

Modeling the Geography of Biodiversity

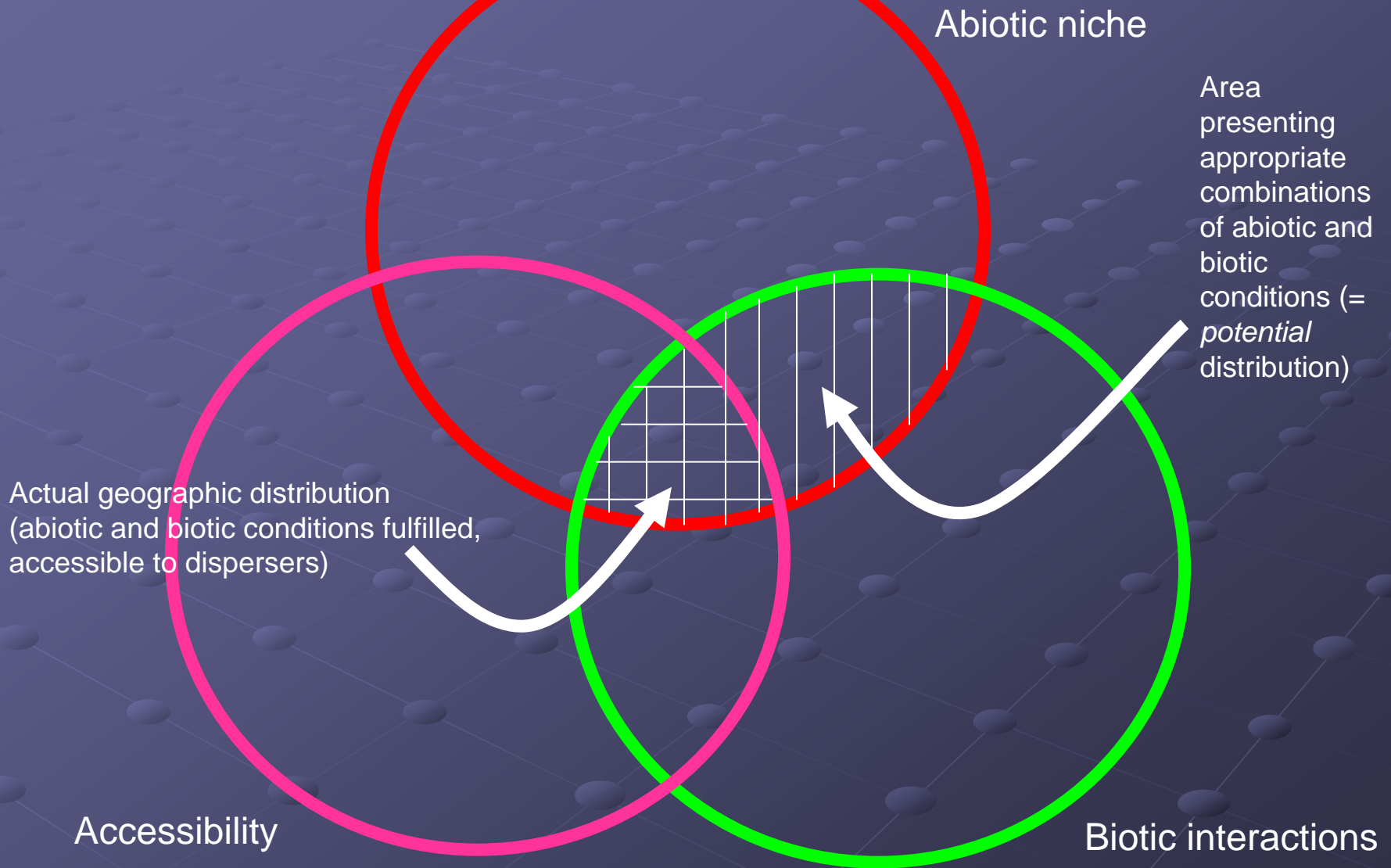
A. Townsend Peterson

University of Kansas Natural History Museum

Why Is A Species Where
It Is

And Why Is It Not Where It Is Not?

The BAM Diagram



G-space		E-space	
Symbol	Name	Symbol	Name
\mathbf{G}_A	Abiotic area. Coincident with A in the BAM diagram	\mathbf{E}_A	Abiotic niche
\mathbf{G}_P	Potential area $\mathbf{G}_P = \mathbf{A} \cap \mathbf{B}$	\mathbf{E}_P	Biotically reduced niche
\mathbf{G}_I	Invadable area $\mathbf{G}_I = \mathbf{A} \cap \mathbf{B} \cap \mathbf{M}^C$	\mathbf{E}_I	Invadable niche space
\mathbf{G}_O	Occupied area $\mathbf{G}_O = \mathbf{A} \cap \mathbf{B} \cap \mathbf{M}$	\mathbf{E}_O	Occupied niche space

Niche Concepts

- Many definitions exist for 'niche' ...
 - I avoid those that are process-oriented (e.g., “the role of species X in its community”)
 - Focus on a more workable definition: “the set of environmental conditions within which a species can maintain populations without immigrational subsidy” (J. Grinnell)
- Grinnellian concept has the advantage of a single focus (environmental conditions)
- Interactive (Eltonian) processes probably act chiefly on finer spatial scales and are not commonly discernable on coarse scales

Species Interactions Important

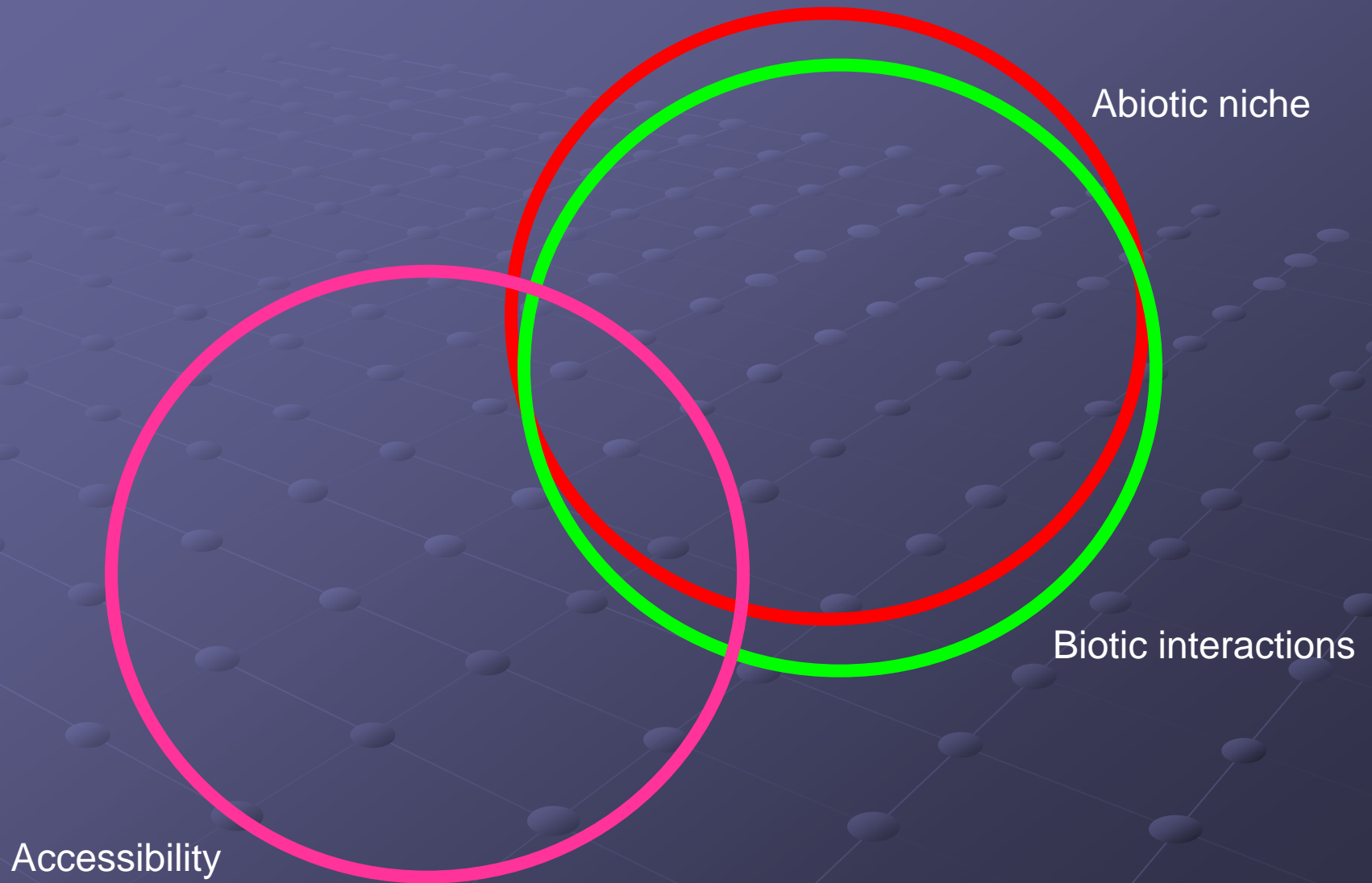


Accessibility

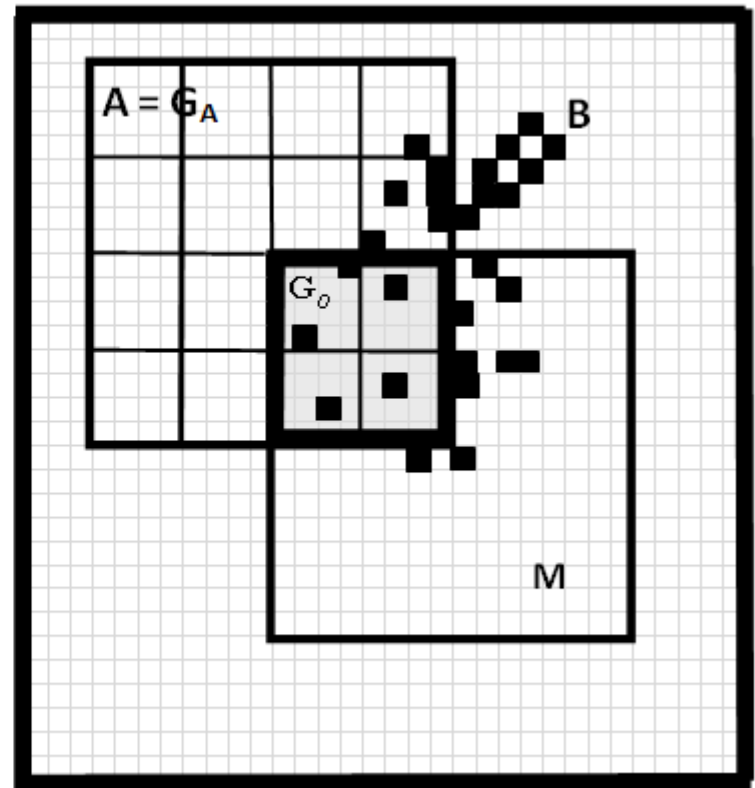
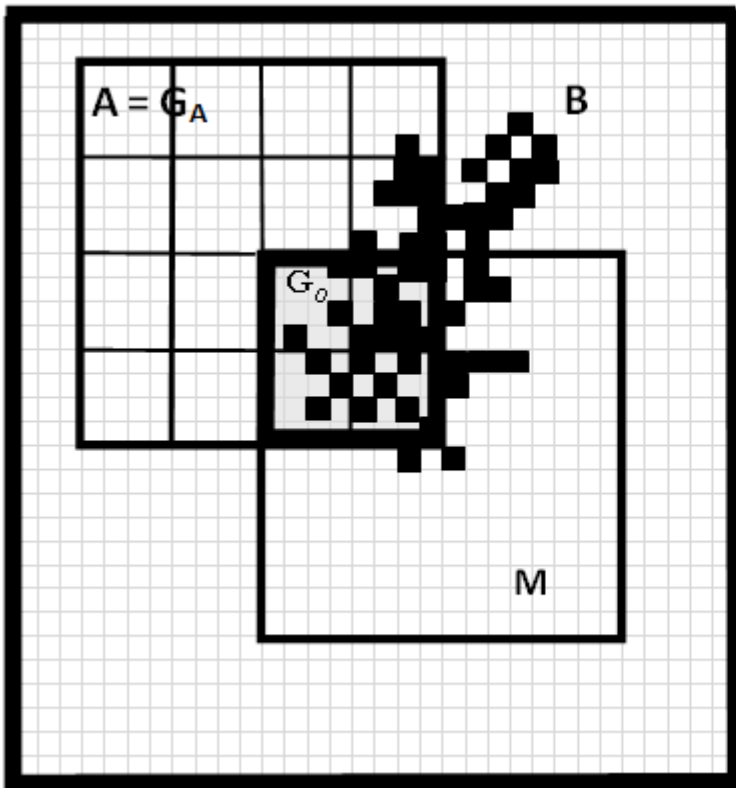
Abiotic niche

Biotic interactions

Species Interactions Unimportant



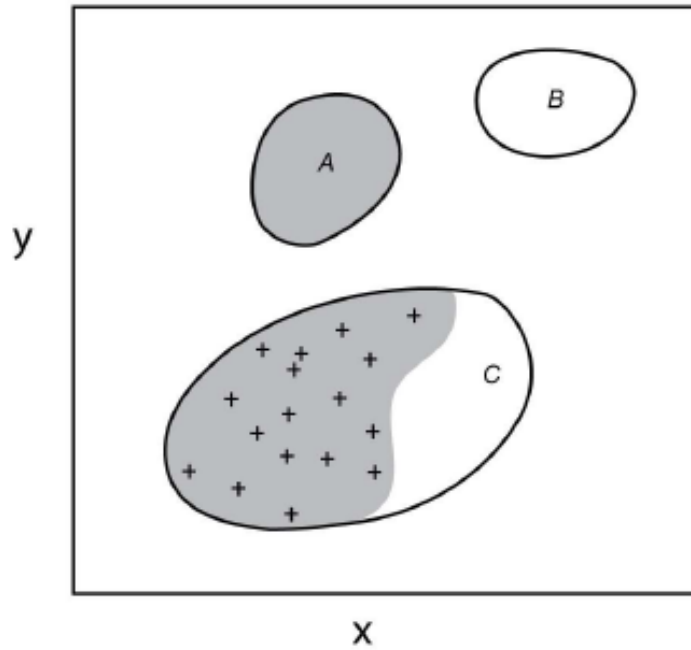
Grinnell vs Elton



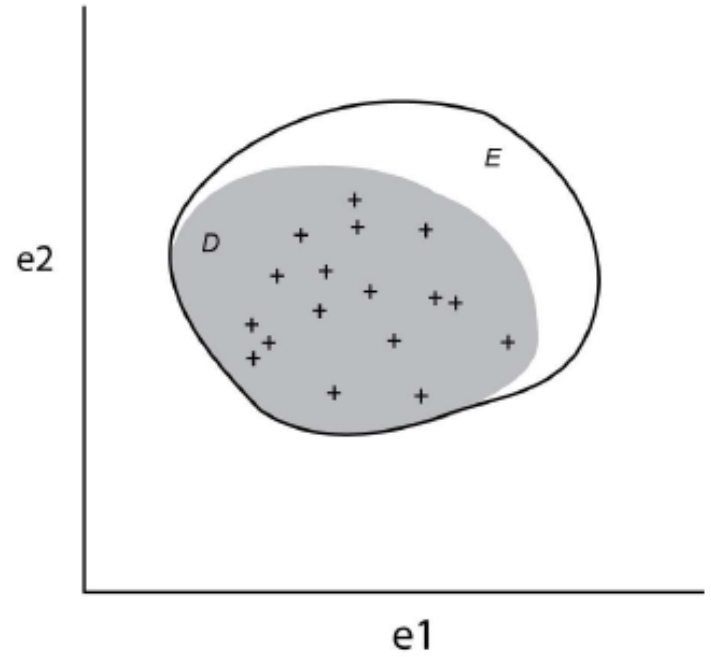
Niche Modeling

- Physiological constraints → Ecological processes → Geographic phenomenon
- As such, geographic phenomena of distributions should be reconstructed in ecological spaces
- Linked spaces, in which there is a one-to-one mapping between elements in G and elements in E
- Modeling best carried out in E

Geographical space



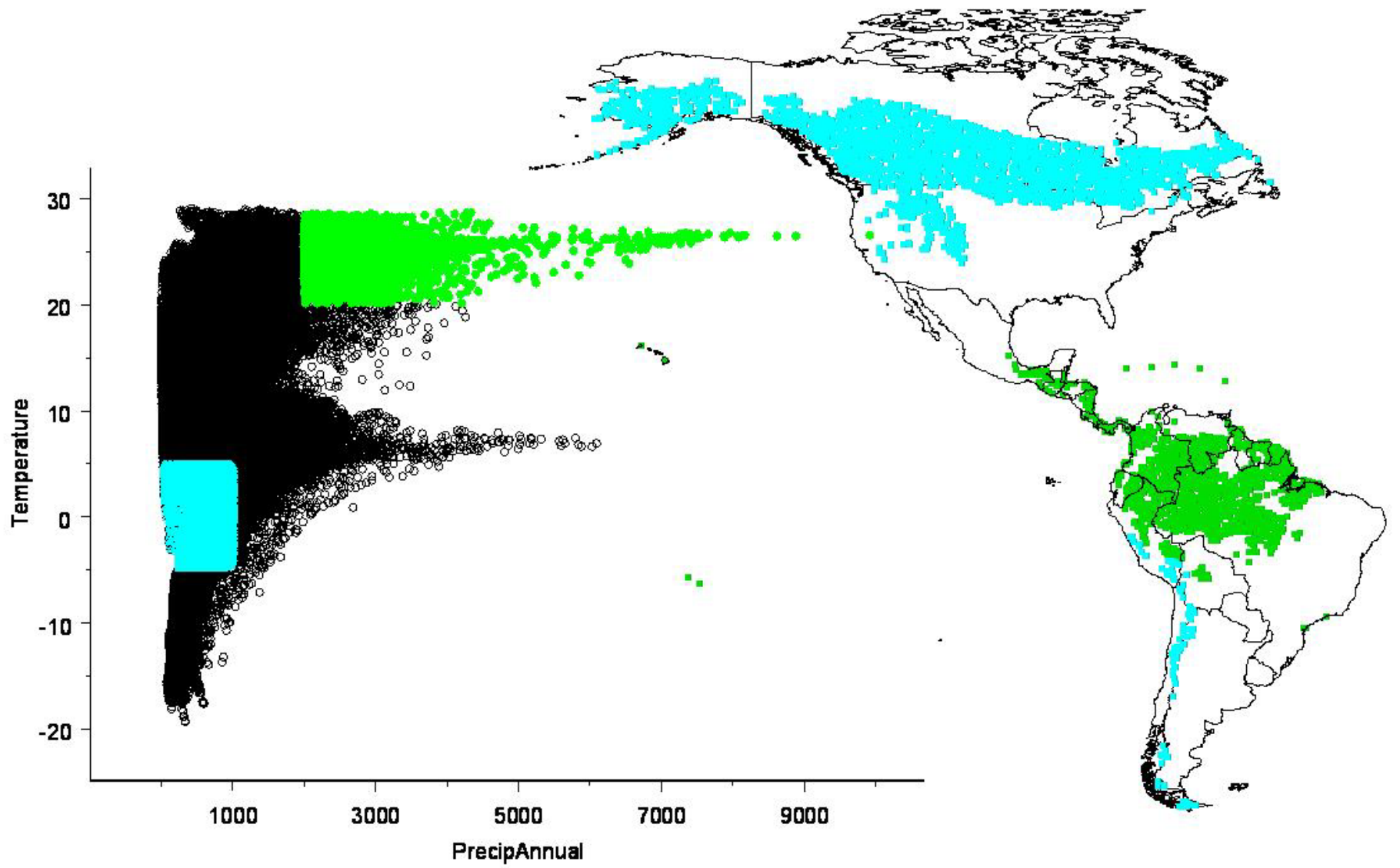
Environmental space



+ Observed species occurrence record

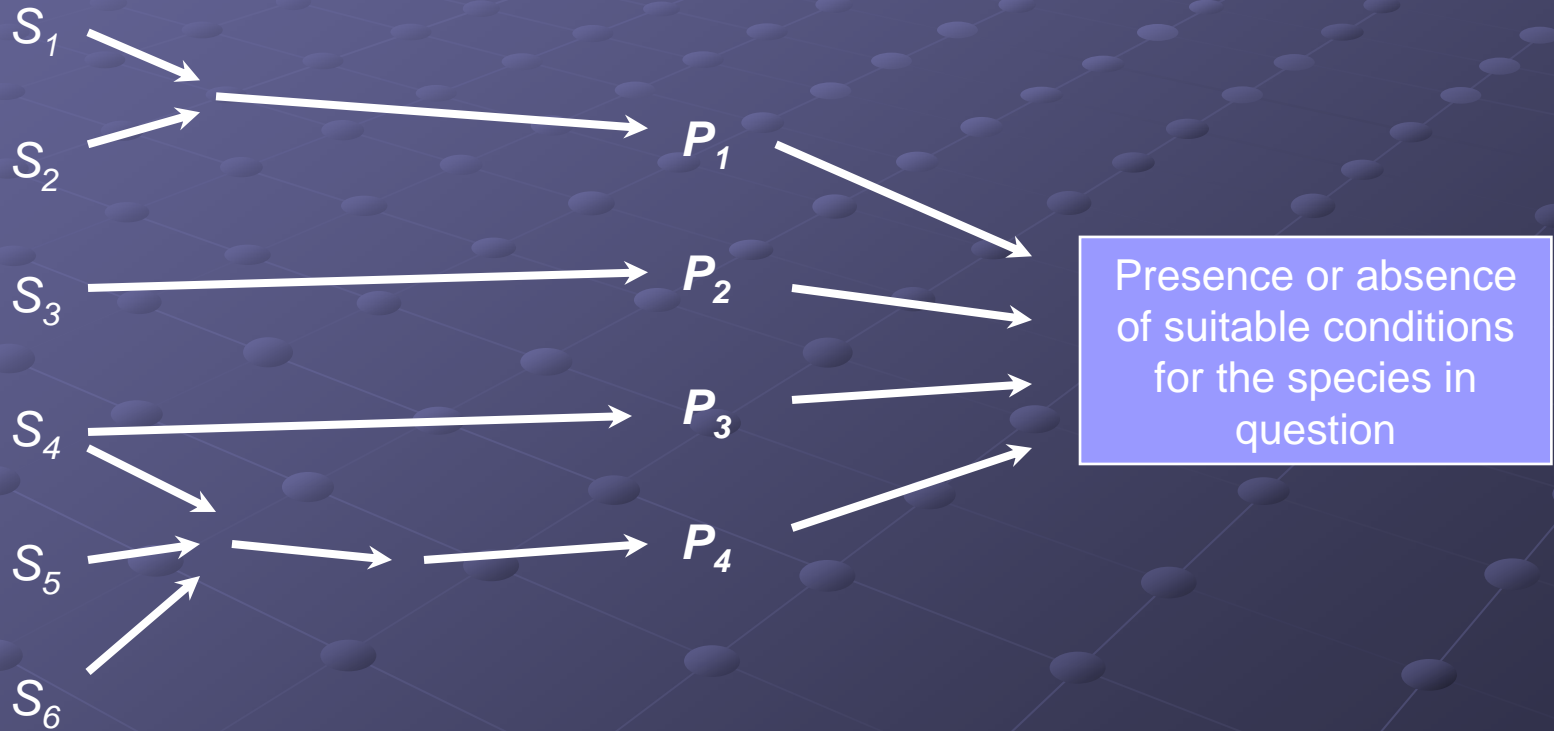
● Actual distribution (left panel)/Occupied niche (right panel)

○ Potential distribution (left panel)/Fundamental niche (right panel)

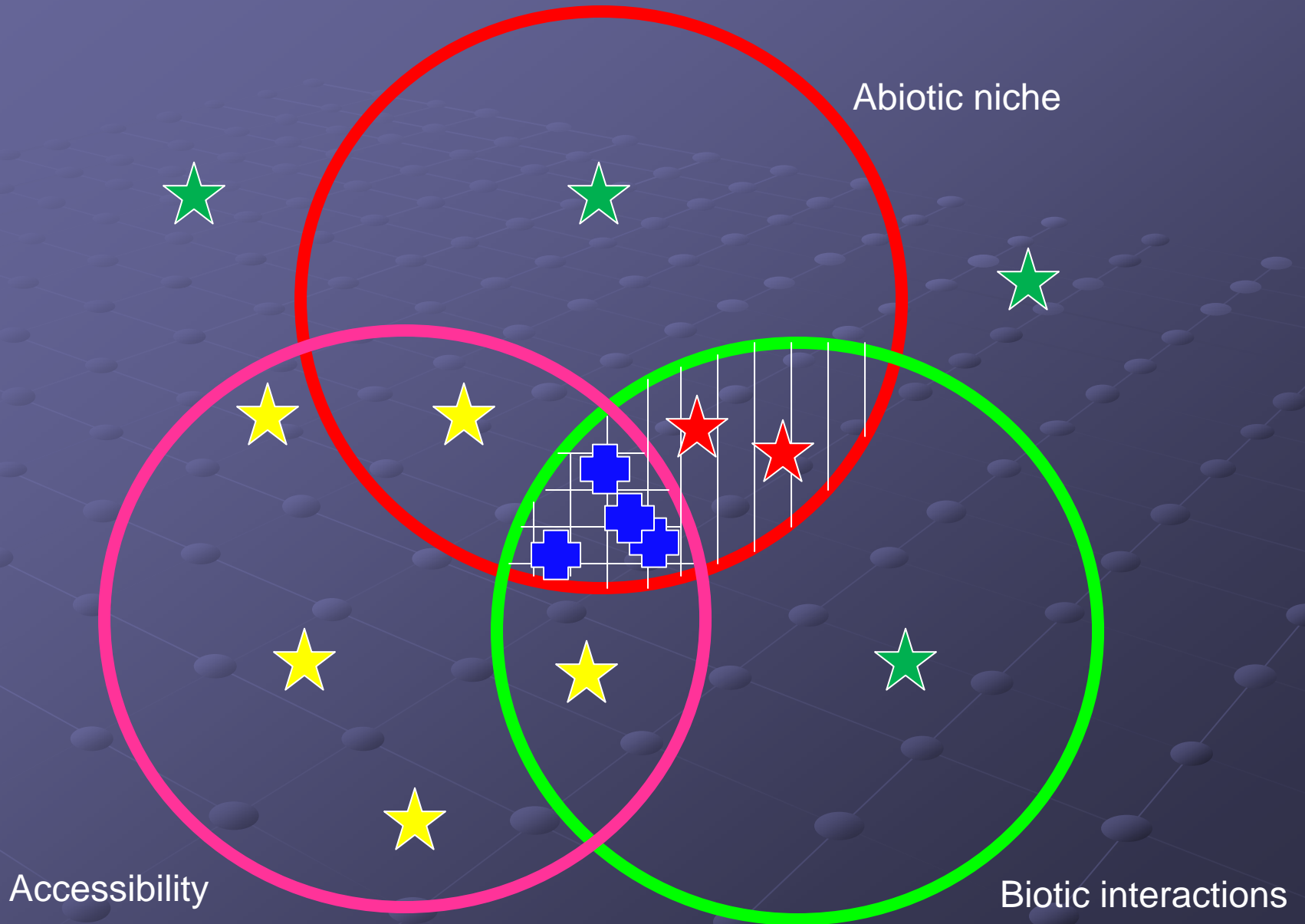


Easy-to-measure
variables
(scenopoetic)

Proximate
variables
(scenopoetic
and/or
bionomic)



Absence Data

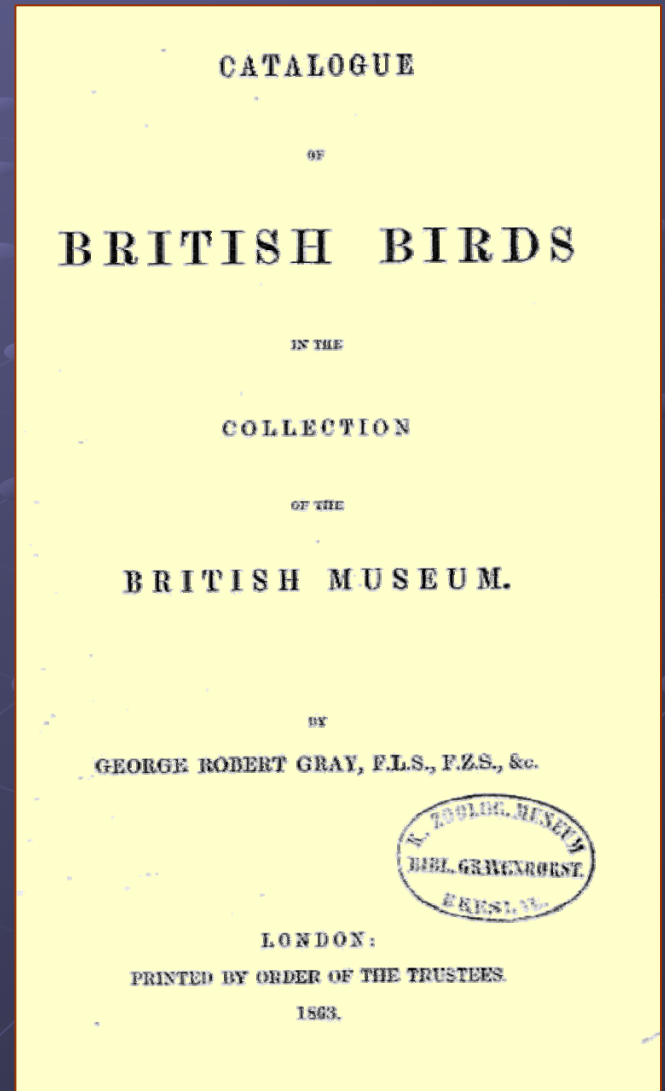


THE PAST...HOUSING DATA



Oriolus Maderaspatanus Jas. Franklin, 1831.
Proc. Comm. of Science and Correspondence of the Zool. Soc. London, pt. I, no. X, Oct. 25, 1831, 118.
(Allied to)

on Ganges,
Colln. made betw. Calcutta + Benares, + in Hind-
lyian hills, betw. Benares + Gurrak Mundela on the
Type locality: Nerbudda.
Type: Zool. Soc. Colln., Jas. Franklin.



THE PAST ... RETREIVING DATA



XEROX.



THE PAST...CENTRALIZED DATA BASES

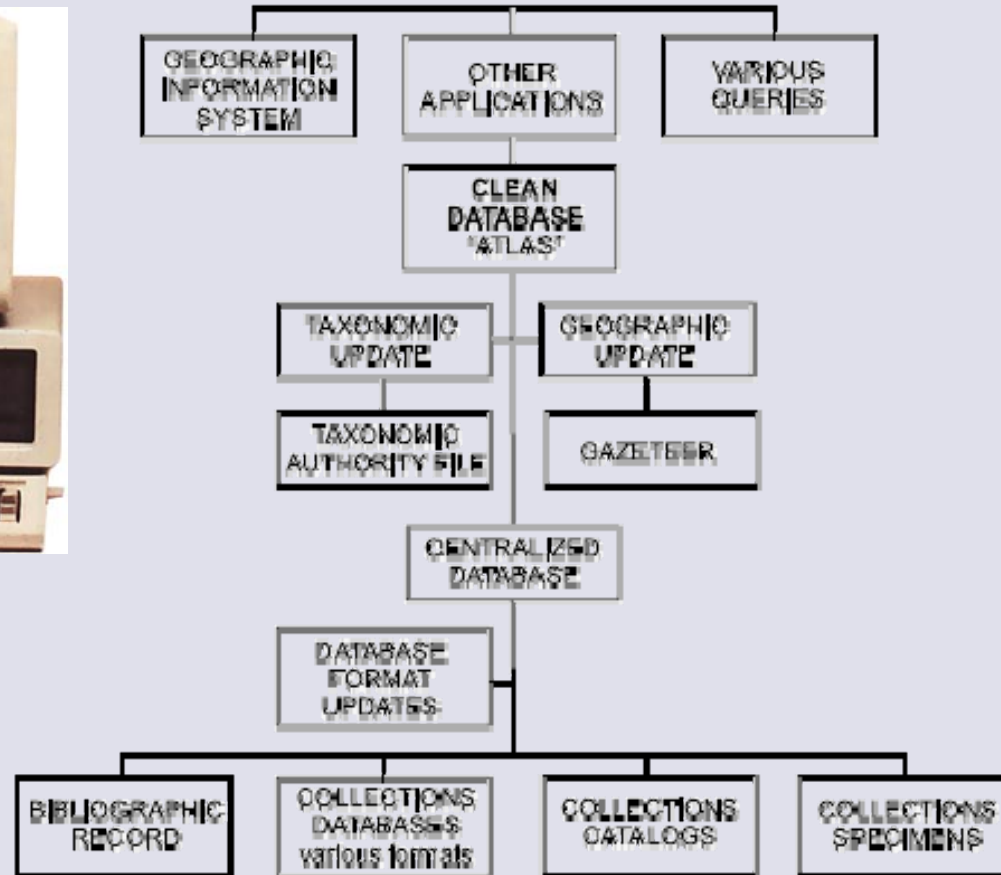
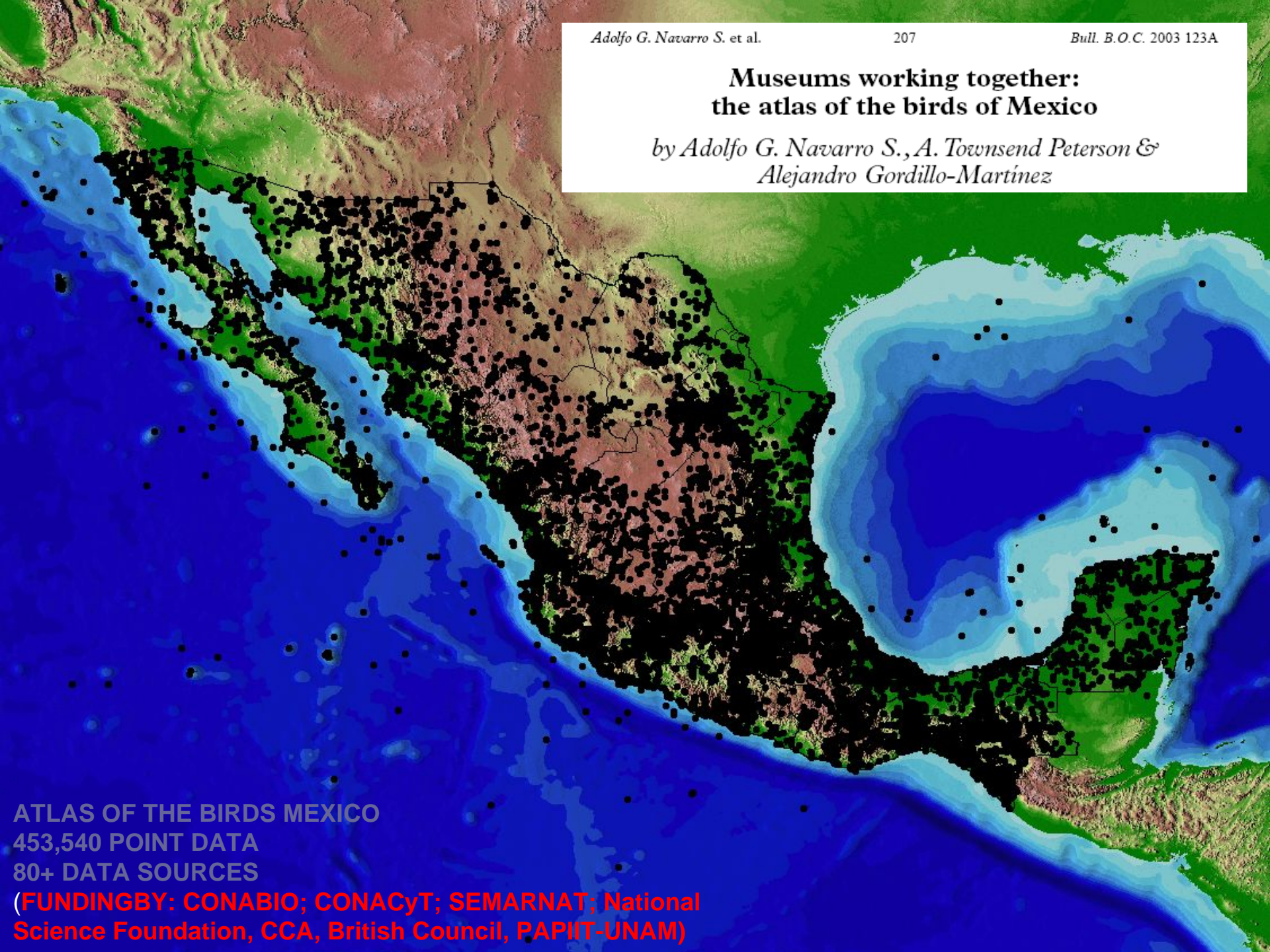


Figure 1. Sources and information flux in the Atlas database: raw data input is shown at the bottom, and updated and edit ascending in the middle; the resulting clean database and applications are shown at the top.

Museums working together: the atlas of the birds of Mexico

*by Adolfo G. Navarro S., A. Townsend Peterson &
Alejandro Gordillo-Martínez*



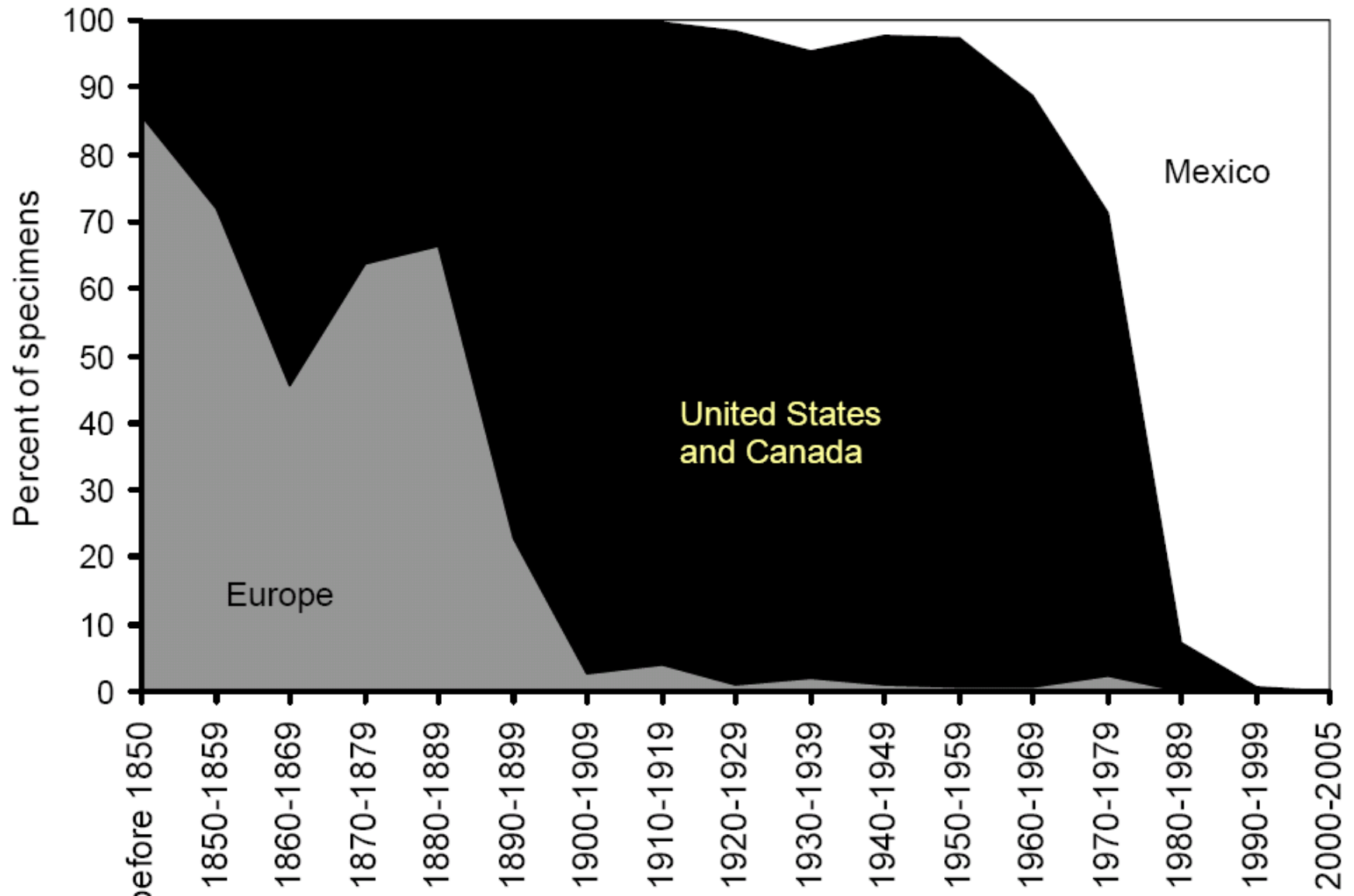
ATLAS OF THE BIRDS MEXICO

453,540 POINT DATA

80+ DATA SOURCES

**(FUNDINGBY: CONABIO; CONACyT; SEMARNAT; National
Science Foundation, CCA, British Council, PAPIIT-UNAM)**

Summary of country of deposition of Mexican bird specimens, as a function of time.



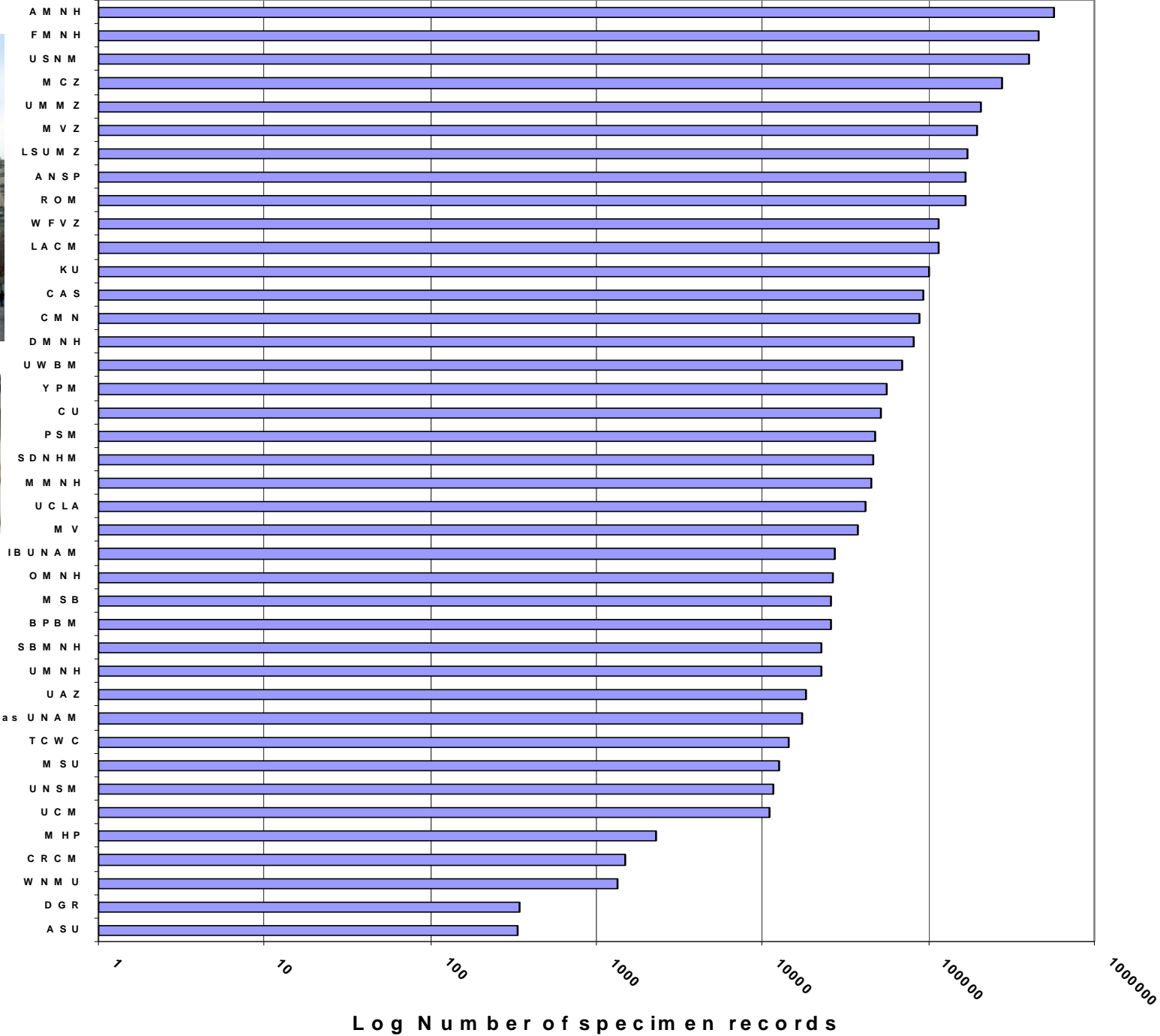
DISTRIBUTED DATABASES

ORNIS is one of many local and global initiatives to improve access to biodiversity data that are housed in museum collections
(3 billion specimens, 2-30 million species)
and other data sources





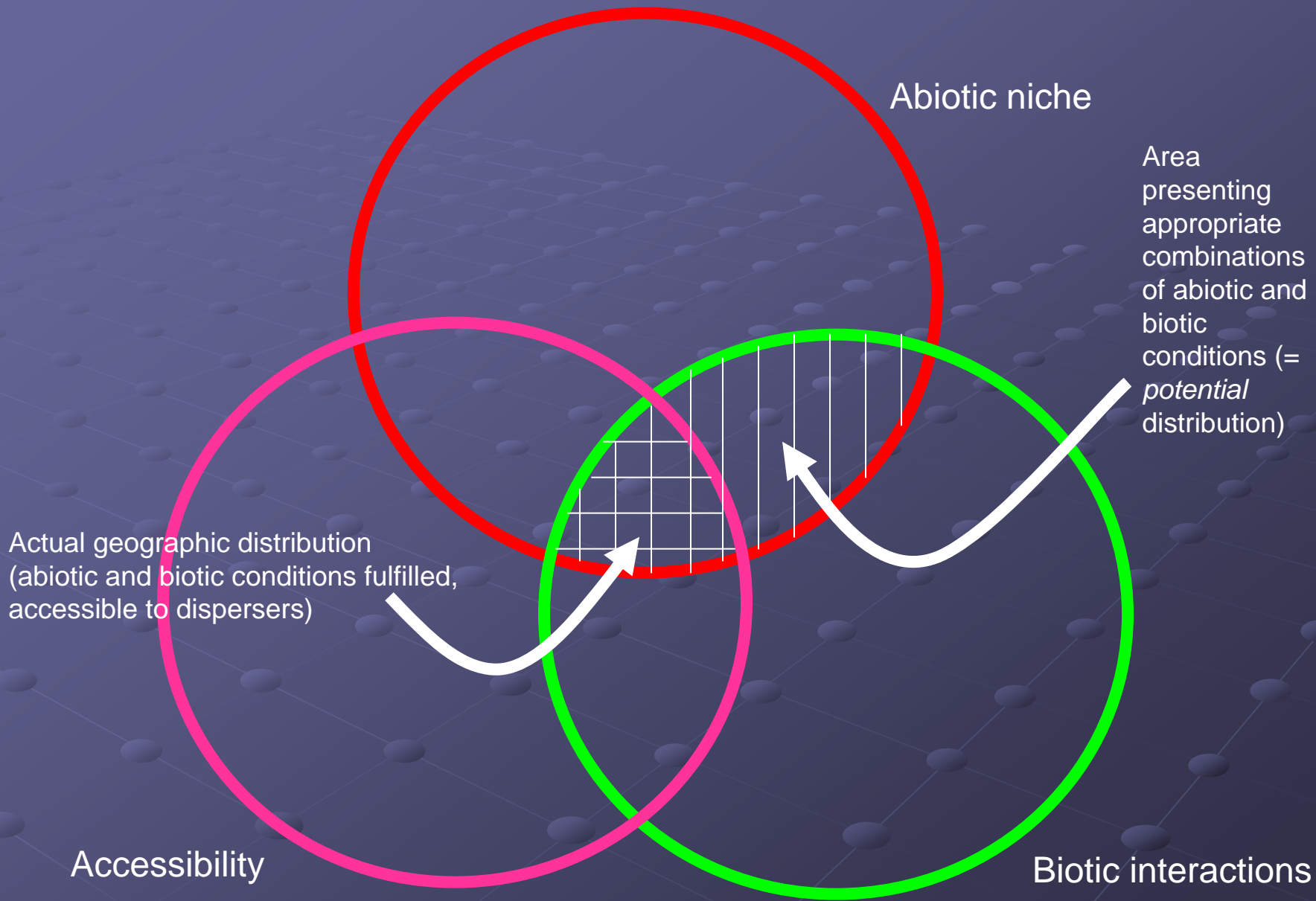
Facultad de Ciencias



SP
IN

Brazil in ORNIS

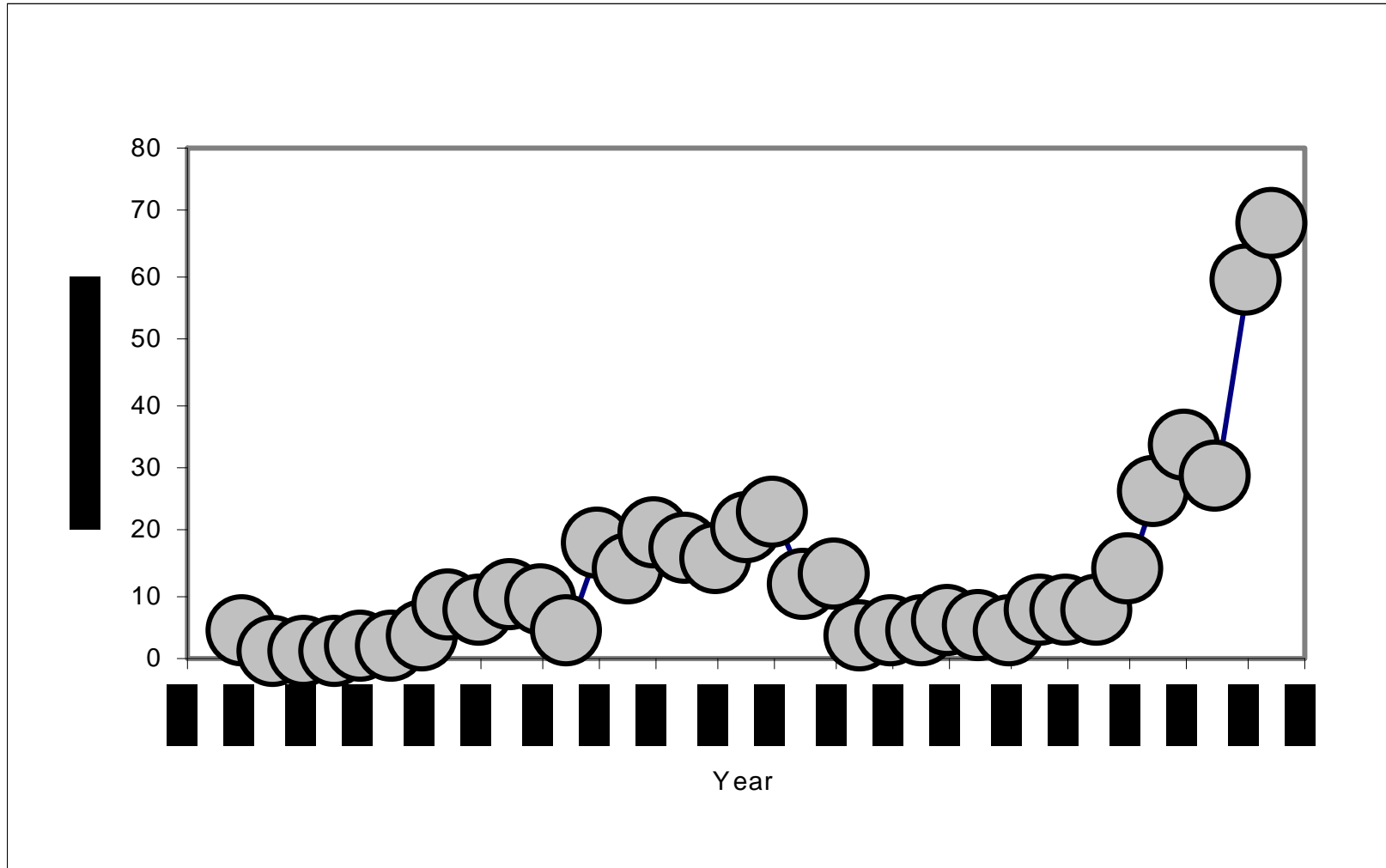
University of Washington Burke Museum - Bird Specimens	0	0
Museum of Vertebrate Zoology (MVZ) - Terrestrial vertebrate specimens	10	287
Louisiana State University Museum of Natural Science (LSUMZ) - Bird specimens	10	3327
Los Angeles County Museum of Natural History (LACM) - Vertebrate specimens	10	10862
Cornell University Museum of Vertebrates (CUMV) - Bird Collection	10	230
Borrer Laboratory of Bioacoustics (BLB) - Borrer Laboratory of Bioacoustics	10	71
Delaware Museum of Natural History - Delaware Museum of Natural History Bird Collection	10	13
Canadian Museum of Nature - Canadian Museum of Nature Bird Collection	0	0
Yale University Peabody Museum - Ornithology DiGIR provider Service	10	5396
University of Kansas Biodiversity Research Center - Bird Collection	10	1060
Michigan State University Museum (MSUM) - Vertebrate specimens	10	29
California Academy of Sciences (CAS) - CAS Bird Collection Catalog	10	91
Academy of Natural Sciences - ORN	10	2864
Royal Ontario Museum - Bird specimens	10	606
Western Foundation of Vertebrate Zoology (WFVZ) - Avian specimens	10	124
University of Michigan Museum of Zoology (UMMZ) - Bird specimens	10	1408
MCZ-Harvard University Provider - MCZ Ornithology Collection	10	10946
National Museum of Natural History, Smithsonian Institution - NMNH Vertebrate Zoology Birds Collections	10	9640
Field Museum - Birds specimens	10	16134
Totals	170	63088



ENM Potential

- Characterize ecological needs of species
- Interpolate between sampling points to predict full distribution
- Predict into broadly unsampled areas to anticipate distribution
- Predict invasive potential in other regions and on other continents
- Predict likely distributional change with changing land use
- Predict likely distributional change with changing climates
- Build scenarios for unknown disease behavior

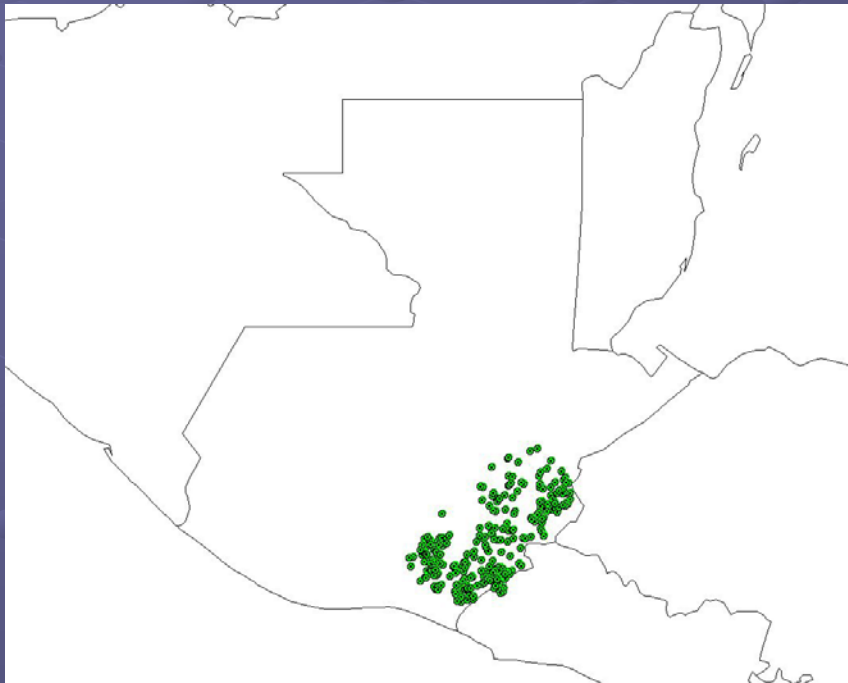
ENM Publications



A 3D grid of spheres on a blue background. The spheres are arranged in a regular, repeating pattern, creating a perspective effect that recedes into the distance. The background is a solid, dark blue color.

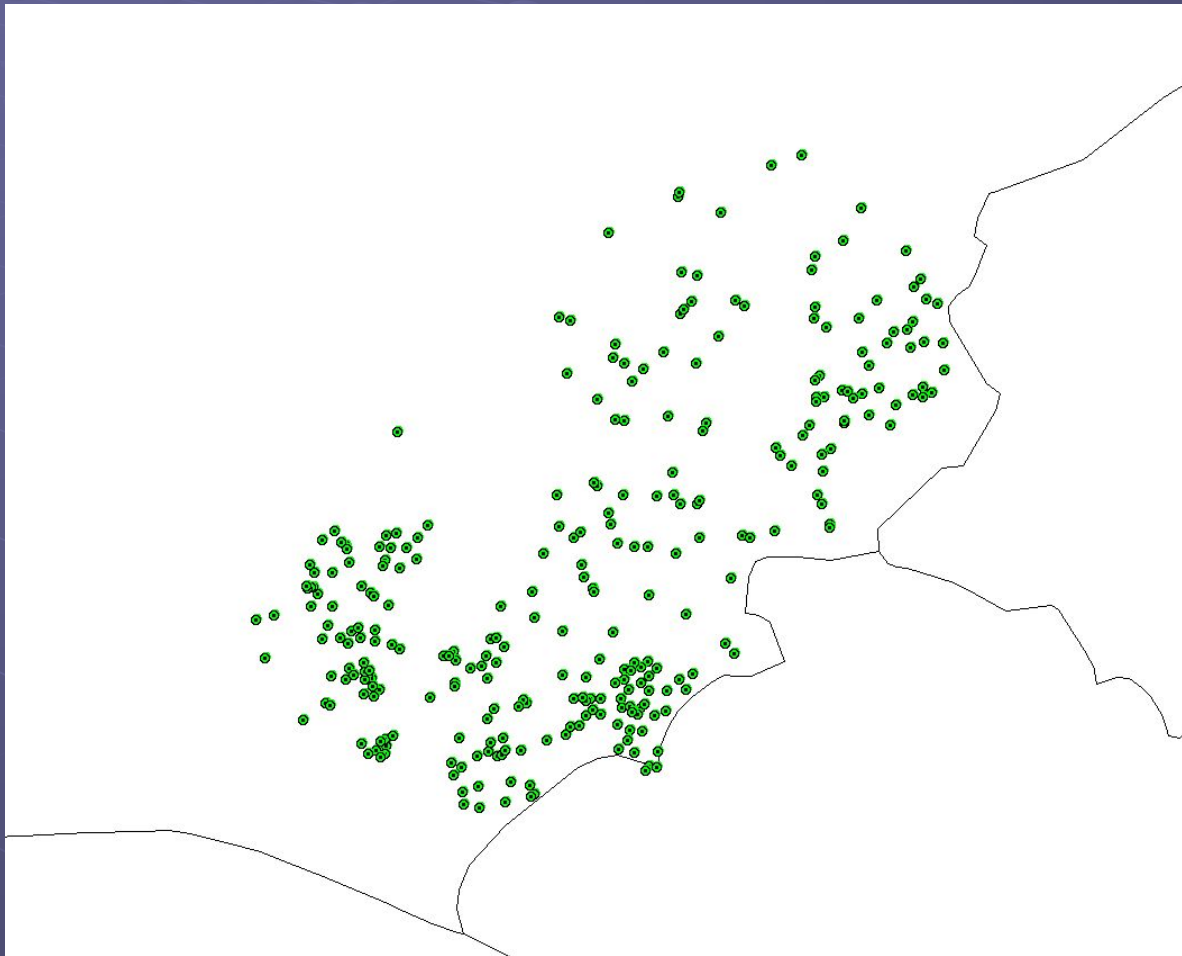
Applications I: Chagas Disease Vector Distributions in Guatemala

Mal de Chagas en Guatemala: *Triatoma dimidiata*

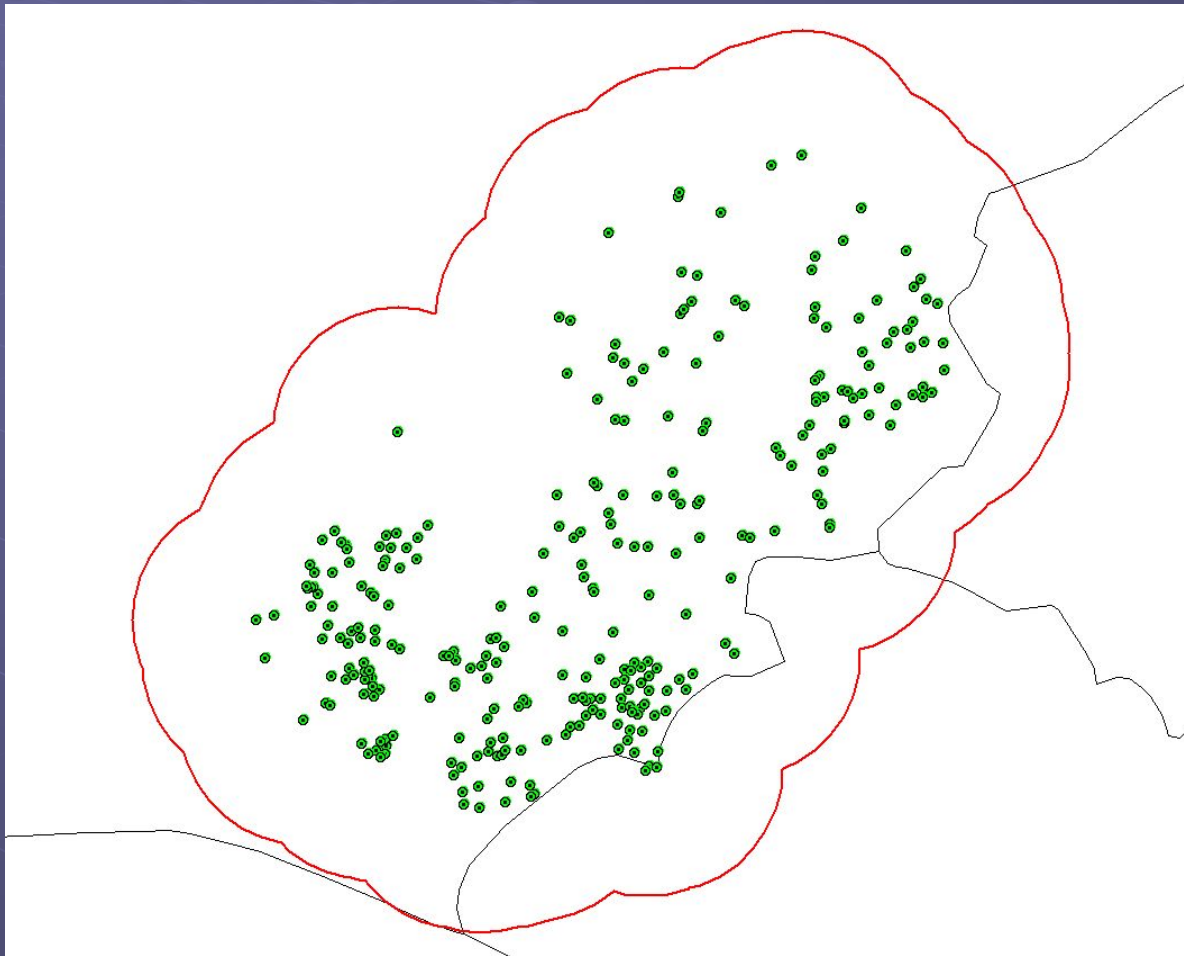


En colaboración con Celia Cordon Rosales (MERTU/Universidad del Valle, Guatemala)
Janine Ramsey (Instituto Nacional de Salud Publica, Mexico)

Acercamiento del área muestreada

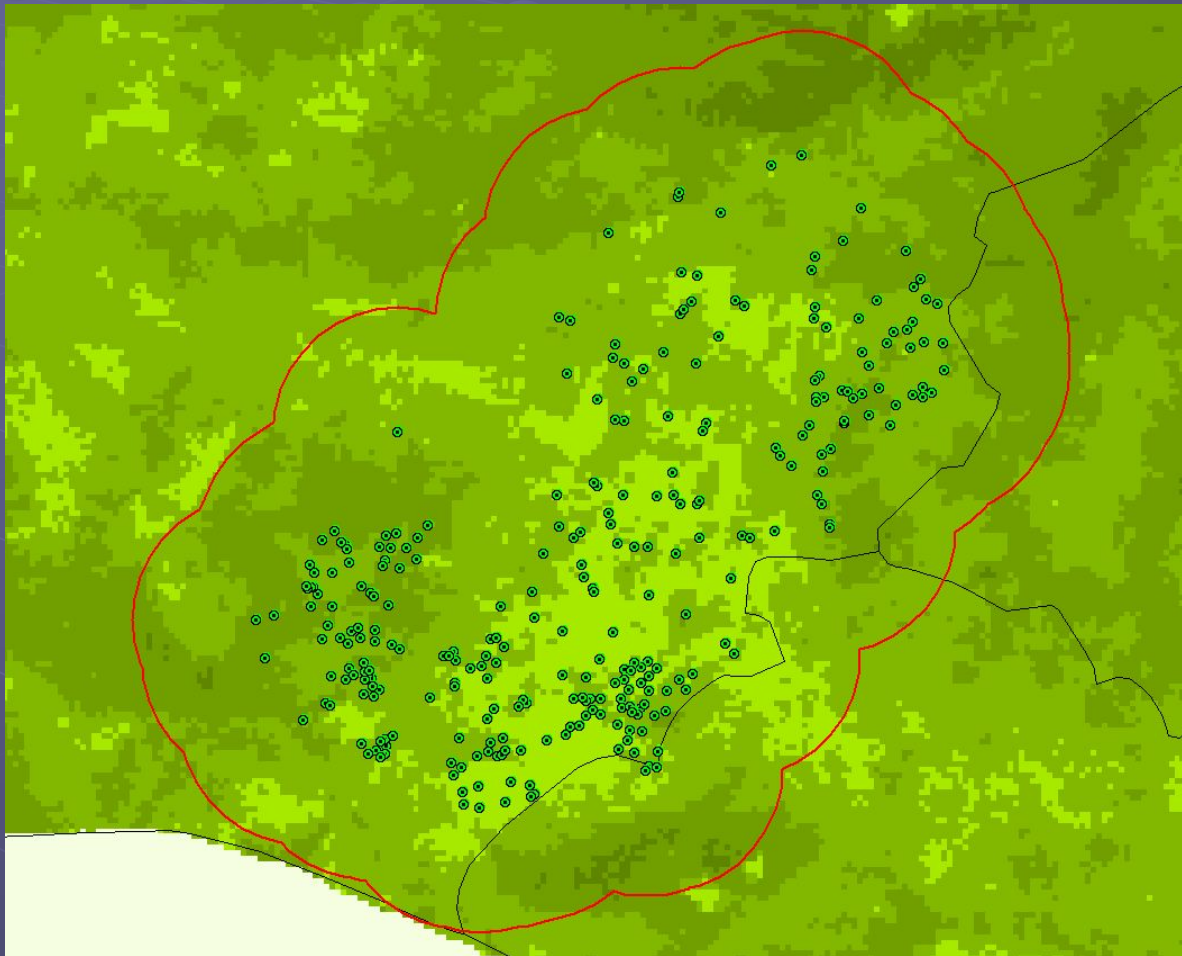


Área Buffer muestreada en círculos de 25 km



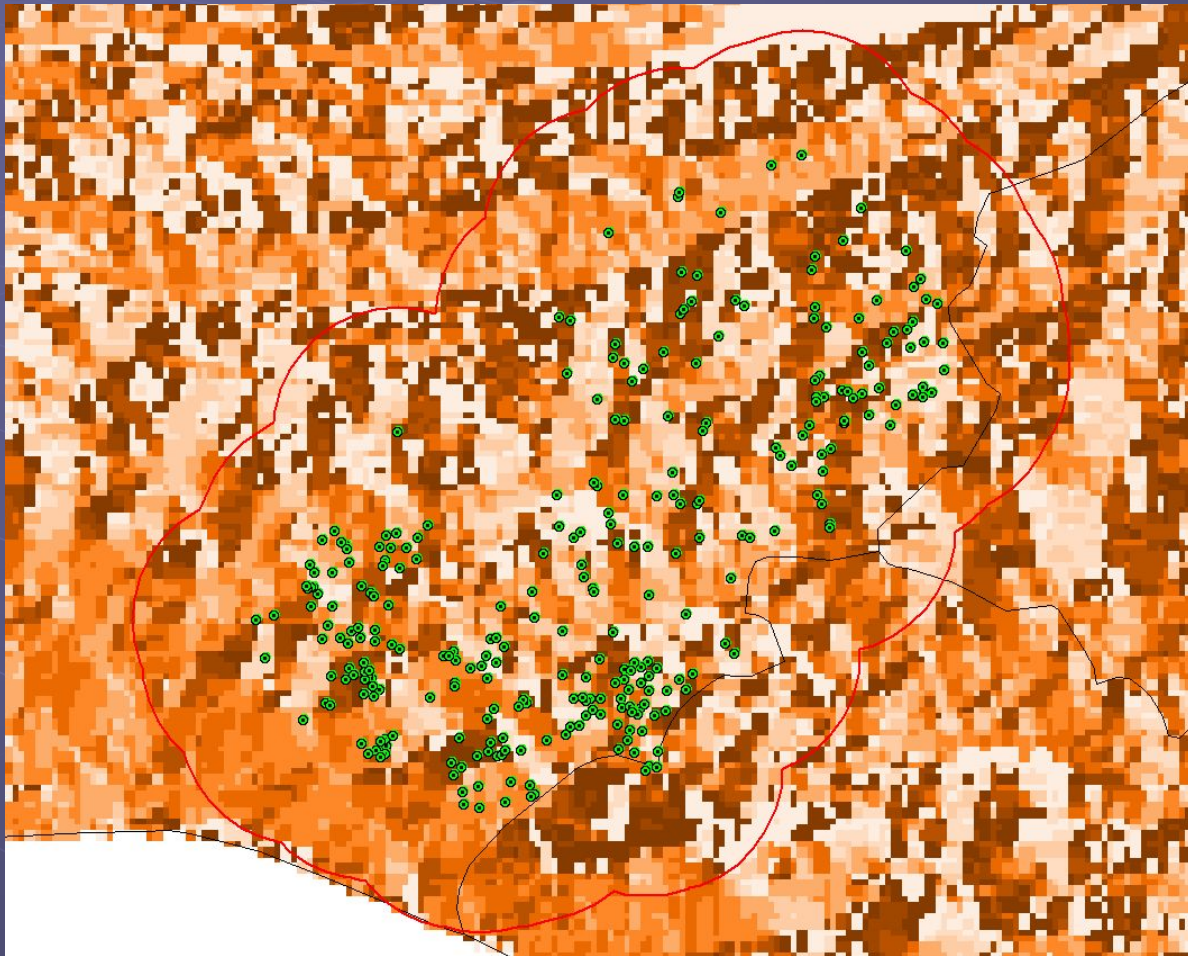
Datos ambientales usados – AVHRR NDVI Data Layer

The Normalized Difference Vegetation Index (NDVI), which is related to the proportion of photosynthetically absorbed radiation, is calculated from atmospherically corrected [reflectances](#) from the visible and near infrared AVHRR

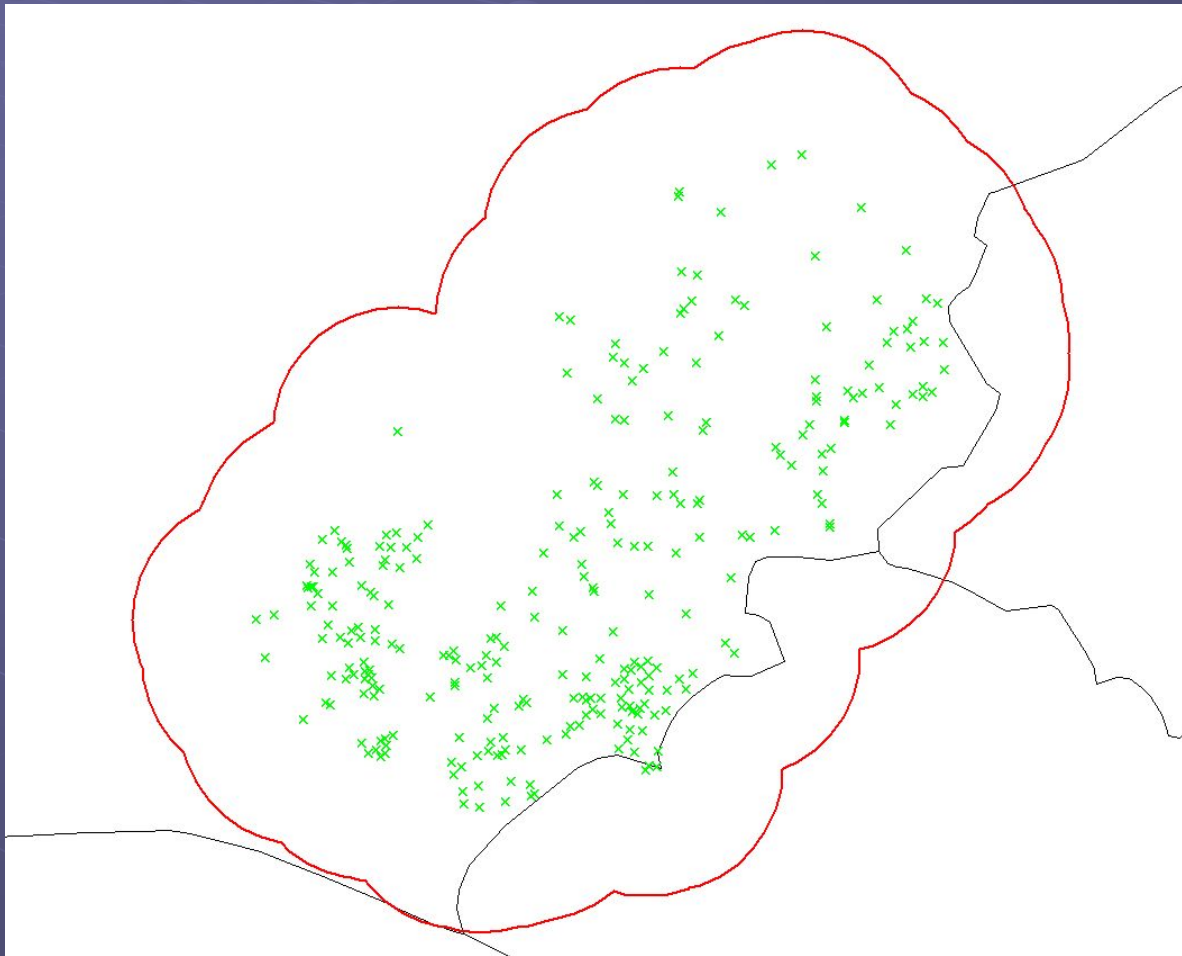


Advanced Very High Resolution Radiometer

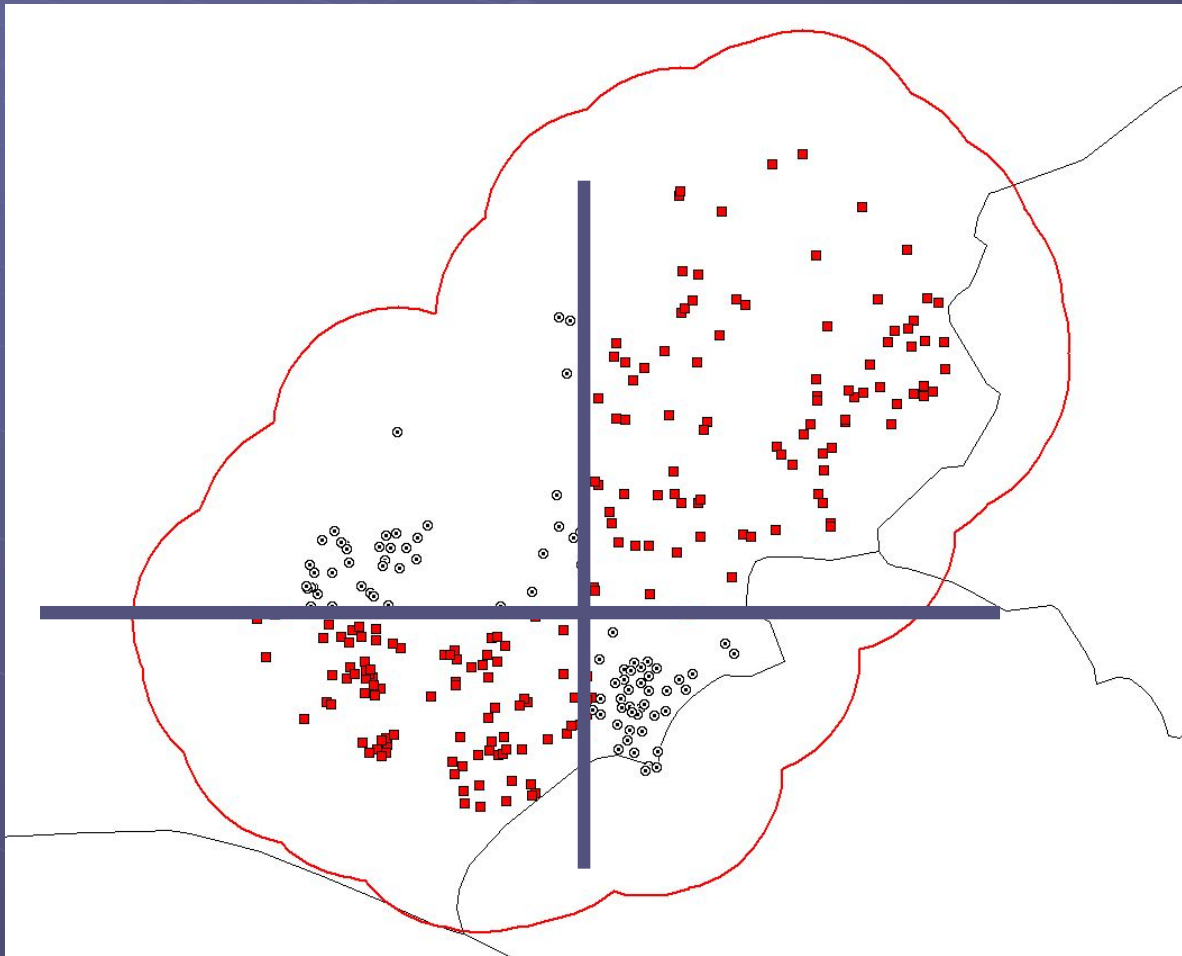
Datos ambientales usados— Vertiente



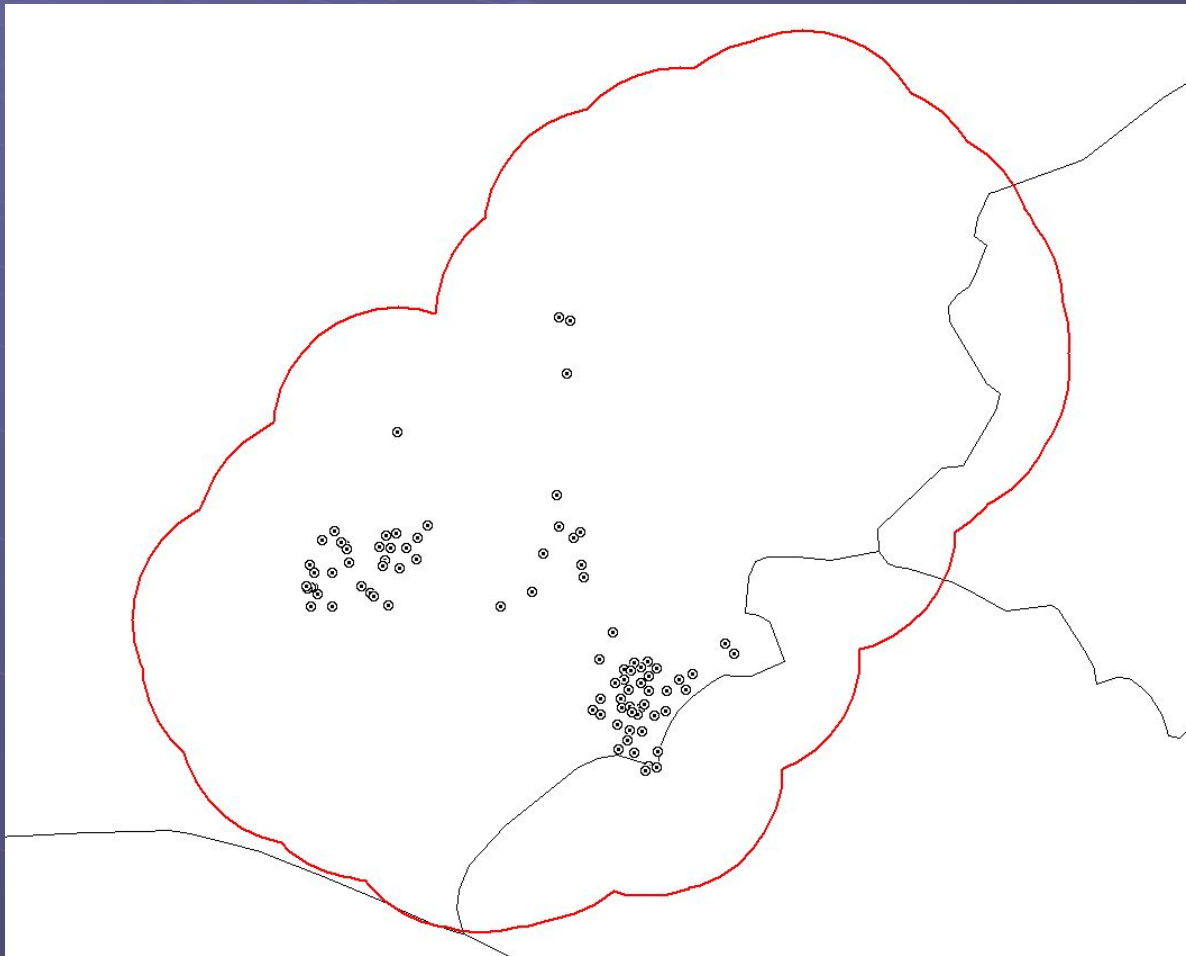
Ocurrencias conocidas – *Triatoma dimidiata*



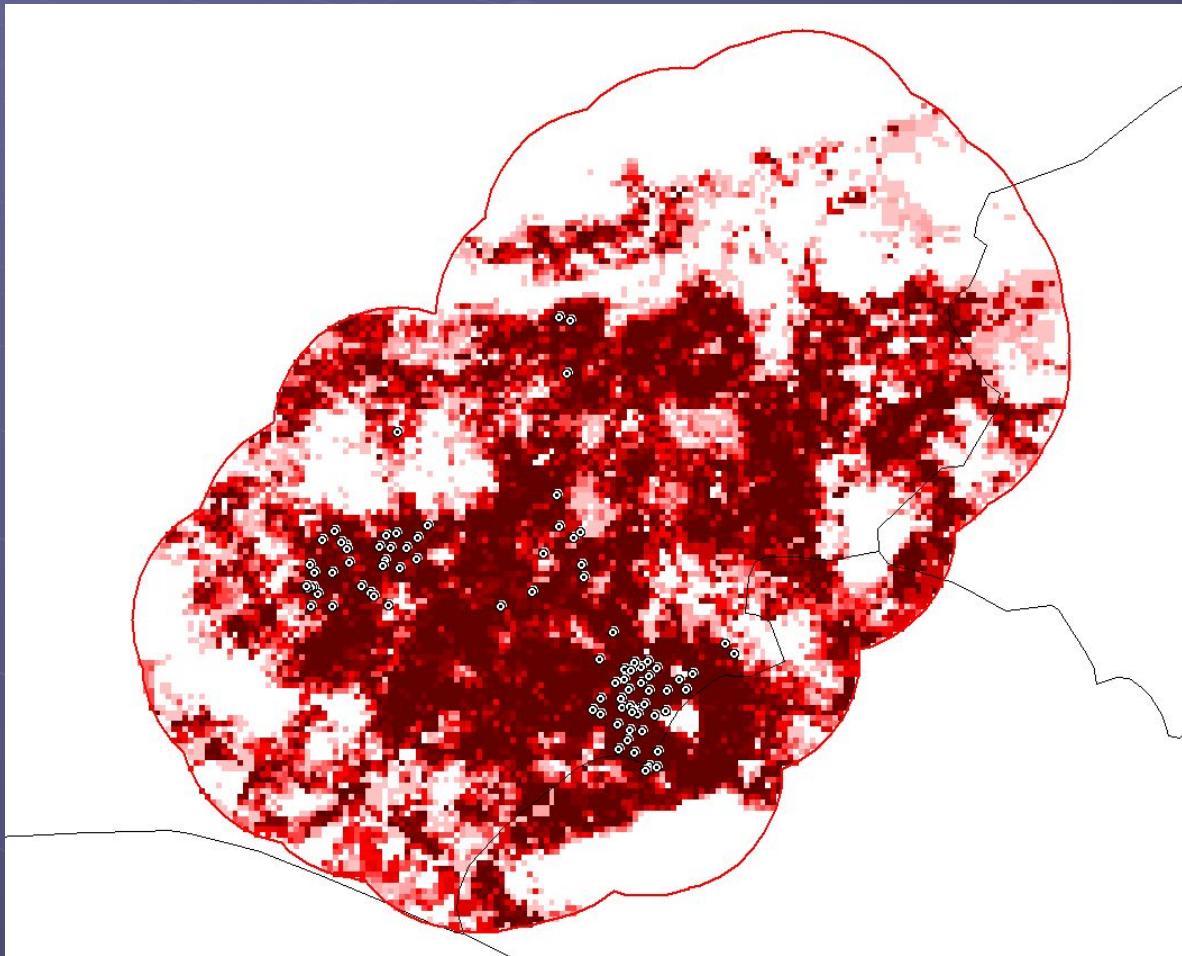
Puntos de Triatoma divididos en cuadrantes (On and Off Diagonal)



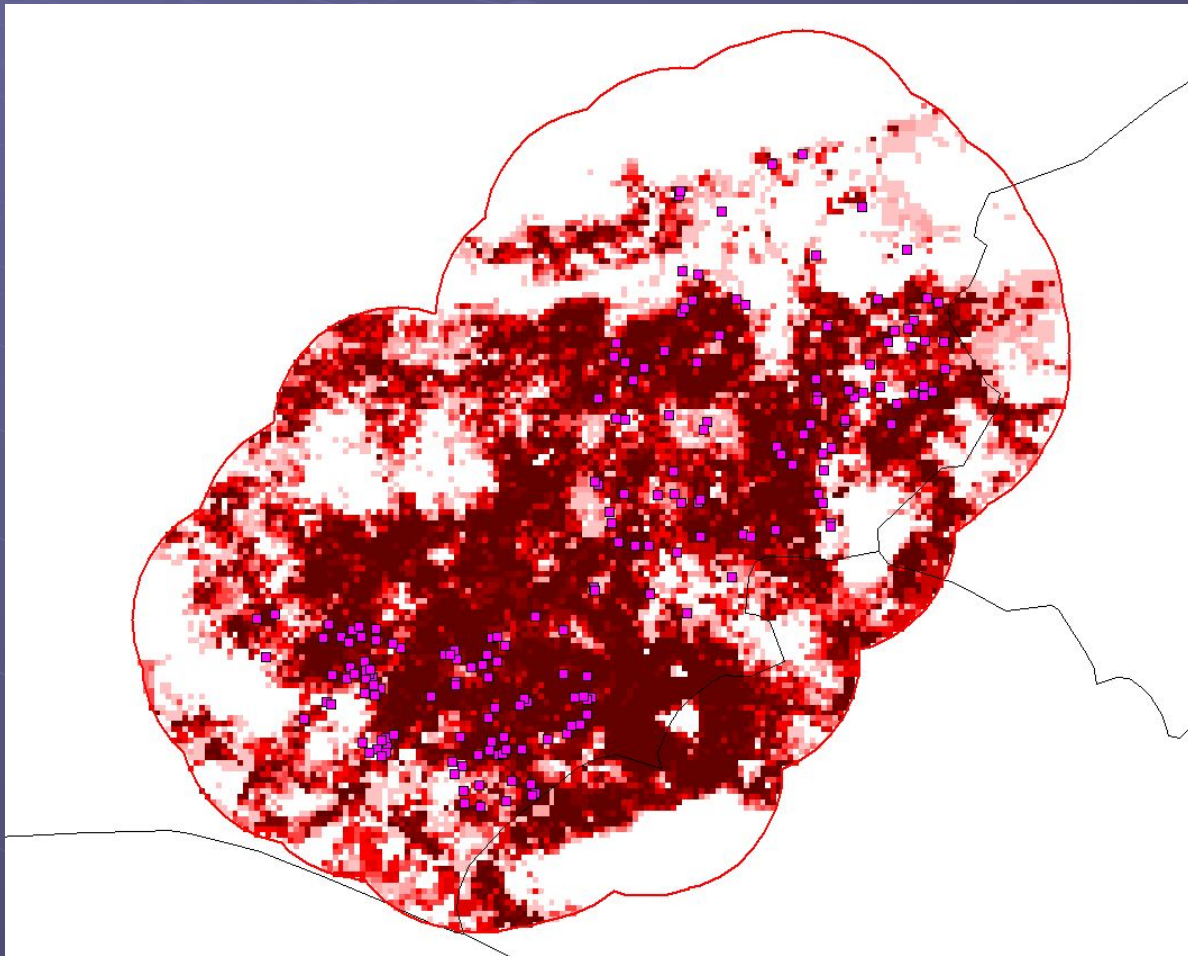
Triatoma Puntos “On-diagonal”



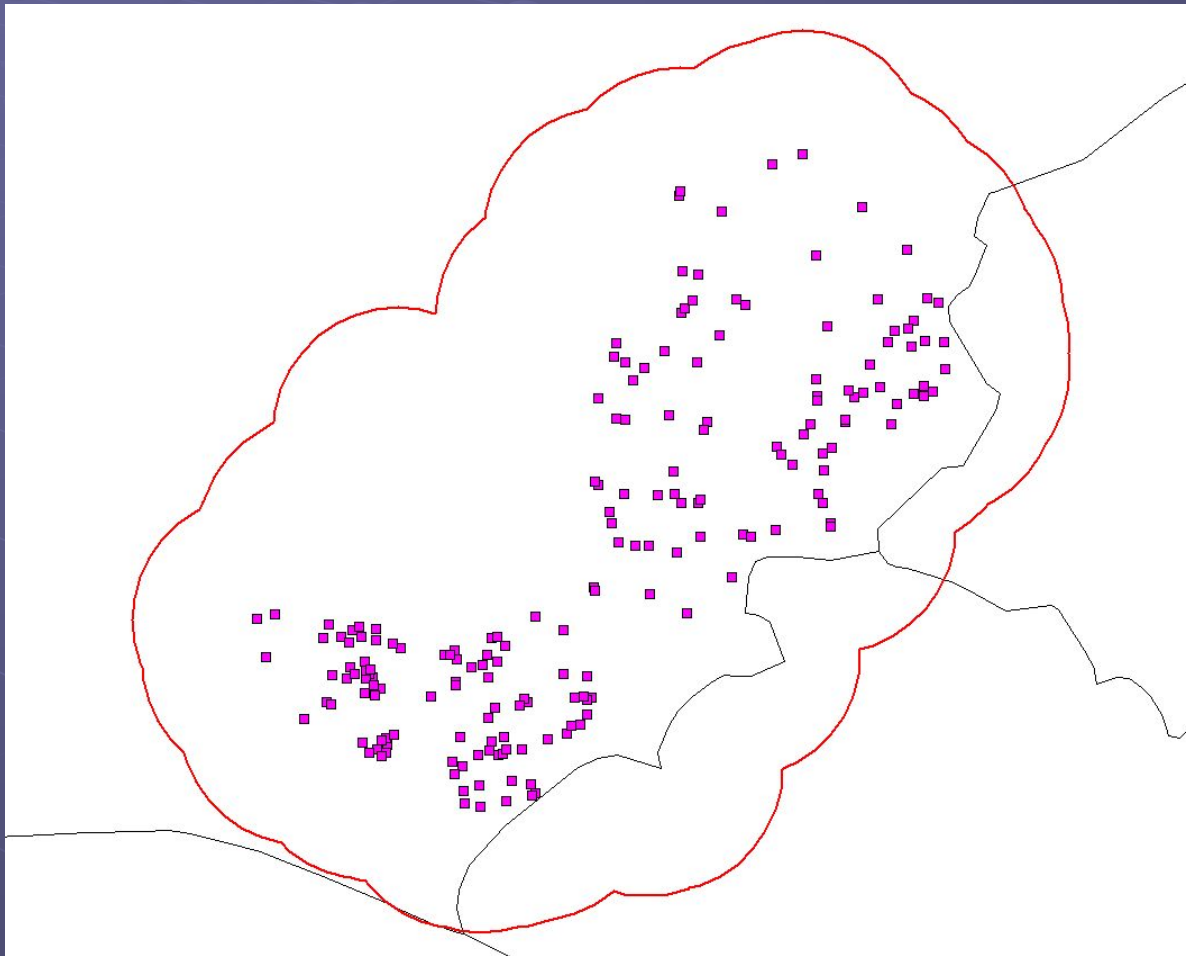
Predicción desarrollada de los puntos “on” de *Triatoma*



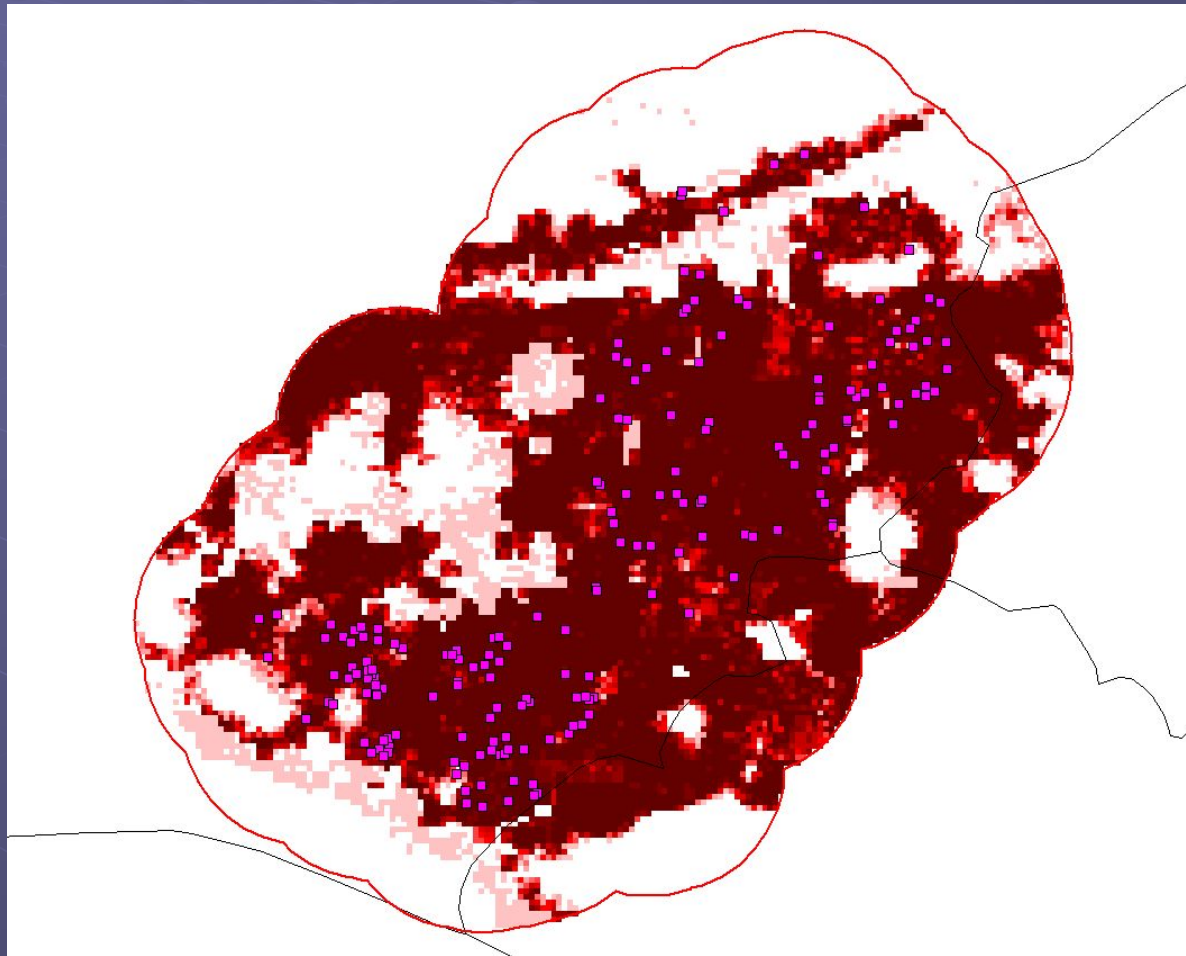
Sobreposición de datos independientes de los puntos Off-diagonal de *Triatoma*



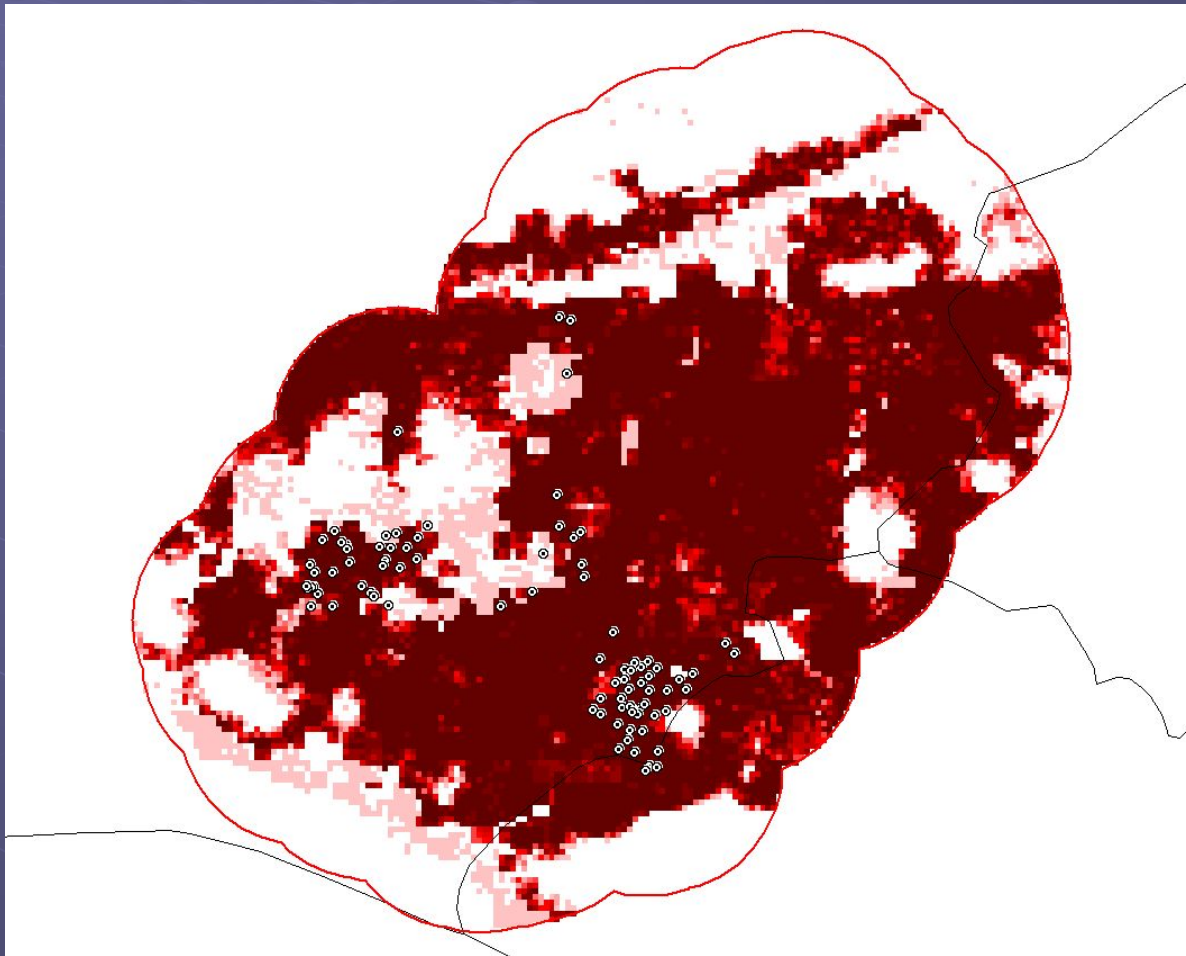
Triatoma Off-diagonal



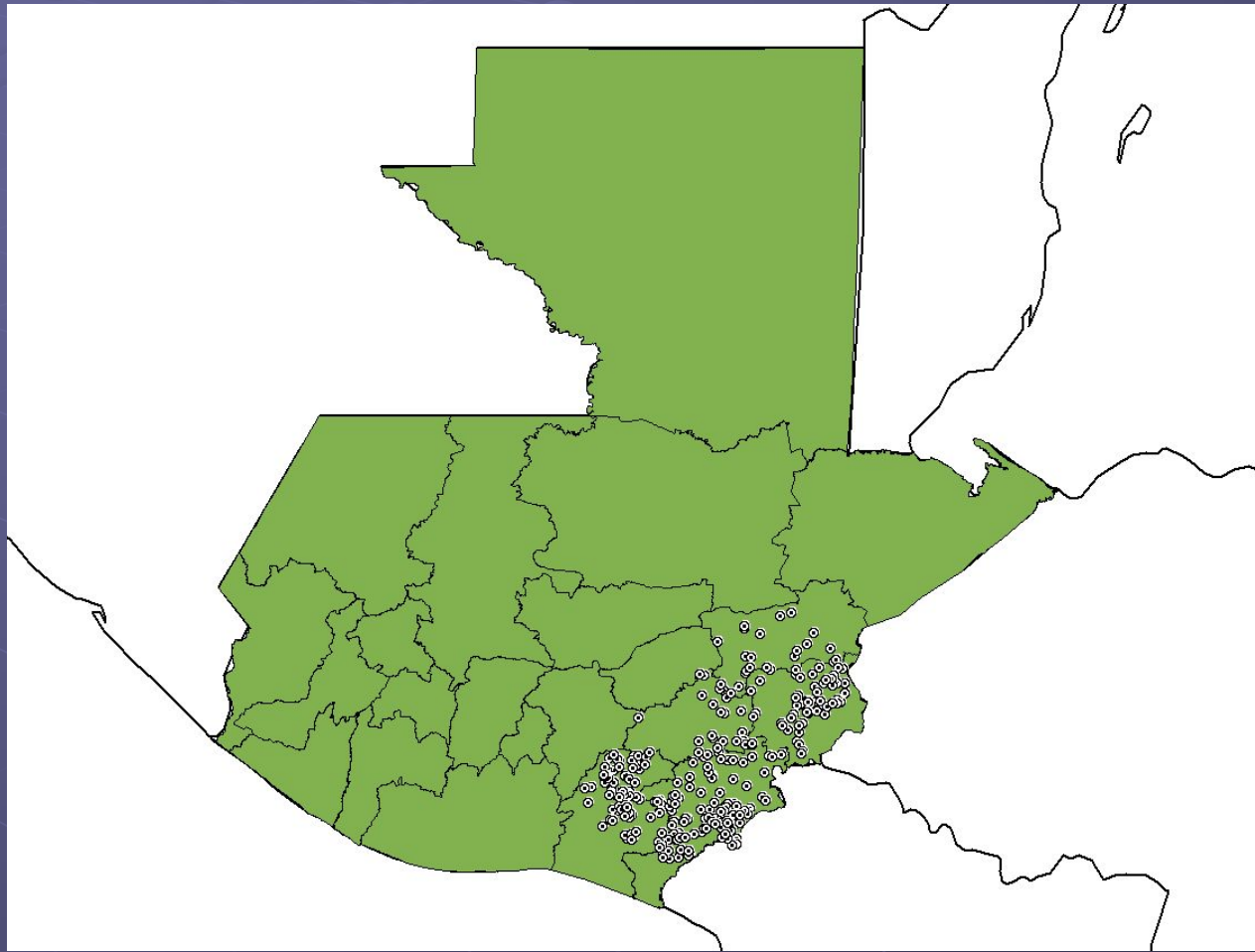
Predicción desarrollada de los puntos Off-diagonal de *Triatoma*



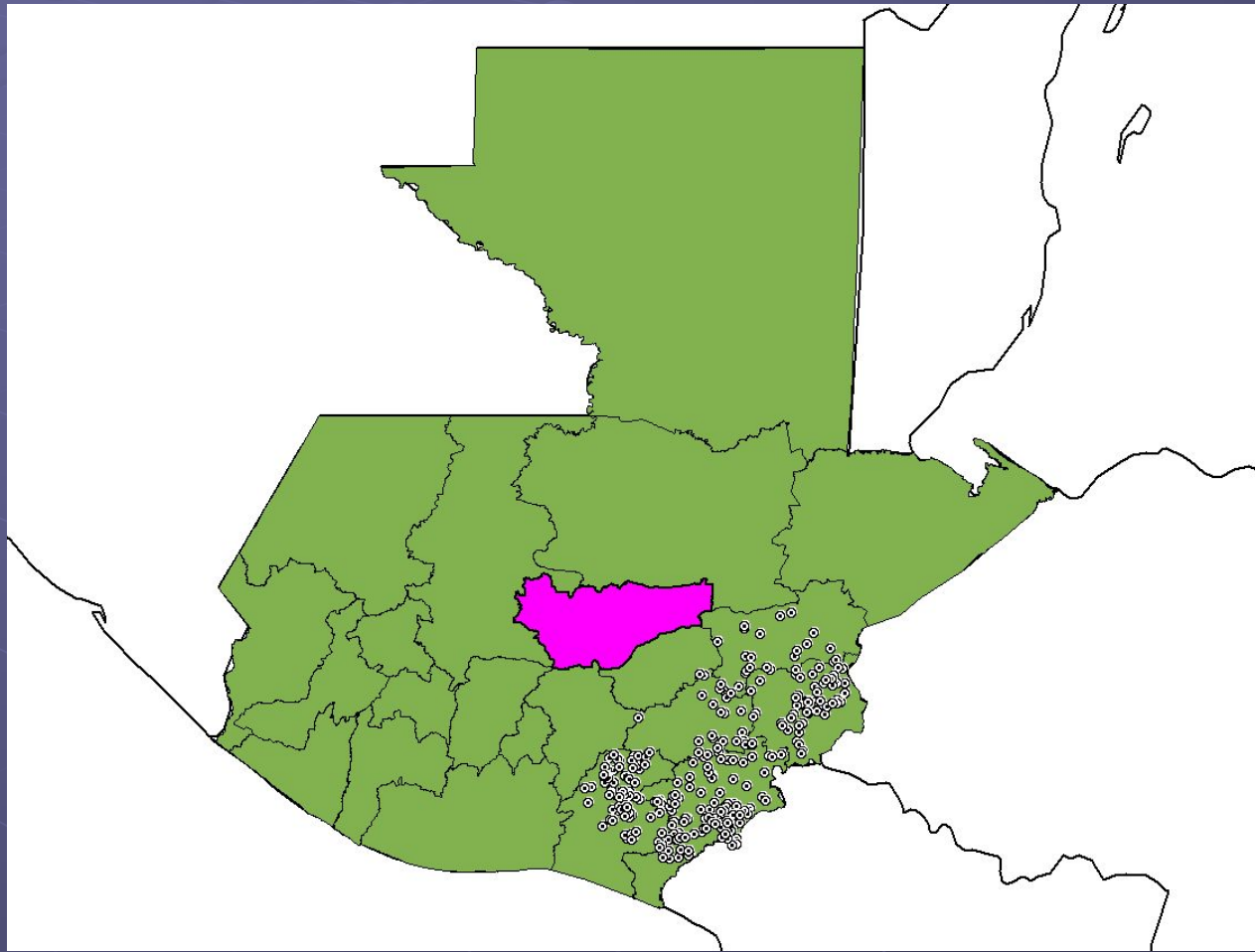
Sobreposición de datos independientes de los puntos On-diagonal de *Triatoma*



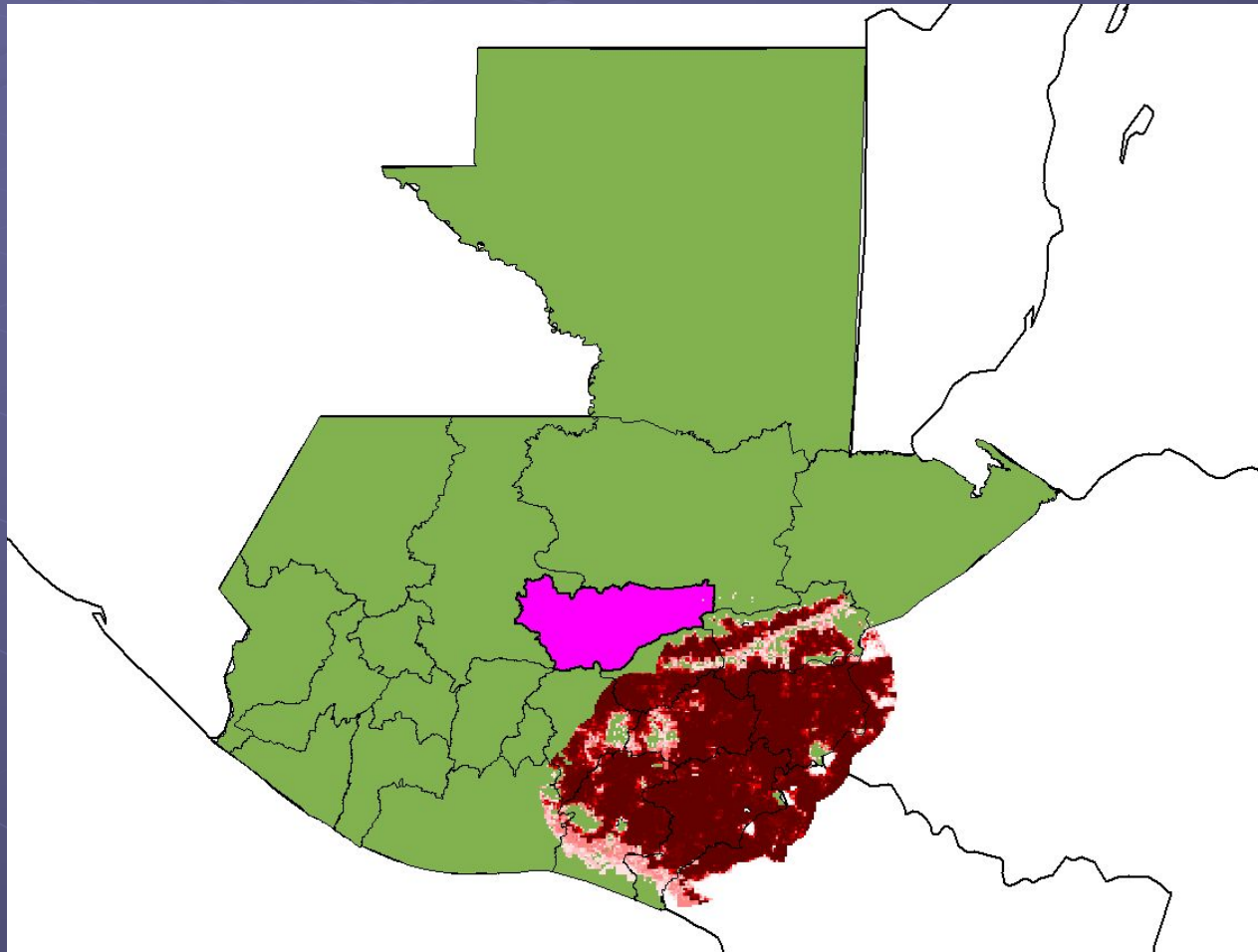
Triatoma – Proyección a otra Región



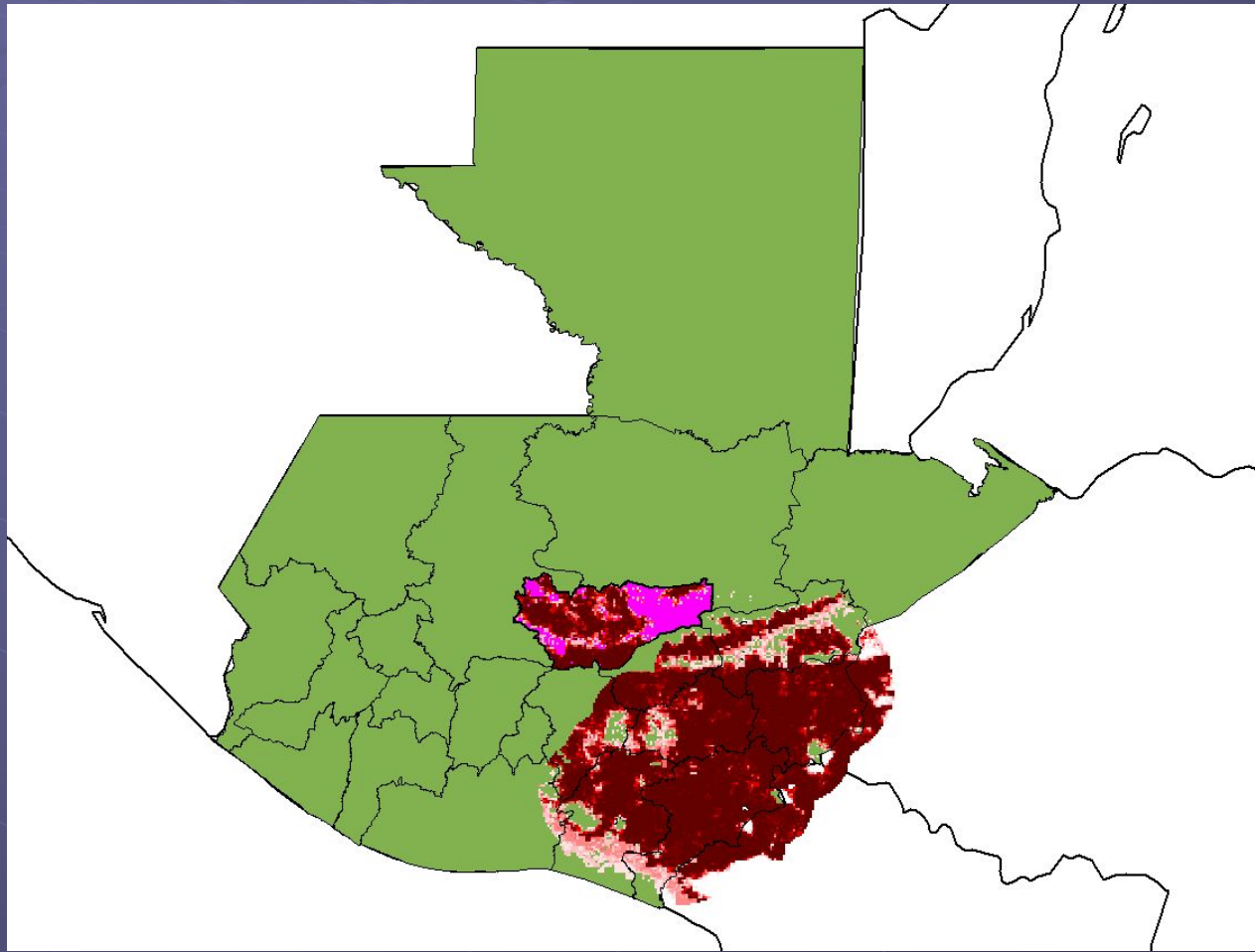
Triatoma – Proyección a otra Región



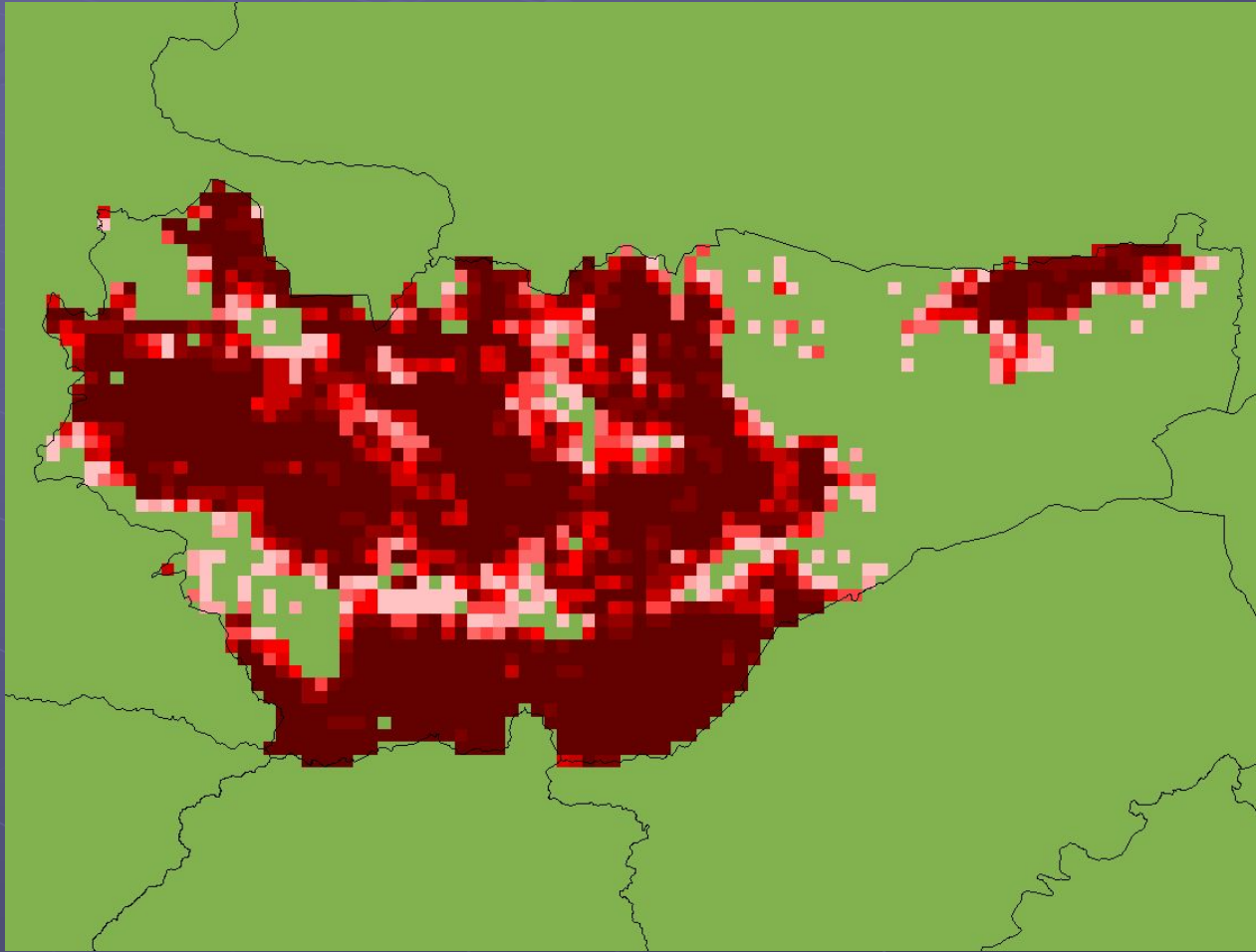
Desarrollo del modelo



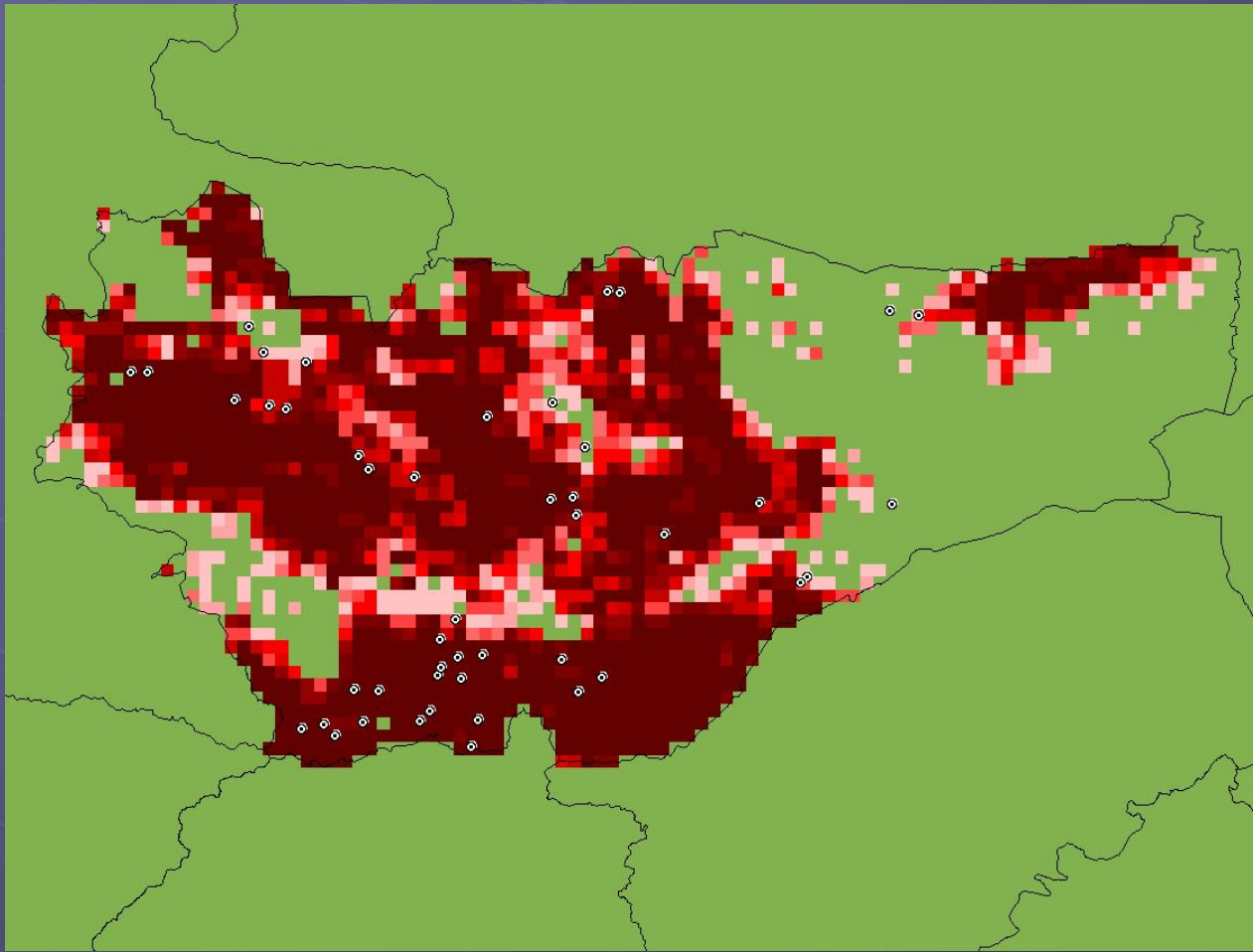
Proyección del Modelo

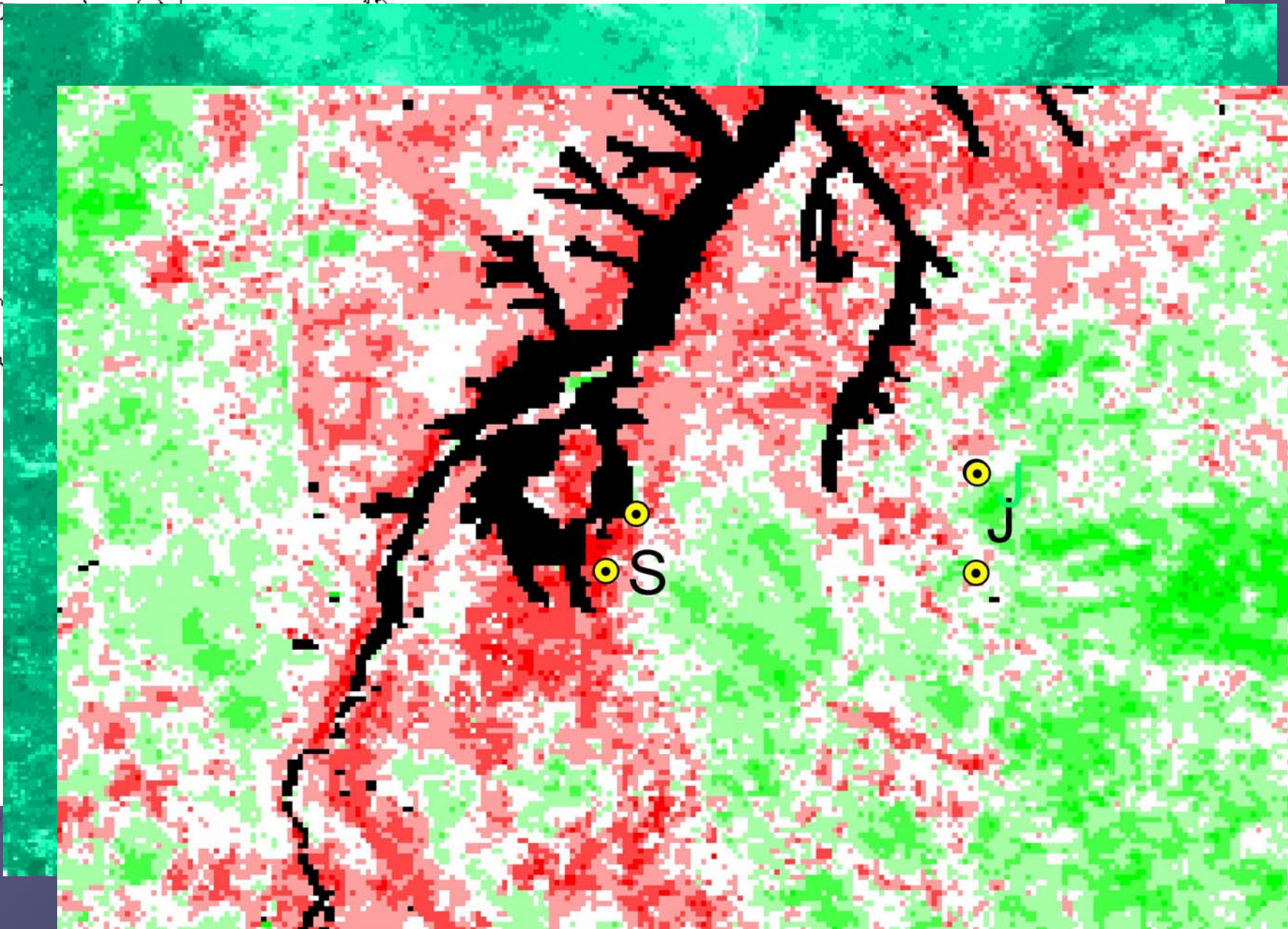


Baja Verapaz “Closeup”



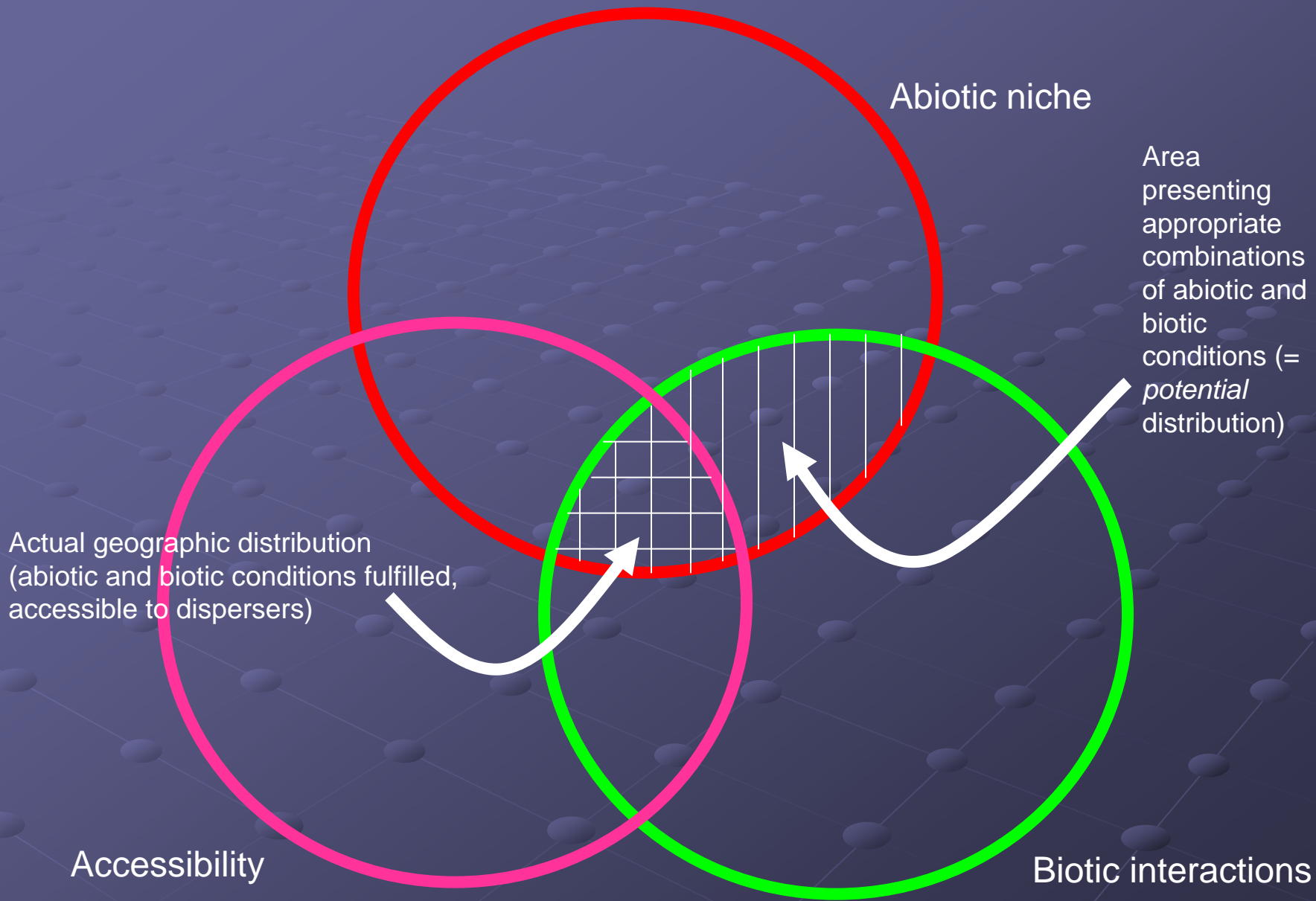
Sobreposición de detecciones de *Triatoma*





A 3D grid of spheres on a blue background. The spheres are arranged in a regular, repeating pattern that recedes into the distance, creating a sense of depth. The background is a solid, dark blue color.

Applications II: Invasive Mosquito Distributions Globally



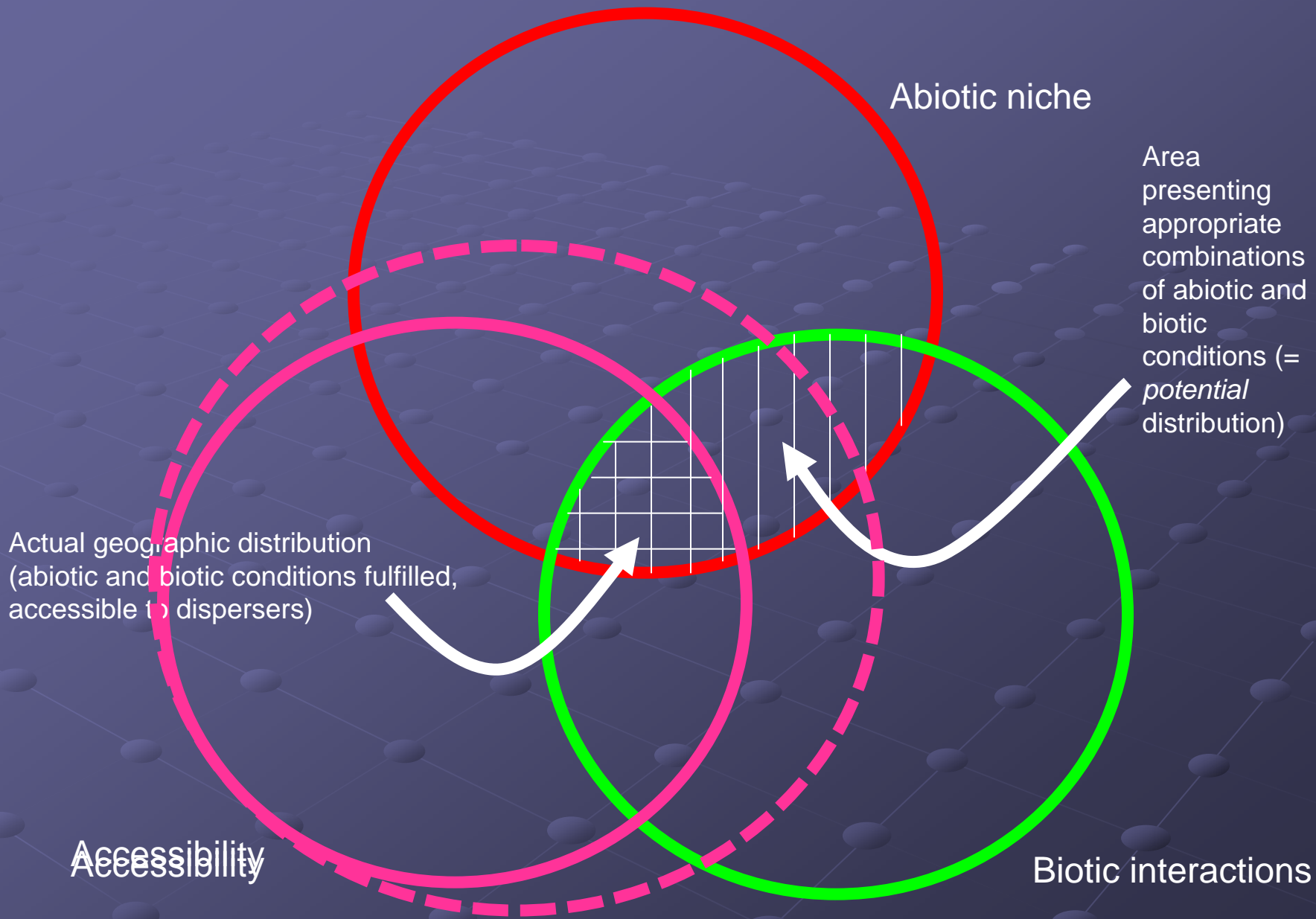
Abiotic niche

Area presenting appropriate combinations of abiotic and biotic conditions (= potential distribution)

Actual geographic distribution (abiotic and biotic conditions fulfilled, accessible to dispersers)

Accessibility

Biotic interactions

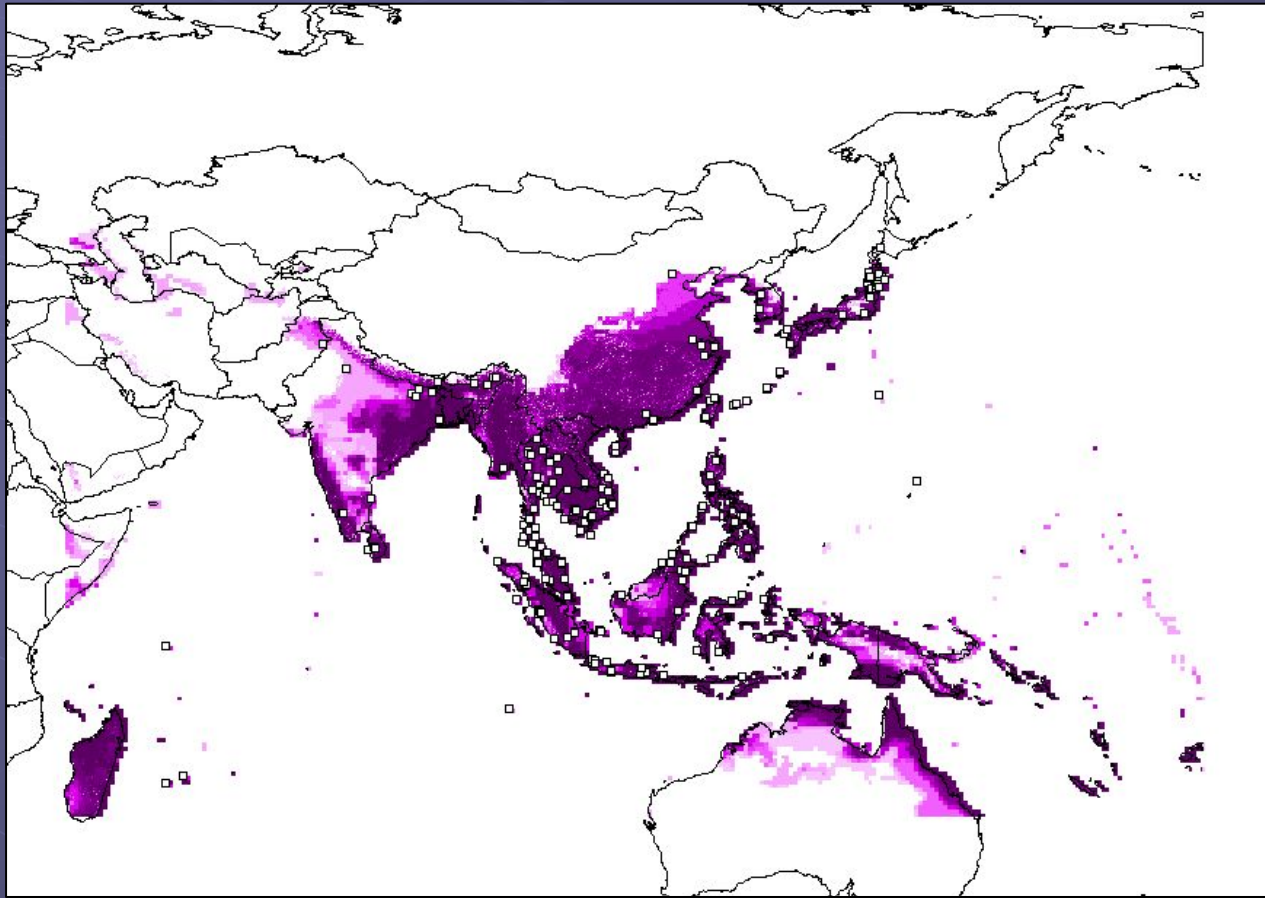


Aedes albopictus



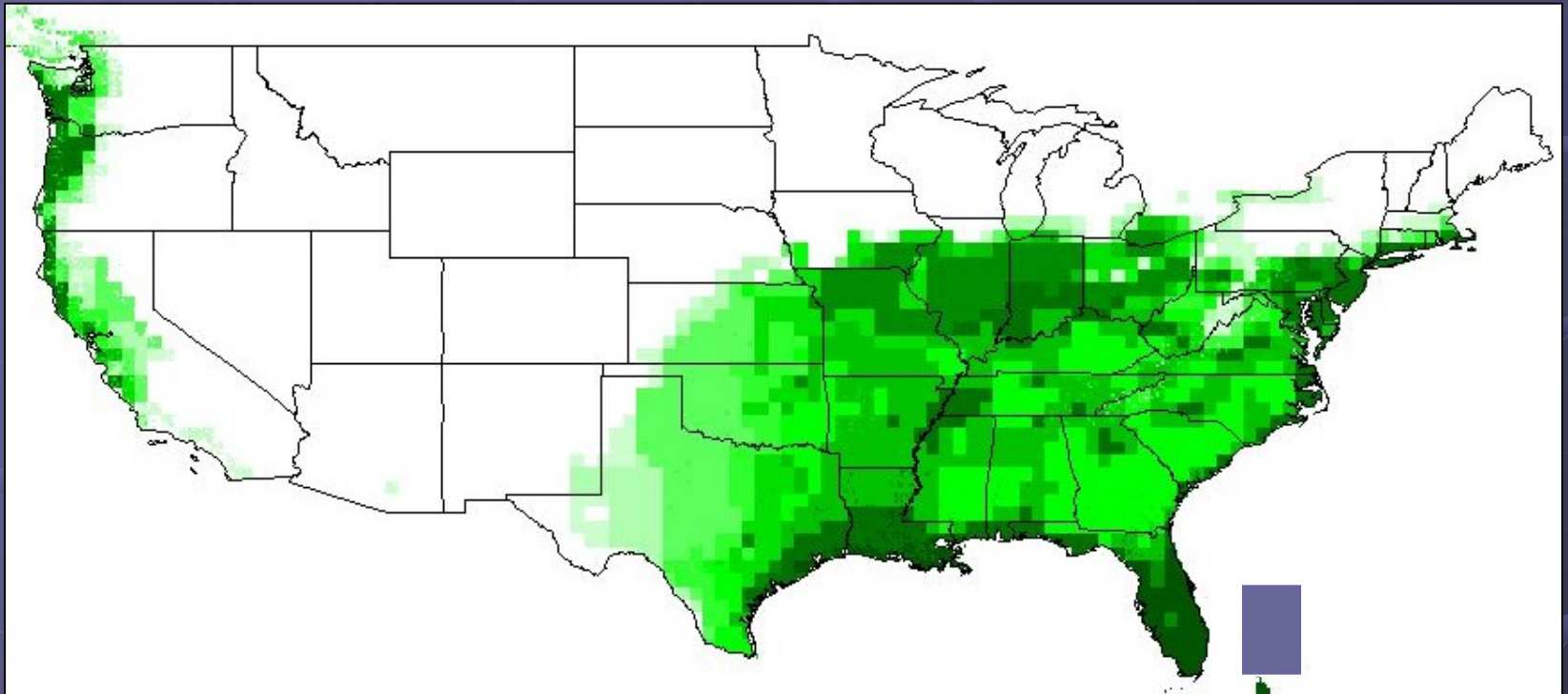
- *Aedes albopictus*
Known as the “Asian Tiger Mosquito”
- Invader; fastest spreading mosquito in the world
- Aggressive daytime biter and pest
- Known to transmit Dengue, La Crosse, St. Louis, Eastern Equine, Ross River, Rift Valley, and West Nile Viruses

Aedes albopictus



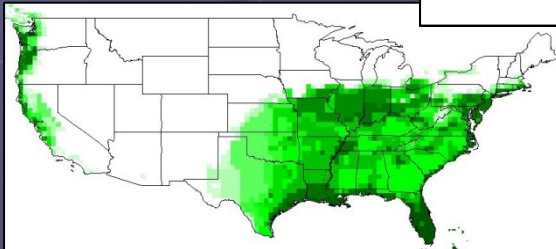
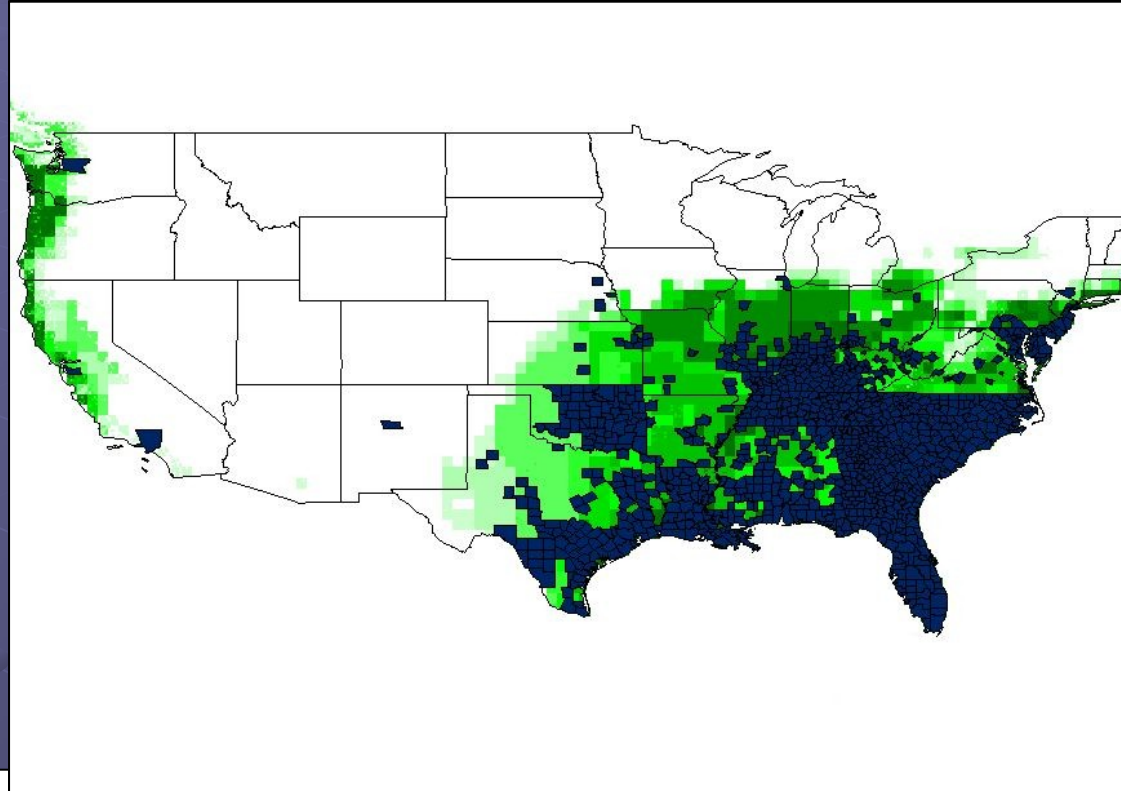
Present predicted distribution, native range in Asia

Aedes albopictus: USA invasion

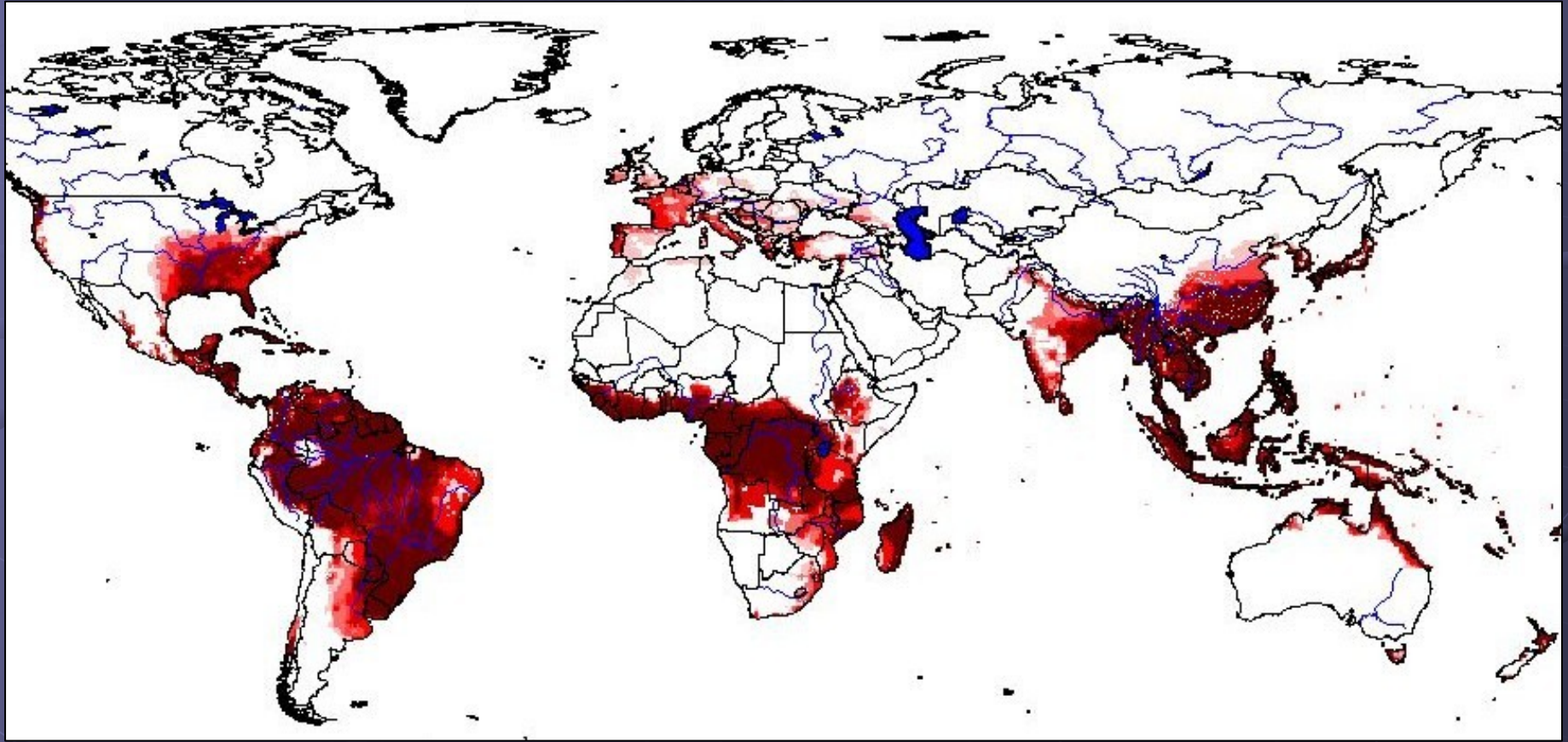


Projected Asian niche into USA present to create invasion risk-map. How well did GARP perform...

Aedes albopictus: USA invasion



Aedes albopictus: world risk-map





APPLICATIONS III: DENGUE DYNAMICS IN MEXICO

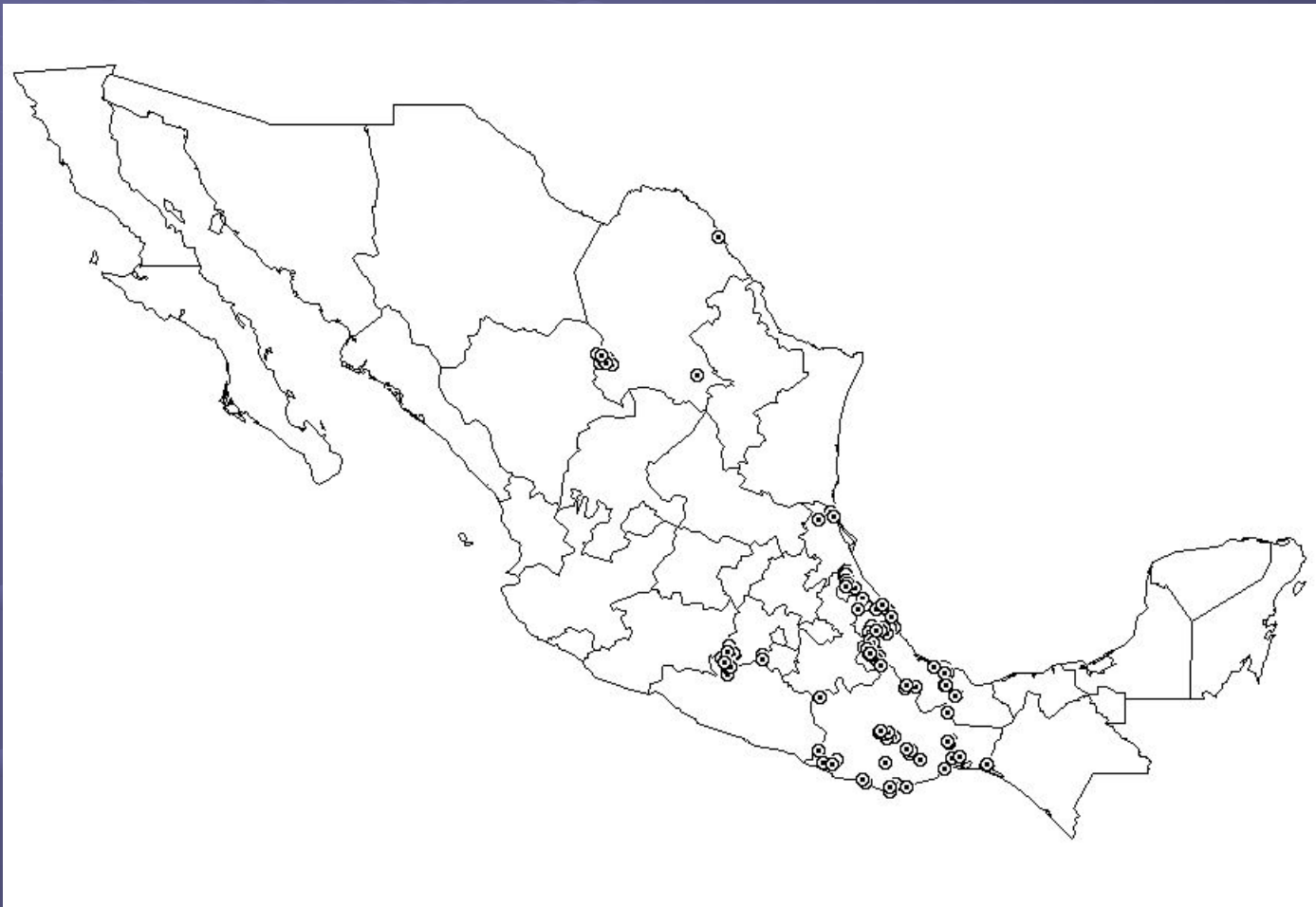
Satellite Imagery

- Advanced Very High Resolution Radiometer (AVHRR) passes over all points on Earth's surface each day
- Raw data include reflectance in different parts of the electromagnetic spectrum
- Normalized Difference Vegetation Index (NDVI) is a composite of two bands of raw data that summarizes 'greenness', and (more precisely) volume of photosynthetic vegetation
- AVHRR NDVI data are available as biweekly or monthly composites

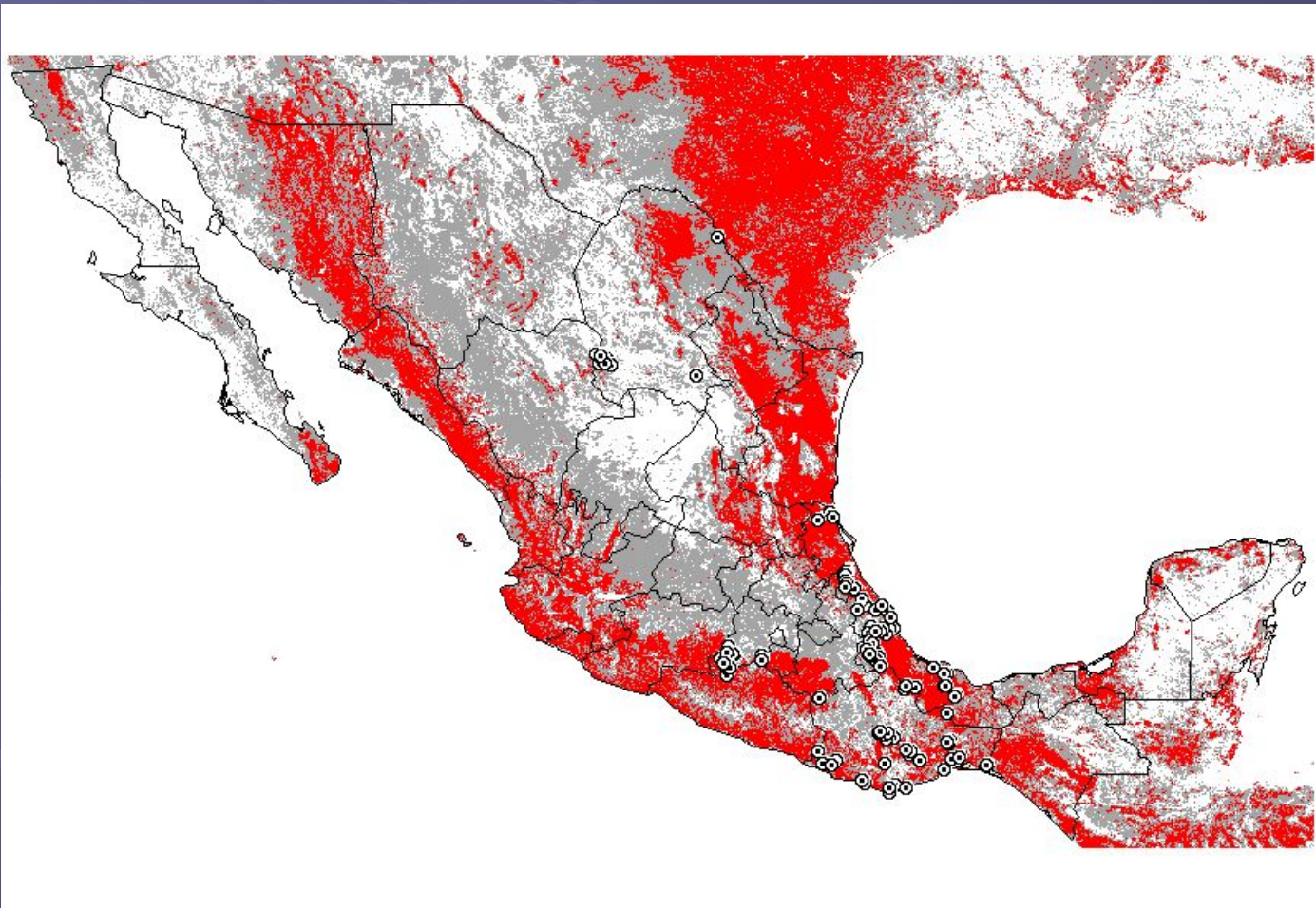
Potential for ENM and Dengue

- ENM is presently developed based on static environmental data that are not temporally precise
- Using occurrence information and ecological data that are precise both in time and space, ENM can be made time-specific
- Would provide detailed predictivity on a weekly or monthly basis for vector distributions and disease transmission
- Potentially applicable to any ephemeral species of epidemiological interest

Distributional Data for *Aedes aegypti*, 1995, in Mexico

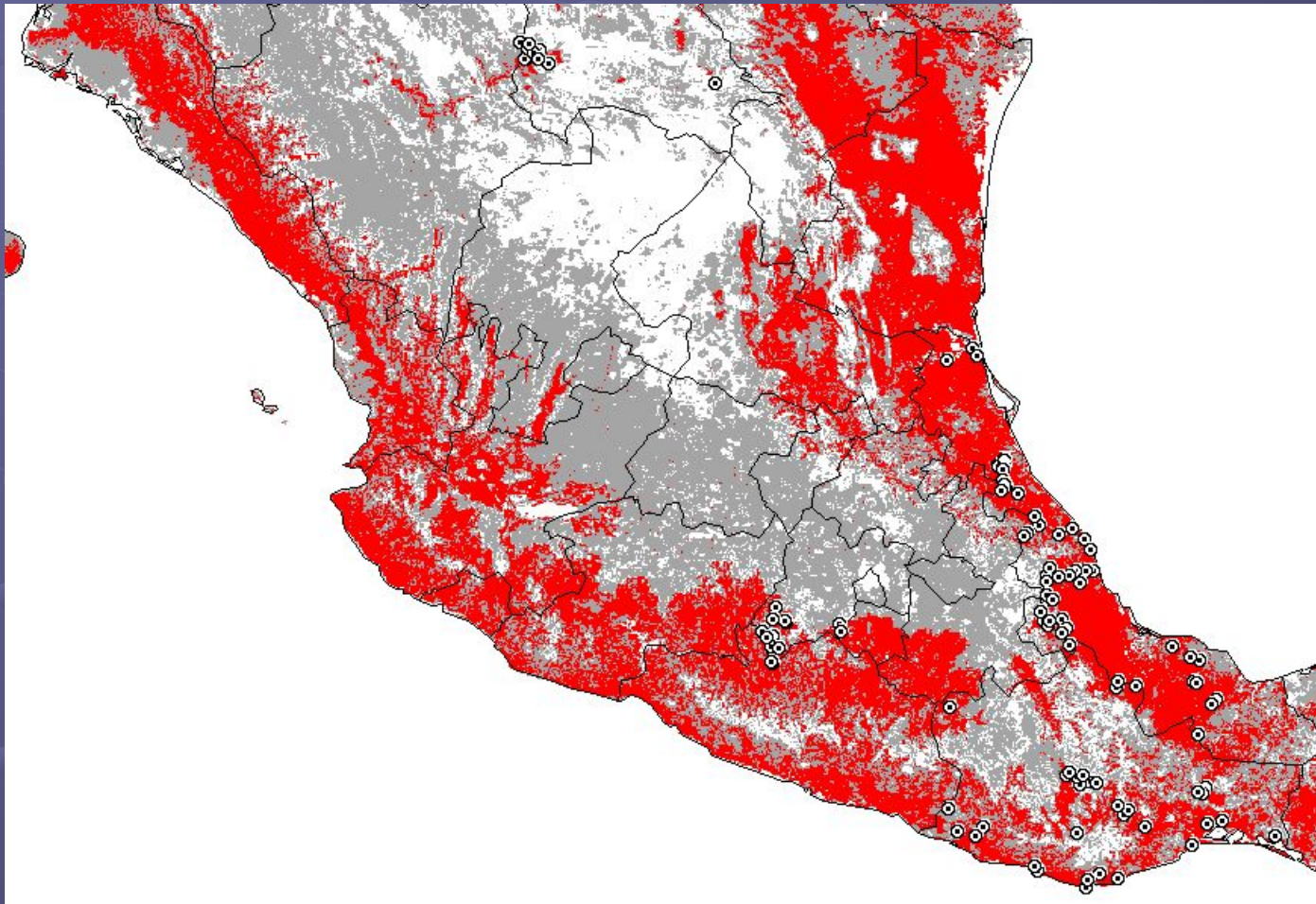


Time-ignorant Prediction

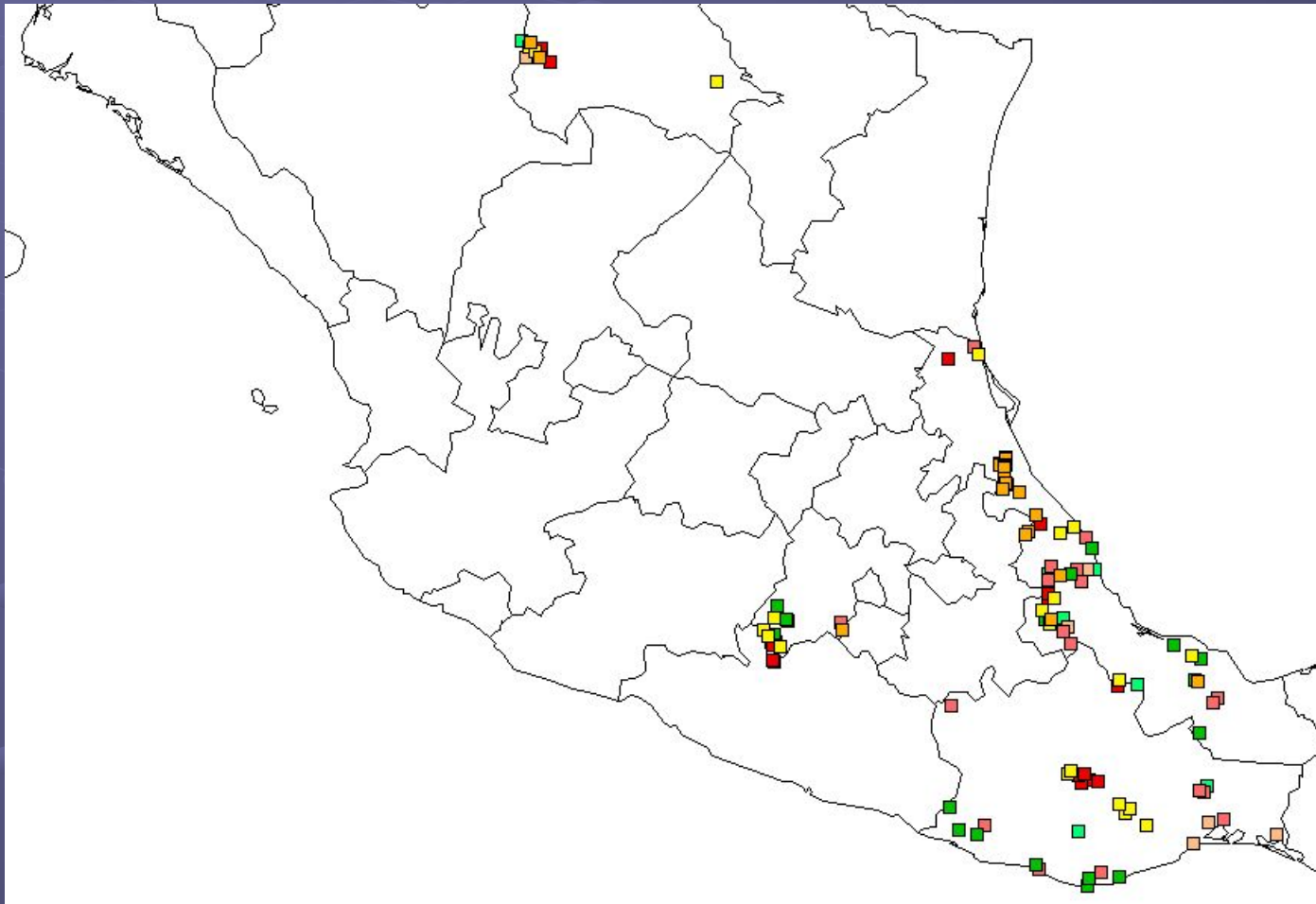


Closer View

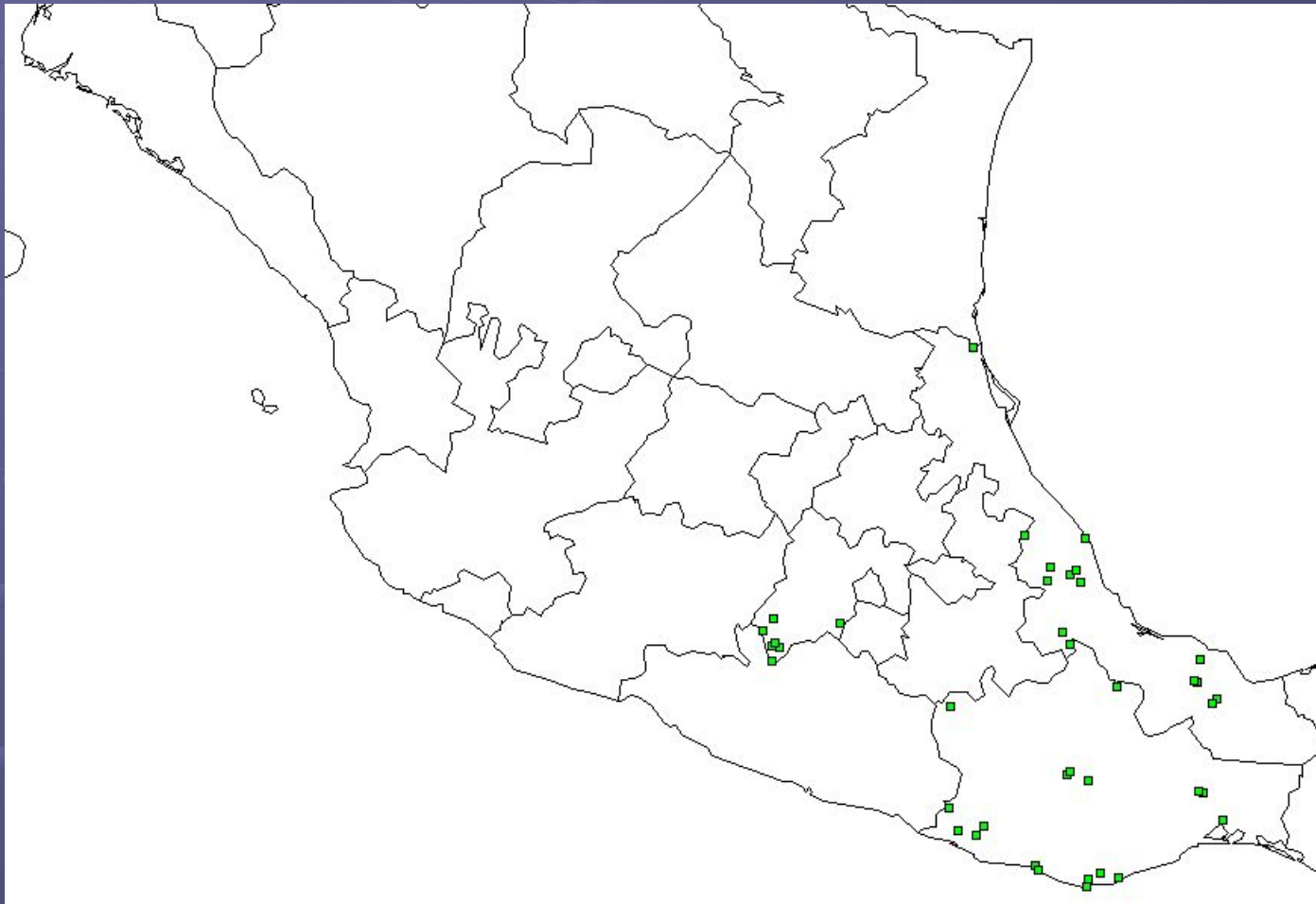
Note broad areas predicted



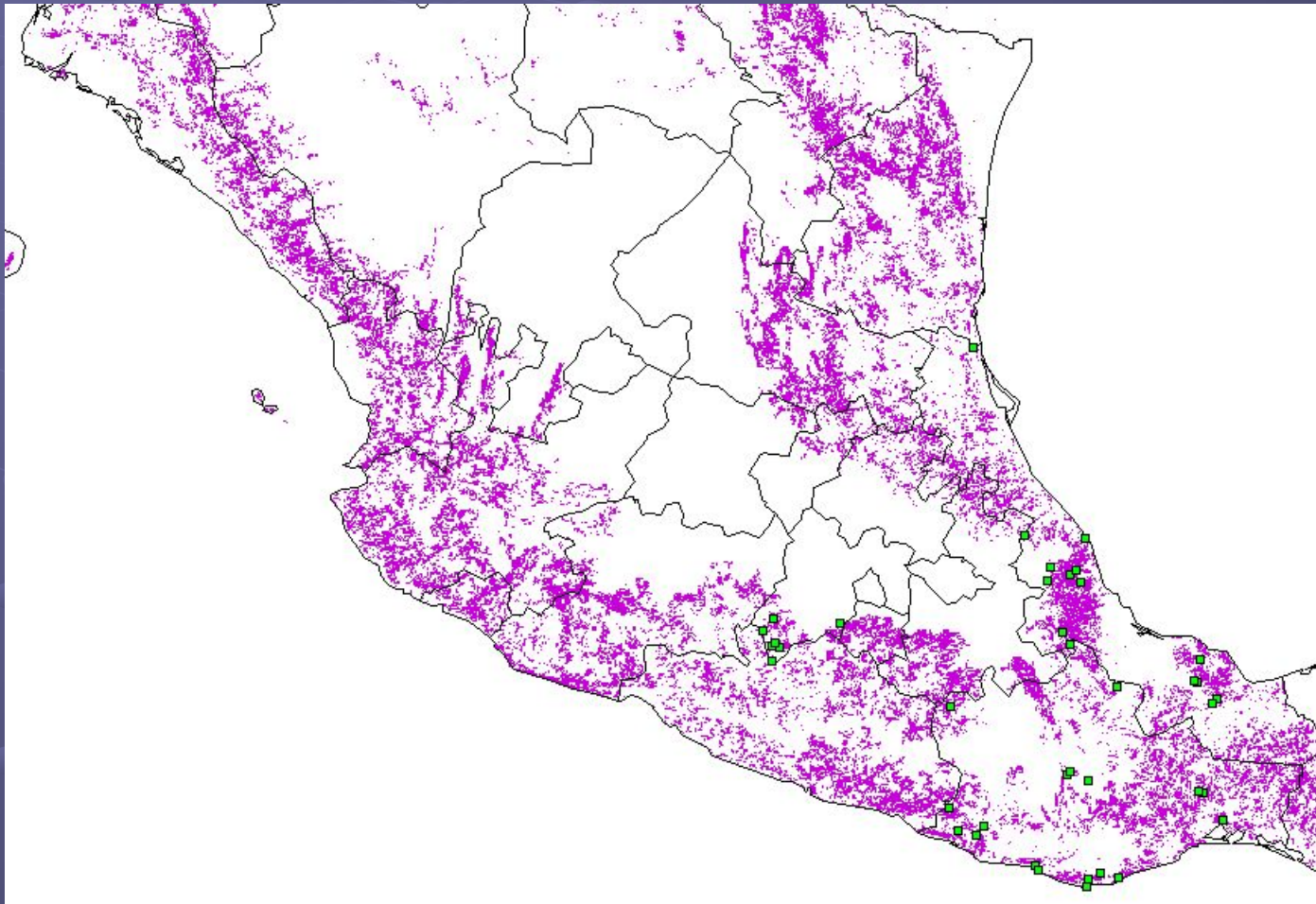
Time-specific Occurrence Data



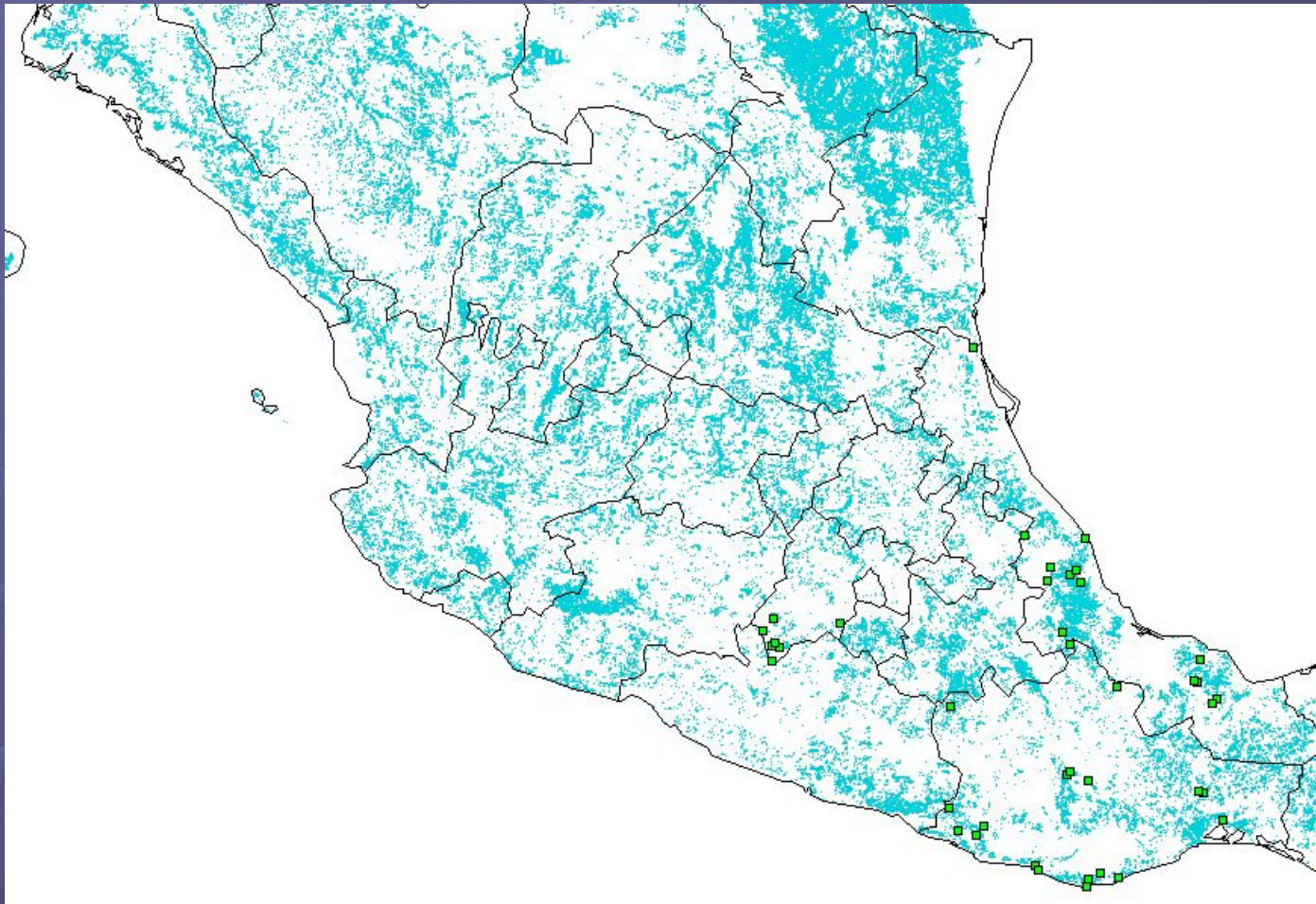
August 1995



August 1995 Predicts August 1995 (easy)

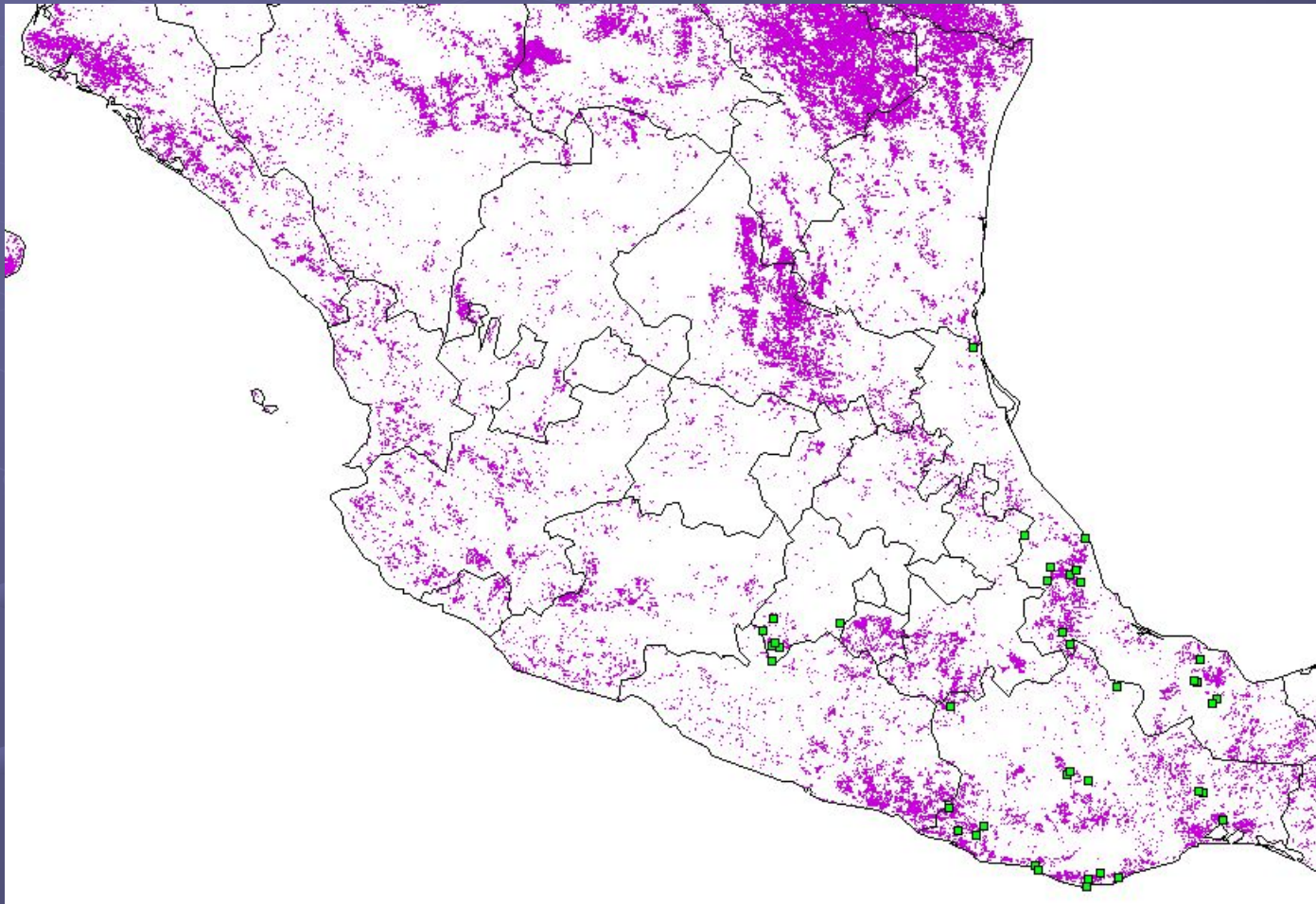


Can We Predict August from Previous Months?

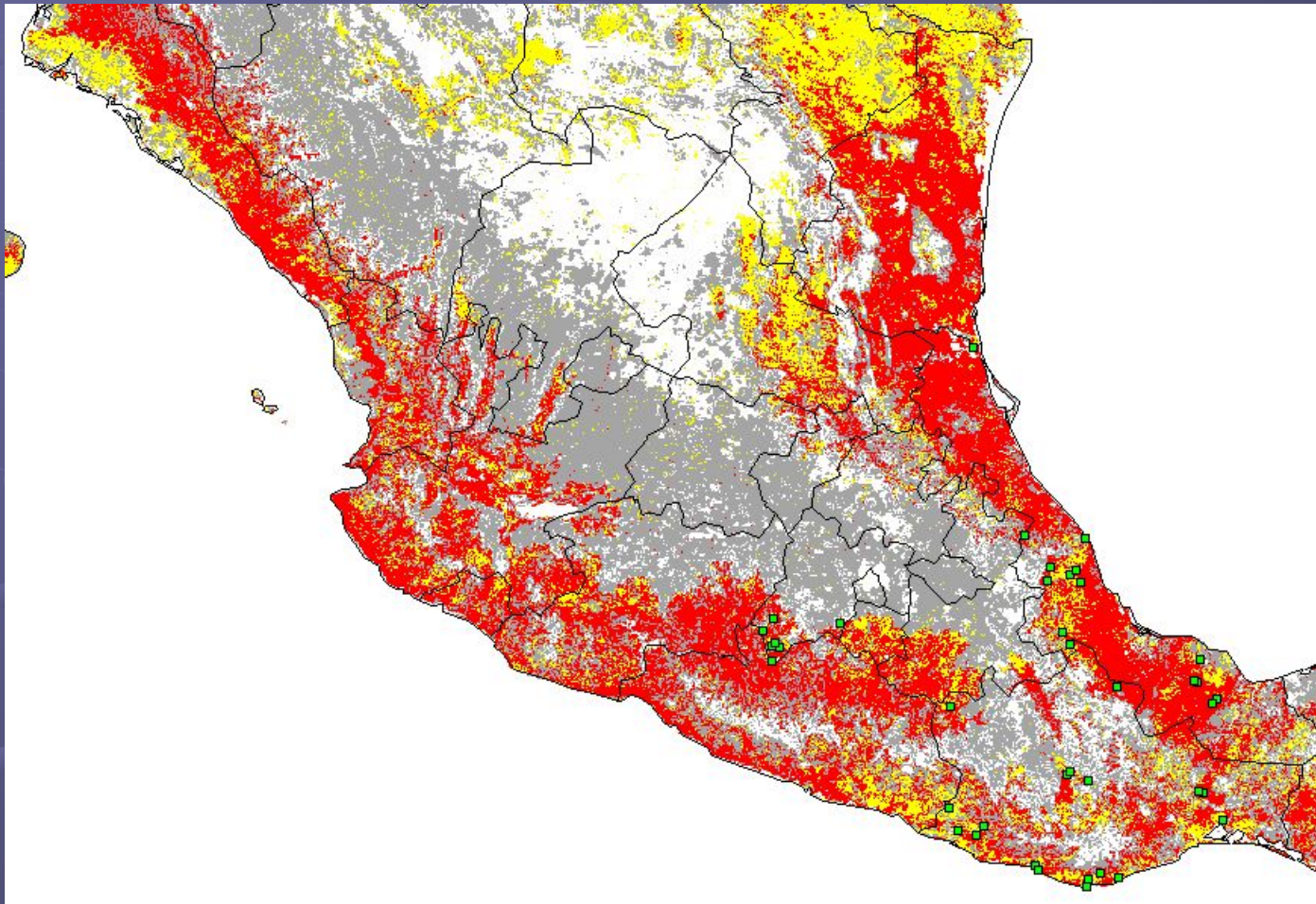


Example: June 1995 predicts August 1995

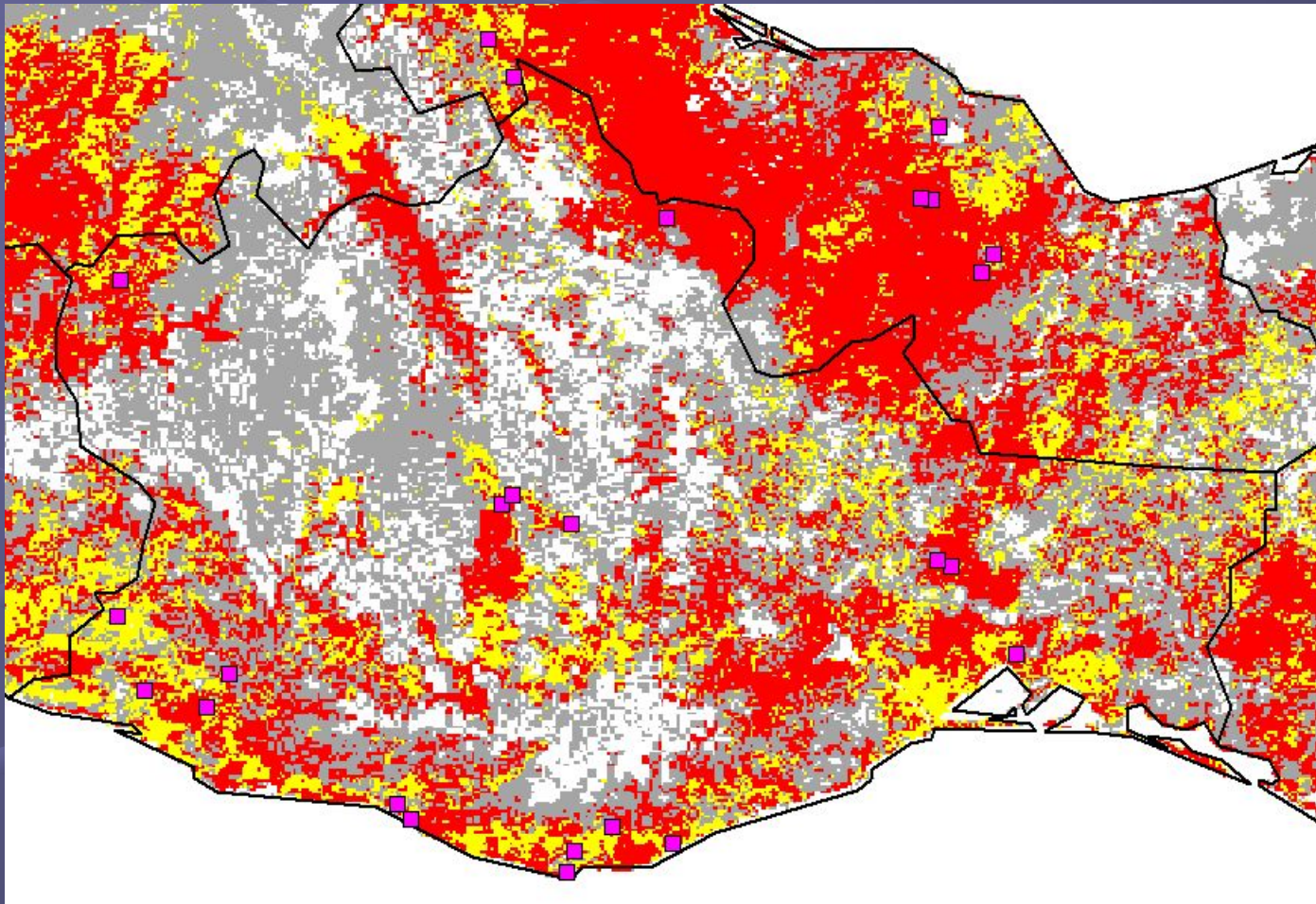
Composite Prediction for August 1995: Two Previous Months Averaged



Time-specific Model Compared with Time-ignorant model



Closer View



Summary of Prototype Tests

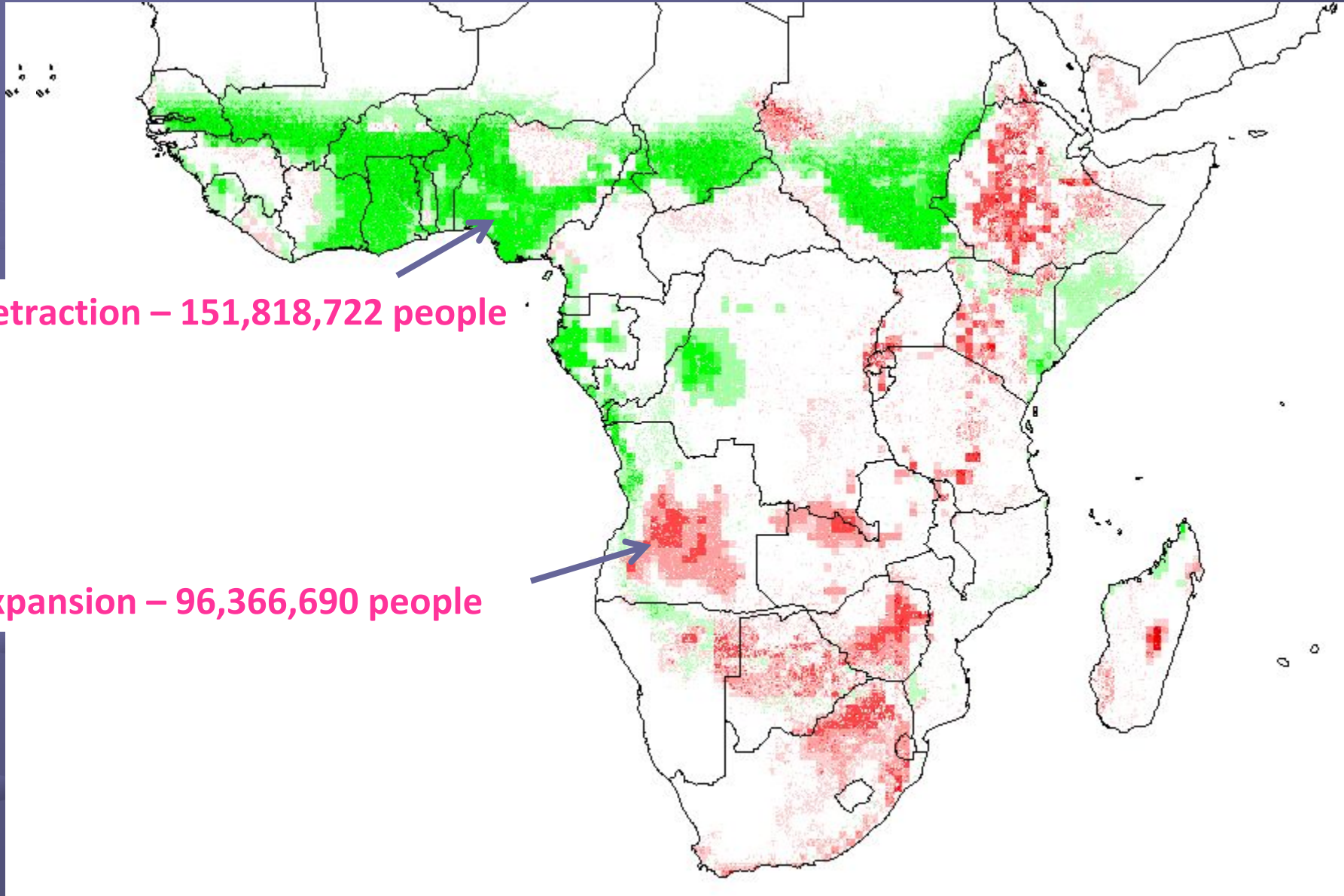
Percent correctly predicted

Month	N	Any	>50%	>80%	
June	22	100	72.7	54.5	←
July	28	100	82.1	67.9	←
August	40	100	75	35	←
September	25	100	80	16	←
October	19	94.7	78.9	21.1	×
November	25	100	76	52	←
December	22	100	95.5	81.8	←

Mosquito survey data

EFFECTS ON HUMAN HEALTH: MALARIA IN AFRICA

Anopheles gambiae



Retraction – 151,818,722 people

Expansion – 96,366,690 people

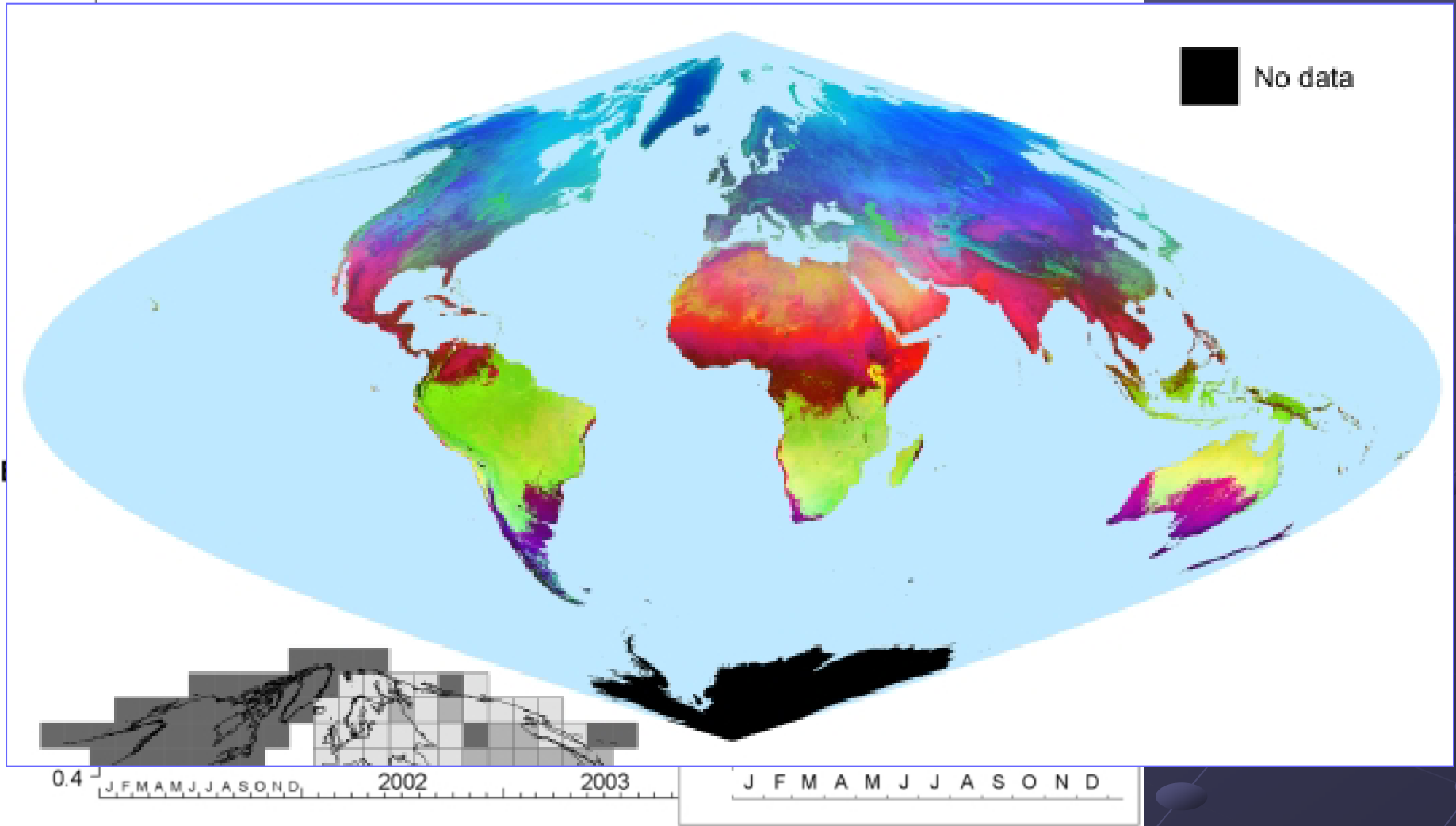
Next Steps

- Develop conceptual framework (biogeography and macroecology)
- Develop analytical approaches
 - Data resources
 - Model development
 - Model validation
 - Model interpretation
- Software development and testing

Example: Get More from RS Data

A

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Next Steps

- Develop conceptual framework (biogeography and macroecology)
- Develop analytical approaches
 - Data resources
 - Model development
 - Model validation
 - Model interpretation
- Software development and testing

Thanks very much
town@ku.edu

Wish BUSH a
GOODBYE

Think good thoughts
about Obama

