Modeling Species Distribution and Species Richness for Fuireneae (sedges) in North America

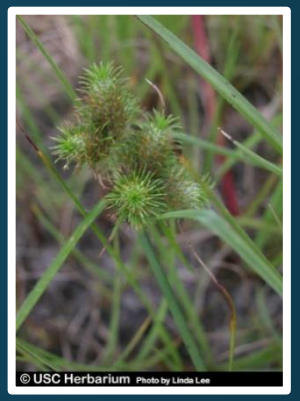
Heather Dame

Fuireneae

- Tribe in Cyperaceae (sedges) containing 6 genera of predominately wetland obligate plants
- 4 genera in North America:
  - *Bolboschoenus*
  - *Fuirena*
  - *Schoenoplectus*
  - *Schoenoplectiella*
- Thesis work:
  - Re-examination of taxonomy of the tribe through molecular systematics

http://www.maine.gov/dacf/mnap/features/bolrob.htm

Bolboschoenus robustus (Pursh) Sojak



Fuirena breviseta (Coville) Coville

http://www.nyis.info/index.php?action=lisma_pages&page=species_alerts

Schoenoplectiella mucronata (L.) Palla

http://www.british-wild-flowers.co.uk/S-Flowers/Schoenoplectus%20pungens.htm

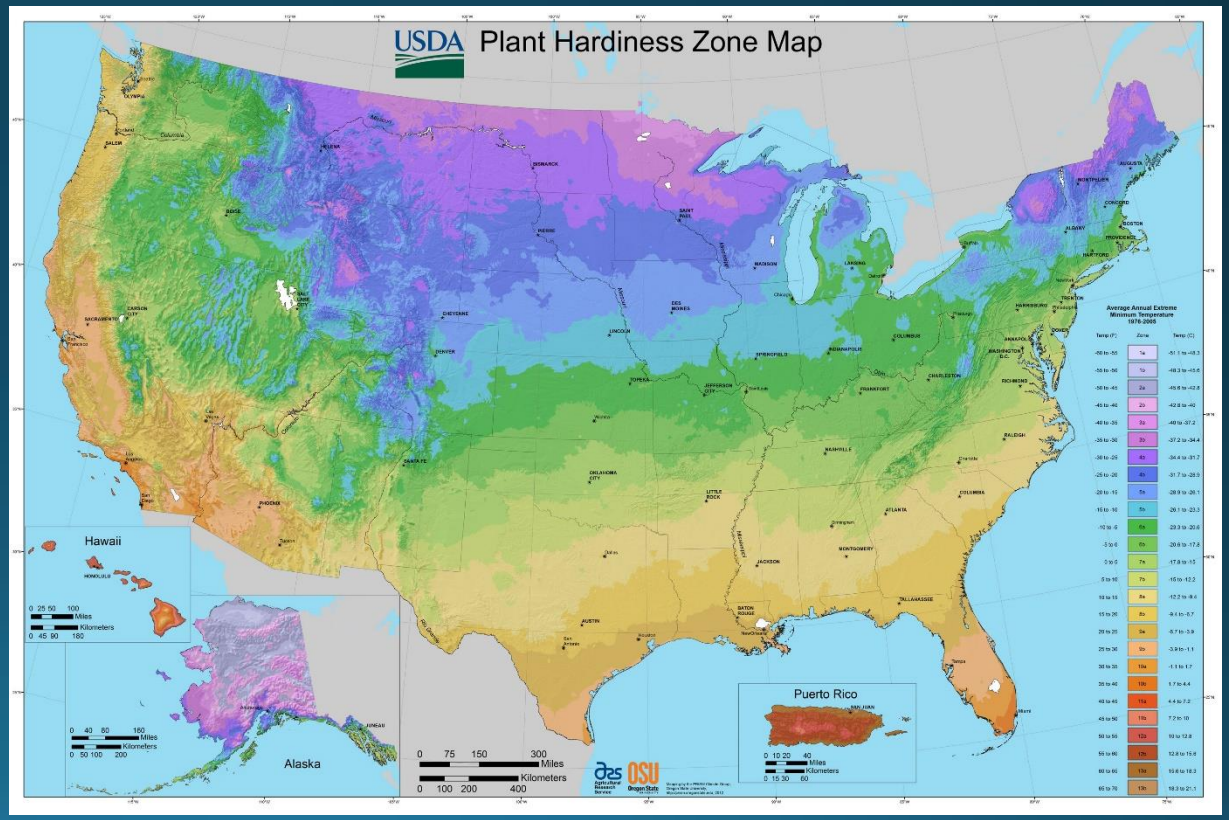
Schoenoplectus pungens (Vahl) Palla

Climate influencing distributions

- Latitudinal Diversity Gradient: There is generally greater species richness of taxa the nearer the equator biodiversity is measured.

- Fuireneae have a mainly tropical to subtropical distribution with some temperate species.

- One of the epicenters of Fuireneae diversity is North America.

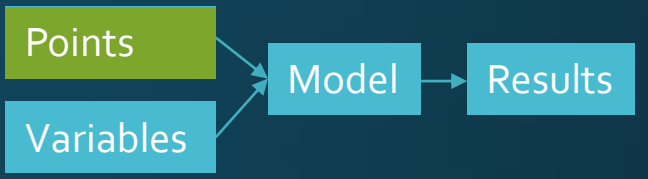


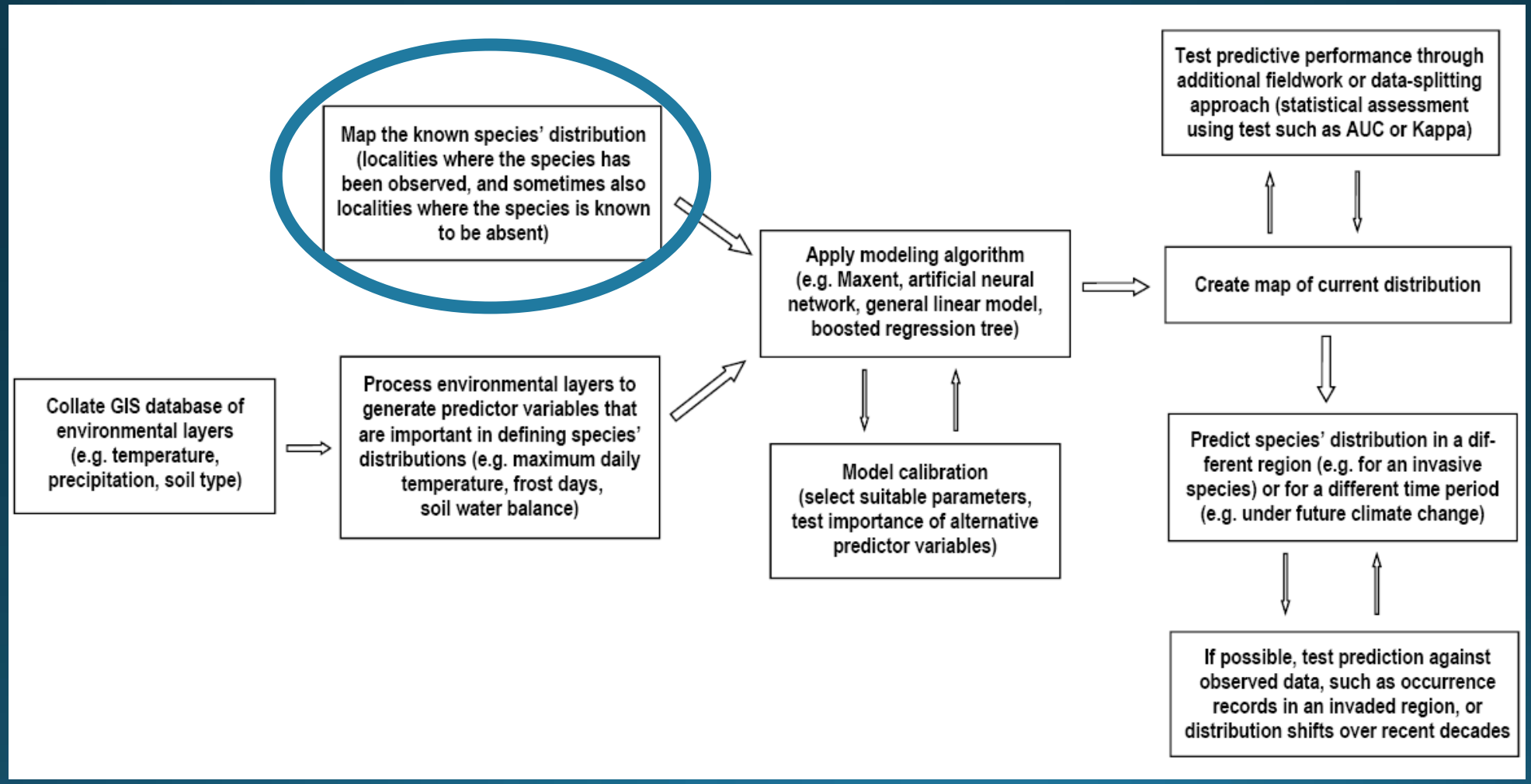
Mittelbach et al. 2007; USDA

Objectives

- Species Distribution Modeling (SDM) Goals:
  - Build a model of a potential climatic distribution (AKA fundamental niche/ climatic envelope/ suitable habitat) of Fuireneae taxa in the US.
  - Use a combination of all these SDM's to build one map of species richness.
  - Investigate what environmental factors have the largest effect on distributions.
  - Investigate how climate affects species richness within Fuireneae.

Building a correlative SDM



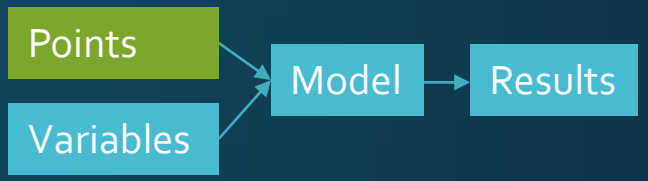


Pearson 2007: Figure 1

Methods

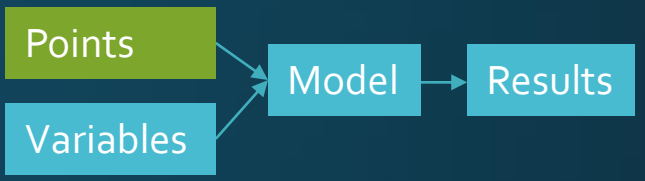
Species Occurrences

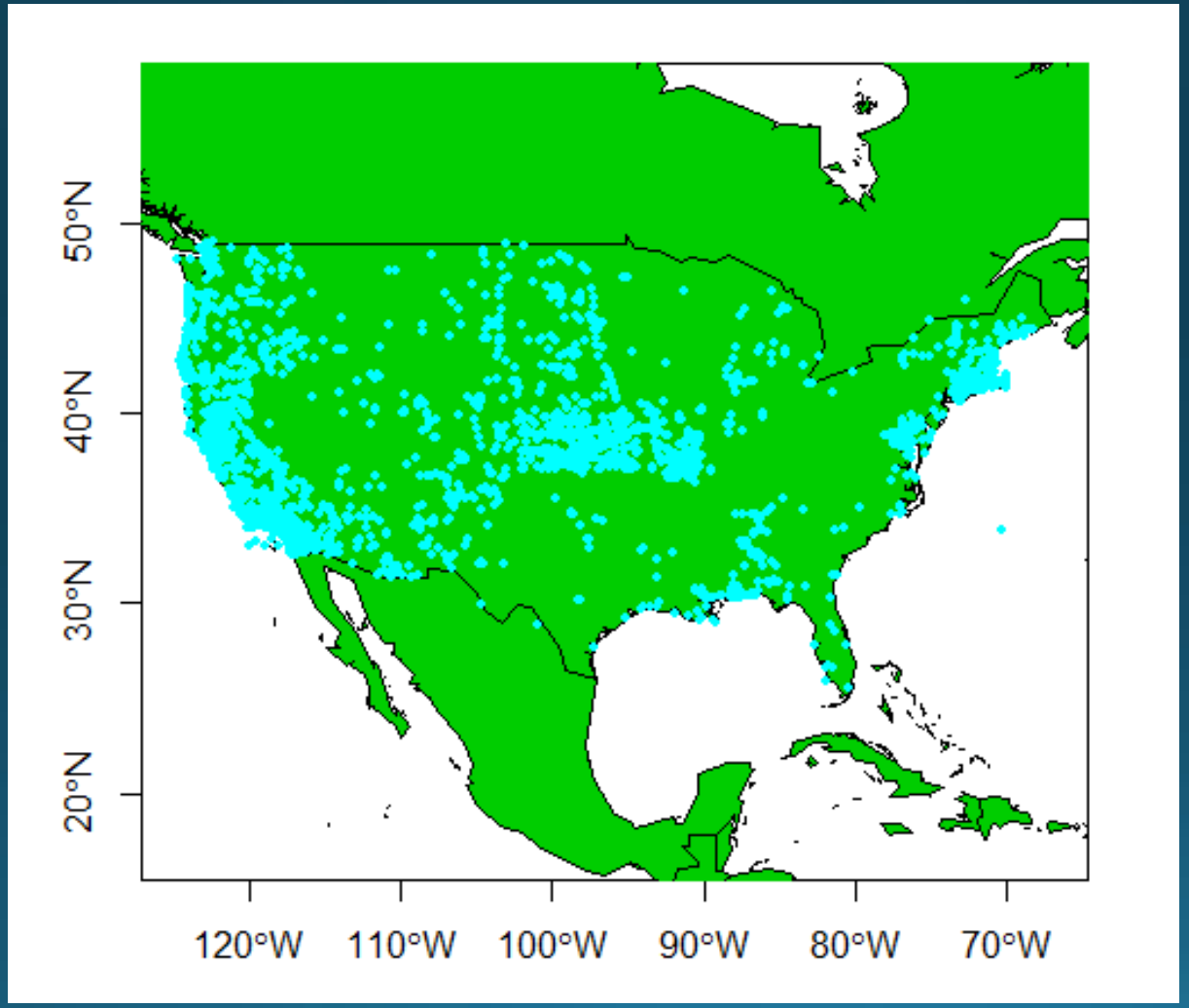
- GBIF (Global Biodiversity Information Facility) contains free access data of species occurrences collected from natural history collections, observations, and published datasets.
- The R package rgbif was used to obtain georeferenced occurrences of Fuireneae species present in the continental US.
- Taxa with <8 occurrence records not included (per Newbold et al. 2009)
- Duplicate records deleted.



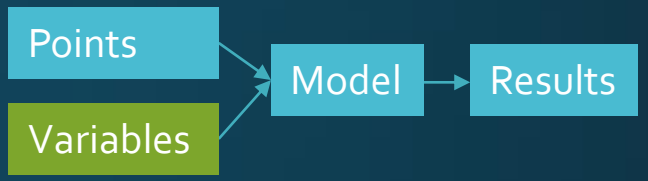
Species	Number of Occurrence records
Bolboschoenus maritimus	740
Bolboschoenus novae-angliae	23
Bolboschoenus robustus	116
Fuirena breviseta	24
Fuirena pumila	17
Fuirena scirpoidea	20
Fuirena simplex	79
Fuirena squarrosa	42
Schoenoplectiella hallii	49
Schoenoplectiella mucronata	68
Schoenoplectialla purshiana	71
Schoenoplectiella saximontana	24
Schoenoplectus acutus	625
Schoenoplectus americanus	480
Schoenoplectus californicus	274
Schoenoplectus deltarum	9
Schoenoplectus etuberculatus	8
Schoenoplectus fluviatilis	170
Schoenoplectus glaucus	37
Schoenoplectus heterochaetus	30
Schoenoplectus pungens	594
Schoenoplectus smithii	48
Schoenoplectus subterminalis	119
Schoenoplectus tabernaemontani	511
Schoenoplectus torreyi	39
Total Occurrence Records	**4219**
Total Species	**25**

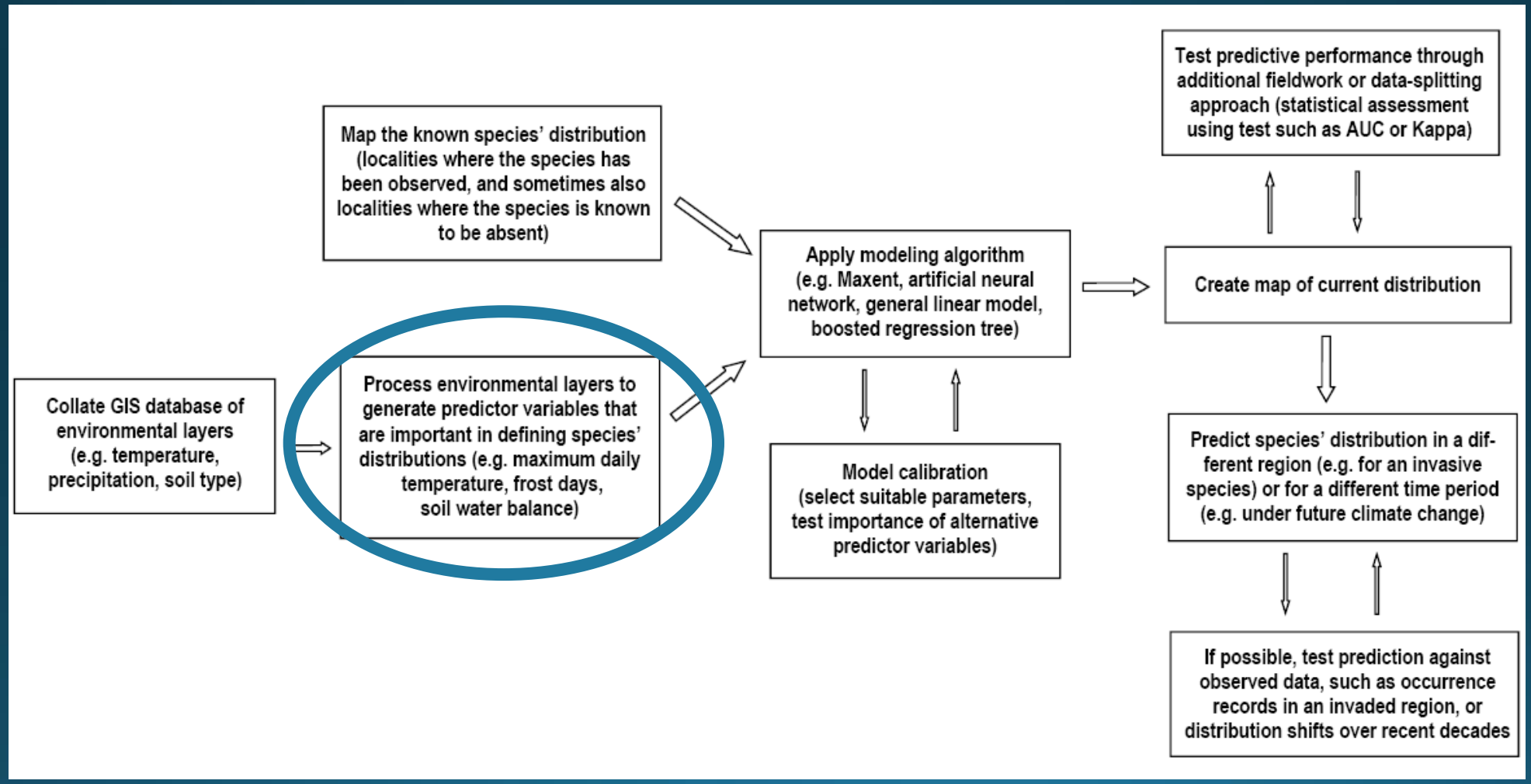
Basic map of GBIF species occurrences





Building a correlative SDM



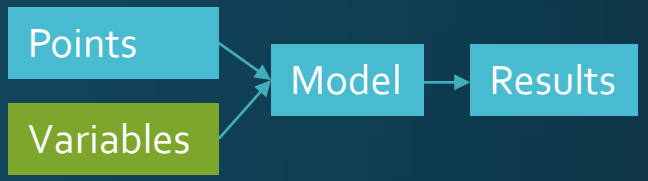


Pearson 2007: Figure 1

Methods

Environmental Layers

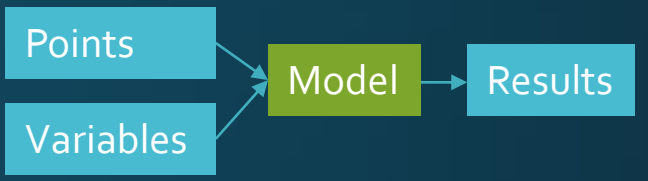
- Worldclim provides free climate data for ecological modeling and GIS projects.
- Downloaded at 2.5 min resolution in R
- Cropped to US boundaries using ArcGIS.
- Each climate grid contains a set of 19 variables representing climate trends.

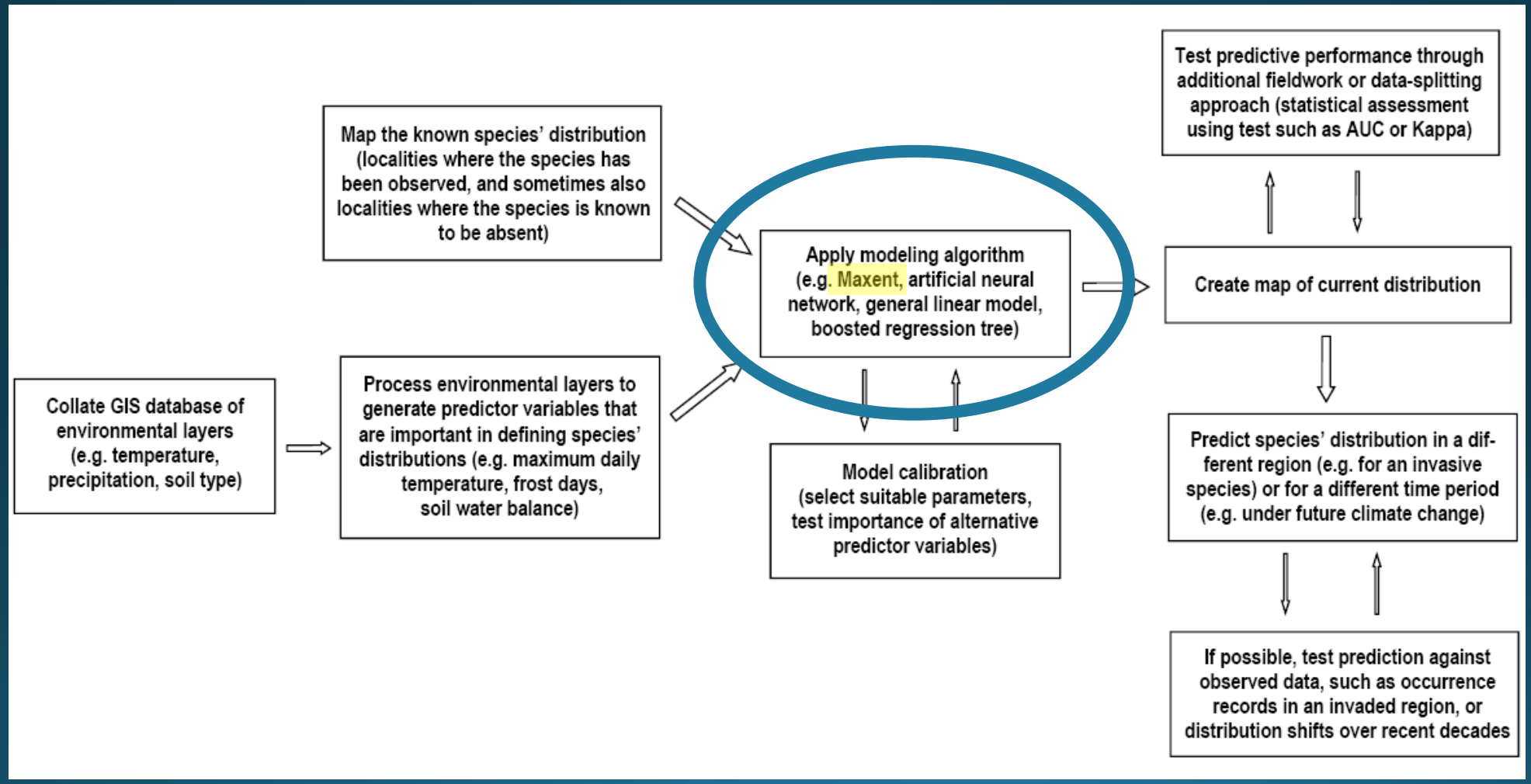


Environmental Variable	Measures
bio1	Annual Mean Temperature
bio2	Mean Diurnal Range (Mean of monthly (max - min temp))
bio3	Isothermality (BIO2/BIO7) (* 100)
bio4	Temperature Seasonality (standard deviation *100)
bio5	Max Temperature of Warmest Month
bio6	Min Temperature of Coldest Month
bio7	Temperature Annual Range (BIO5-BIO6)
bio8	Mean Temperature of Wettest Quarter
bio9	Mean Temperature of Driest Quarter
bio10	Mean Temperature of Warmest Quarter
bio11	Mean Temperature of Coldest Quarter
bio12	Annual Precipitation
bio13	Precipitation of Wettest Month
bio14	Precipitation of Driest Month
bio15	Precipitation Seasonality (Coefficient of Variation)
bio16	Precipitation of Wettest Quarter
bio17	Precipitation of Driest Quarter
bio18	Precipitation of Warmest Quarter
bio19	Precipitation of Coldest Quarter

Hijmans et al. 2005; Pearson 2007

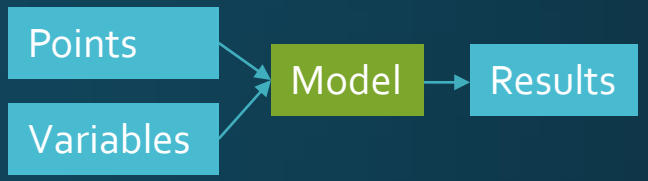
Building a correlative SDM





Pearson 2007: Figure 1

Model: Maxent 3.3.3k



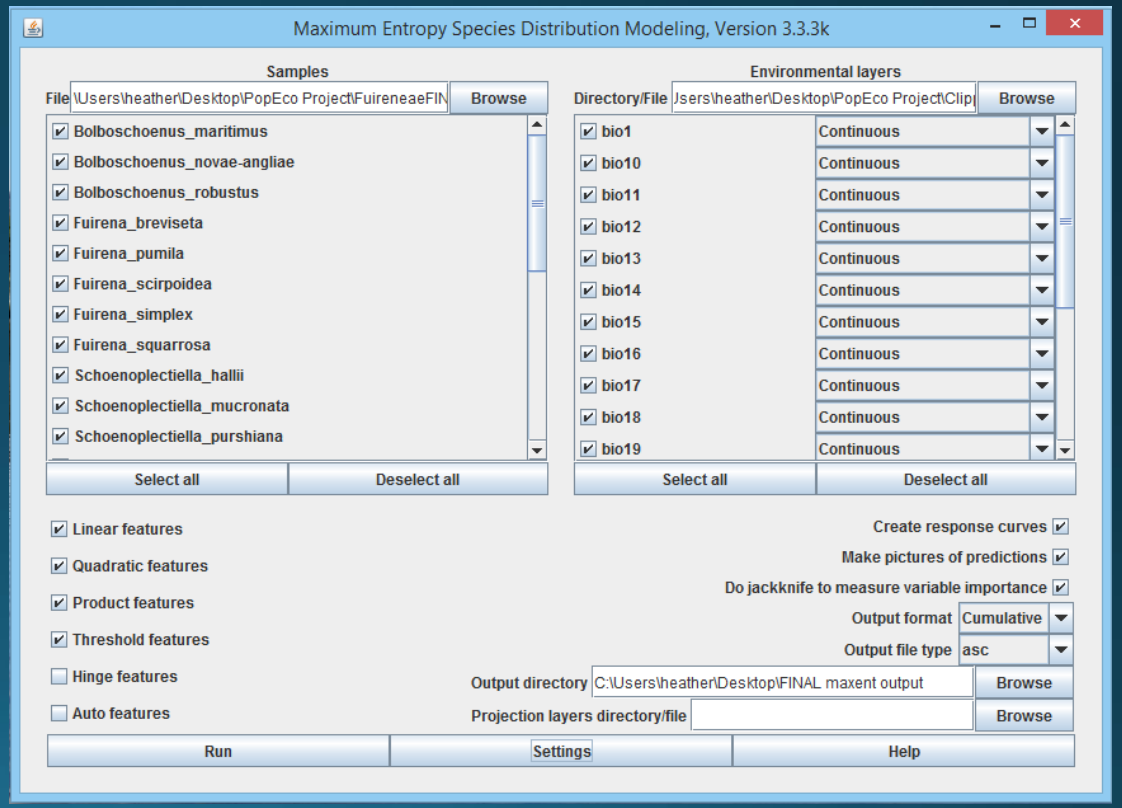
Models potential species distributions from presence only species occurrence data.

Builds background grid of environmental variables across landscape (US)

Correlates presence points (GBIF) to grid

Defines fundamental niche based on the mean and variance of grid cells containing presence points

Builds predictions for each grid cell in the background across US



Hutchinson 1957; Hirzel et al. 2002; Pearson 2007; Elith et al. 2011

Model

- The relative occurrence rate ($P * (z(x_i))$) is predicted as a function of the environmental predictors at a single location:

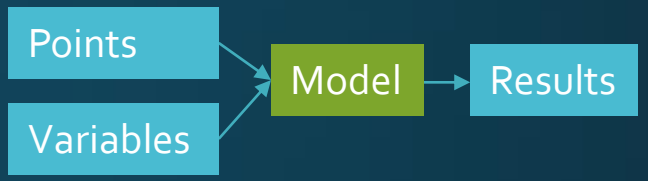
$$P * (z(x_i)) = \frac{\exp(z(x_i)\lambda)}{\Sigma_i \exp(z(x_i)\lambda)}$$

Where: $z(x_i)\lambda = z_1(x_i) * \lambda_1 + z_2(x_i) * \lambda_2 + \cdots + z_J(x_i) * \lambda_J$

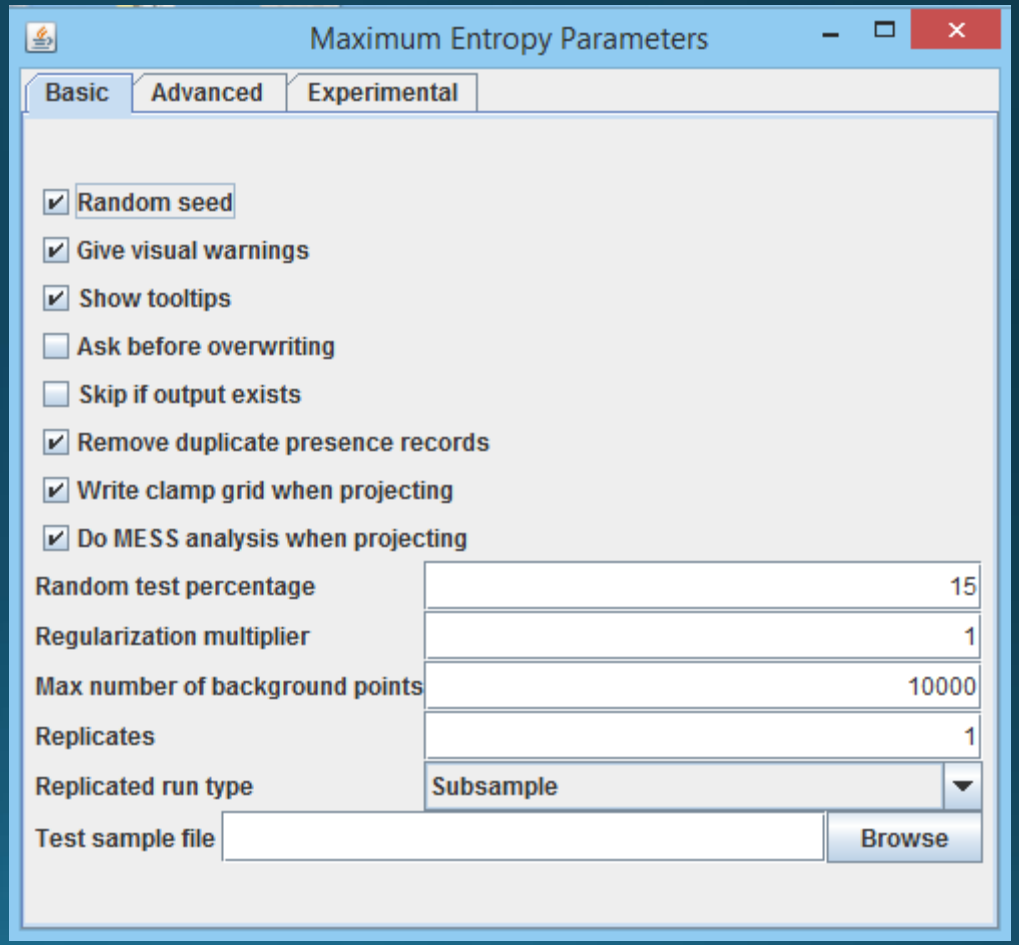
- z is vector of J environmental variables (Worldclim data) at location x_i
- λ is a vector of regression coefficients
- Denominator is the relative occurrence rate over all grid cells in the study, and serves to normalize the occurrence rates

Merow et al. 2013

Model

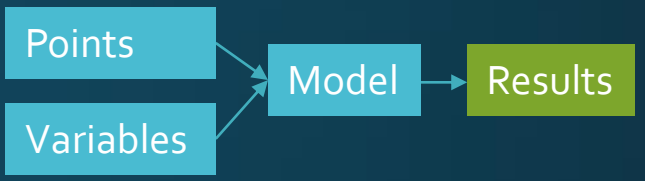


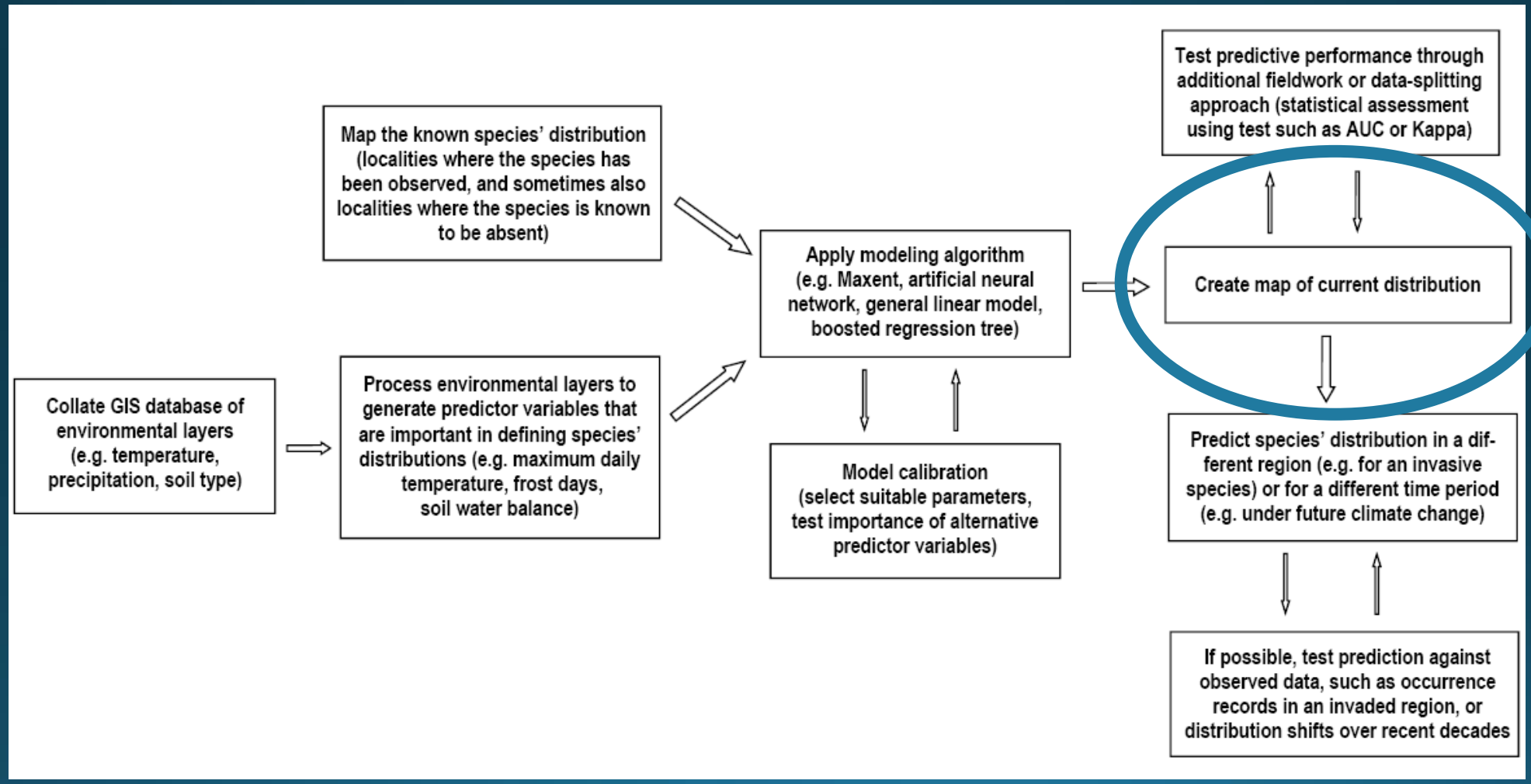
- Training the model: 85% of presence records used
- Testing the model: 15% of presence records reserved
- Fixed cumulative value threshold: 10
  - Gives an output of binary presence points
  - Used to create species richness map



Kumar et al. 2014; Pearson et al. 2007; Newbold et al. 2009

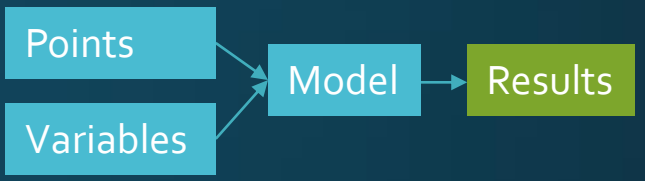
Building a correlative SDM



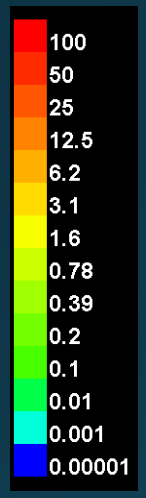


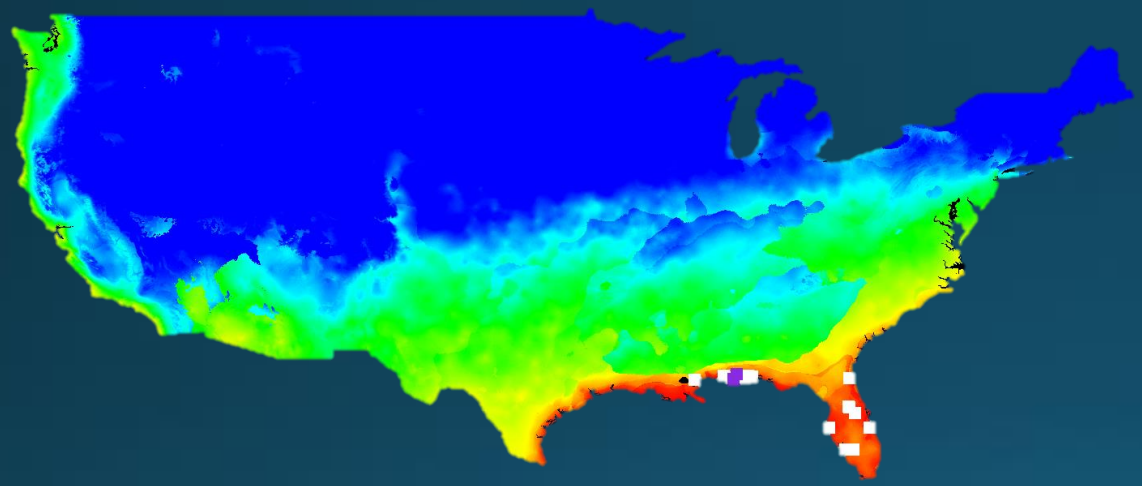
Pearson 2007: Figure 1

Results



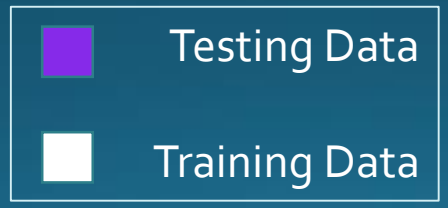
2 of the 25 Species Distribution Model maps

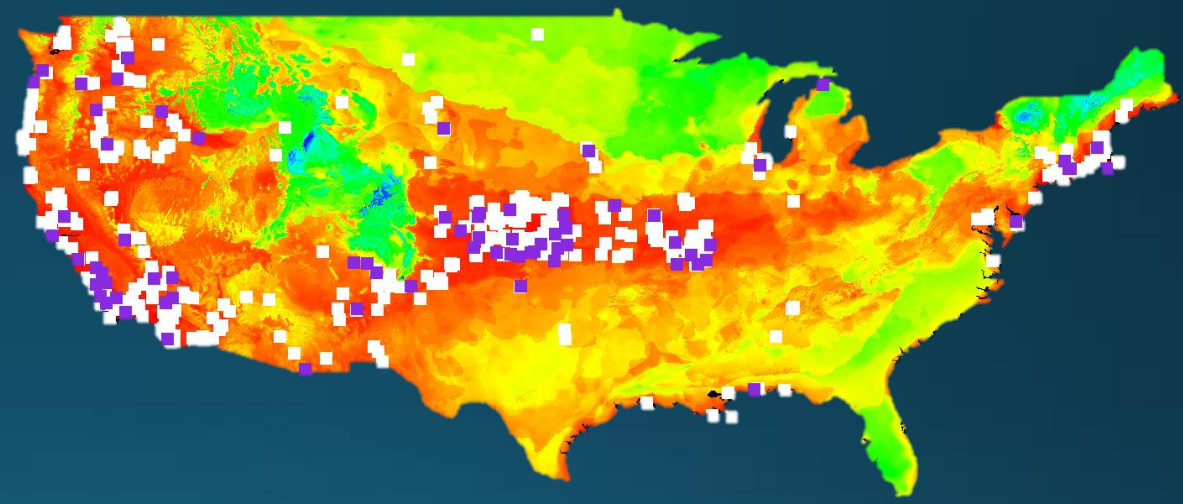




Fuirena scirpoidea

Limited distribution

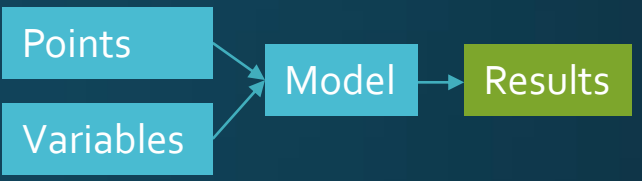


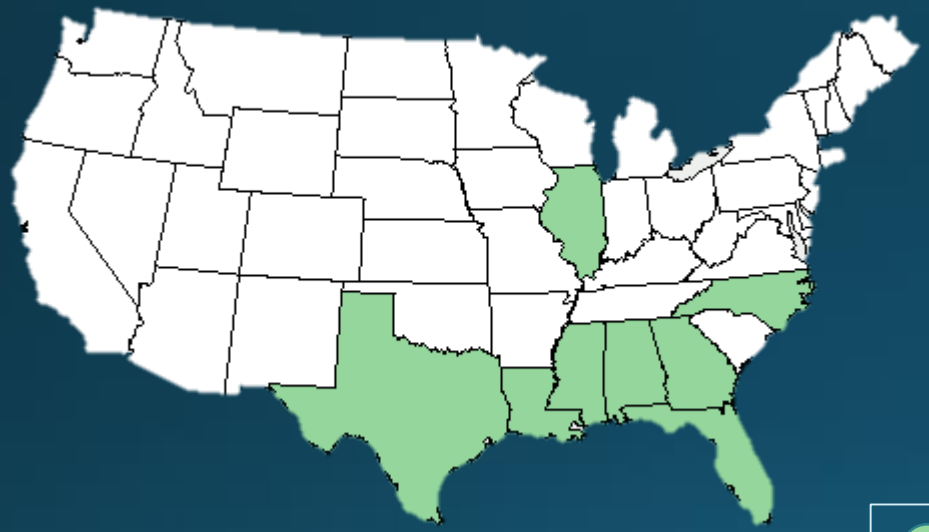


Schoenoplectus pungens

Broad distribution

Results Comparison
Actual distribution according to USDA



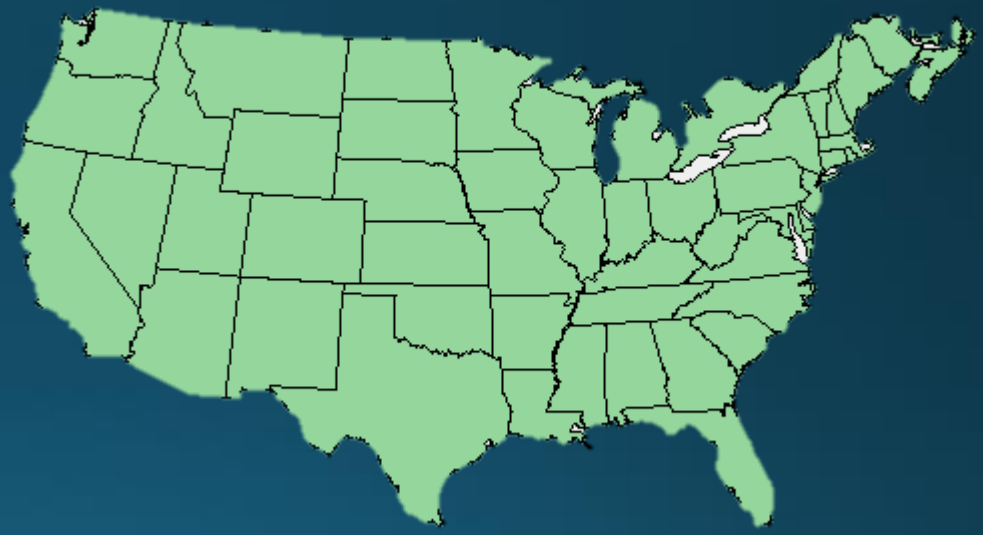


Fuirena scirpoidea

Limited distribution

State Present

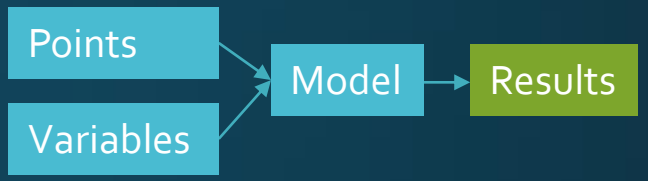
State Absent



Schoenoplectus pungens

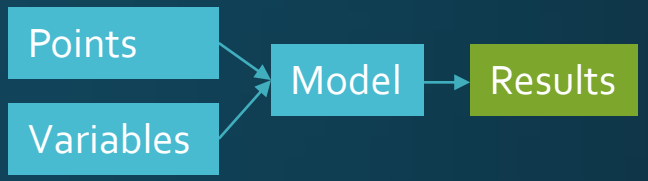
Broad distribution

Area under the receiver operating characteristic curve statistics (AUC)



- How successful is the model in predicting distributions based on the training and test data?

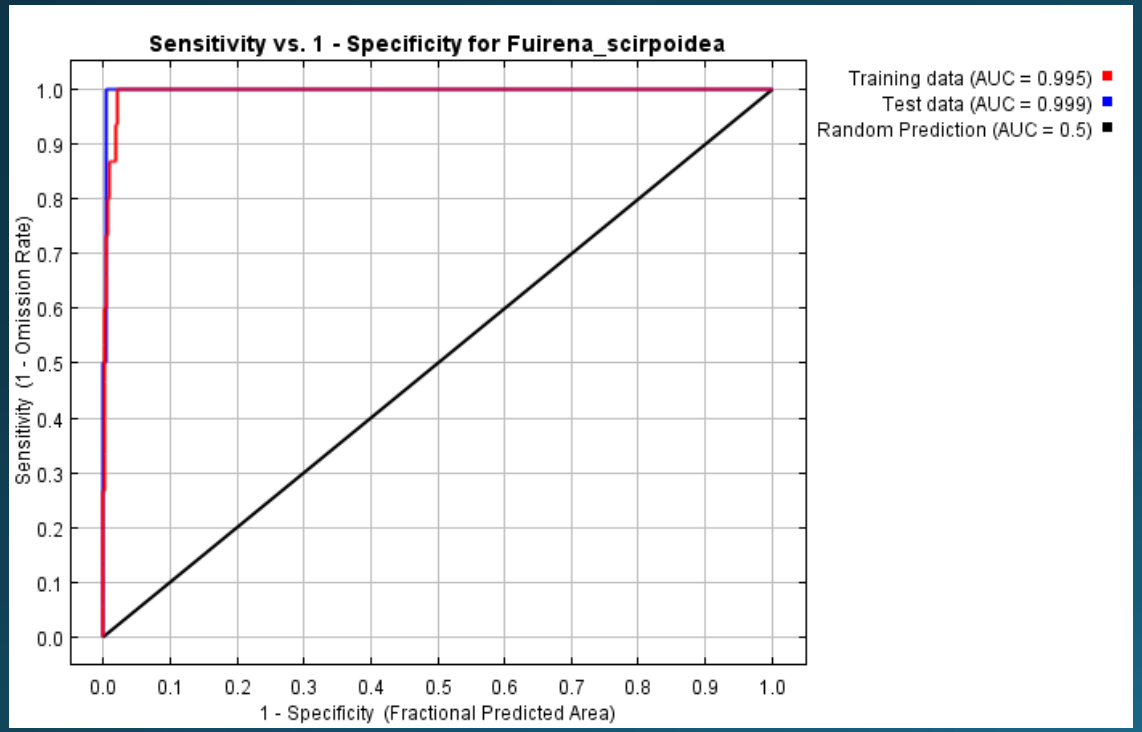
- Measured on a scale of 0-1
  - 0.5 is no better than random
  - 1.0 is a successful model



Results

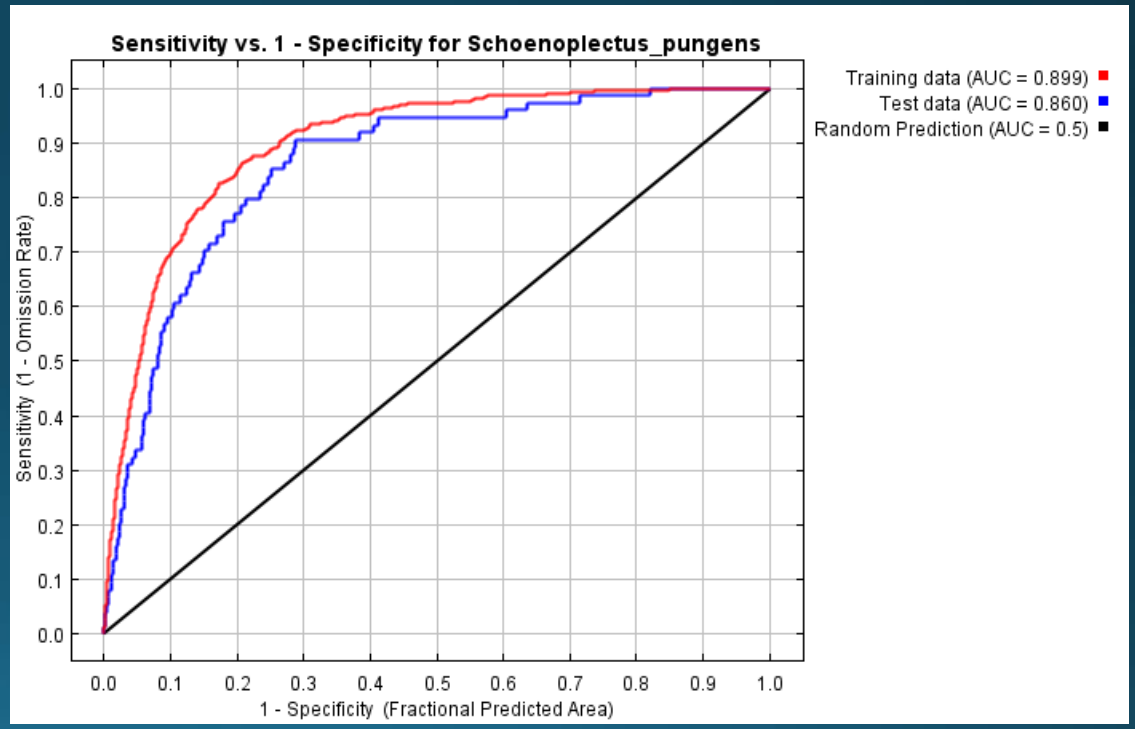
AUC Statistics: How successful was the model?

Fuirena scirpoidea

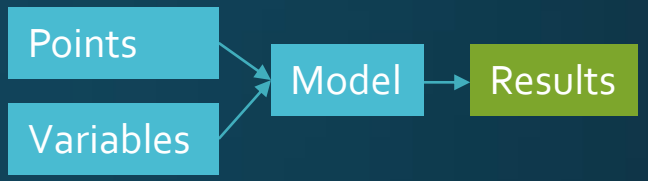


Training AUC = 0.995

Schoenoplectus pungens



Training AUC = 0.899



Results

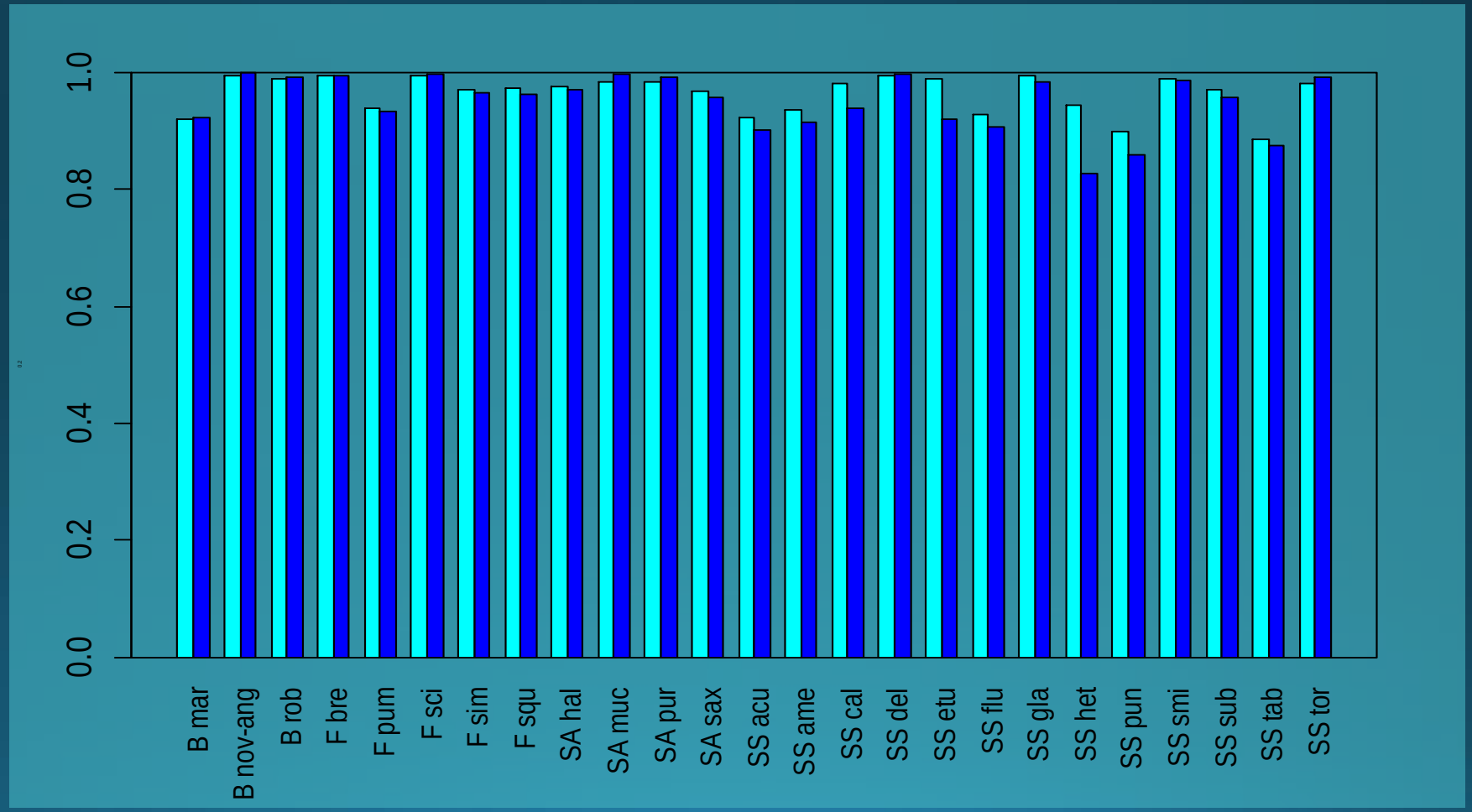
Area Under Curve (AUC) for all species

Training AUC Mean:

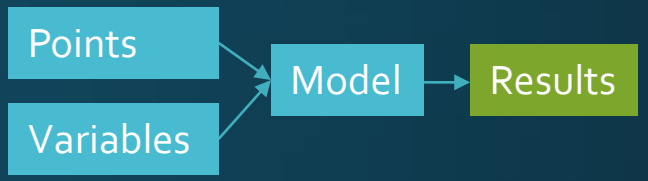
0.97

Test AUC Mean:

0.95



Jackknife Statistics

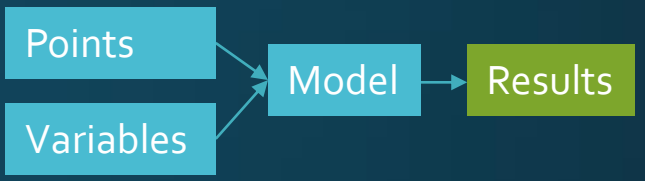


- How useful is each environmental variable in creating results?

- Evaluates model based on how the results are influenced when:
  - One variable is left out
  - Only one variable is used

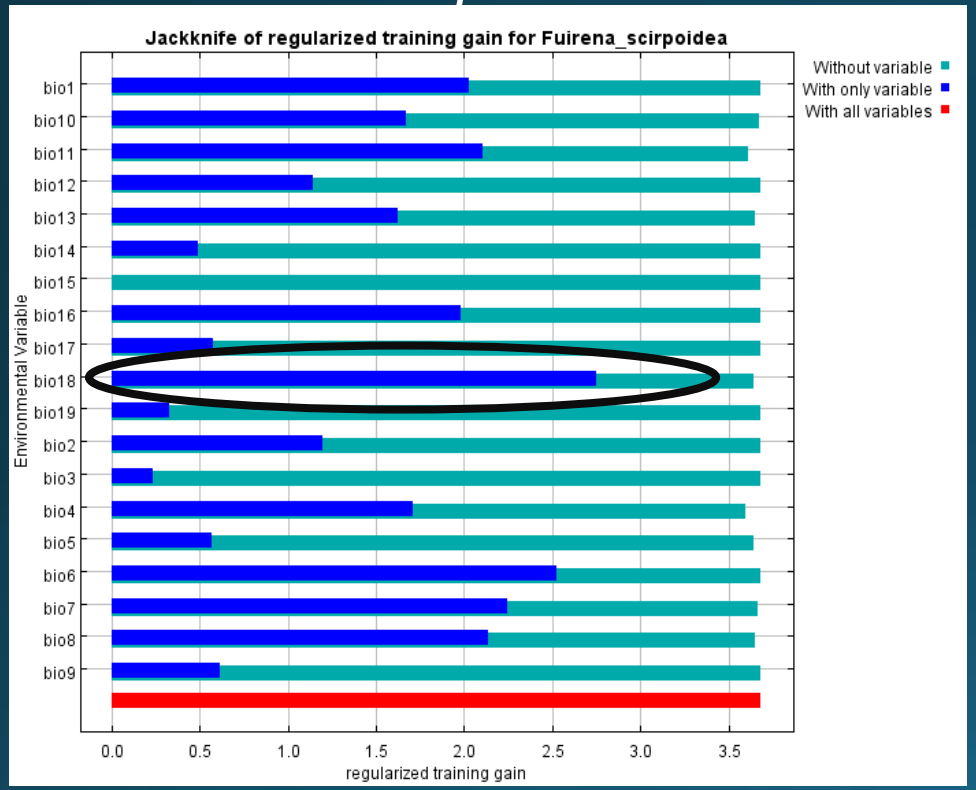
Pearson et al. 2007

Results



Jackknife training gain of environmental variables

Fuirena scirpoidea



Highest regularized training gain: bio18

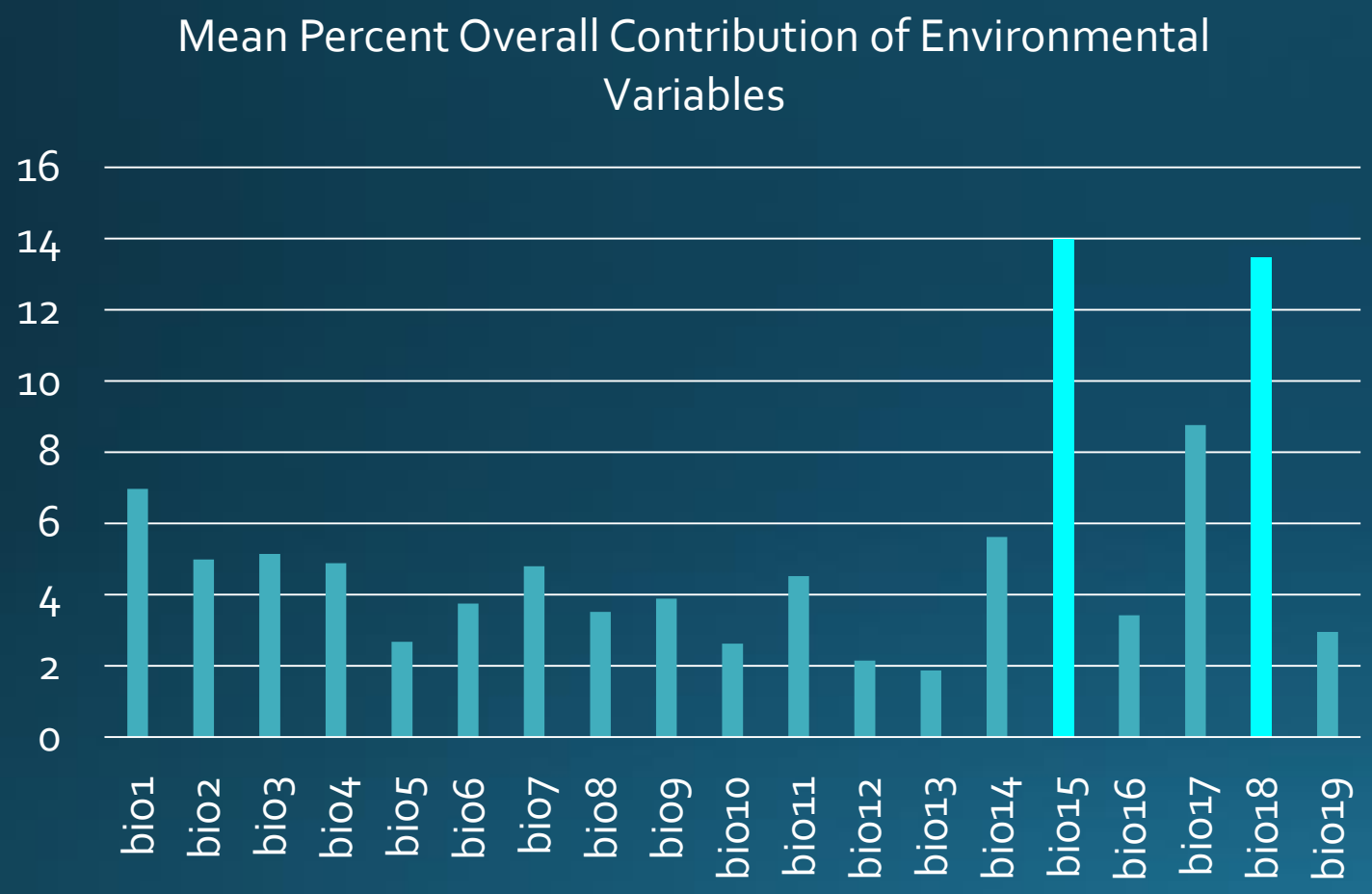
Precipitation of warmest quarter

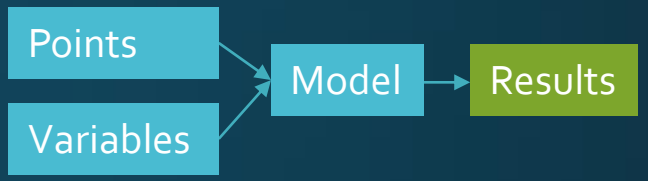
Schoenoplectus pungens

Highest regularized training gain: bio9

Mean Temperature of Driest Quarter

Results





BIO	Translation
bio1	Annual Mean Temperature
bio2	Mean Diurnal Range (Temp)
bio3	Isothermality (BIO2/BIO7) (* 100)
bio4	Temperature Seasonality
bio5	Max Temperature of Warmest Month
bio6	Min Temperature of Coldest Month
bio7	Temperature Annual Range (BIO5-BIO6)
bio8	Mean Temperature of Wettest Quarter
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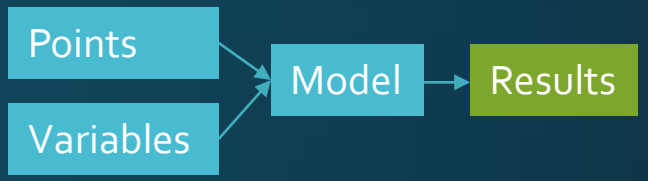
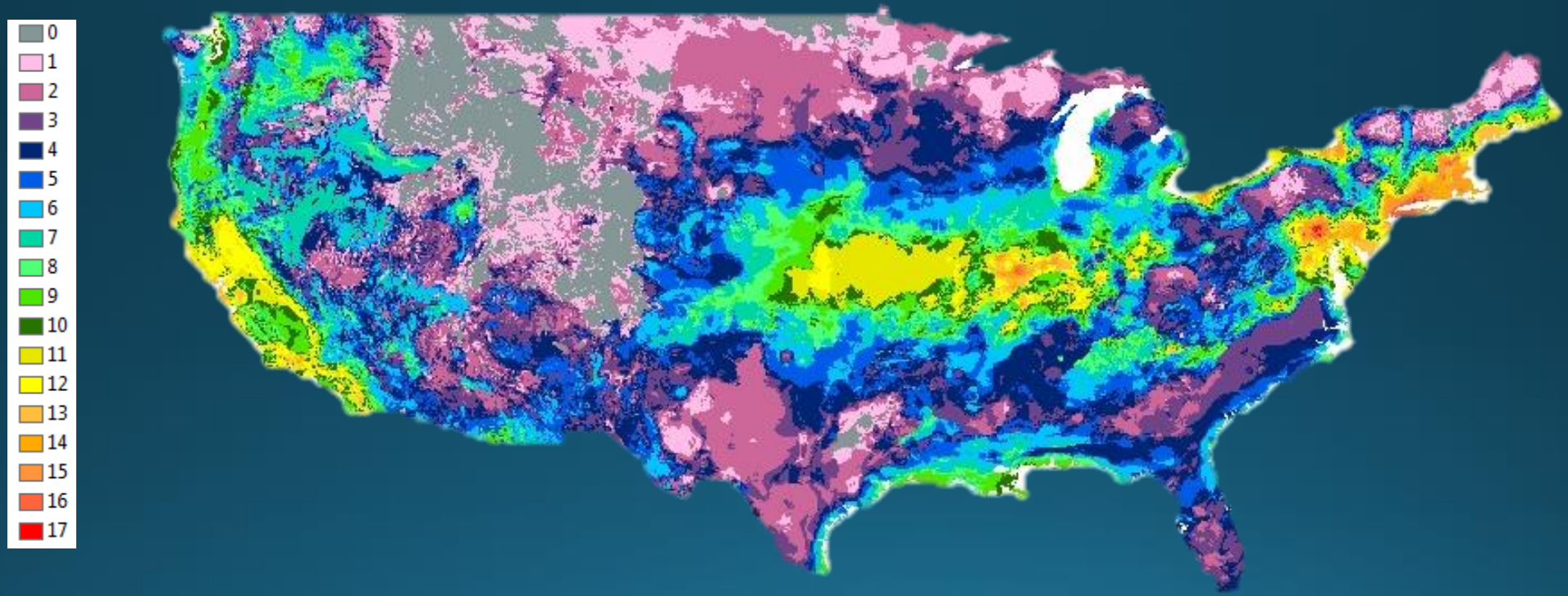
bio12	Annual Precipitation
bio13	Precipitation of Wettest Month
bio14	Precipitation of Driest Month
bio15	**Precipitation Seasonality**
bio16	Precipitation of Wettest Quarter
bio17	Precipitation of Driest Quarter
bio18	**Precipitation of Warmest Quarter**
bio19	Precipitation of Coldest Quarter

Species Richness Map

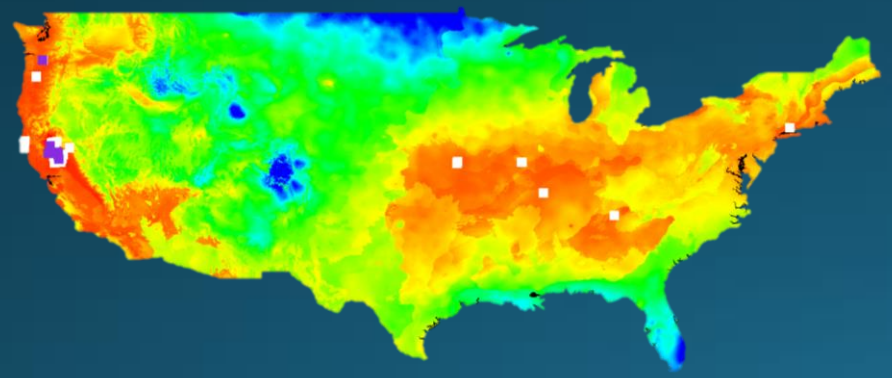


- Raster maps of thresholded output were summed in ArcGIS to create a species richness map

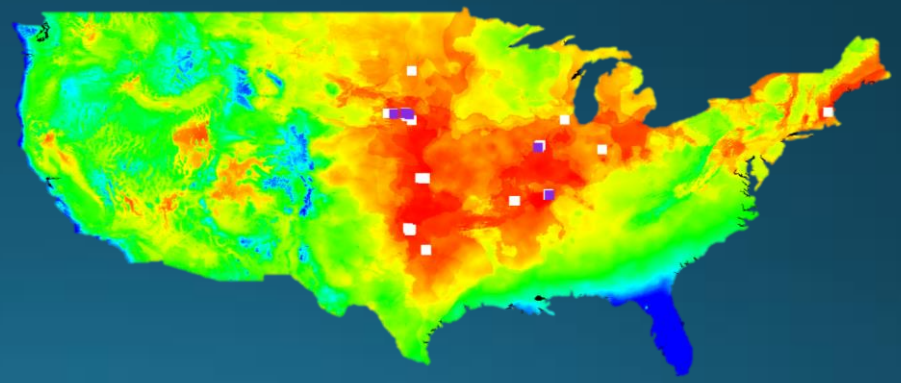


Discussion

- Applications:
  - Invasive Species: One of the species modeled, *Schoenoplectiella mucronata*, is noted as being one of the world's worst weeds. Can pinpoint areas of potential invasion.
  - Threatened Species: Focus conservation efforts on areas with strong climatic fundamental niche.
  - Incorporate climate change projection environmental data from Worldclim to evaluate how distributions could change as climate changes.



SDM of *Schoenoplectiella mucronata*



SDM of *Schoenoplectiella hallii* – state threatened in Michigan

Issues and Improvements

- Inconsistent number of occurrence records between species, ranging from several hundred to 8.
- GBIF data at this time may not accurately portray accurate species occurrences; may have geographical gaps missing.
- Add topography, soil, or land use to environmental predictors to gain more informative distributions.
- Increase iterations to gain an average of several predictions for a single species

References and Acknowledgements

- Clint Pogue , Rachel Hackett, Dr. Kevin Pangle – Thank you!
- Elith, J., S. J. Phillips, T. Hastie, M. Dudík, Y. E. Chee, and C. J. Yates. 2011. A statistical explanation of MaxEnt for ecologists. Diversity and Distributions 17:43–57.
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Questions?