



Species Distribution Modeling with Remote Sensing

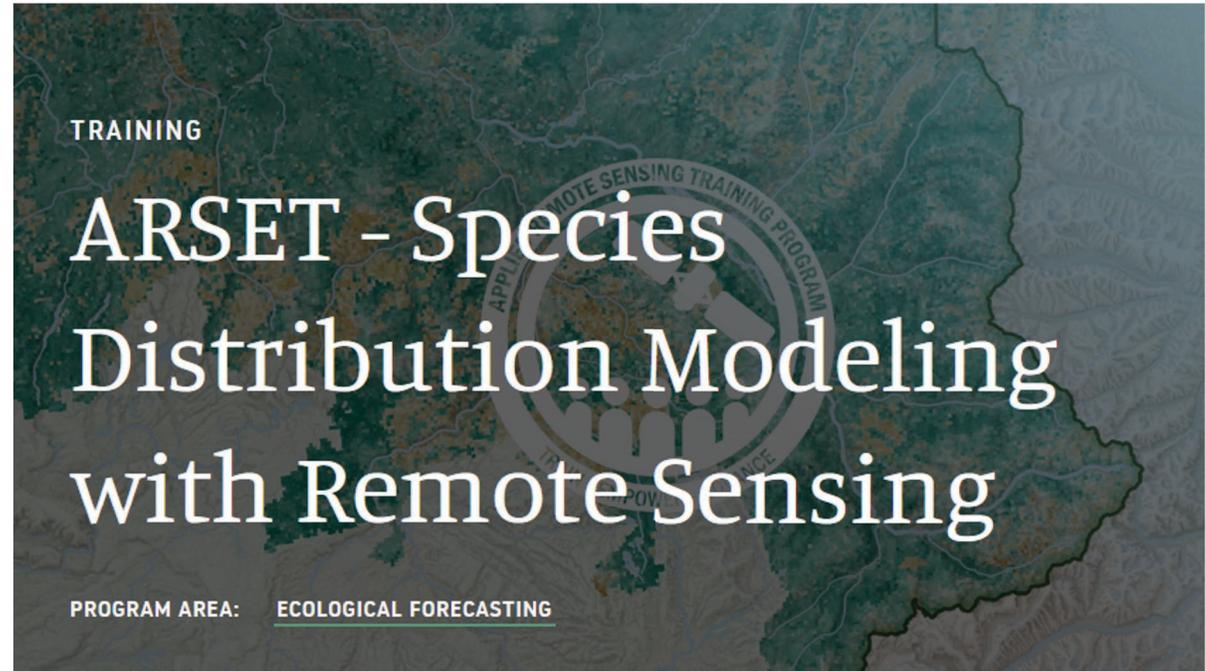
Amber McCullum, Juan Torres-Perez, Zach Bengtsson
Guest Speakers: Erica E. Johnson, Andrea Paz Velez, Mary E. Blair

Aug 17, 2021



Course Structure and Materials

- Three 1.5-hour sessions on August 12, 17, & 19
- Sessions will be presented once in English 12:00-13:30 EDT
- Webinar recordings, PowerPoint presentations, and the homework assignment can be found after each session at:
 - <https://appliedsciences.nasa.gov/join-mission/training/english/arset-species-distribution-modeling-remote-sensing>
- Q&A following each lecture and/or by email at:
 - amberjean.mccullum@nasa.gov
 - juan.l.torresperez@nasa.gov
 - bengtsson@baeri.org



Amber McCullum



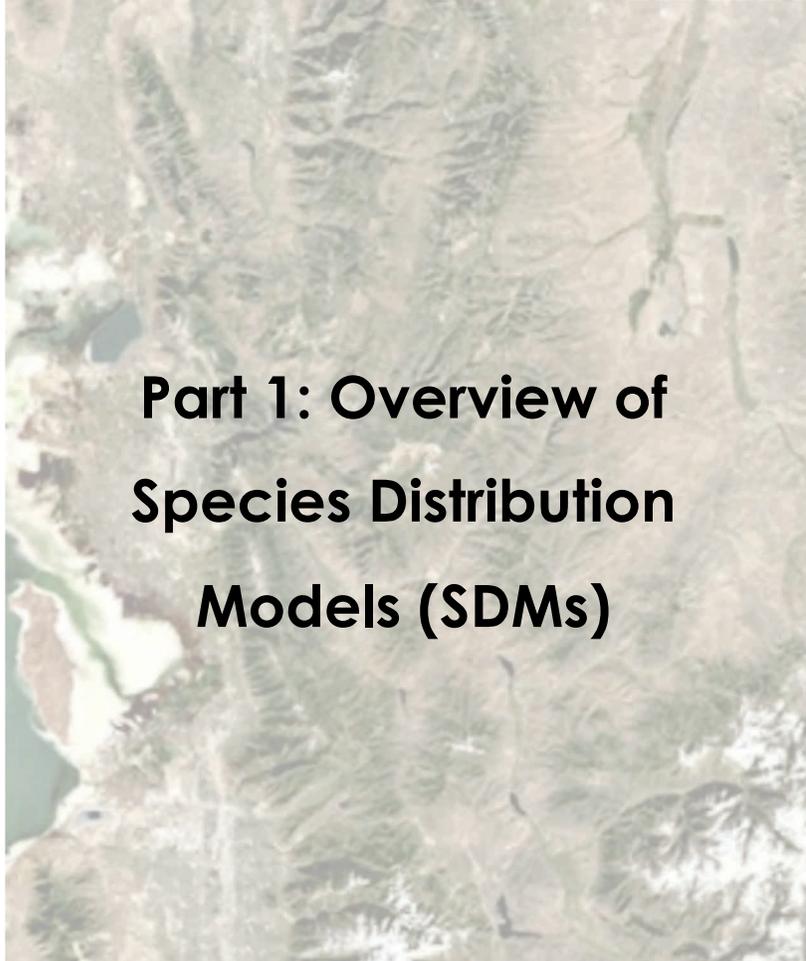
Juan Torres-Pérez



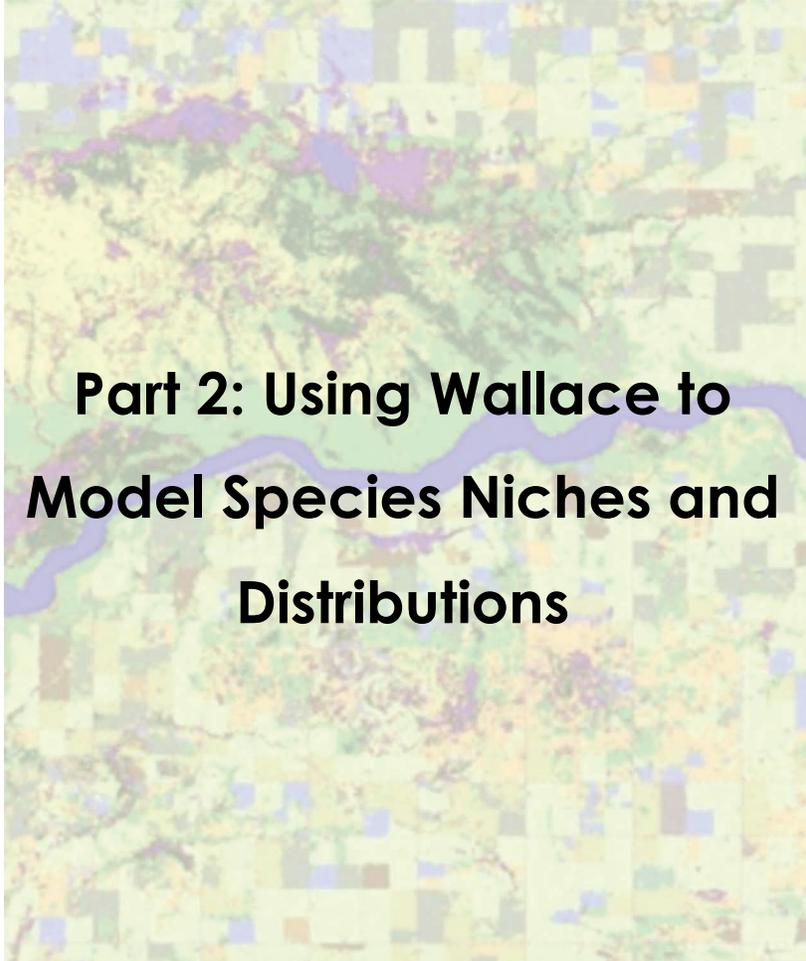
Zach Bengtsson



Webinar Agenda



**Part 1: Overview of
Species Distribution
Models (SDMs)**



**Part 2: Using Wallace to
Model Species Niches and
Distributions**



**Part 3: Additional SDM
Tools and Techniques, ASP
Projects, and Summary**





Using **Wallace** to Model Species Niches & Distributions

Session 2 Overview

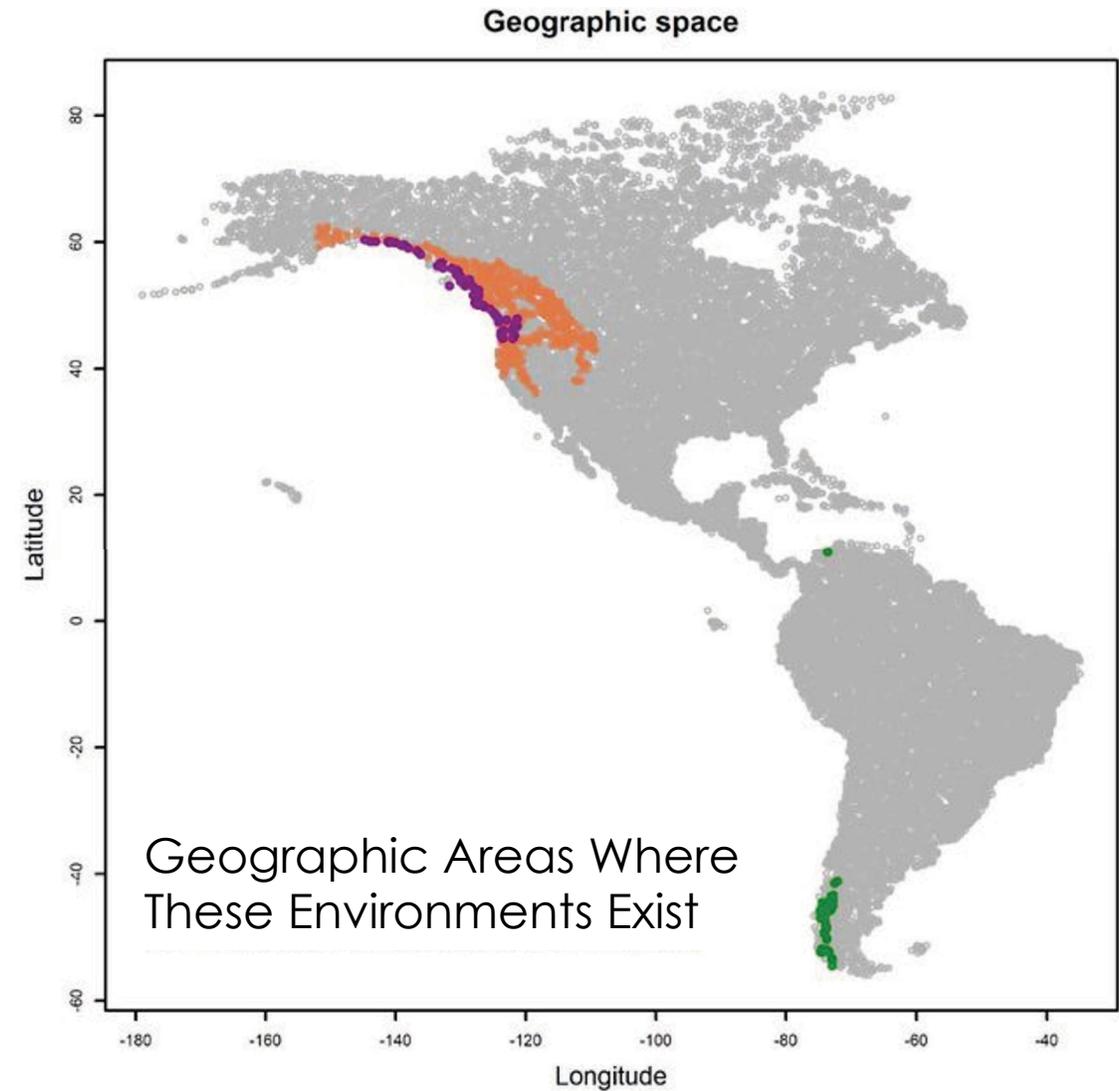
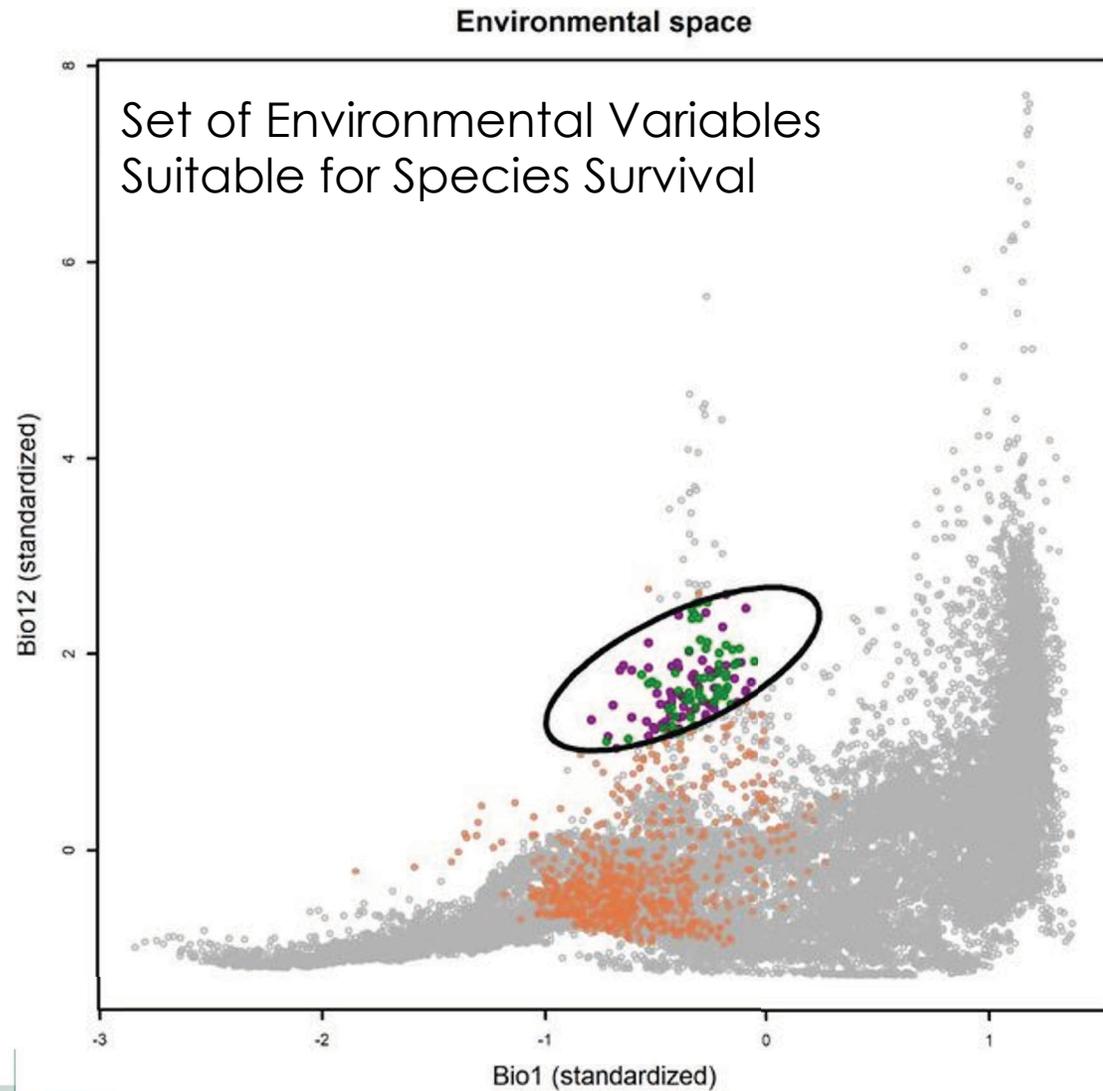
1. Species Distribution Models in **Wallace**
2. **Wallace** Walkthrough: Running a Full SDM Workflow
3. Redesign & Expansion: Making it Easier to Visualize Results and Add New Modules
4. Extensions: SDM Post-Processing for Conservation Decision-Making and Beyond





Species Distribution Models in **Wallace**

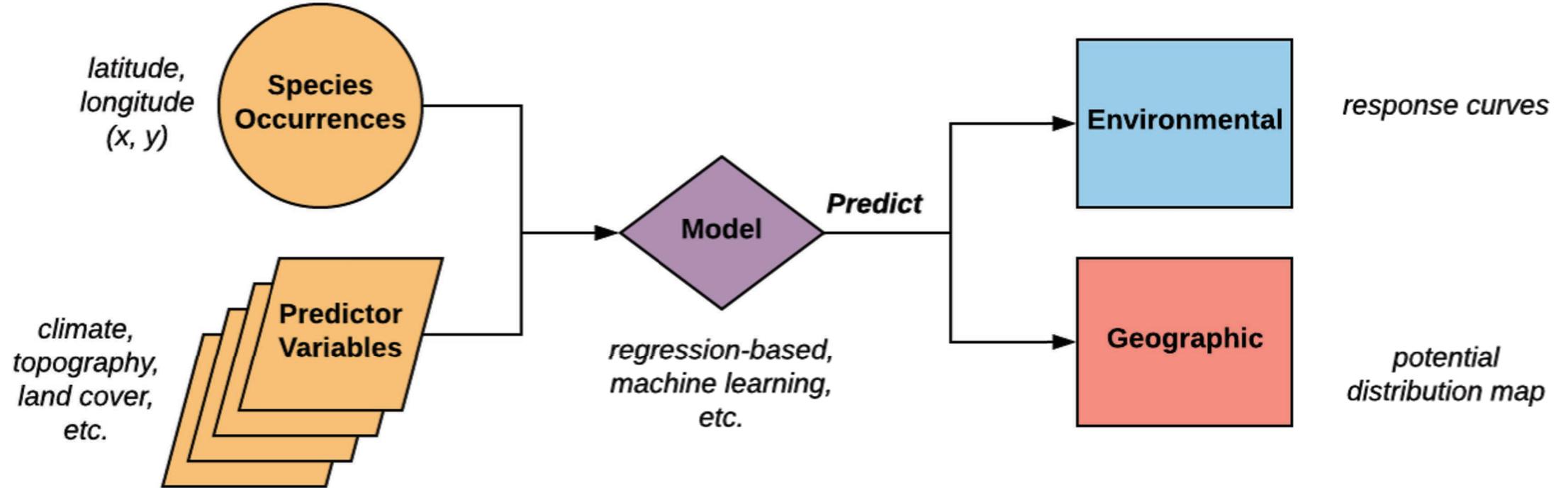
From Ecological Niches to Geographic Distributions



Jiménez & Soberón (2021)



Species Distribution Modeling Overview



Elith & Graham 2009, Phillips et al. 2017; Guisan et al. 2017



Needed in Species Distribution Modeling

Software that achieves a balance between automation and supervision by:

- **Automating** repetitive tasks
- **Forcing** the user to make critical biological and conceptual decisions
- **Being general** with respect to the algorithm(s) used



Needed in Species Distribution Modeling

Software that achieves a balance between automation and supervision by:

- **Automating** repetitive tasks
- **Forcing** the user to make critical biological and conceptual decisions
- **Being general** with respect to the algorithm(s) used

Received: 9 October 2017 | Accepted: 16 November 2017

DOI: 10.1111/2041-210X.12945

APPLICATION

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

Jamie M. Kass^{1,2}  | Bruno Vilela³  | Matthew E. Aiello-Lammens⁴  |
Robert Muscarella⁵  | Cory Merow⁶ | Robert P. Anderson^{1,2,7} 

Methods in Ecology and Evolution 

 **EBBE NIELSEN CHALLENGE**
bringing biodiversity information to life

 National Science Foundation
WHERE DISCOVERIES BEGIN



Anderson 2012; Kass et al. 2017



Wallace: An Ecological Modeling Application

A **user-friendly** application for species distribution modeling that provides **guidance** towards following **best-practices** at each step.



Wallace is:

- Accessible
- Instructive
- Flexible
- Interactive
- Reproducible
- Expandable
- Open

The screenshot displays the Wallace application interface. At the top, a navigation bar shows the current step: 1 Wallace, with other steps like 'Intro', '1 Occ Data', '2 Process Occs', etc. The main content area is divided into several sections:

- Obtain Occurrence Data** (labeled 2): A section with 'Modules Available' including 'Query Database' (selected) and 'User-specified Occurrences'.
- Module: Query Database** (labeled 2a): A sub-section with the description 'via spocc package: Interface to Species Occurrence Data Sources'.
- Choose Database:** (labeled 2b): Radio buttons for 'GBIF' (selected), 'VertNet', and 'BISON'.
- Enter scientific name (format: Genus species):** A text input field containing 'Tremarctos ornatus'.
- Search Database:** A button to execute the search.
- Maximum number of occurrences:** A slider control set to 75, with a range from 1 to 3,000.
- Download DB Occurrences:** A button to download the results.
- spocc references:** A section with developer information: 'Developers: Scott Chamberlain, Karthik Ram, Ted Hart' and a link to 'CRAN | documentation'.

On the right side, a map of South America is displayed (labeled 3b), showing the distribution of 'Tremarctos ornatus' as red dots. A search status box (labeled 3a) indicates: '... Searching gbif ... * Total gbif records for Tremarctos ornatus returned [75] out of [209] total (limit 75). Records without coordinates removed [53], Duplicated records removed [0], Remaining records [22].' A 'Change Base Map' dropdown menu is also visible, currently set to 'ESRI Topo'.



Wallace is:

Accessible

- Lowers barriers to implement cutting-edge SDM techniques
- Allows users to download occurrence & environmental data from diverse sources
- Users can find support from the community through our various networks
 - Google Groups
 - GitHub

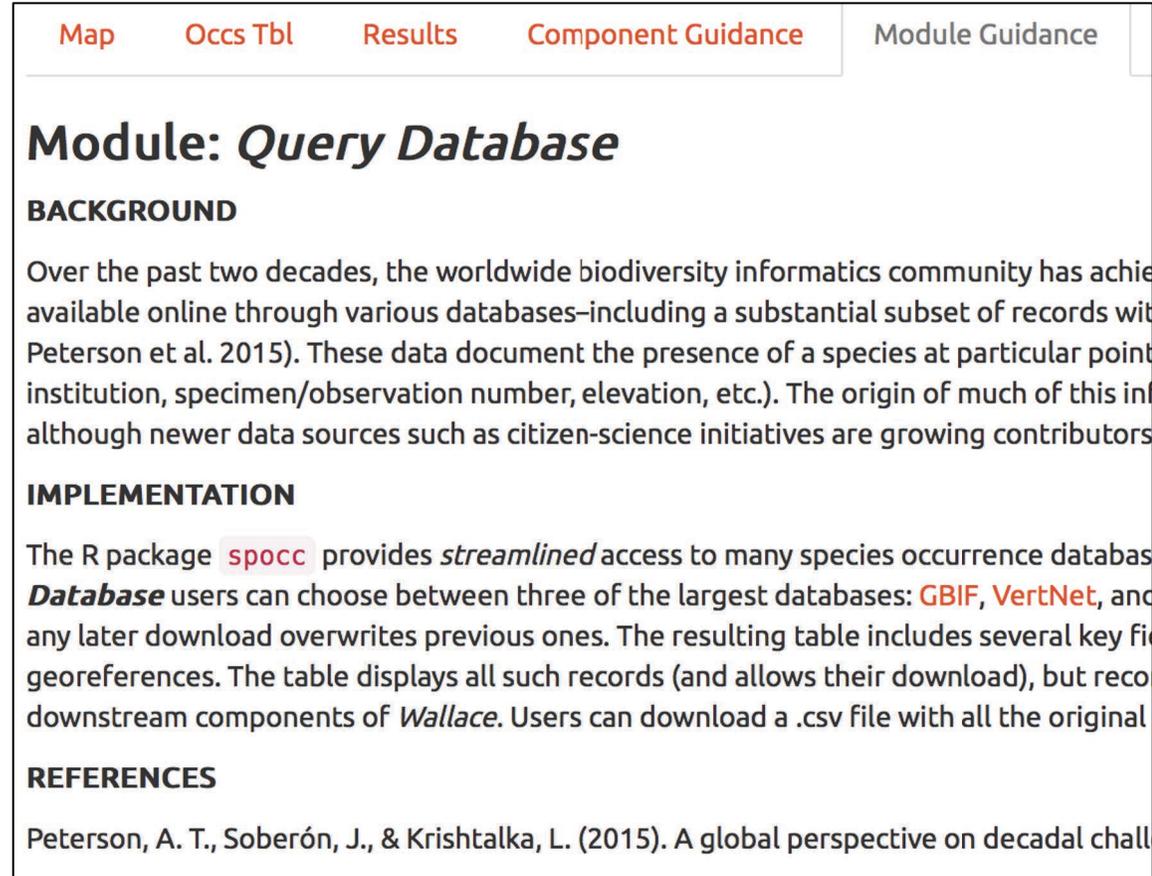
The screenshot displays the Wallace web interface with a navigation bar at the top containing '1 Wallace', 'Intro', '1 Occ Data', and '2 Process Occs'. The main content area is titled 'Obtain Occurrence Data' and includes a 'Modules Available' section with radio buttons for 'Query Database' (selected) and 'User-specified Occurrences'. Below this is a section for 'Module: Query Database' with the description 'via spocc package: Interface to Species Occurrence Data Sources'. The 'Choose Database' section has radio buttons for 'GBIF' (selected), 'VertNet', and 'BISON'. A text input field contains 'Tremarctos ornatus' and a 'Search Database' button is below it. A slider for 'Maximum number of occurrences' is set to 75, with a range from 1 to 3,000. A 'Download DB Occurrences' button is at the bottom. The footer contains 'spocc references' and links for 'Developers: Scott Chamberlain, Karthik Ram, Ted Hart' and 'CRAN | documentation'.



Wallace is:

Instructive

- Provides educational & instructional resources addressing:
 - Concepts/Theories
 - Methods
- Guides users in following best-practices



Map Occs Tbl Results Component Guidance Module Guidance

Module: *Query Database*

BACKGROUND

Over the past two decades, the worldwide biodiversity informatics community has achieved significant progress in making biodiversity data available online through various databases—including a substantial subset of records with detailed metadata (e.g., species name, location, date, institution, specimen/observation number, elevation, etc.). The origin of much of this information is historical, although newer data sources such as citizen-science initiatives are growing contributors.

IMPLEMENTATION

The R package `spocc` provides *streamlined* access to many species occurrence databases. **Database** users can choose between three of the largest databases: **GBIF**, **VertNet**, and **GBIF**. Any later download overwrites previous ones. The resulting table includes several key fields, including georeferences. The table displays all such records (and allows their download), but records are processed through downstream components of *Wallace*. Users can download a .csv file with all the original data.

REFERENCES

Peterson, A. T., Soberón, J., & Krishtalka, L. (2015). A global perspective on decadal challenges in biodiversity informatics.



Wallace is:

Flexible

- Allows users to select from multiple:
 - Data Sources
 - Analytical Tools
- Designed to fit the user's needs

Module: Select Study Region

via `sp` and `rgeos` packages: *Title Classes and Methods for Spatial Data | Interface to Geometry Engine - Open Source (GEOS)*

Background Extents:

- Bounding box
- Minimum convex polygon
- User-specified polygon

Study region buffer distance (degree)

1

Clip Env Data by Polygon

Select File Type

GRD

Download Clipped Env Data



Leaflet | Tiles © Esri — Esri, DeLorme, NAVTEQ, 1 GeoBase, Kadaster NL, Ordnance Survey, Esri Ja Community, Map data: © OpenStreetMap, SRTM Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye,

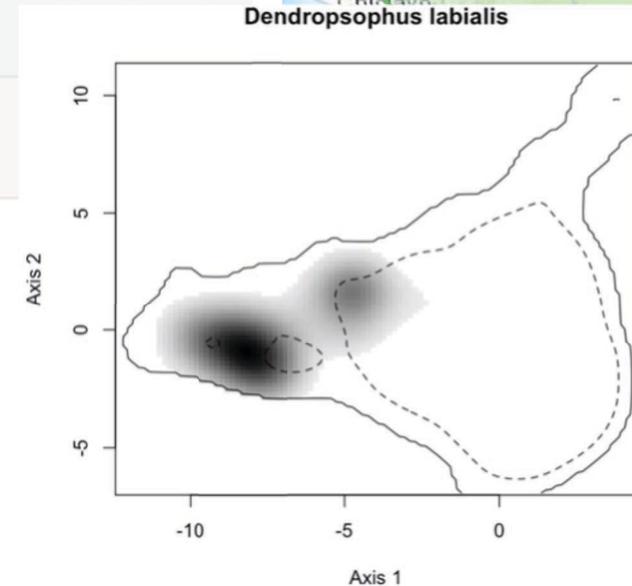
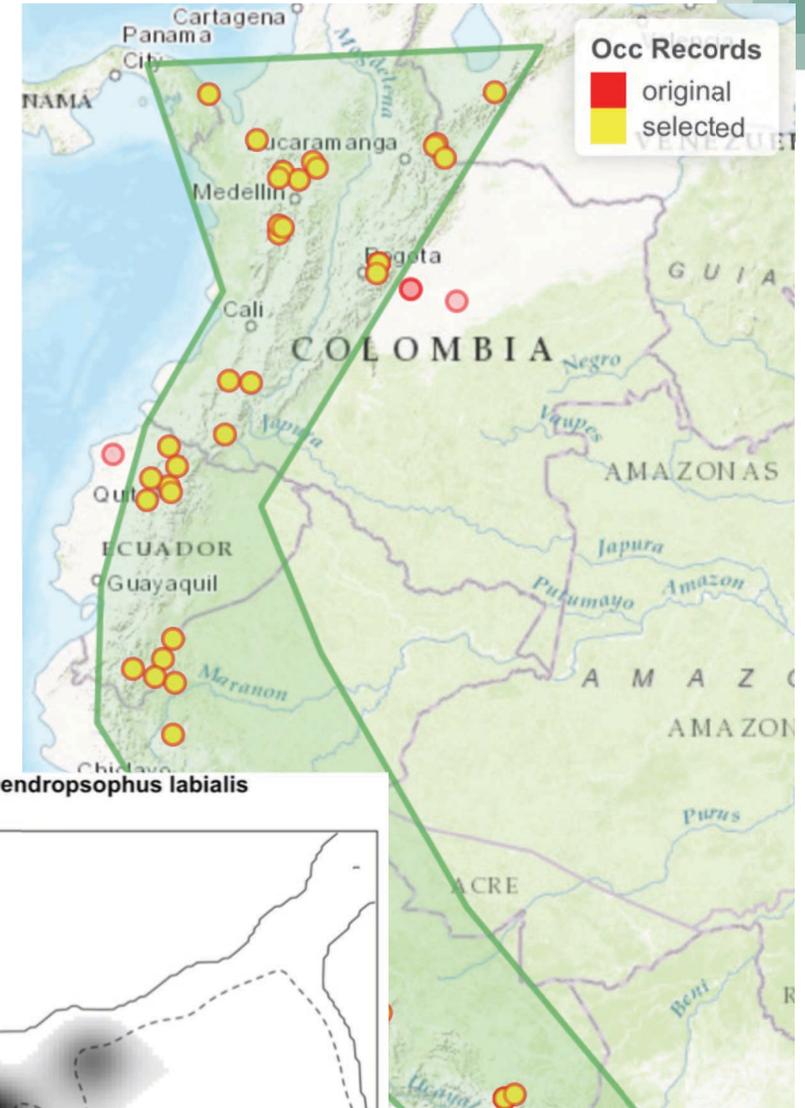


Wallace is:

Interactive

- Provides an assortment of dynamic visualizations to explore data and results
 - Maps
 - Tables
 - Graphs

occID	scientific_name	longitude	latitude	country
1	Dendropsophus labialis (Peters, 1863)	-73.87	4.77	Colombia
2	Dendropsophus labialis (Peters, 1863)	-73.85		
4	Dendropsophus labialis (Peters, 1863)	-73.85		
7	Dendropsophus labialis (Peters, 1863)	-73.81		



Wallace is:

Reproducible

- Allows users to:
 - Download executable code
 - Replicate analyses
 - Save work and load later (no need to redo steps)

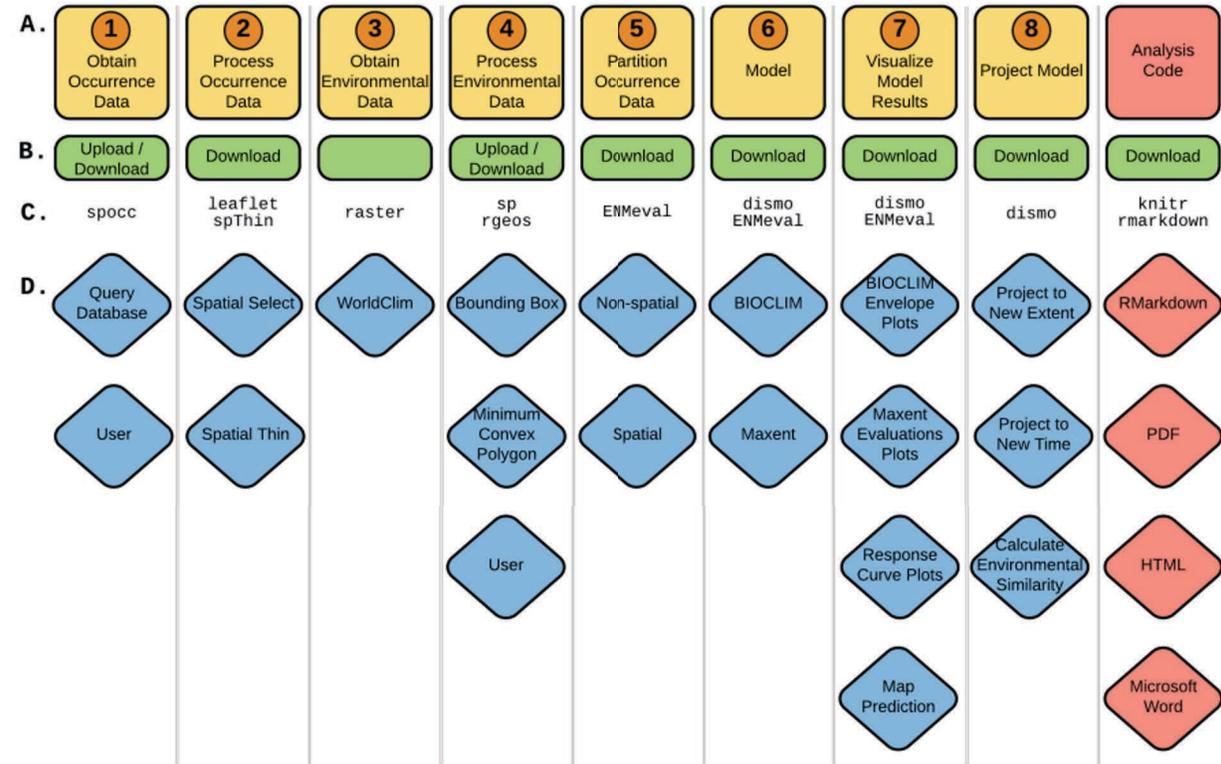
```
1 Please find below the R code history from your *Wallace* session. You can reproduce your session results by running the .Rmd
2 file in RStudio (for more information see <http://rmarkdown.rstudio.com>).
3
4 ### Package installation
5 Wallace uses the following R packages that must be installed and loaded before starting.
6
7 ```{r}
8 library(devtools)
9 library(spocc)
10 library(maptools)
11 library(spThin)
12 library(dismo)
13 library(rgeos)
14 library(repmis)
15 library(maps)
16 library(ENMeval)
17 ```
18
19 Wallace also includes several functions developed to help integrate different packages and some additional functionality. For
20 this reason, it is necessary to load the file 'functions.R', which can be found on Wallace's GitHub page
21 (<https://github.com/wallaceEcoMod/wallace>). Download the file, place it in your working directory (find this with `getwd()`)
22 and then load it:
23
24 ```{r}
25 source(file.path("~/Users/musasaki/Documents/github/wallace", 'functions.R'))
26 ```
27
28 Record of analysis for *Tremarctos ornatus*.
29 -----
30
31 ### Obtain Occurrence Data
32
33 The search for occurrences was limited to 81 records. Obtain occurrence records of the selected species from the database:
34
35 ```{r}
36 results <- occ(query = "Tremarctos ornatus", from = "gbif", limit = 81, has_coords = TRUE)
37 results.data <- results[["gbif"]]$data[[formatSpName("Tremarctos ornatus")]]
38 occs <- remDups(results.data) # remove rows with duplicate coordinates
39 ```
40
41 ### Process Occurrence Data
42
43 You chose 42 of 51 total occurrence localities via polygon selection to keep in the analysis.
44
45 ```{r}
46 occs <- occs[c(1, 2, 3, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20, 21, 22, 24, 25, 26, 27, 30, 31, 34, 35, 36, 37, 39,
47 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51), ] # subset occs by selected rows
```



Wallace is:

Expandable

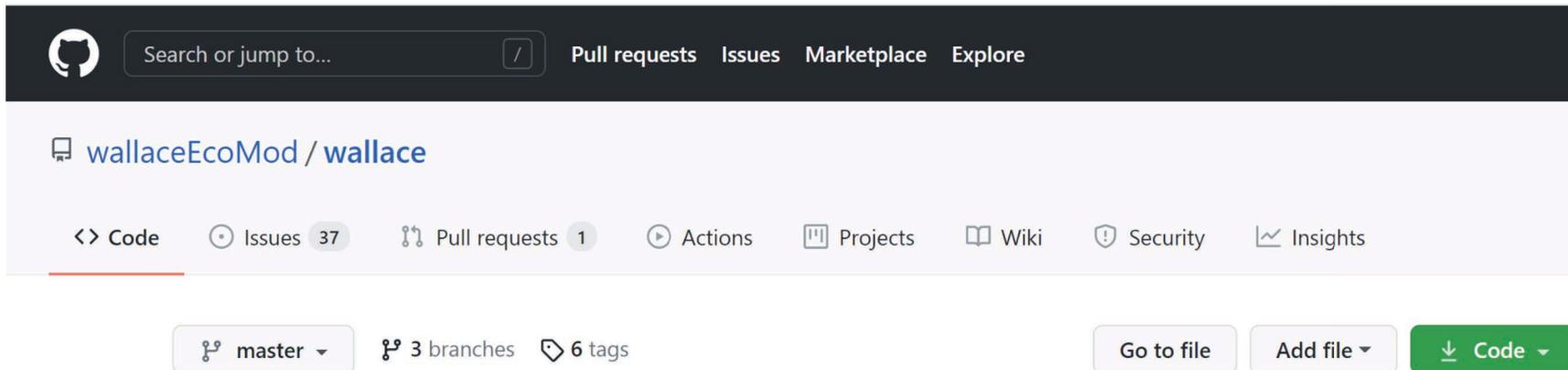
- Users can contribute new functions & analytical tools to be integrated as:
 - Components (A)
 - Modules (D)



Wallace is:

Open

- Code is publicly available for users to:
 - Download (CRAN, GitHub)
 - Modify & suggest enhancements
- Enables users to become contributors





Wallace Walkthrough: Running a Full SDM Workflow

Install and Run **Wallace**

1. Install R (version \geq v.3.5.0) and RStudio
2. Install the **Wallace** package from CRAN (v.1.1; stable)
3. Run **Wallace** in RStudio

```
# install the package  
install.packages('wallace')  
# load the package  
library(wallace)  
# run the app  
run_wallace()
```





Redesign & Expansion: Making it Easier to Visualize Results
and Add New Modules

Wallace V2 Coming Soon

- **New modules** added with help from collaborators around the world
 - More data sources
 - More analytical features
- Re-designed to make **module additions easier**
- Now based on RMMS **metadata** (Merow et al. 2019)
- Development guided by **user feedback**:
 - Conference workshops, emails, Google group





Extensions: SDM Post-Processing for Conservation Decision-Making and Beyond

Wallace V3 Partnership for Conservation

Wallace

1 Wallace Home 1 Occ Data 2 Process Occs 3 Env Data 4 Process Env 5 Partition Occs 6 Model 7 Visualize 8 Project 9 Session Code

Obtain Occurrence Data
Modules Available:
 Query Database
 Unspecified Occurrences

Module: Query Database
via SPiDCE package interface to Species Occurrence Data Sources

Choose Database:
 GBIF
 VertNet
 BISON

Enter scientific name (format: Genus species)
Tremarctos ornatus
Search Database

Maximum number of occurrences:
1000

Download DB Occurrences

SPiDCE references
Developers: Scott Chamberlain, Karthik Ram, Ted Hart
CRAN: Documentation

Searching gbif ...
• Total gbif records for Tremarctos ornatus returned [75] out of [200] total limit.
75 | Records without coordinates removed [53] | Duplicated records removed [0]
Remaining records [22]

Map Occs TM Results Component Guidance Module Guidance

Change Base Map
ESRI Type

BioModelos
MEJORES MODELOS CON
EL APOYO DE EXPERTOS
biomodelos.humboldt.org.co

GEO BON BON in a Box

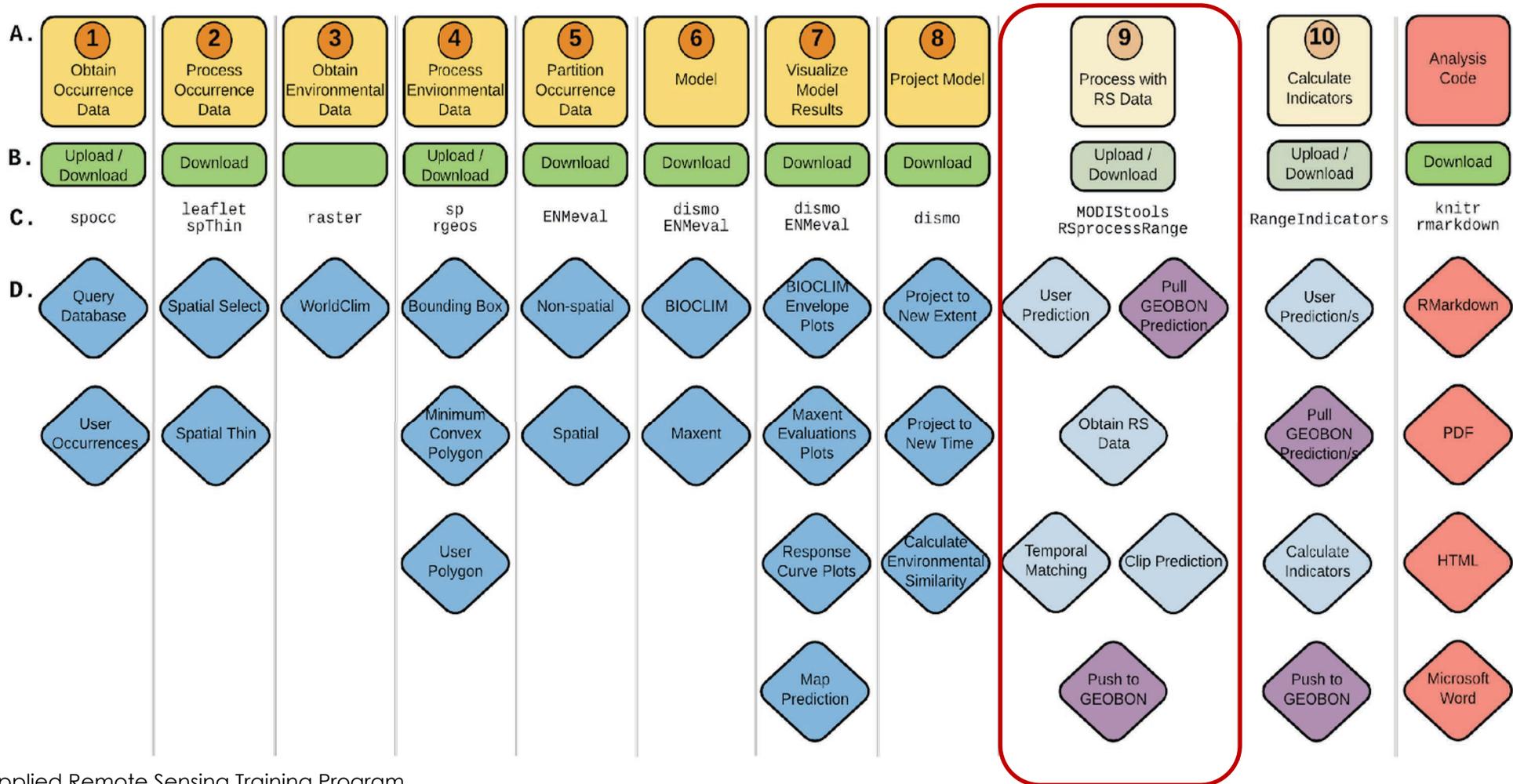
Galante et al. *in prep.*



New Components Added to Wallace (v3)



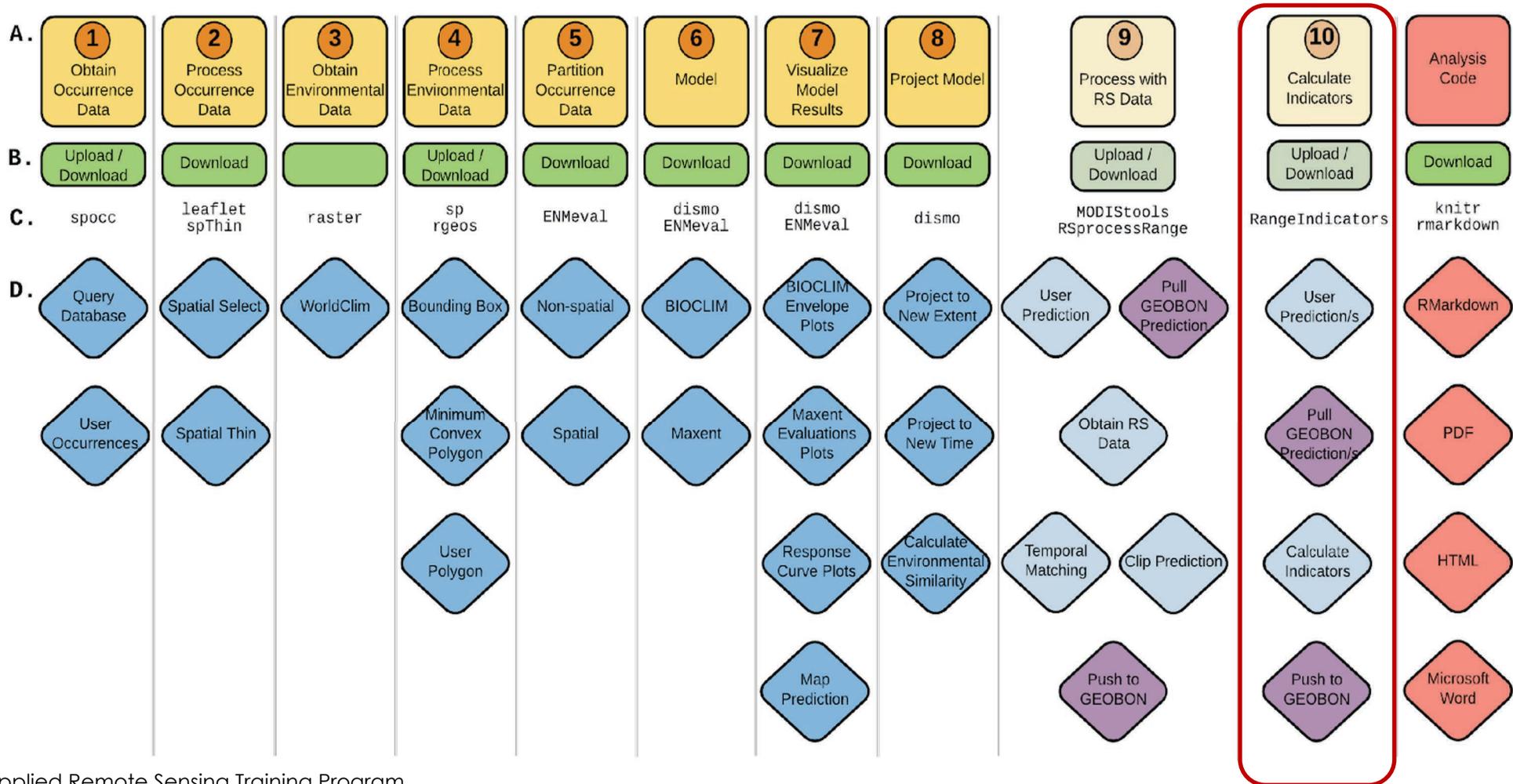
- Intro
- Occ Data
- Env Data
- Proc Occs
- Procs Envs
- Env Space
- Part Occs
- Model
- Visualize
- Project
- User SDM
- Mask
- ChangeRR
- Alpha Div



New Components Added to Wallace (v3)

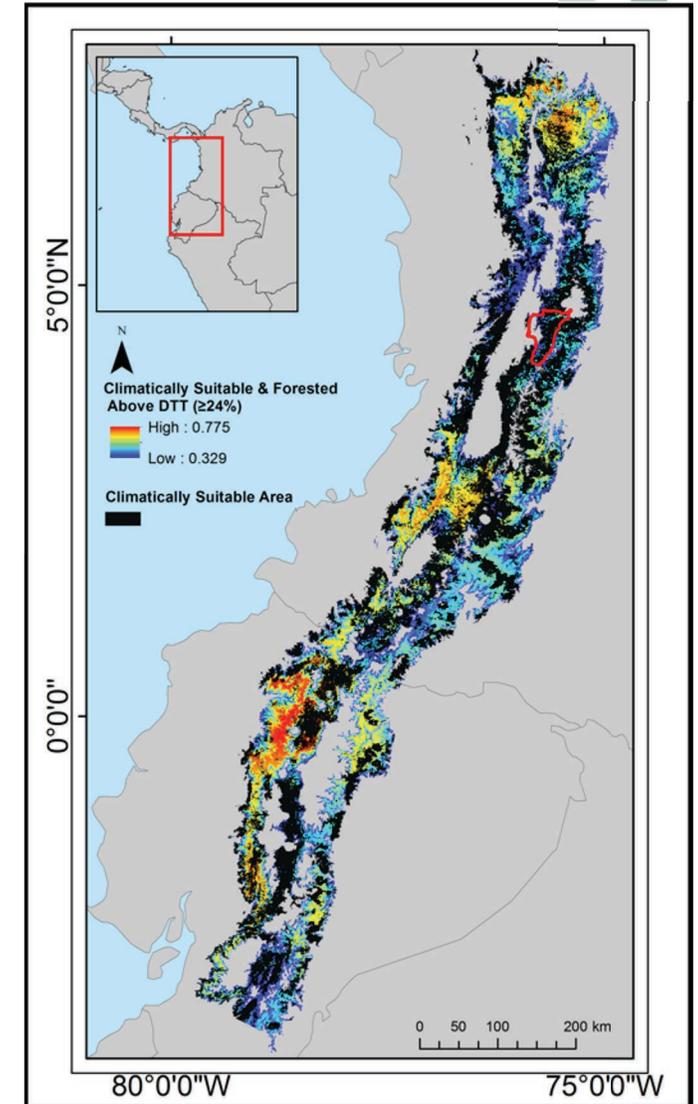


- Intro
- Occ Data
- Env Data
- Proc Occs
- Procs Envs
- Env Space
- Part Occs
- Model
- Visualize
- Project
- User SDM
- Mask
- ChangeRR
- Alpha Div



Mask SDM (Based on maskRangeR)

- Post-processes SDMs to estimate current ranges:
 - RS Products
 - E.g., Forest Cover, Urbanization, Cultivars
 - User-Defined Polygons
 - E.g., Protected Areas, Land Cover
 - Expert-Defined Maps/Ranges



Mask Example: Olinguito (*Bassaricyon neblina*)

- Recently described small carnivore
- Limited to high-altitude cloud forests
- Data-poor
- Needs IUCN status update given recent deforestation

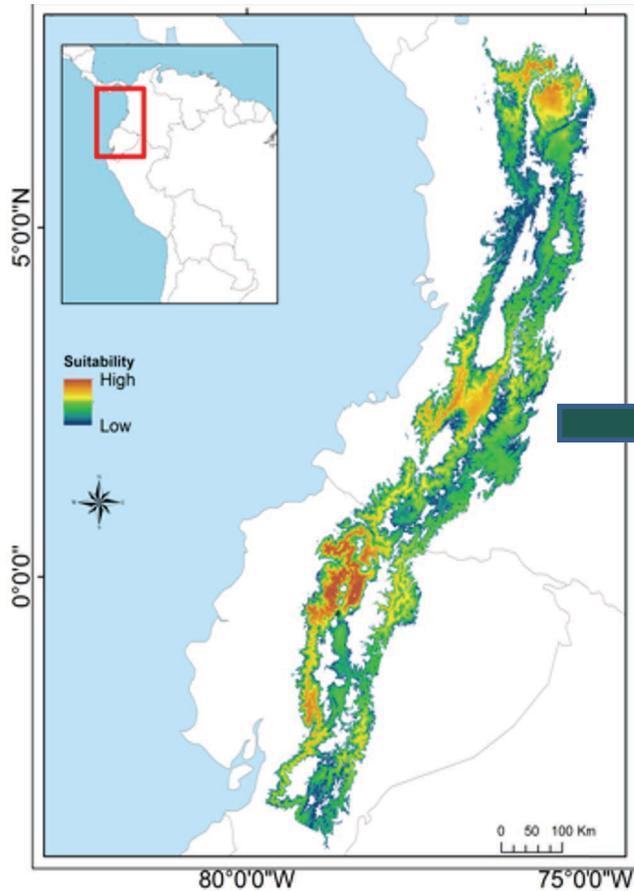


Merow et al. *In rev.*

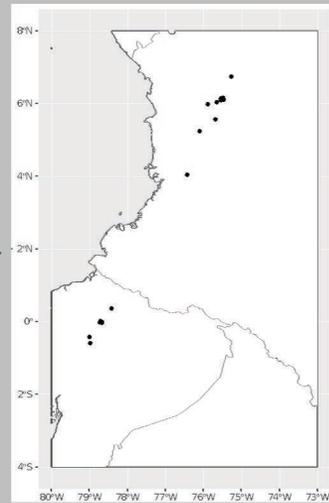


Mask Example: Olinguito (*Bassaricyon neblina*)

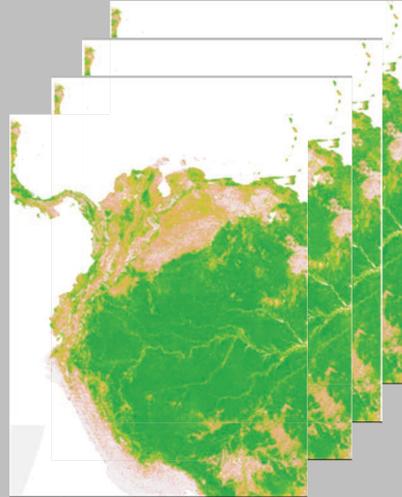
SDM



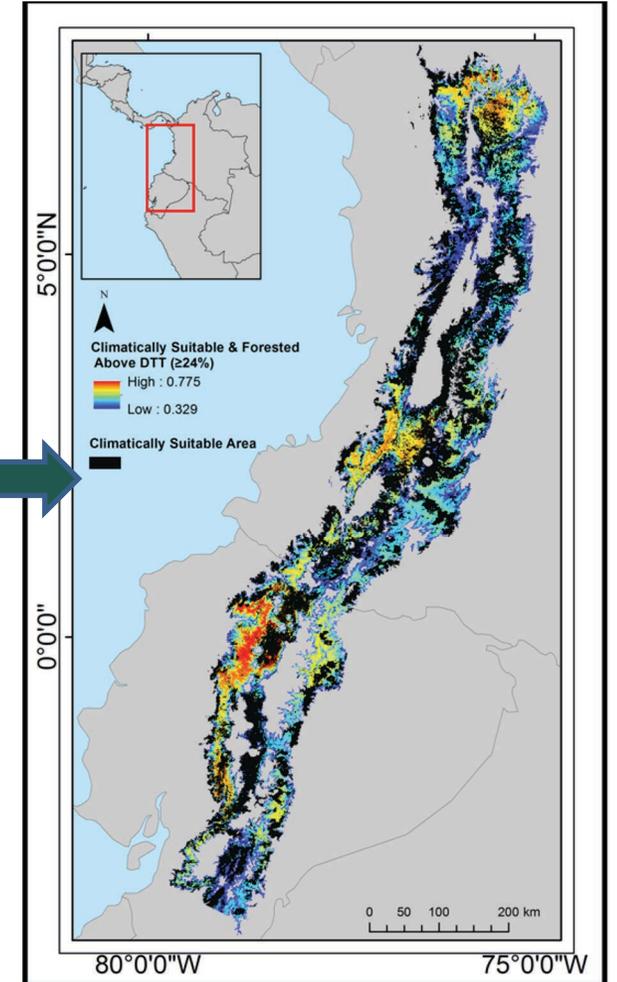
Recent Occurrences



MODIS Yearly Forest Cover

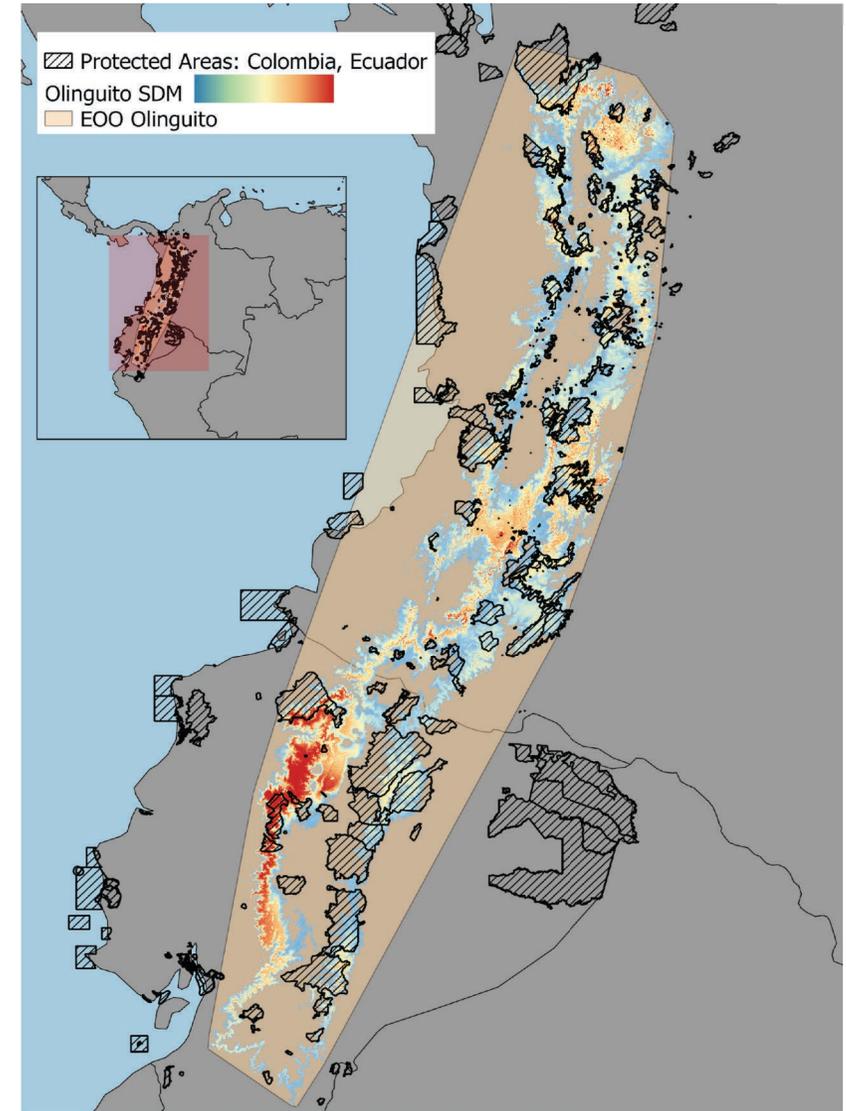


Masked Distribution



Calculate Indicators (Based on changeRangeR)

- Calculate key biodiversity change indicators
 - IUCN AOO & EOO
 - Percentage of Suitable Land Cover
 - Protected Area Representativeness



Calculate Indicators Example: Olinguito (*Bassaricyon neblina*)

- Changes in Range, AOO, EOO given GIS data:

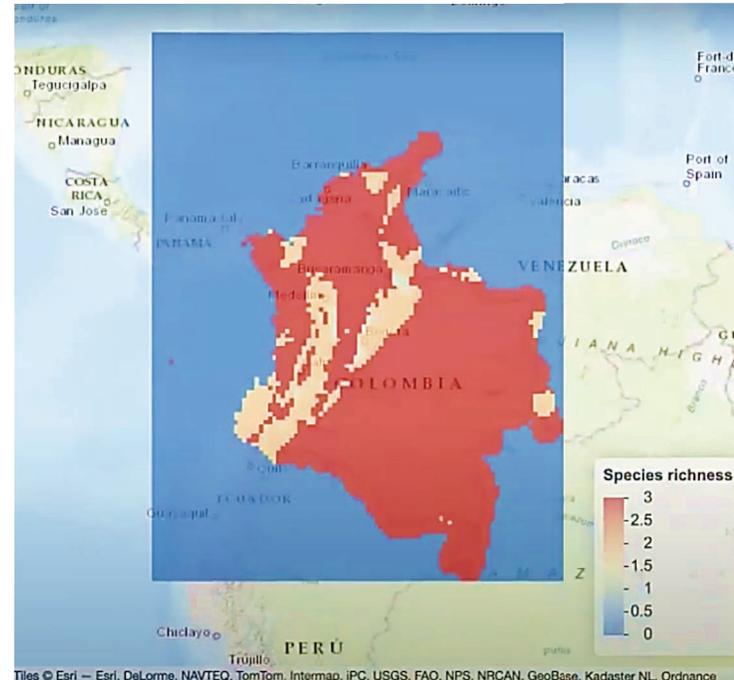
- Changes over time/space
- E.g., deforestation over time



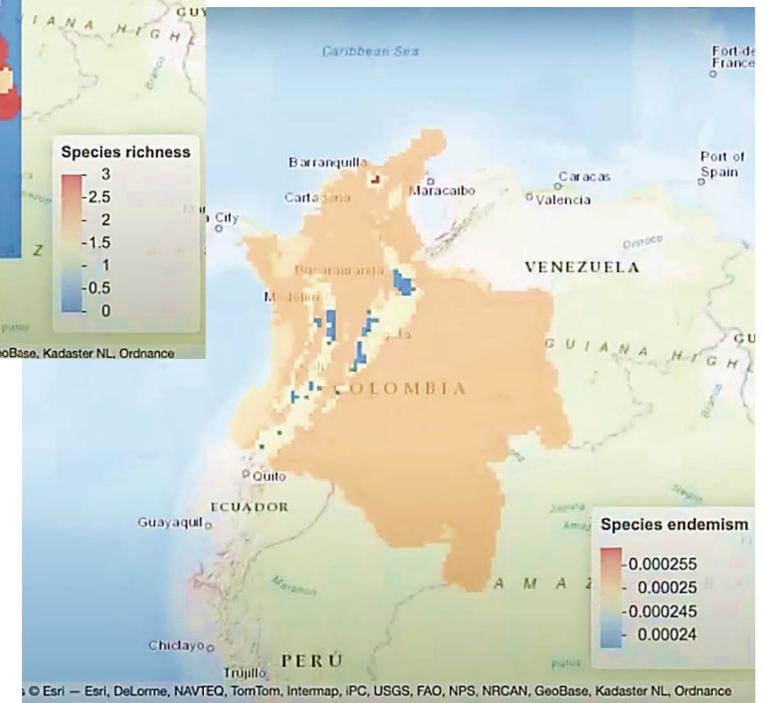
Calculate Indicators Example: Colombian Primates

Richness

- Multispecies Diversity Metrics:
 - Species Richness
 - Species Endemism
- Soon in **Wallace**:
 - Phylogenetic Diversity
 - Phylogenetic Endemism
 - Complementarity



Endemism



Summary

- **Wallace** is a **user-friendly** application for species distribution modeling that provides **guidance** towards following **best-practices** at each step.
 - Accessible, Instructive, Flexible, Interactive, Reproducible, Expandable, Open
- **Wallace V2** (coming soon)
 - Provides additional SDM data sources & analytical tools.
 - Facilitates module contributions (from user community)
- **Wallace V3** (in development)
 - Added tools for conservation applications
 - Estimate species ranges
 - Calculate biodiversity indicators.
- Next Session: Additional SDM Tools and Techniques



Contacts

- Trainers:

- Juan Torres-Pérez: juan.l.torresperez@nasa.gov
- Amber McCullum: amberjean.mccullum@nasa.gov
- Zach Bengtsson: bengtsson@baeri.org

Follow us on Twitter
[@NASAARSET](https://twitter.com/NASAARSET)

- Training Webpage:

- <https://appliedsciences.nasa.gov/join-mission/training/english/arset-species-distribution-modeling-remote-sensing>
- ARSET Website:
- <https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset>





18-GEOBON-0020



DBI 1650241
DBI 1661510

Thank You!

 wallaceecomod.github.io

 groups.google.com/g/wallaceecomod





Supplemental: **Wallace** Walkthrough Slides

Component 1: Obtain Presence Data (Occ Data)

- User-specified
- Download from online databases



The screenshot shows the '1 Occ Data' step of the spocc application. The interface includes a navigation bar with tabs for Wallace, Intro, 1 Occ Data (highlighted), 2 Process Occs, 3 Env Data, 4 Process Envs, 5 Partition Occs, 6 Model, 7 Visualize, 8 Project, and Session Code. The main content area is titled 'Obtain Occurrence Data' and includes a 'Modules Available' section with 'Query Database' selected. The 'Module: Query Database' section shows the species name 'Tremarctos ornatus' and a slider for 'Set maximum number of occurrences' set to 200. A 'Query Database' button is visible. A log window on the right displays the message: '> Total gbif records for Tremarctos ornatus returned [200] out of [237] total (limit 200). Records without coordinates removed [129]. Duplicated records removed [5]. Remaining records [66].' A red arrow points to this log message. Below the log is a map of South America with red dots indicating occurrence locations, and a photo of a black bear. The bottom of the page includes copyright information for Leaflet and Esri.



Component 2: Process Presence Data (Process Occ)

Wallace v1.9.9.0 Intro OccData Env Data **Process Occs** Process Envs Partition Occs Model Visualize Project Data for Post-Processing Post-processing

Process Occurrence Data
Modules Available:
 Select Occurrences On Map
 Remove Occurrences By ID
 Spatial Thin

Module: Spatial Thin
spThin : Functions for Spatial Thinning of Species Occurrence Records for Use in Ecological Models

Thinning distance (km)

Batch

Reset to original occurrences

Module Developers: Jamie M. Kass, Matthew E. Aiello-Lammens, Robert P. Anderson
spThin references
Package Developers: Matthew E. Aiello-Lammens, Robert A. Boria, Aleksandar Radosavljevic, Bruno Vilela, and Robert P. Anderson
[CRAN | documentation](#)

Tremarctos_ornatus

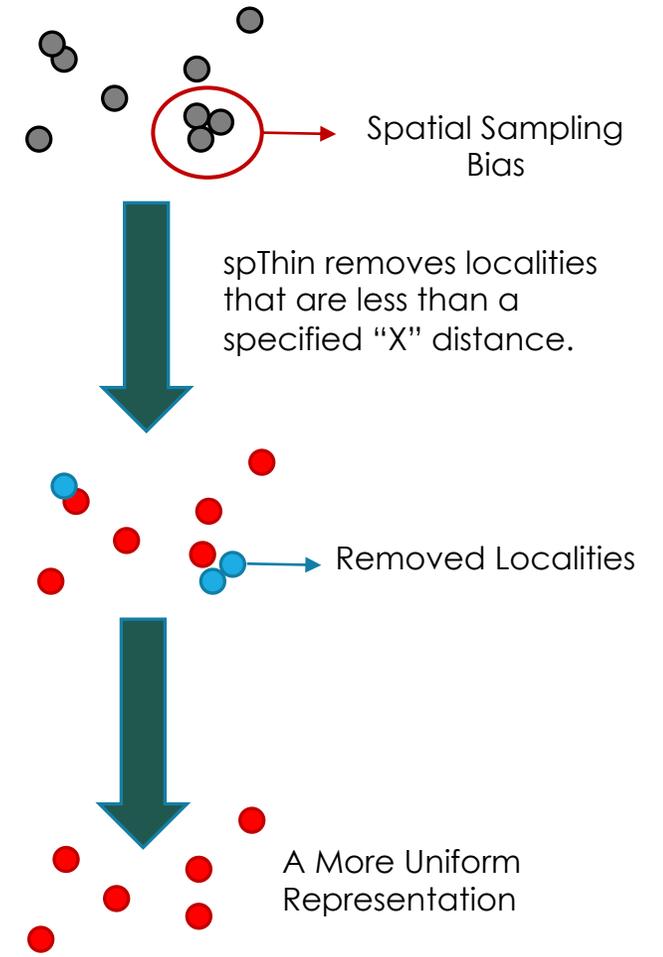
Duplicated records removed [8]. Remaining records [14].
> WorldClim bioclimatic variables bio1-19 at 10 arcmin resolution.
> **!WARNING:** Removed records without environmental values with occIDs: 55.

Map Table Results Component Guidance Module Guidance Download

Map

ESRI Topo

Map of South America showing occurrence points for Tremarctos ornatus. The map includes labels for countries like Colombia, Ecuador, Peru, Venezuela, and Bolivia, and geographical features like the Amazon Basin and Andes.



Component 3: Obtain Environmental Data (Env Data)

- User-specified
- Download from online databases
 - [WorldClim](#)

Wallace Intro 1 Occ Data 2 Process Occs **3 Env Data** 4 Process Envs 5 Partition Occs 6 Model 7 Visualize 8 Project Session C

Obtain Environmental Data

Modules Available:

WorldClim Bioclimes
 User-specified

Module: WorldClim Bioclimes
raster : Geographic Data Analysis and Modeling

Select WorldClim bioclimatic variable resolution

2.5 arcmin

Specify variables to use in analysis?

Select

bio1 bio2 bio3 bio4 bio5 bio6
 bio7 bio8 bio9 bio10 bio11
 bio12 bio13 bio14 bio15 bio16
 bio17 bio18 bio19

Using map center coordinates as reference for tile download.
Using map center -75.512, 4.356

Load Env Data

> Removed occurrence with ID = 159 . Updated data has n = 56 records.
> Total records thinned to [44] localities.
> Environmental predictors: WorldClim bioclimatic variables bio1-19 at 2.5 arcmin resolution.

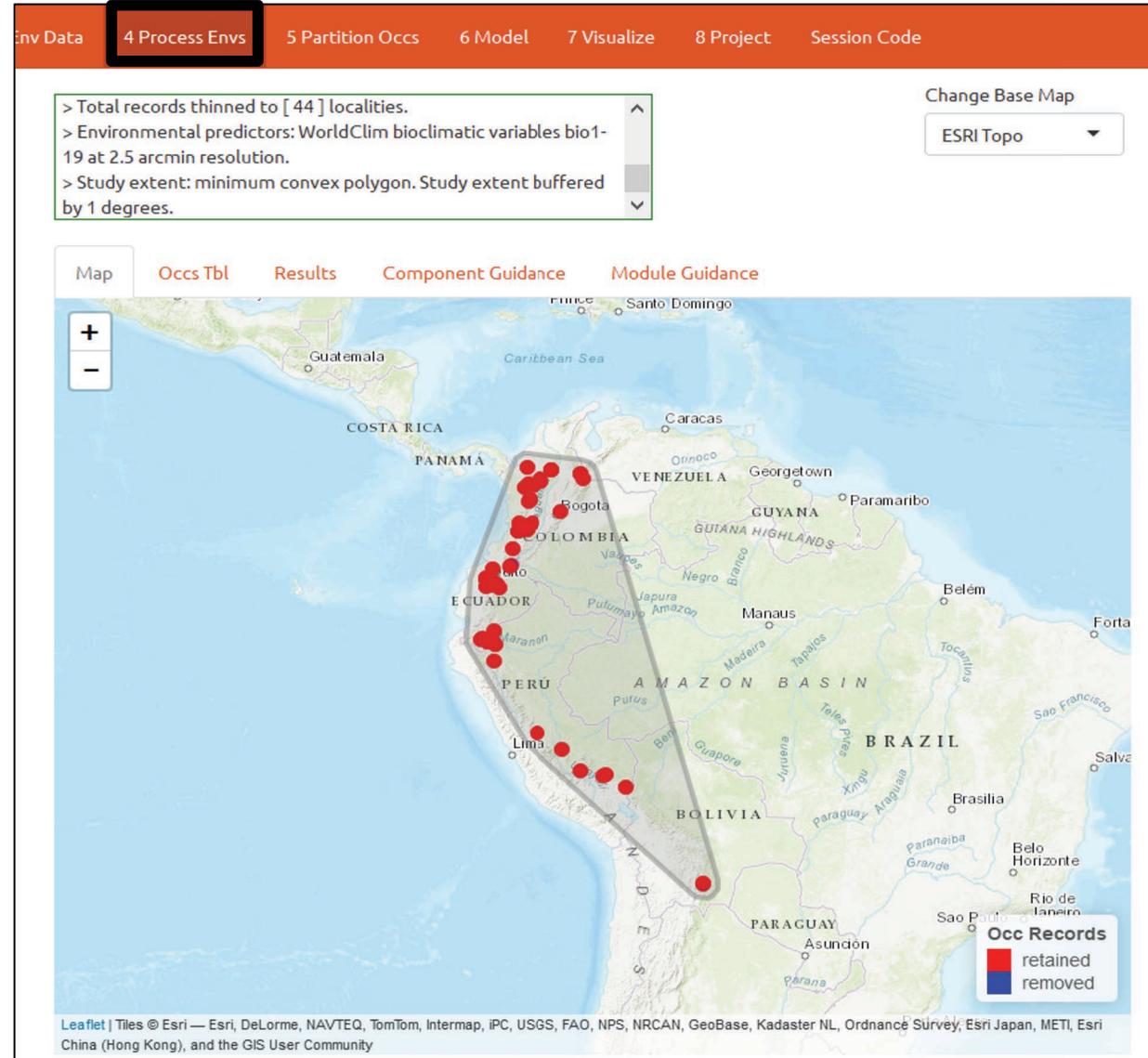
Map Occs Tbl **Results** Component Guidance Module Guidance

```
class      : RasterStack
dimensions : 3600, 8640, 31104000, 19  (nrow, ncol, ncell, nlayers)
resolution : 0.04166667, 0.04166667  (x, y)
extent     : -180, 180, -60, 90  (xmin, xmax, ymin, ymax)
coord. ref.: +proj=longlat +datum=WGS84 +ellps=WGS84 +towgs84=0,0,0
names      : bio01, bio02, bio03, bio04, bio05, bio06, bio07, bio08, bio09,
             bio13, bio14, bio15, ...
min values : -278, 9, 8, 64, -86, -559, 53, -278, -501,
             0, 0, 0, ...
max values : 319, 213, 96, 22704, 489, 258, 725, 376, 365,
             2437, 697, 265, ...
```



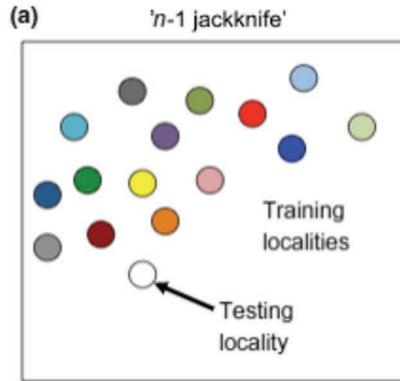
Component 4: Process Environmental Data (Process Envs)

- Select Study Region
 - User-Specified
 - Bounding Box
 - Minimum Convex Polygon
 - Point-Buffers
- Sample Background Points



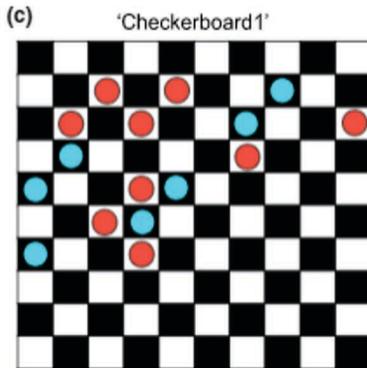
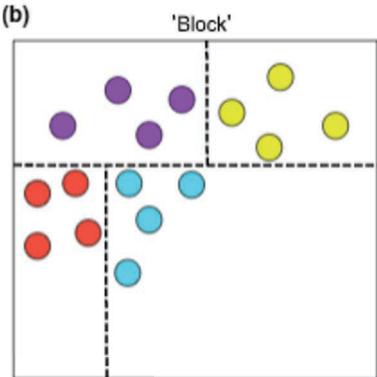
Component 5: Partition Occurrence Data (Partition Occs)

- Non-Spatial (Random)

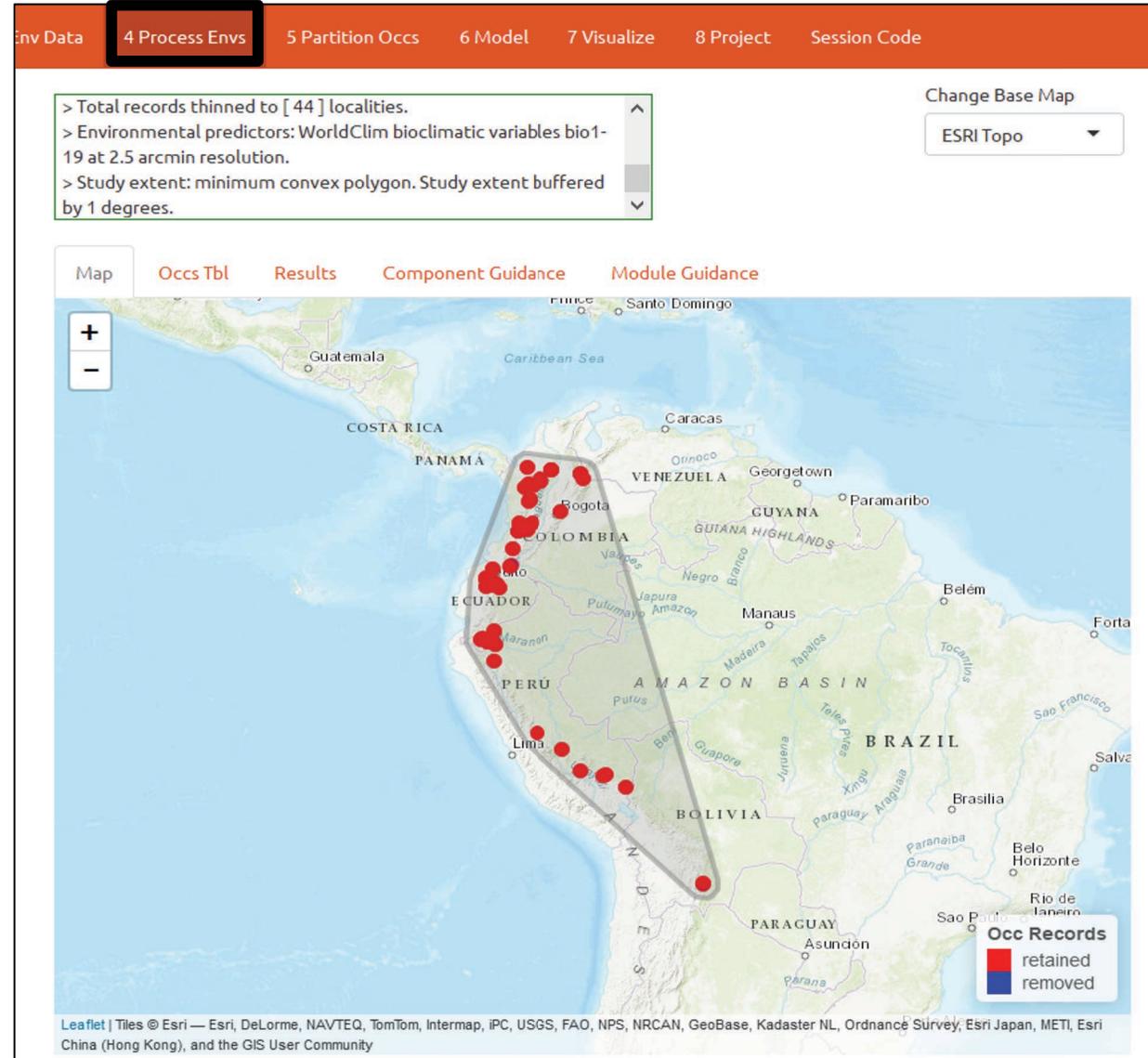


Muscarella et al. 2014

- Spatial



Muscarella et al. 2014



Muscarella et al. 2014



Component 6: Model Building & Evaluation (Model)

- Modeling Algorithms:

- Bioclim
- Maxent
 - maxent.jar
 - Maxnet

- Model Tuning:

- Test parameter combinations
- Find best-performing model
- Reduce complexity

The screenshot displays the ENMeval web interface. The top navigation bar includes tabs for Wallace, Intro, 1 Occ Data, 2 Process Occs, 3 Env Data, 4 Process Envs, 5 Partition Occs, 6 Model (highlighted), 7 Visualize, 8 Project, and Session Code. The main content area is titled "Build and Evaluate Niche Model" and includes a "Modules Available" section with radio buttons for BIOCLIM and Maxent (selected). Below this is the "Module: Maxent" section, which provides information about ENMeval and dismo. A note mentions module guidance for troubleshooting. The "Select feature classes" section includes checkboxes for L, LQ, H, LQH, LQHP, and LQHPT. The "Select regularization multipliers" section features a slider and a "Multiplier step value" input field set to 0.5. A "Run" button is located at the bottom of the configuration section. On the right side, there is a log window showing the execution progress, a "Results" tab, and two tables of evaluation statistics. The first table, "Full model and partition bin average evaluation statistics", lists 10 different model configurations with their respective performance metrics. The second table, "Individual partition bin evaluation statistics", shows detailed AUC values for two different partition bins across the same configurations.

	settings	features	rm	fullAUC	avg.test.AUC	var.test.AUC	avg.diff.AUC
1	L_1	L	1	0.817	0.767	0.046	0.09
2	LQ_1	LQ	1	0.9	0.781	0.033	0.116
3	H_1	H	1	0.926	0.806	0.024	0.124
4	LQH_1	LQH	1	0.93	0.801	0.023	0.132
5	L_1.5	L	1.5	0.816	0.779	0.032	0.075
6	LQ_1.5	LQ	1.5	0.88	0.785	0.029	0.11
7	H_1.5	H	1.5	0.914	0.83	0.02	0.092
8	LQH_1.5	LQH	1.5	0.917	0.821	0.018	0.108
9	L_2	L	2	0.819	0.79	0.025	0.06
10	LQ_2	LQ	2	0.864	0.798	0.028	0.093

	AUC_bin.1	AUC_bin.2	AUC_bin.3	AUC_bin.4	AUC.DIFF_bin.1	AUC.DIFF_bin.2
1	0.641	0.709	0.786	0.934	0.206	0.125
2	0.695	0.791	0.71	0.927	0.201	0.081



Component 6: Model Building Background

Feature Classes

L

Q

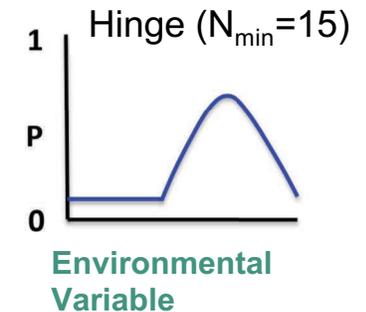
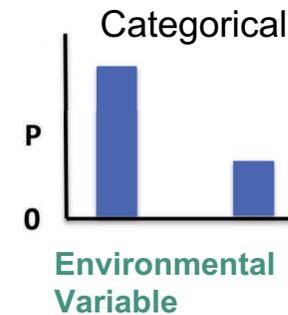
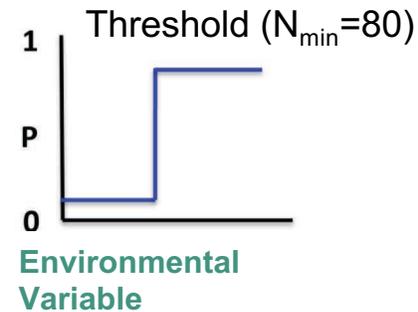
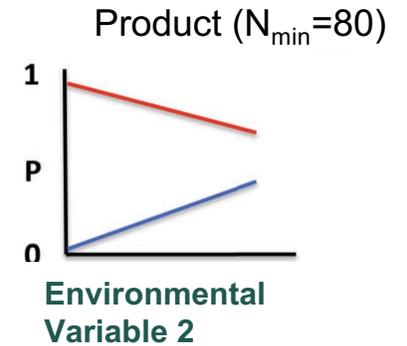
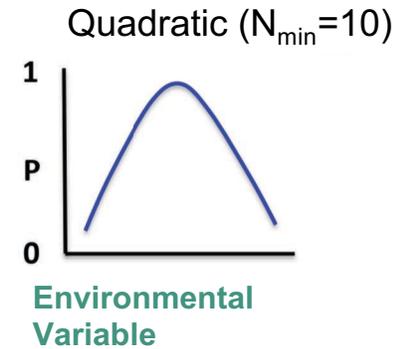
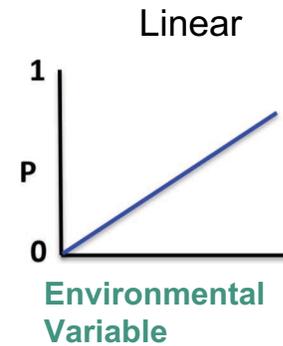
H

P

T

■
■

'features'



Component 6: Model Building Background

Regularization
Multiplier

0.5

1

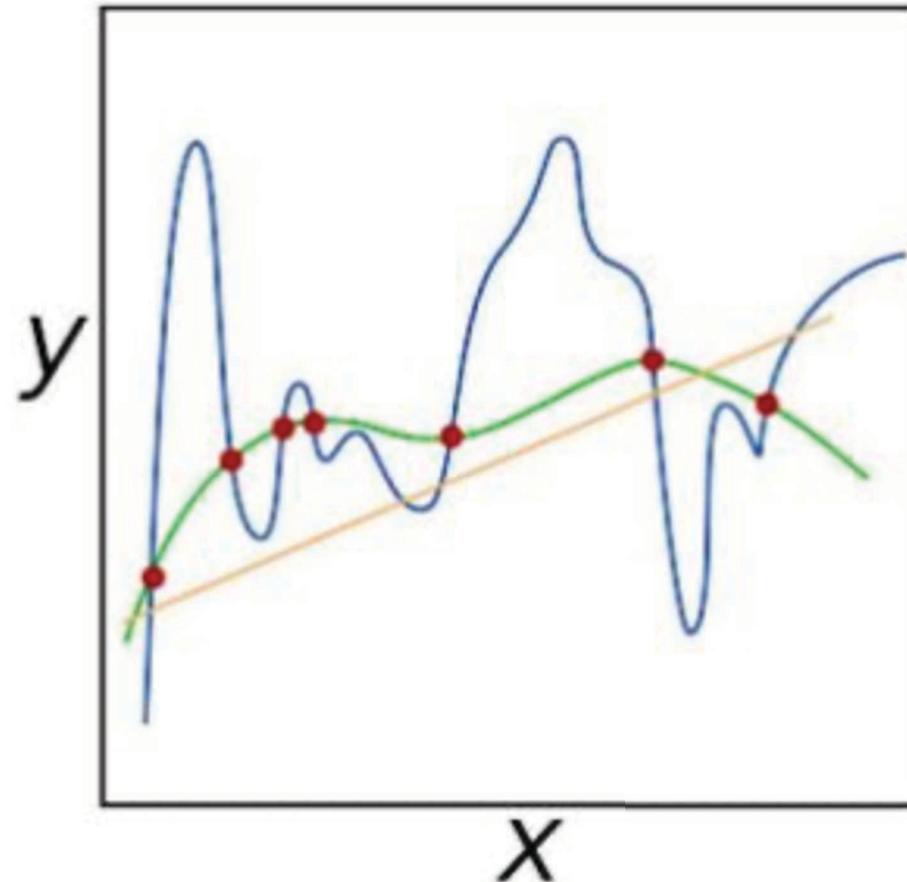
1.5

2

2.5

⋮

RMs penalize higher complexity.



Overfit Model
(blue)

Underfit Model
(yellow)

Generalized Model
(green) **Desired**



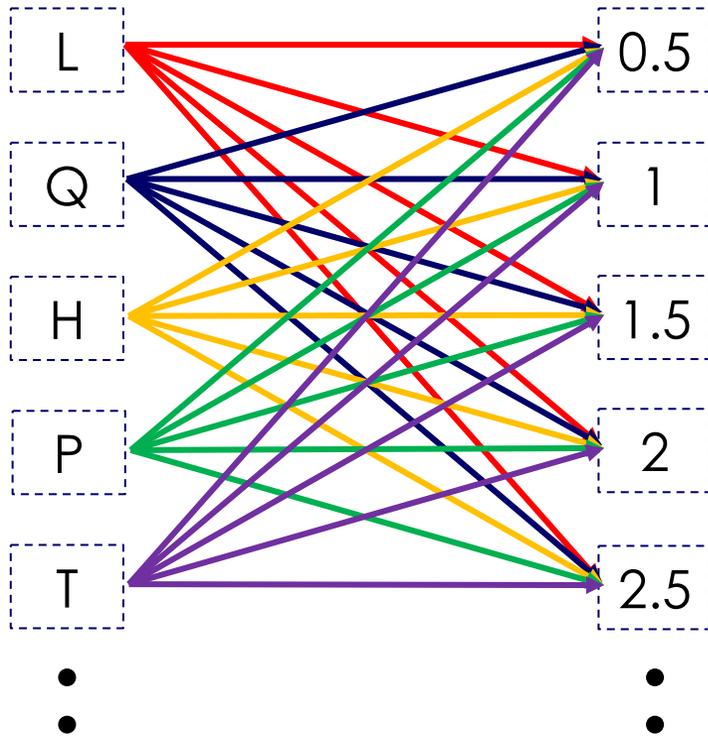
Component 6: Model Tuning

Environmental Response

Penalty to Model Complexity

Feature Classes

Regularization Multiplier



	rm ↕	fc ↕
1	1	L
2	1	LQ
3	1.5	L
4	1.5	LQ
5	2	L
6	2	LQ
7	2.5	L
8	2.5	LQ
9	3	L
10	3	LQ

Recommendations:

- >80 occurrence records:
All Feature Classes
- 15 – 79 occurrence records: L, Q, H
- 10 – 14 occurrence records: L and Q
- < 10 occurrence records: L only



Component 6: Model Evaluation

- Modeling Evaluation Metrics
 - AUC
 - Omission Rate
 - AICc
 - N Parameters
- Applicable To:
 - Entire Model
 - Each Partition

The screenshot shows a software interface for model evaluation. At the top, there are navigation tabs: 'env Data', '4 Process Envs', '5 Partition Occs', '6 Model' (highlighted with a red box), '7 Visualize', '8 Project', and 'Session Code'. Below the tabs, there is a text area with log output: '> Occurrences partitioned by block method.', '> Occurrences partitioned by block method.', '> BIOCLIM ran successfully and output evaluation results.', and '> Maxent ran successfully and output evaluation results for 28 models.'. To the right, there are controls for 'Change Base Map' (set to 'ESRI Topo'), 'Current Env Variable' (set to 'bio02'), and 'Current model' (set to 'L_1'). Below these are tabs for 'Map', 'Occs Tbl', 'Results' (selected), 'Component Guidance', and 'Module Guidance'. The main content area is titled 'Full model and partition bin average evaluation statistics'. A red arrow points to a table with the following columns: '.test.AUC', 'avg.diff.AUC', 'var.diff.AUC', 'avg.test.or10pct', 'var.test.or10pct', 'avg.test.orMTP', and 'var.test.orMTP'. The table contains 10 rows of data. Below the table is a pagination control with 'Previous', '1', '2', '3', and 'Next'. At the bottom, there is a section for 'Individual partition bin evaluation statistics' with labels for 'AUC bin.1', 'AUC bin.2', 'AUC bin.3', 'AUC bin.4', 'People', 'DIFF bin.1', 'AUC.DIFF bin.2', and 'AUC.DIFF bi'.

.test.AUC	avg.diff.AUC	var.diff.AUC	avg.test.or10pct	var.test.or10pct	avg.test.orMTP	var.test.orMTP
0.013	0.049	0.009	0.159	0.046	0.045	0.045
0.025	0.071	0.026	0.182	0.066	0.091	0.091
0.013	0.049	0.01	0.182	0.066	0.045	0.045
0.01	0.043	0.008	0.182	0.066	0.023	0.023
0.008	0.037	0.006	0.182	0.066	0.023	0.023
0.01	0.036	0.006	0.182	0.066	0.023	0.023
0.009	0.033	0.005	0.182	0.066	0.023	0.023
0.008	0.029	0.004	0.182	0.066	0.023	0.023
0.051	0.095	0.055	0.205	0.057	0.114	0.114
0.025	0.07	0.026	0.205	0.09	0.091	0.091



Component 6: Model Evaluation

AUC	orMTP/10pct	AICc	Nparam
Measures a model's ability to distinguish true & false presences	Measures the % of true presence points predicted as absences	Measures the relative quality of a model by balancing fit & complexity	More parameters increase model complexity

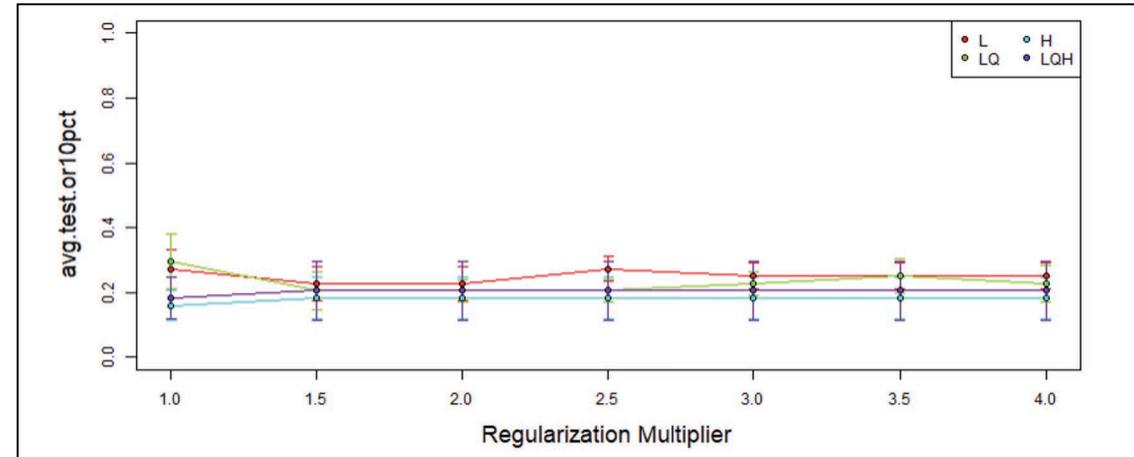
Generally, we want models with:

- High AUC
- Low Omission Rate
- Low AICc
- Fewer Parameters



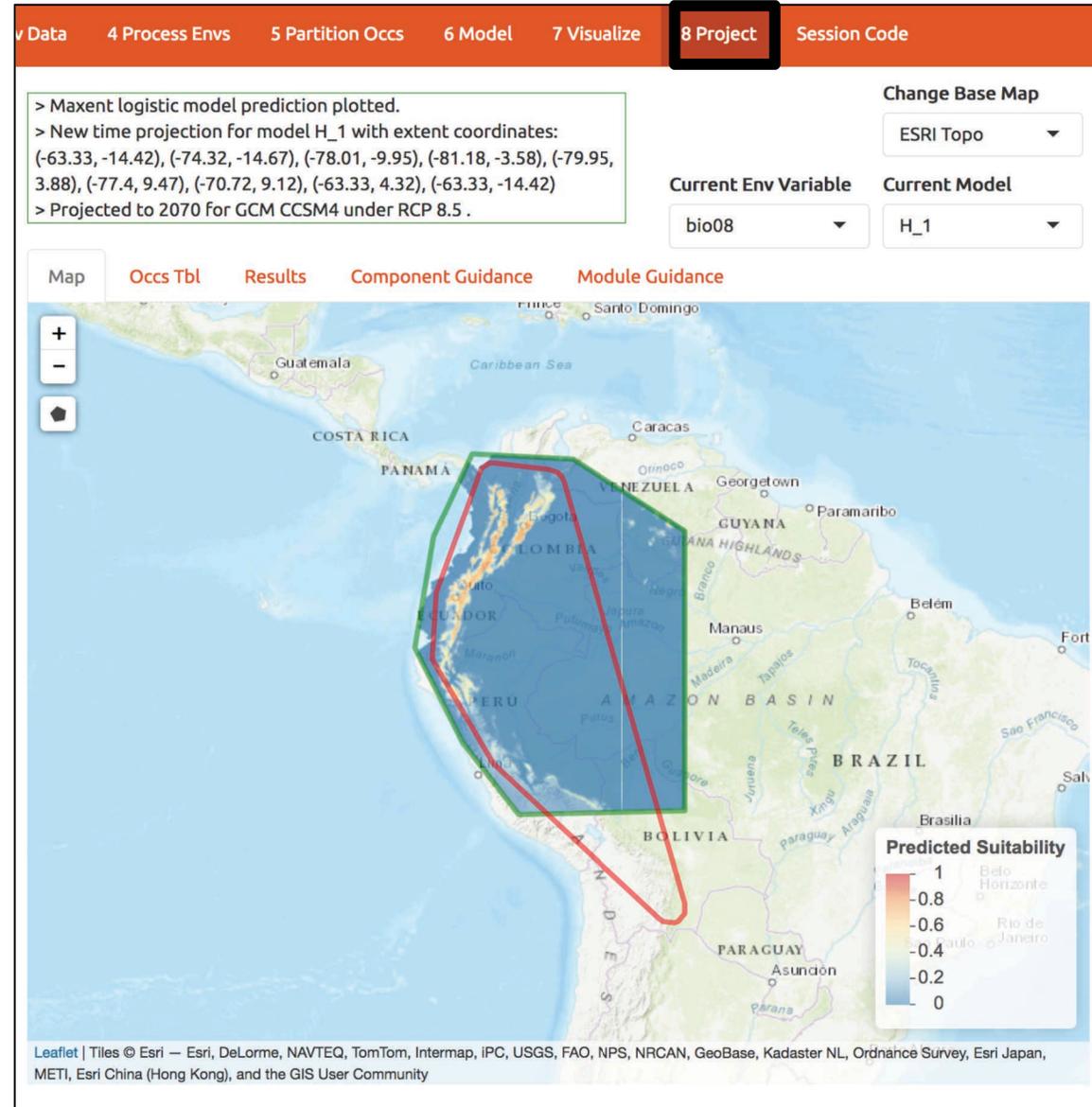
Component 7: Visualizing Results (Visualize)

- Visualize results as:
 - Model Evaluation Plots
 - Response Curves
 - Prediction Maps
 - Continuous
 - Binary



Component 8: Spatial & Temporal Projections (Project)

- Allows us to project models to:
 - New Geographic Extents
 - Different Time Periods
 - Future
 - Past





Thank You!

