Expanding *Wallace* species distribution modeling software to support national biodiversity change indicator calculations for GEO BON assessment and reporting

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Species Distribution Models (SDMs)

Occurrence localities + bioclimatic variables (Hijmans, 2005) → Suitable areas

biodiversityinformatics.amnh.org/open_source/maxent/
Maxent - Phillips et al., Blair 2017 Ecography
Species Distribution Models (SDMs)

SDMs for conservation decision-making:
- Planning and prioritization
- Guiding surveys, monitoring and reintroductions
- Danger of misuse, false precision
Species Distribution Models (SDMs)

Occurrence localities + bioclimatic variables (Hijmans, 2005) → Maxent

- Easy use
- Inflexible/“Black box”
- Flexible
- Steep learning curve

Suitable areas
APPLICATION

WALLACE: A flexible platform for reproducible modeling of species niches and distributions built for community expansion

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... and Mary E. Blair, Ned Horning, Jorge Velásquez-Tibatá, Gonzalo E. Pinilla-Buitrago, Beth E. Gerstner & Sarah I. Meenan
Open-source, flexible, reproducible
https://wallaceecomod.github.io/
Wallace

Components each with modules

A. Obtain Occurrence Data
   Process Occurrence Data
   Obtain Environmental Data
   Process Environmental Data
   Partition Occurrence Data
   Model
   Visualize Model Results
   Project Model
   Session Code

B. Upload / Download
   Download
   Upload
   Upload / Download
   Download
   Download
   Download
   Download
   Download

C. spocc
   leafletextras
   spThin
   raster
   spgeos
   ENMeval
   dismo
   ENMeval
   dismo
   knitr
   markdown

D. Query Database
   Select On Map
   WorldClim Bioclims
   Select Study Region
   Non-spatial
   BIOCLIM
   BIOCLIM Envelope Plots
   Plot Response Curves
   Calculate Environmental Similarity
   Map Prediction
   RMarkdown
   PDF
   HTML
   Microsoft Word

User
Remove By ID
User
User
Spatial
Maxent
Evaluation Plots
Project to New Time
Plot Response Curves
Calculate Environmental Similarity
Map Prediction
Microsoft Word
We are expanding *Wallace* to:

1. Bridge the gap between SDM best practices and biodiversity conservation decision-making
We are expanding *Wallace* to:

1. Bridge the gap between SDM best practices and biodiversity conservation decision-making
2. Facilitate responsible reporting on biodiversity change by national BONs, with the Colombia BON as a model.
Develop new R packages to add to Wallace

1. maskRangeR – Estimates a species’ current range
   – Post-processing of species distribution models with RS products
“Thank you... it is not common for software developers to include such a broad range of end-users in their decisions.”

Wallace end-user consultation workshop in Bogotá, Colombia – April, 2018
Recently described small carnivore

Limited to high altitude, cloud forests

Data-poor, in need of status update given recent deforestation

*maskRangeR* example:

**Olinguito** (*Bassaricyon neblina*)
Olinguito SDM

Recent occurrences

MODIS yearly forest cover

Masked Distribution

Climatically Suitable & Forested
Above DTT (≥24%)
High: 0.775
Low: 0.329
Climatically Suitable Area

Suitability
High
Low
**maskRangeR** example: parapatric species

- Use biotic information to improve modeling outputs
- 3 species of three-toed sloths as example

maskRangeR example: parapatric species

SDMs

B. variegatus

B. tridactylus

B. torquatus

Masked Distributions

SVM for range boundary estimation

Kass et al. In Prep; Babich Morrow et al. In Prep
Expert-driven use cases
Next, add to *Wallace* as new modules
Second end-user consultation workshop June 11-12, 2019 in Bogotá
Develop new R packages

1. maskRangeR – Estimate a species’ current range
   – Post-processing of species distribution models with RS products

2. Package B – Calculate key biodiversity change indicators
   – IUCN AOO and EOO upper bounds
   – % suitable land cover
   – Protected Area representativeness, taxonomic diversity...
Supporting the Colombia BON

BON in a Box Tools include software, protocols, and other tools that facilitate effective biodiversity change reporting

/boninabox.geobon.org/
Integrate *Wallace & BioModelos*
Create interactive web-based training materials

Network of Conservation Educators and Practitioners

ncep.amnh.org
Bridging the gap to decision-making with co-creation

Wallace end-user consultation workshop in Bogotá, Colombia – April, 2018
https://wallaceecomod.github.io/

Thanks to:

NASA

GROUP ON EARTH OBSERVATIONS 16-GEO16-0027

NSF

DBI 1650241
DBI 1661510

GBIF

GC Digital Initiatives
Wallace software

Open-source, flexible, reproducible

https://wallaceecomod.github.io/
Group on Earth Observations Biodiversity Observation Network
WORKFLOW
Wallace (v1.0.4) currently includes the following components and modules:
1: Obtain Occurrence Data
   - Query Database
   - User-specified
2: Process Occurrence Data
   - Select Occurrences on Map
   - Remove Occurrences by ID
   - Spatial Thin
3: Obtain Environmental Data
   - WorldClim
   - User-specified
4: Process Environmental Data
   - Select Study Region
   - User-specified
5: Partition Occurrence Data
   - Non-spatial Partition
   - Spatial Partition
6: Build and Evaluate Niche Model
   - BIOCLIM
   - Maxent
7: Visualize Model Results
   - BIOCLIM Envelope Plot
   - Maxent Evaluation Plots
   - Plot Response Curves
   - Map Prediction
8: Project Model
   - Project to New Area
   - Project to New Time

What is Wallace?
Welcome to Wallace, a flexible application for reproducible ecological modeling, built for community expansion. The current version of Wallace (v1.0.4) steps the user through a full niche/distribution modeling analysis, from data acquisition to visualizing results.

The application is written in R with the web app development package shiny. Please find the stable version of Wallace on CRAN, and the development version on Github. We also maintain a Wallace website that has some basic info, links, and will be updated with tutorial materials in the near future.

Wallace is designed to facilitate spatial biodiversity research, and currently concentrates on modeling species niches and distributions using occurrence datasets and environmental predictor variables. These models provide an estimate of the species’ response to environmental conditions, and can be used to generate maps that indicate suitable areas for the species (i.e., its potential geographic distribution; Gulsan & Thuiller 2005; Elith & Leathwick 2009; Franklin 2010a; Peterson et al. 2011). This research area has grown tremendously over the past two decades, with applications to pressing environmental issues such as conservation biology (Franklin 2010b), invasive species (Ficetola et al. 2007), zoonotic diseases (González et al. 2010), and climate-change impacts (Kearney et al. 2010).

Also, for more detail, please see our paper in Methods in Ecology and Evolution.

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Who is Wallace for?
We engineered Wallace to be used by a broad audience that includes graduate students, ecologists, conservation practitioners, natural resource managers, educators, and programmers. Anyone, regardless of programming ability, can use Wallace to perform an analysis, learn about the methods, and share the results. Additionally, those who want to disseminate a technique can author a module for Wallace.

Attributes of Wallace
- **open**: the code is free to use and modify (GPL 3.0), and it gives users access to some of the largest public online biodiversity databases
- **expandable**: users can author and contribute modules that enable new methodological options
- **flexible**: options for user uploads and downloads of results
Source: MAAProject.org
BioModelos

- Connects biodiversity experts to species distribution models (SDMs)

- Facilitates:
  1. Curating records
  2. Editing models
  3. Suitable ecological variables
  4. Model approval

- Model statistics
  - Extent of occurrence
  - Percent in Protected Areas
  - Change under projected forest loss
maskRangeR vignette example: Swamp Forest Crab

IUCN defined range  Elevation  Temperature  MODIS derived tree cover
maskRangeR vignette
eexample: Swamp Forest Crab

IUCN defined range

<table>
<thead>
<tr>
<th>Layer</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation</td>
<td>16</td>
<td>26</td>
</tr>
<tr>
<td>Temperature</td>
<td>26</td>
<td>34</td>
</tr>
<tr>
<td>Hansen tree cover</td>
<td>75</td>
<td>100</td>
</tr>
</tbody>
</table>
maskRangeR vignette example: Swamp Forest Crab

IUCN defined range

Elevation

Temperature

MODIS derived tree cover

Limited to expert
Indicated values:
maskRangeR vignette example: Swamp Forest Crab

IUCN defined range

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Limited to expert indicated values: