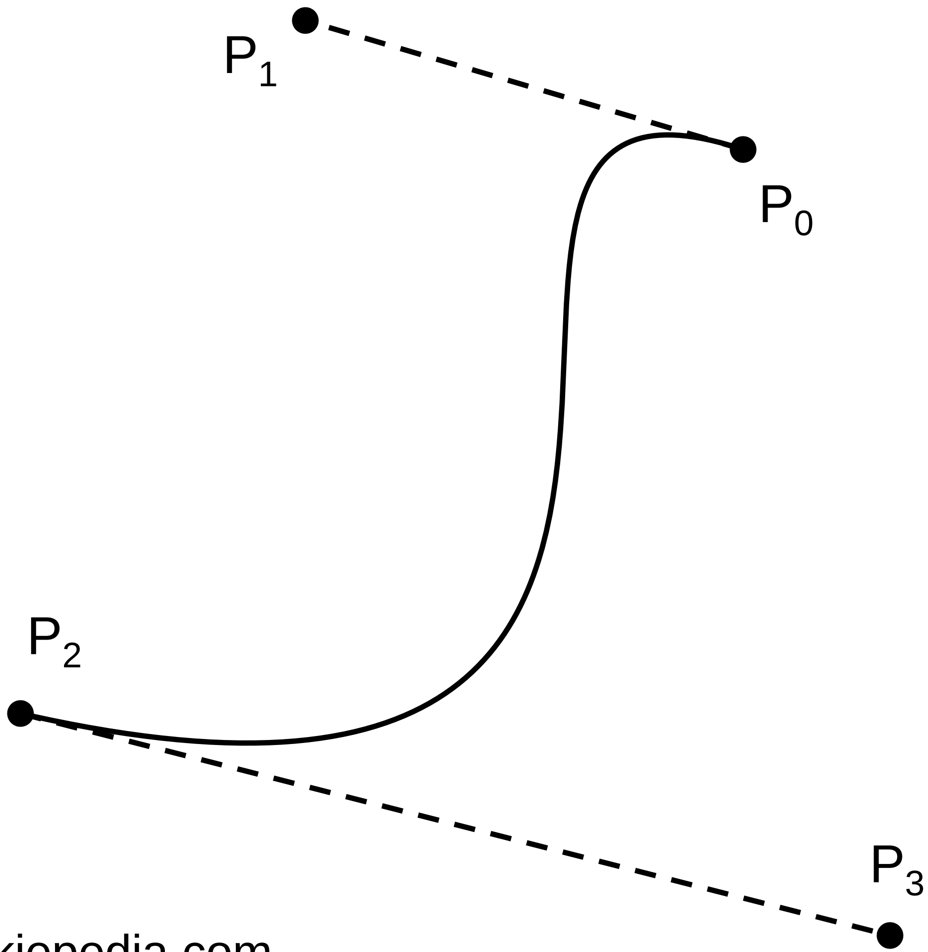
- Lack flexibility
- Not well behaved at boundaries

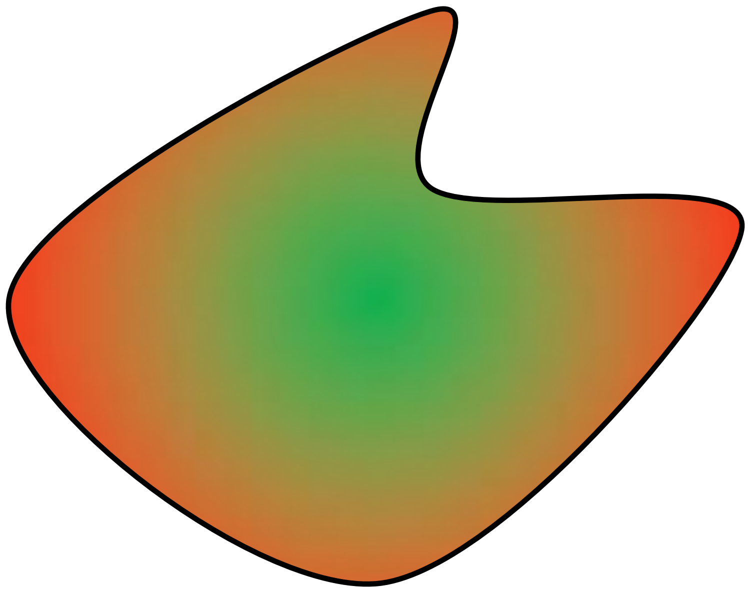


Wikipedia.com

Bezier and Spline Curves

$$\mathbf{B}(t) = (1-t)^3\mathbf{P}_0 + 3(1-t)^2 t\mathbf{P}_1 + 3(1-t)t^2\mathbf{P}_2 + t^3\mathbf{P}_3 \ , \ t \in [0,1].$$





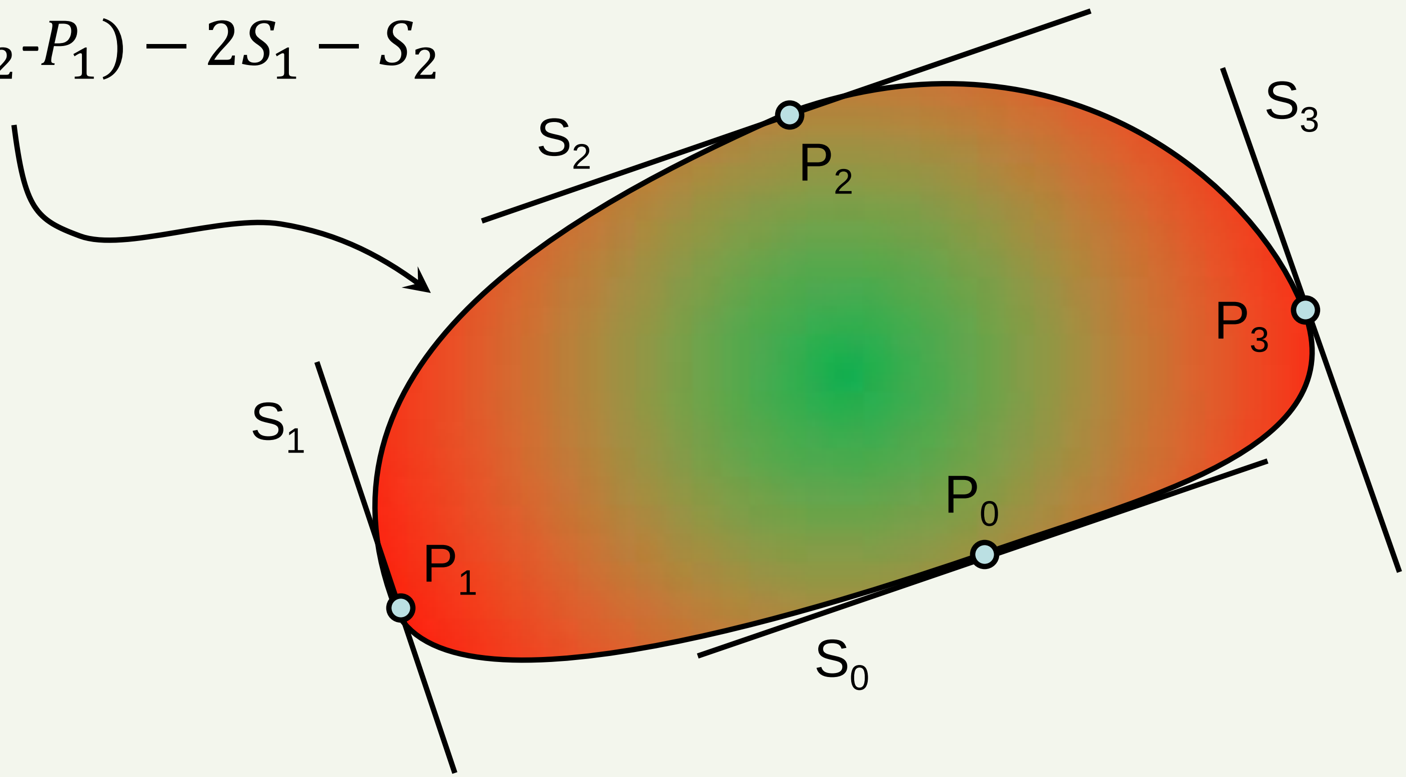
Wikiepedia.com

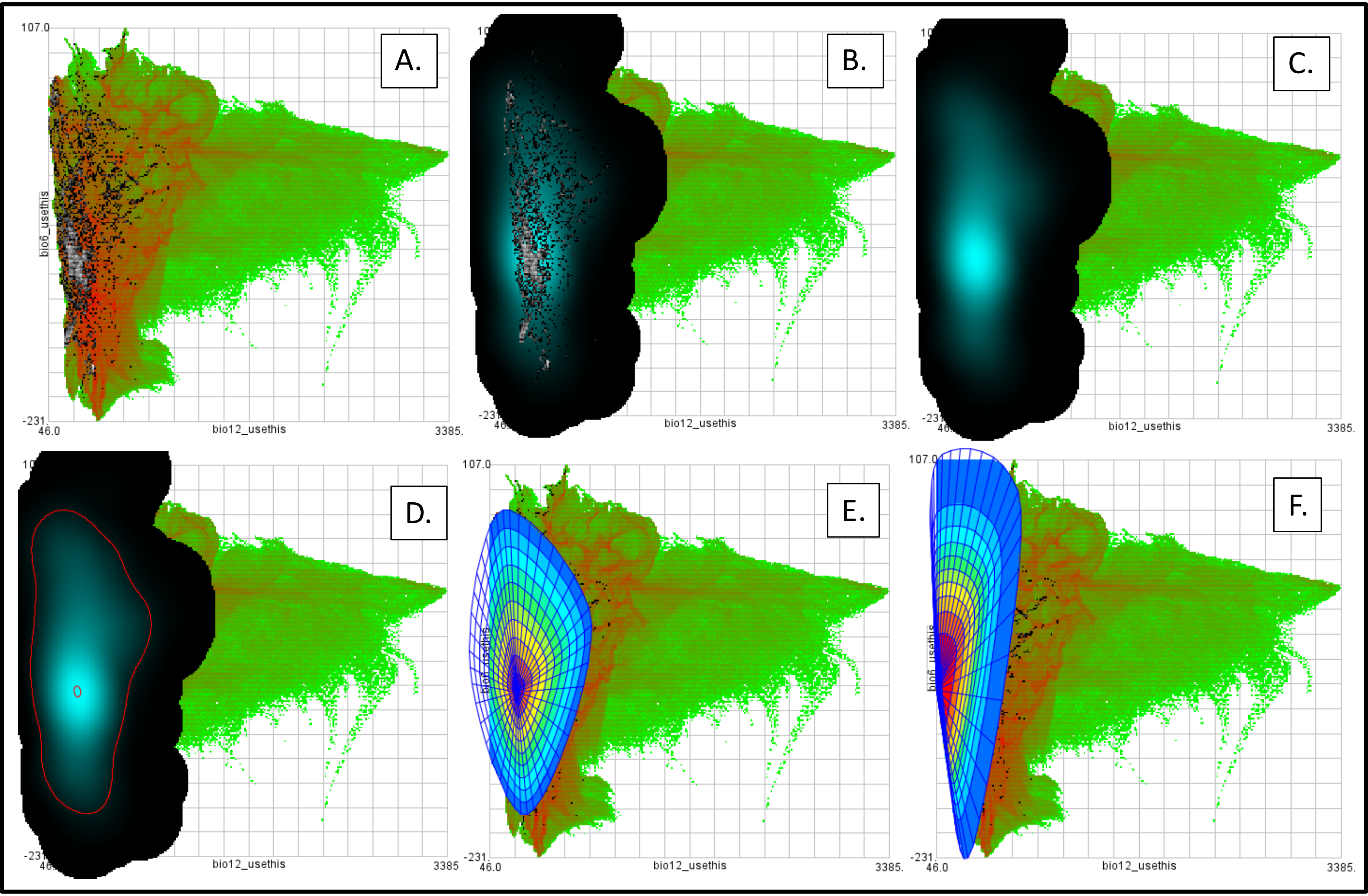
Modified Bezier Curves

$$B(t) = at^3 + at^2 + S_1 t + P_1$$

$$a = 2(P_1\text{-}P_2) + S_1 + S_2$$

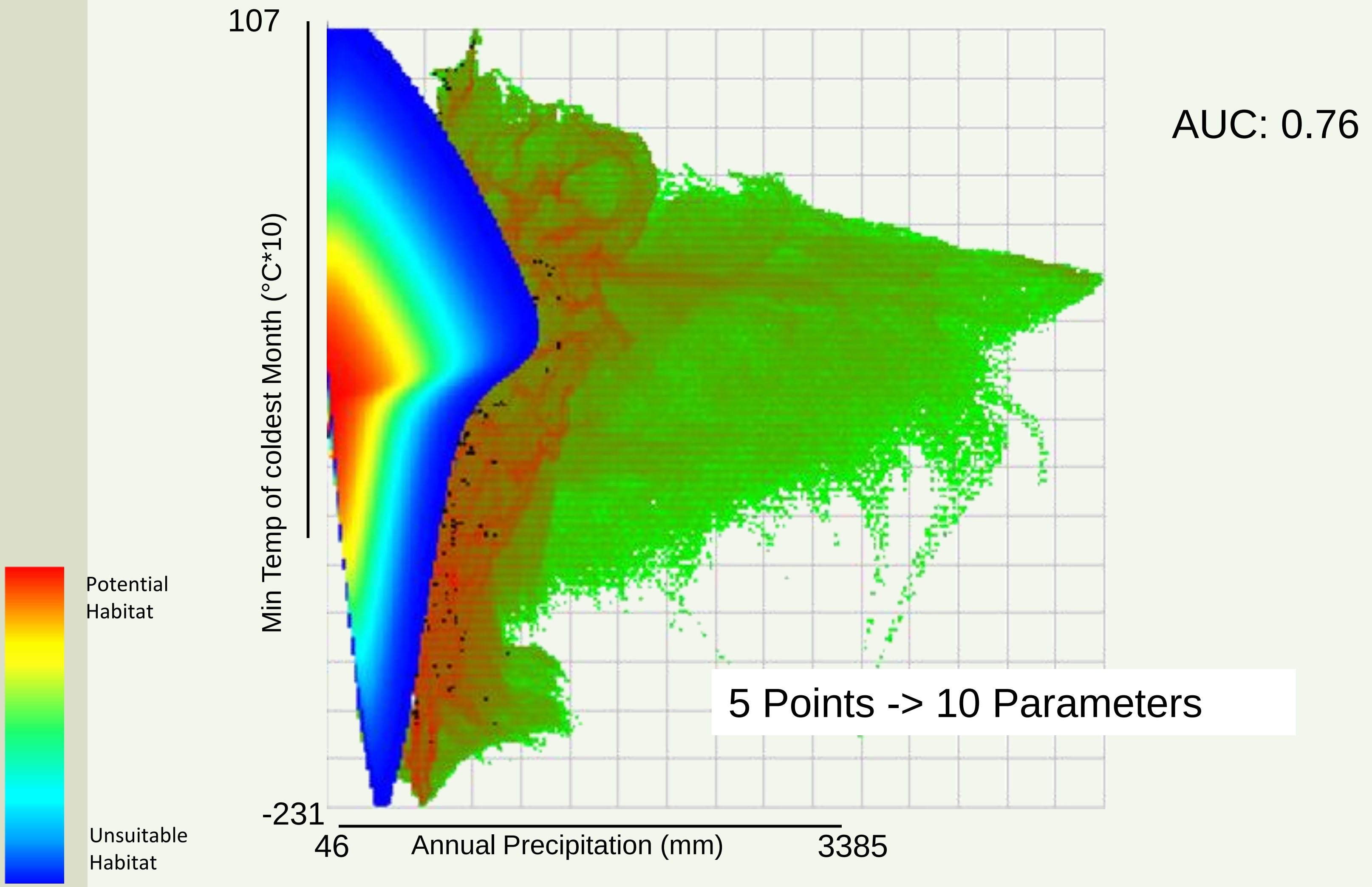
$$b = 3(P_2\text{-}P_1) - 2S_1 - S_2$$





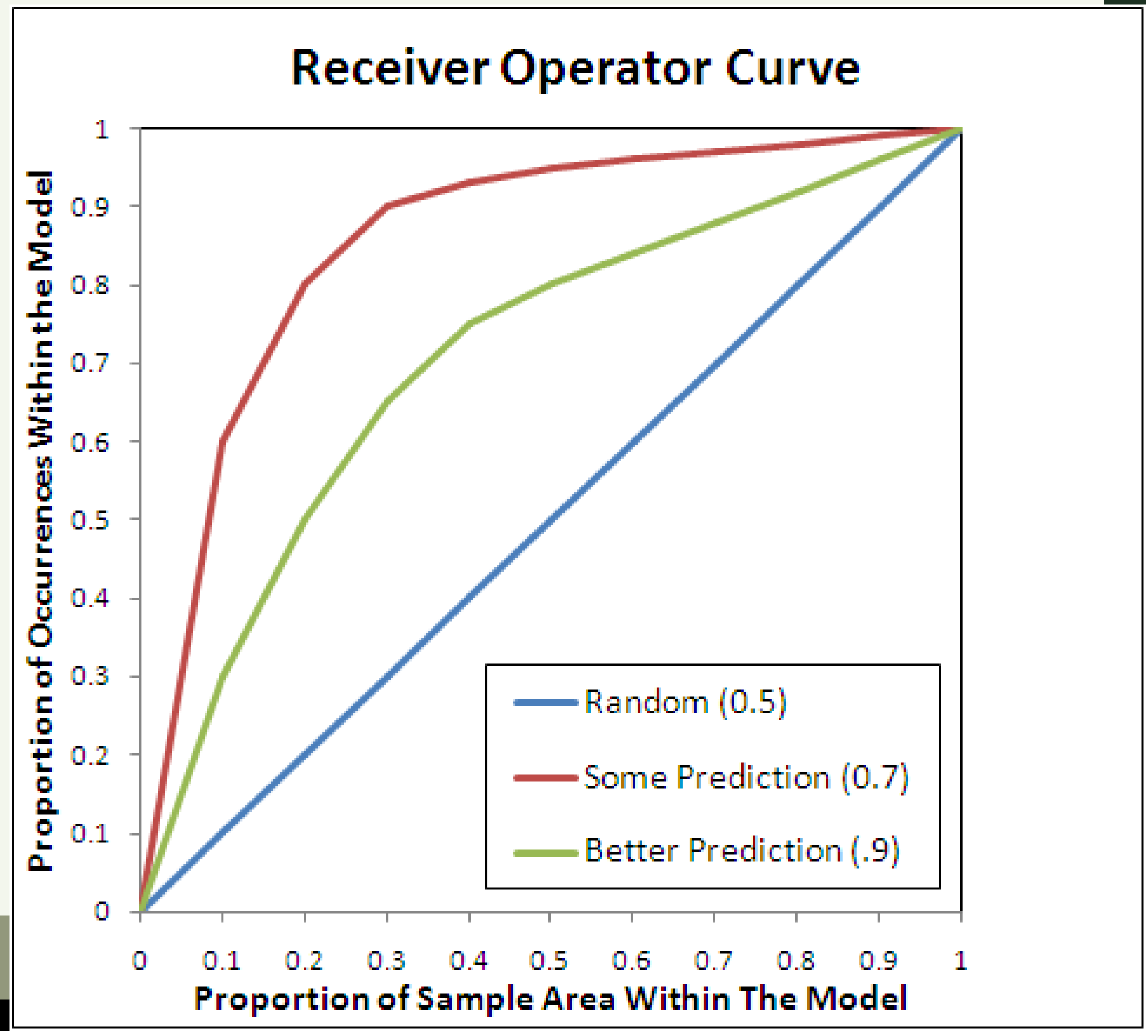
A.
B.
C.
D.
E.
F.
107.0
-231
46.0
3385.
bio12_usethis
bio6_usethis

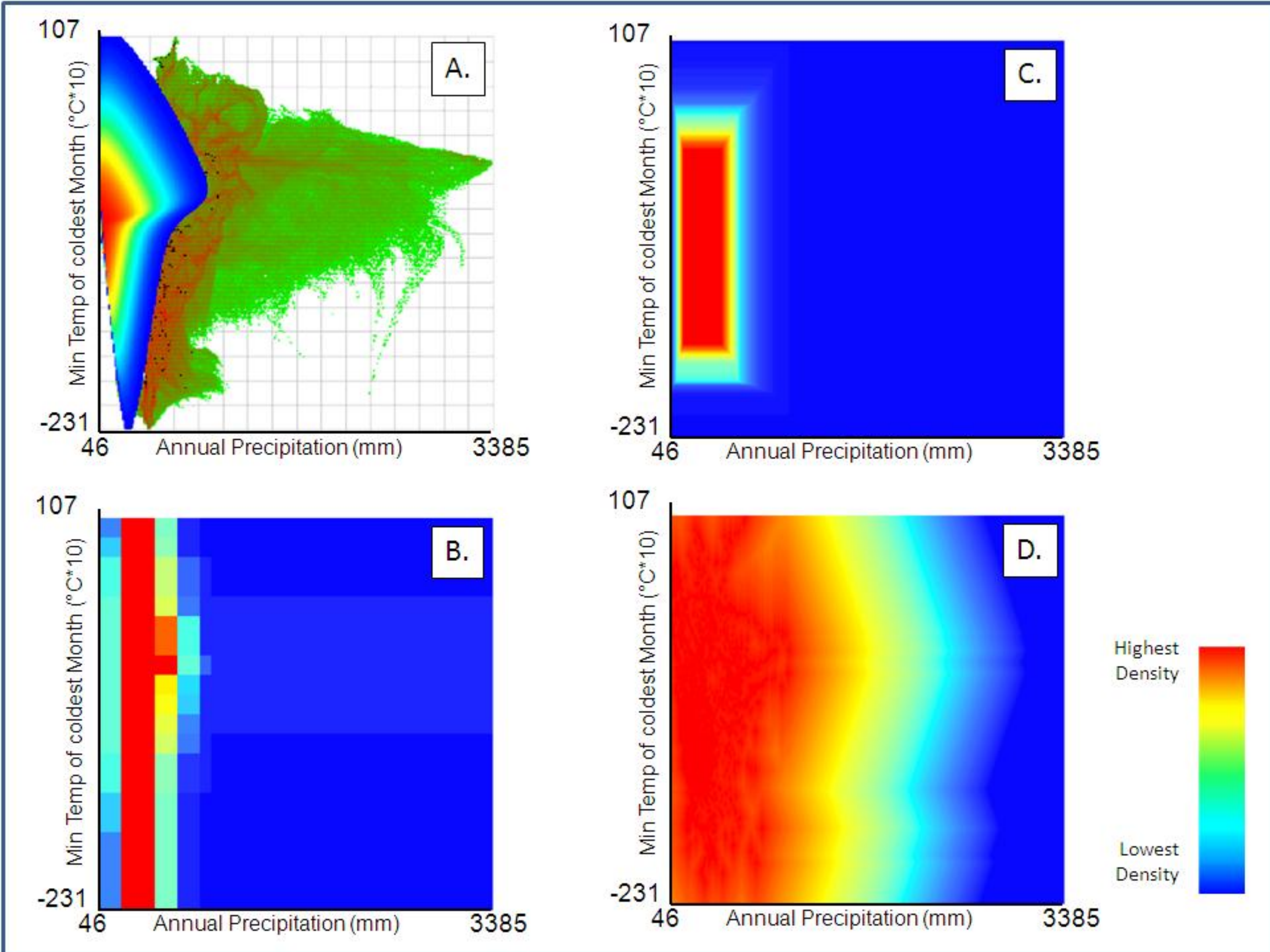
HEMI *Tamarix* Model



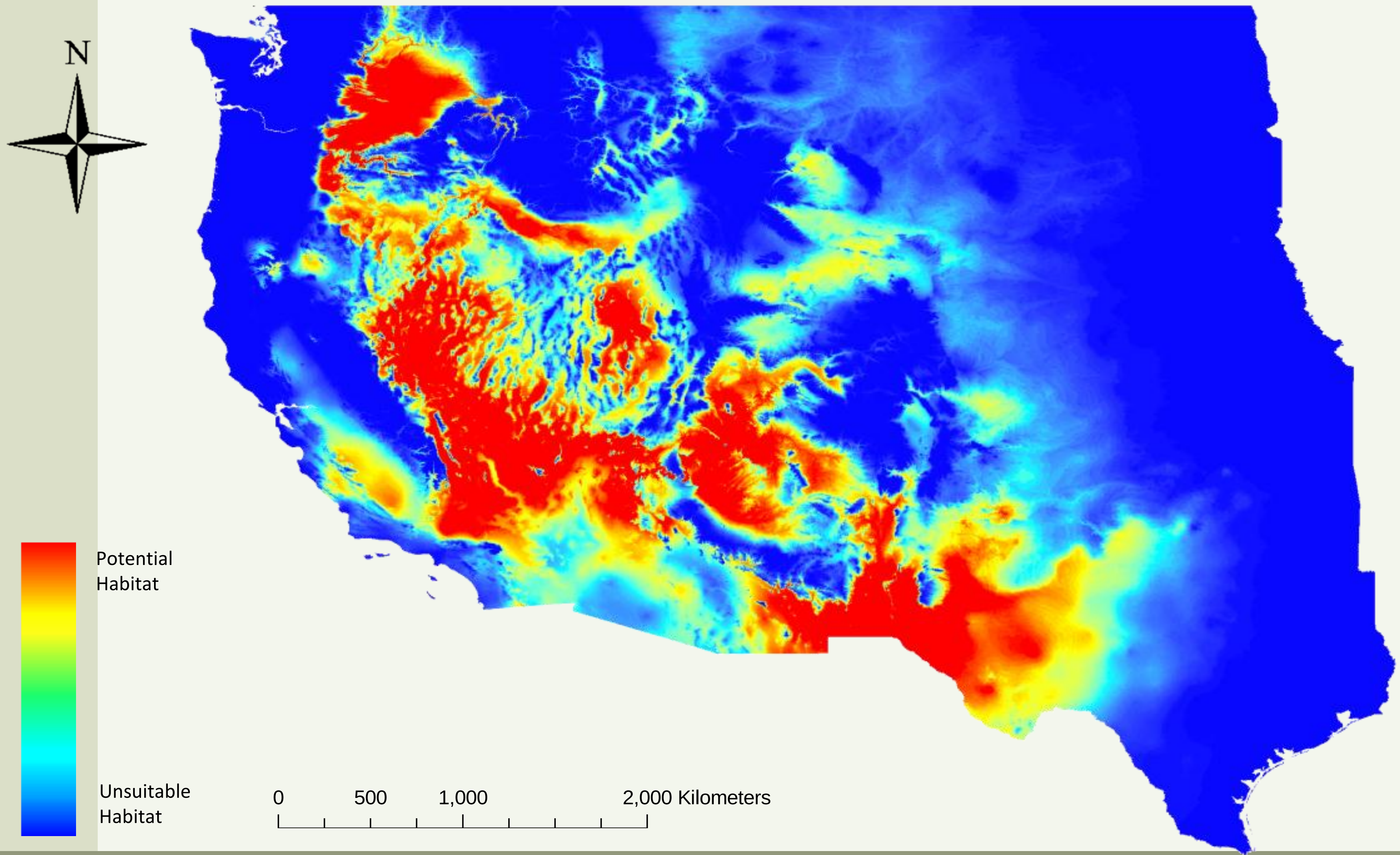
Area Under the Curve Metric

- Area Under the Curve (AUC)
  - 1=Perfect
  - 0=Worthless

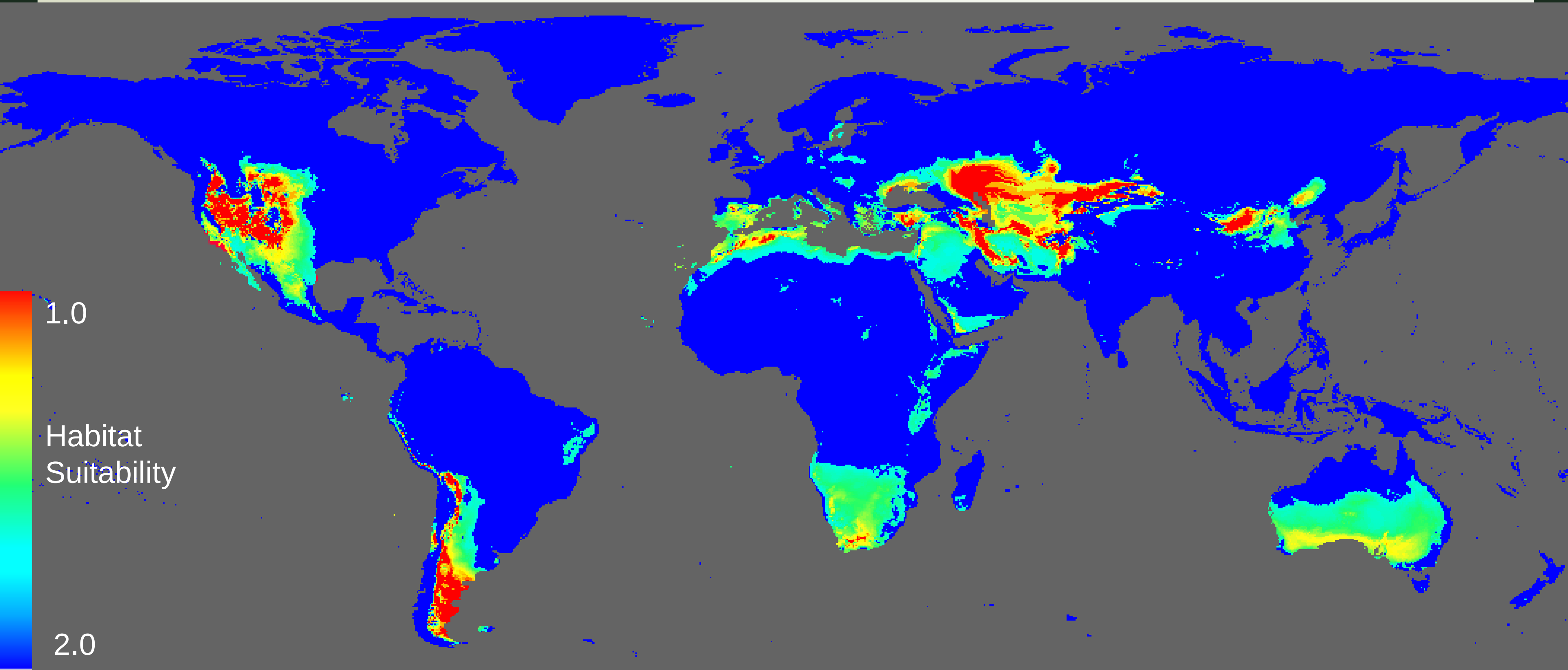



107
-231
46
3385
Min Temp of coldest Month (°C*10)
Annual Precipitation (mm)
A.
B.
C.
D.
Highest Density
Lowest Density

Potential Habitat



Global Tamarisk Map?



Migration Animations

- Jim's web site
  - http://tinyurl.com/6krghts
- Gray whale model
  - http://tinyurl.com/4xtmzho
- Barn swallows

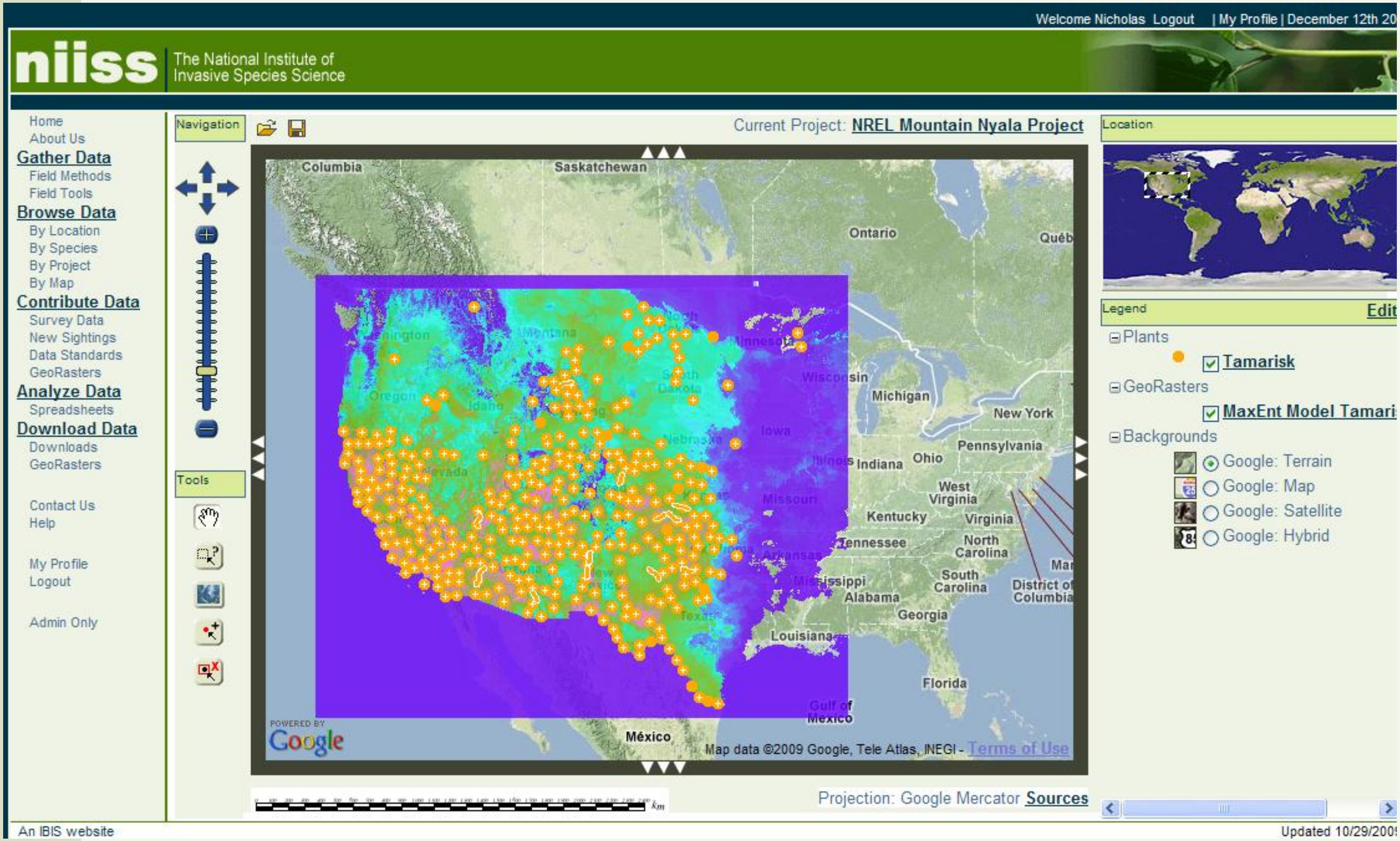
Conclusions

- We can visualize models in environmental space
  - At least in 2 dimensions
- We can build constrained models and edit the models for scenarios
- We can reduce the complexity of the models
- Absence points are not required
- Categorical variables have to be modeled separately for each category

Next Steps

- Characterize a number of species to determine how to constrain the envelopes
- Develop likelihood model to fit Bezier curves?
- Include uncertainty analysis and error surfaces
- Move HEMI to the web?
- More “good” data!

Modeling Online



Acknowledgements

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- Funding: USGS, NASA, NSF, GBIF, NBII
  - NSF Grant #OCI-0636210