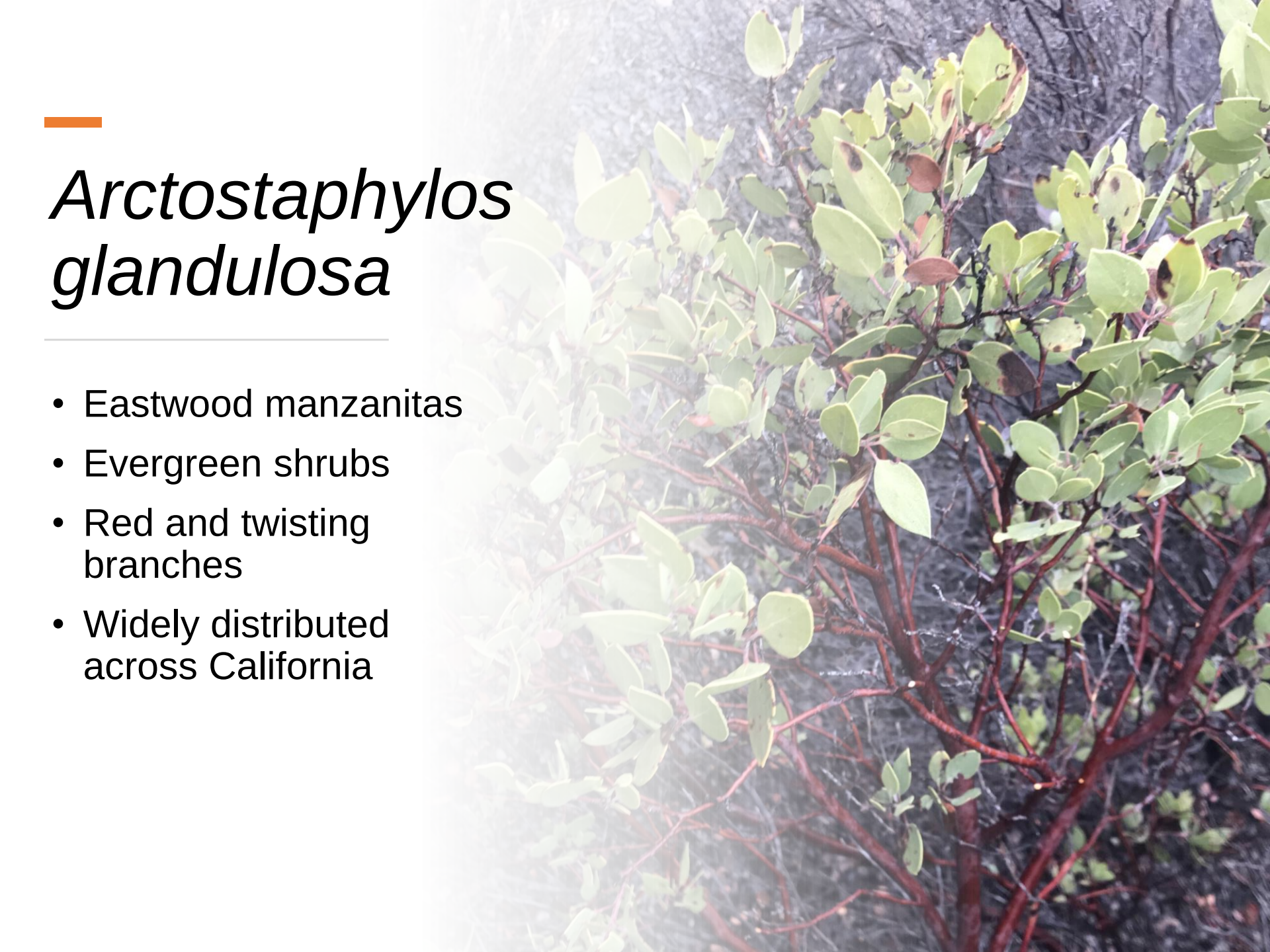
Ecological differentiation between *Arctostaphylos glandulosa* subspecies

Yi Huang

Arctostaphylos glandulosa

- Eastwood manzanitas
- Evergreen shrubs
- Red and twisting branches
- Widely distributed across California

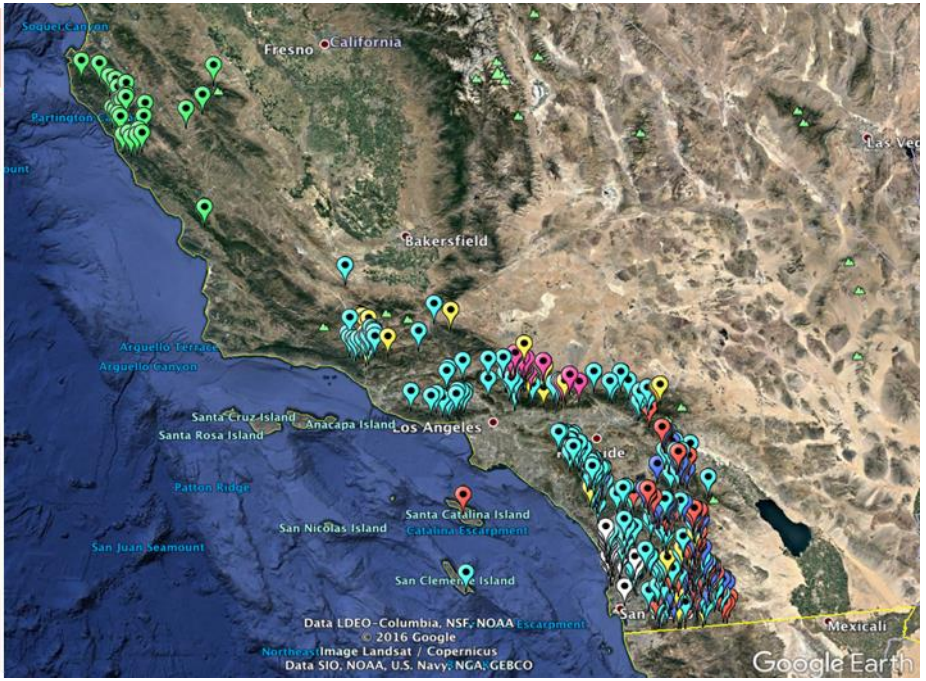


Arctostaphylos glandulosa

- 8 subspecies in California, two of which have narrow distribution and are considered rare by California Native Plant Society

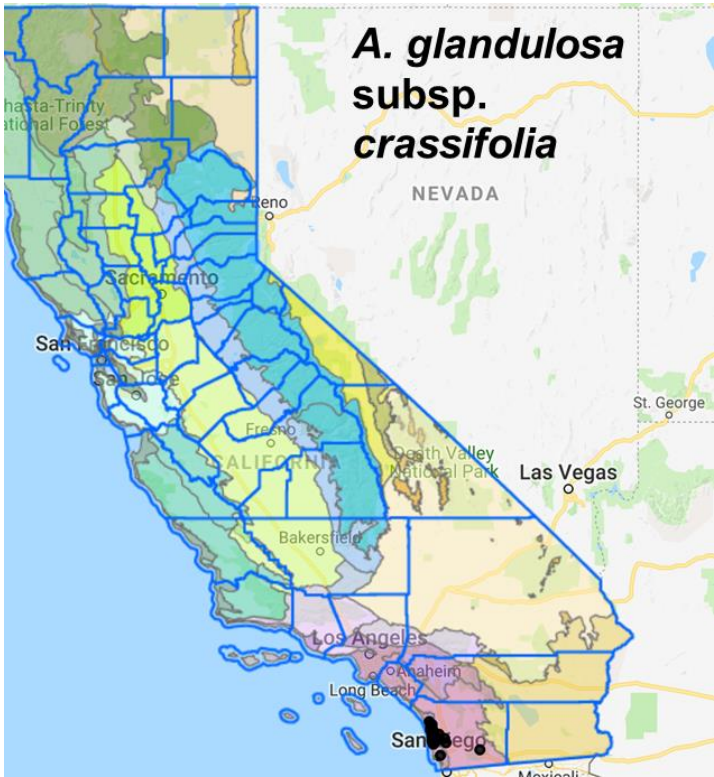
Two Rare and/or endangered subspecies ★ ★

Subspecies	color
leucophylla	
howellii	
glandulose	
gabrielensis	
cushingiana	
crassifolia	
adamsii	

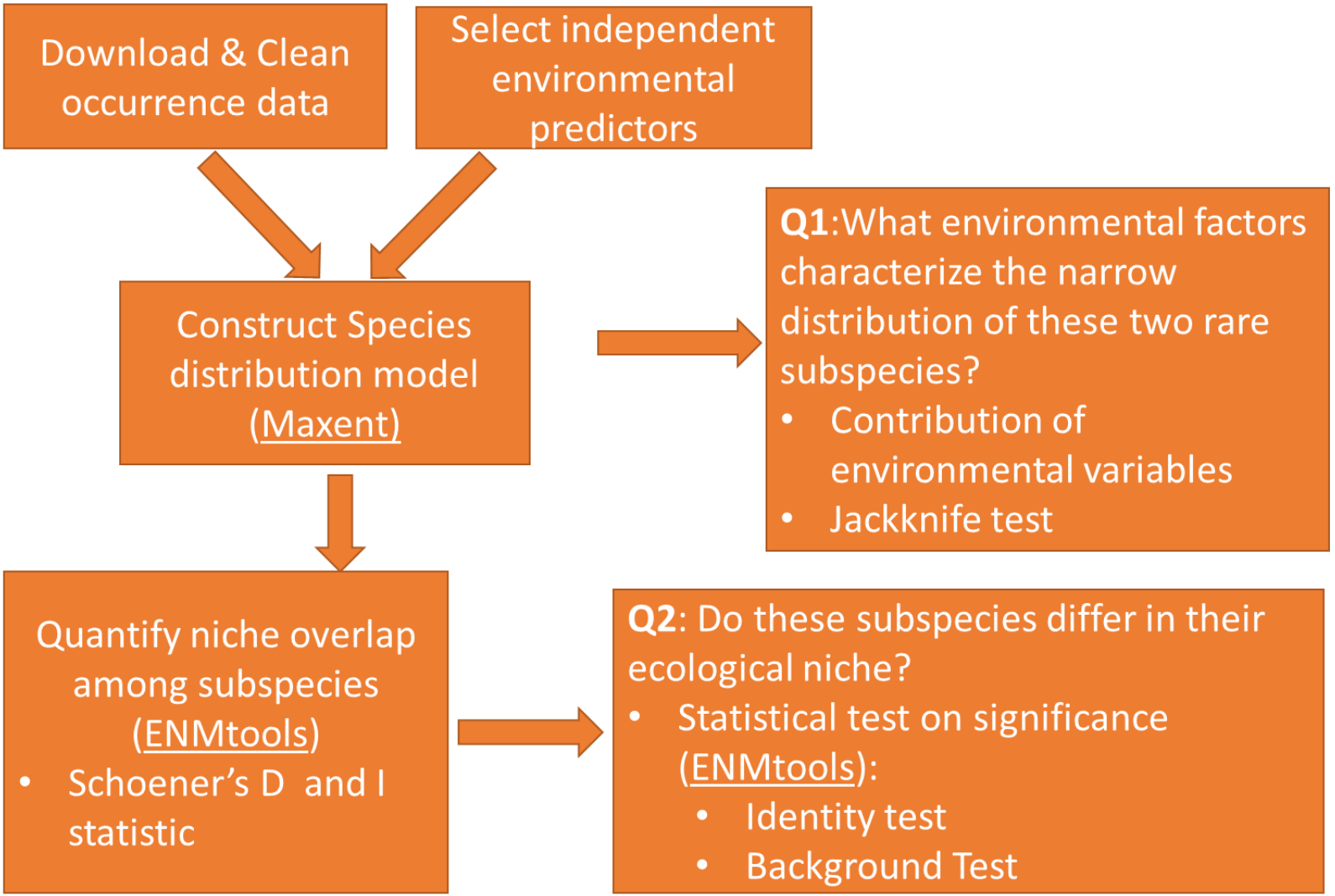


Arctostaphylos glandulosa

- Q1: What environmental factors characterize the narrow distribution of these two rare subspecies?
- Q2: Do these subspecies differ in their ecological niche?



Pipeline


Download & Clean occurrence data
Select independent environmental predictors
Construct Species distribution model (Maxent)
Q1:What environmental factors characterize the narrow distribution of these two rare subspecies?
• Contribution of environmental variables
• Jackknife test
Quantify niche overlap among subspecies (ENMtools)
• Schoener's D and I statistic
Q2: Do these subspecies differ in their ecological niche?
• Statistical test on significance (ENMtools):
• Identity test
• Background Test

Occurrence data

Download & Clean occurrence data

- Herbarium collection of California Herbarium Consortium
- Taxonomy history
- Remove duplicate

Subspecies	Number of occurrence points after removing duplicates
adamsii	266
crassifolia	112
cushingiana	221
gabrielensis	35
glandulosa	830
howelli	32
mollis	266

Download & Clean occurrence data

Select independent environmental predictors

Environmental predictors

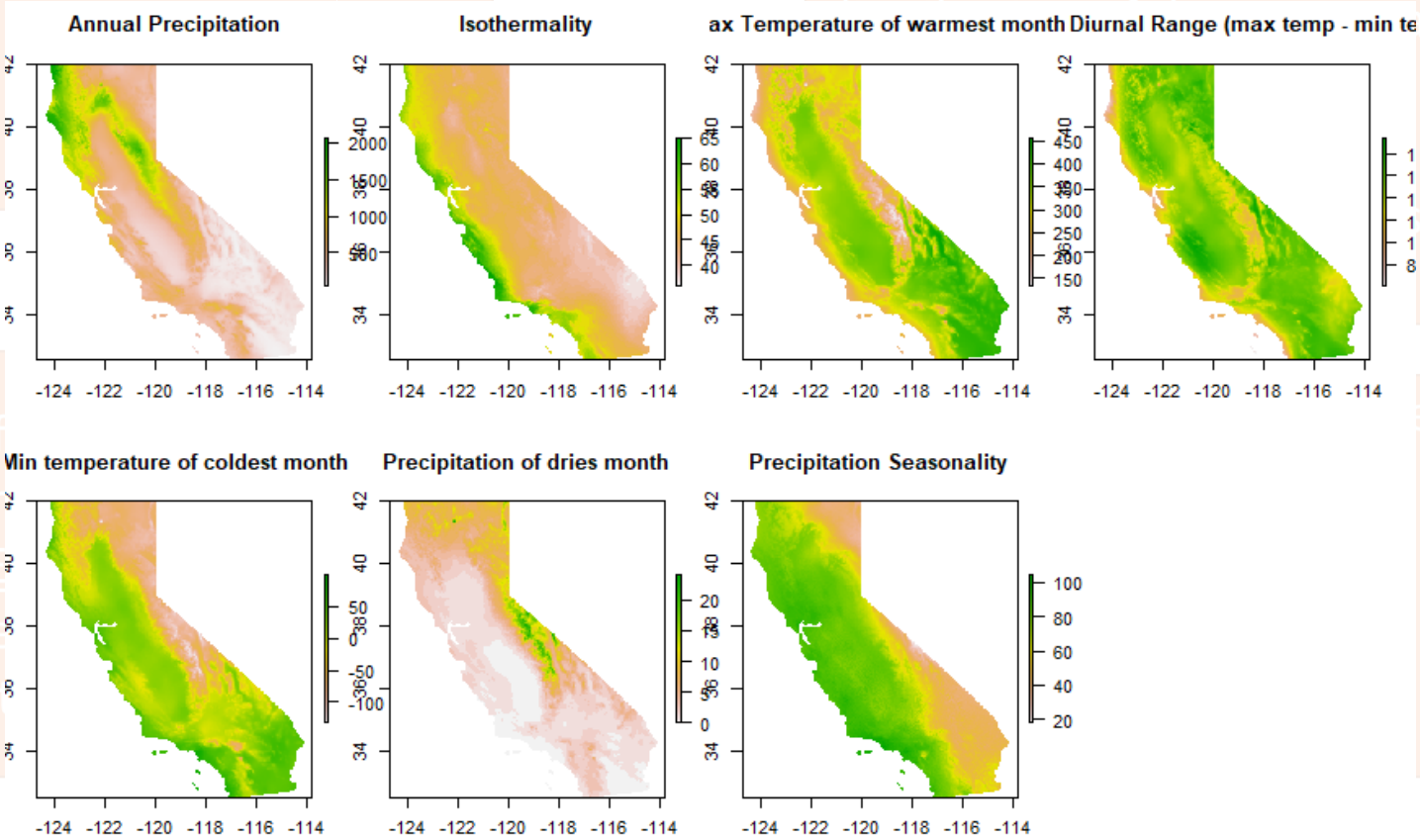
- Use CA shapefile to clip these raster files
- Use the important bioclimate predictors suggested by literature
- Use other predictors that are not highly correlated (pearson coefficient < 0.7)

  - ❖ **Bio5: Max Temperature of Warmest Month**
  - ❖ **Bio6: Min Temperature of Coldest Month**
  - ❖ **Bio12: Annual Precipitation**
  - ❖ Bio2: Mean Diurnal Range
  - ❖ Bio3: Isothermality
  - ❖ Bio14: Precipitation of Driest Month
  - ❖ Bio15: Precipitation Seasonality

Download & Clean occurrence data

Select independent environmental predictors

Environmental predictors



Importance of environmental predictors in *A. glandulosa* subsp. *crassifolia*

Construct Species distribution model (Maxent)

AUC: 0.964

Q1:What environmental factors characterize the narrow distribution of these two rare subspecies?

- Contribution of environmental variables
- Jackknife test

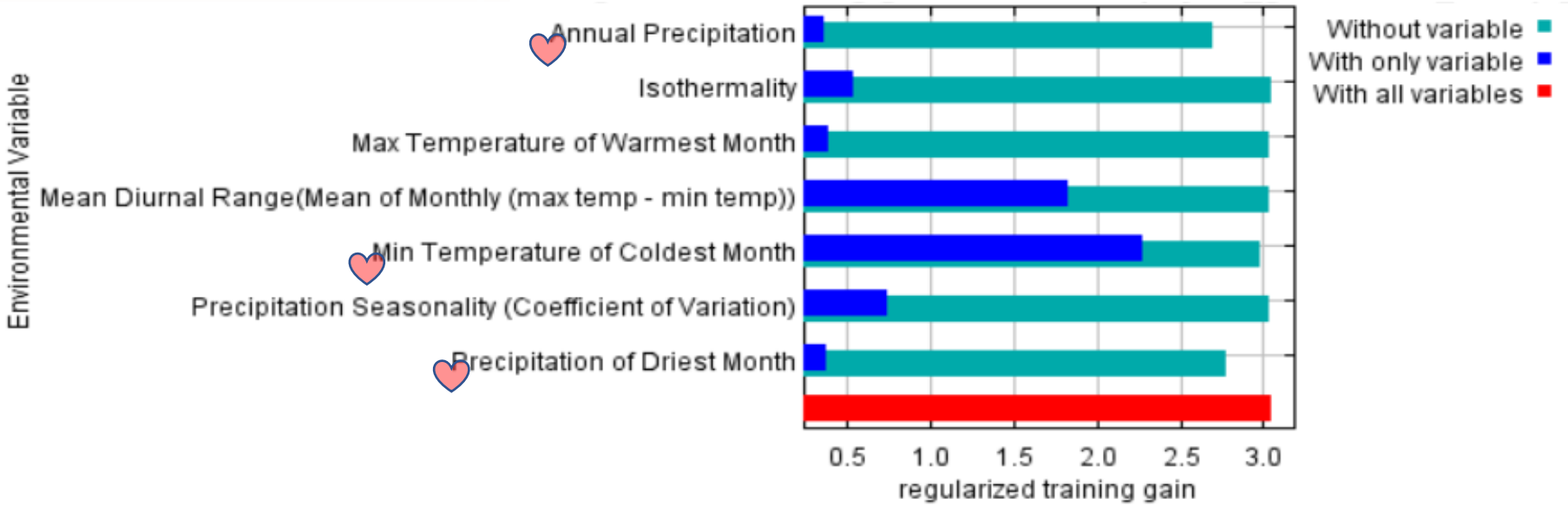
Variable	Percent contribution	Permutation importance
Min Temperature of Coldest Month	64.9	21.3
Annual Precipitation	17.8	61
Precipitation of Driest Month	12.9	14.2
Isothermality	2.7	0
Max Temperature of Warmest Month	1.7	1.8
Precipitation Seasonality (Coefficient of Variation)	0	0
Mean Diurnal Range(Mean of Monthly (max temp - min temp))	0	1.7

Importance of environmental predictors in *A. glandulosa* subsp. *crassifolia*

Construct Species distribution model (Maxent)

Q1:What environmental factors characterize the narrow distribution of these two rare subspecies?

- Contribution of environmental variables
- Jackknife test



Importance of environmental predictors in *A. glandulosa* subsp. *gabrielensis*

Construct Species distribution model (Maxent)

AUC: 0.980

Q1:What environmental factors characterize the narrow distribution of these two rare subspecies?

- Contribution of environmental variables
- Jackknife test

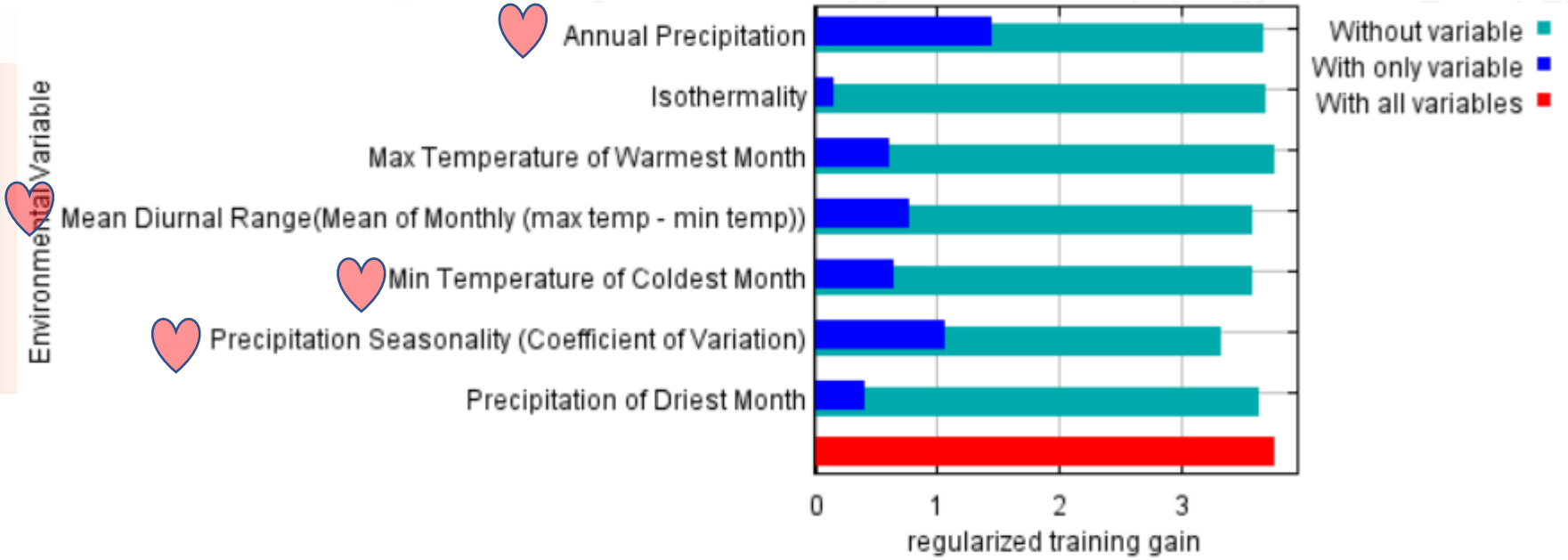
Variable	Percent contribution	Permutation importance
Annual Precipitation	52.3	0.6
Min Temperature of Coldest Month	29.4	33.1
Precipitation of Driest Month	10.8	7
Isothermality	7.4	0.7
Precipitation Seasonality (Coefficient of Variation)	0	50.5
Mean Diurnal Range(Mean of Monthly (max temp - min temp))	0	8.1
Max Temperature of Warmest Month	0	0

Importance of environmental predictors in *A. glandulosa* subsp. *gabrielensis*

Construct Species distribution model (Maxent)

Q1:What environmental factors characterize the narrow distribution of these two rare subspecies?

- Contribution of environmental variables
- Jackknife test



Niche overlap

- Schoener's D: 0 (no overlap) ~ 1(niche models identical)

$$D(p_X, p_Y) = 1 - \frac{1}{2}\sum_i |p_{X,i} - p_{Y,i}|,$$

- I statistics: 0(no overlap) ~ 1(niche models identical)
  - Do not require biological assumption that Px,i is proportional to local species densities.

Quantify niche overlap among subspecies (ENMtools)

- Schoener's D and I statistic

$$H(p_X, p_Y) = \sqrt{\sum_i \left(\sqrt{p_{X,i}} - \sqrt{p_{Y,i}}\right)^2}.$$

$$I(p_X, p_Y) = 1 - \frac{1}{2}H(p_X, p_Y),$$

Niche overlap between subspecies: Schoener's D

Species	admsii	crassifolia	cushingiana	Gabrielensis	glandulosa	howelli	leucophylla	mollis
admsii	1	0.32874	0.252979	0.134537	0.370438	0.09969	0.654508	0.268323
crassifolia	0.32874	1	0.201683	0.077019	0.282917	0.041531	0.169199	0.248195
cushingiana	0.252979	0.201683	1	0.363701	0.74123	0.280437	0.206663	0.481497
gabrielensis	0.134537	0.077019	0.363701	1	0.275357	0.116745	0.11056	0.443395
glandulosa	0.370438	0.282917	0.74123	0.275357	1	0.239691	0.276732	0.460528
howelli	0.09969	0.041531	0.280437	0.116745	0.239691	1	0.112524	0.094586
leucophylla	0.654508	0.169199	0.206663	0.11056	0.276732	0.112524	1	0.17921
mollis	0.268323	0.248195	0.481497	0.443395	0.460528	0.094586	0.17921	1

Quantify niche overlap among subspecies (ENMtools)

- Schoener's D and I statistic

- For subspecies crassifolia, gabrielensis & howelli, their calculated Schoener's D with other subspecies is smaller than 0.5

Niche overlap between subspecies: *I statistics*

Species	admsii	crassifolia	cushingiana	Gabrielensis	glandulosa	howelli	leucophylla	mollis
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howelli	0.09969	0.041531	0.280437	0.116745	0.239691	1	0.112524	0.094586
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mollis	0.268323	0.248195	0.481497	0.443395	0.460528	0.094586	0.17921	1

Quantify niche overlap among subspecies (ENMtools)

- Schoener's D and I statistic

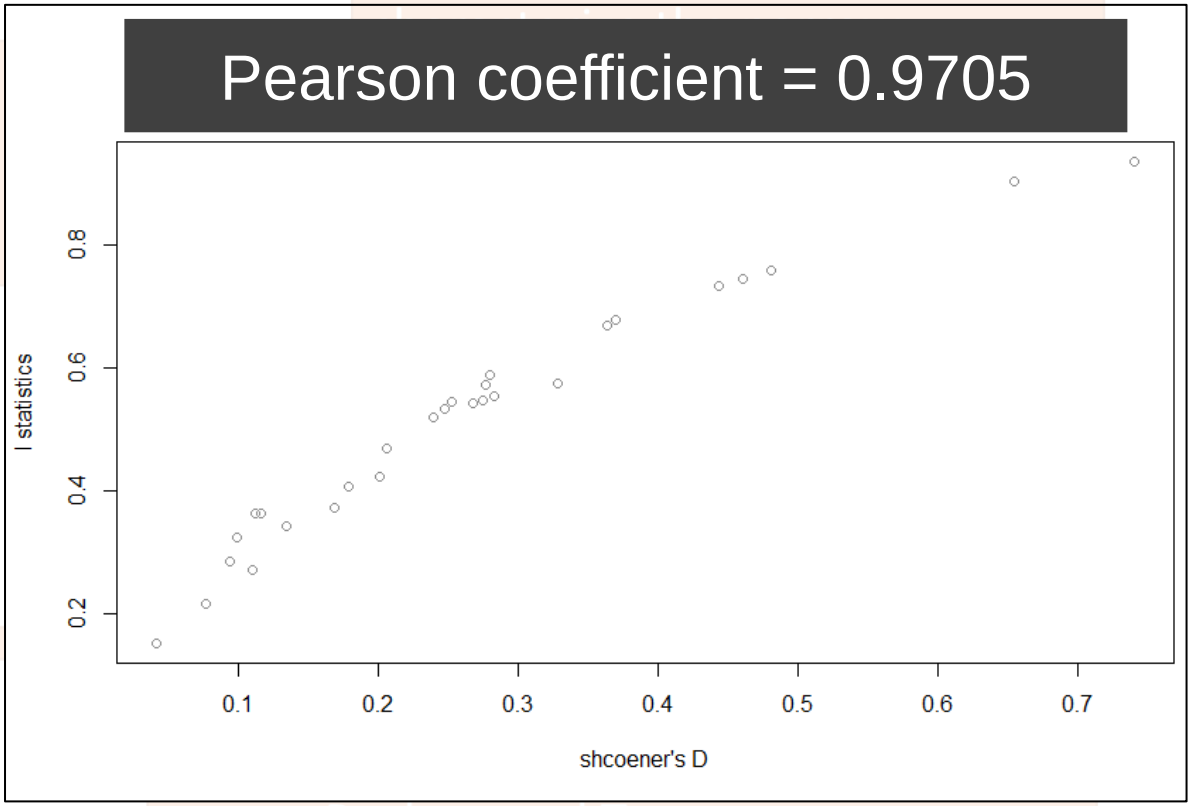
- Correspond with Schoener's D
- Maximum niche overlap: cushingiana vs glandulosa
- Minimum niche overlap: crassifolia vs gabrielensis

Schoener's D and *I statistics* are highly correlated

- Maximum niche overlap: cushingiana vs glandulosa
- Minimum niche overlap: crassifolia vs gabrielensis

Quantify niche overlap among subspecies (ENMtools)

- Schoener's D and I statistic



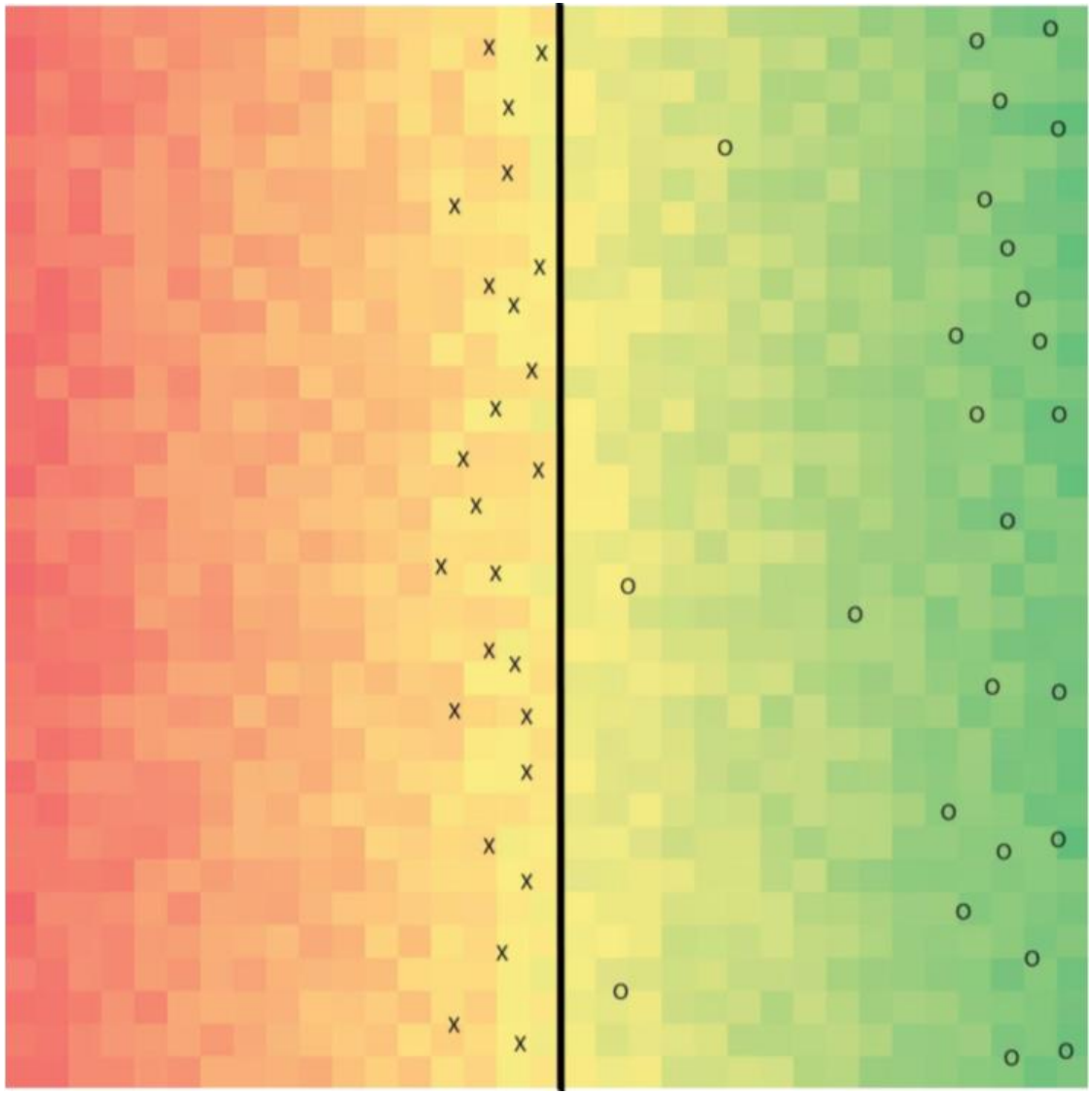
Identity Test and Background Test
(Time consuming: rep=10 ~ 30min)

- Randomization tests
- Different null hypothesis
  - Identity test: This test is used to ask whether ENMs generated from two species are more different than expected if they are drawn from the same underlying distribution.
  - Background: whether two species are more or less similar than expected based on the differences in the environmental background in which they occur.

Q2: Do these subspecies differ in their ecological niche?

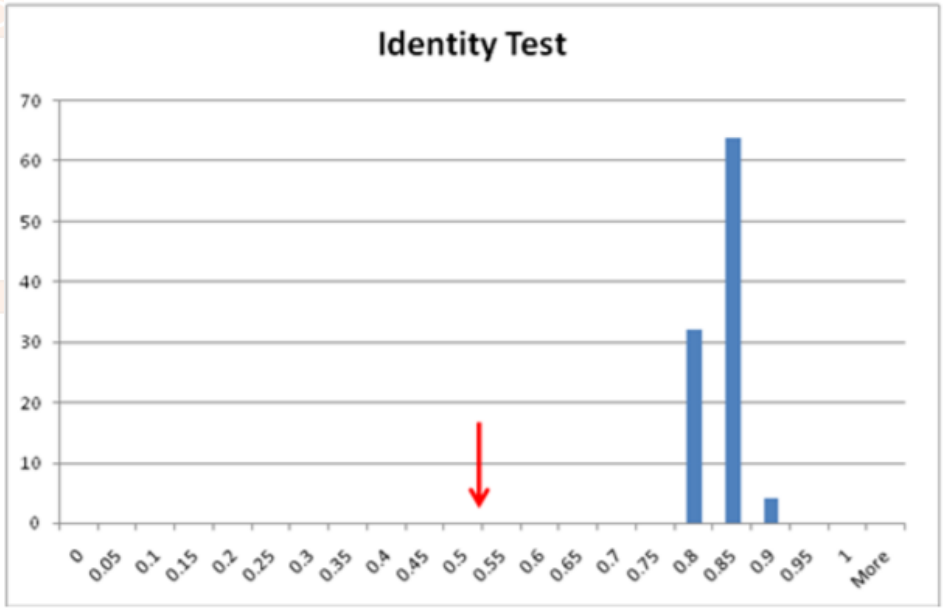
- Statistical test on significance (ENMtools):
  - Identity test
  - Background Test

https://mafiadoc.com/enmtools-user-manual_5b7dc952097c477e058b464d.html



Identity Test and Background Test
(Time consuming: rep=10 ~ 30min)

- Red arrow: measured niche overlap between real species data
- Histogram: distribution of overlap from pseudoreplicates
- Reject hypothesis of identity



Q2: Do these subspecies differ in their ecological niche?

- Statistical test on significance (ENMtools):
  - Identity test
  - Background Test

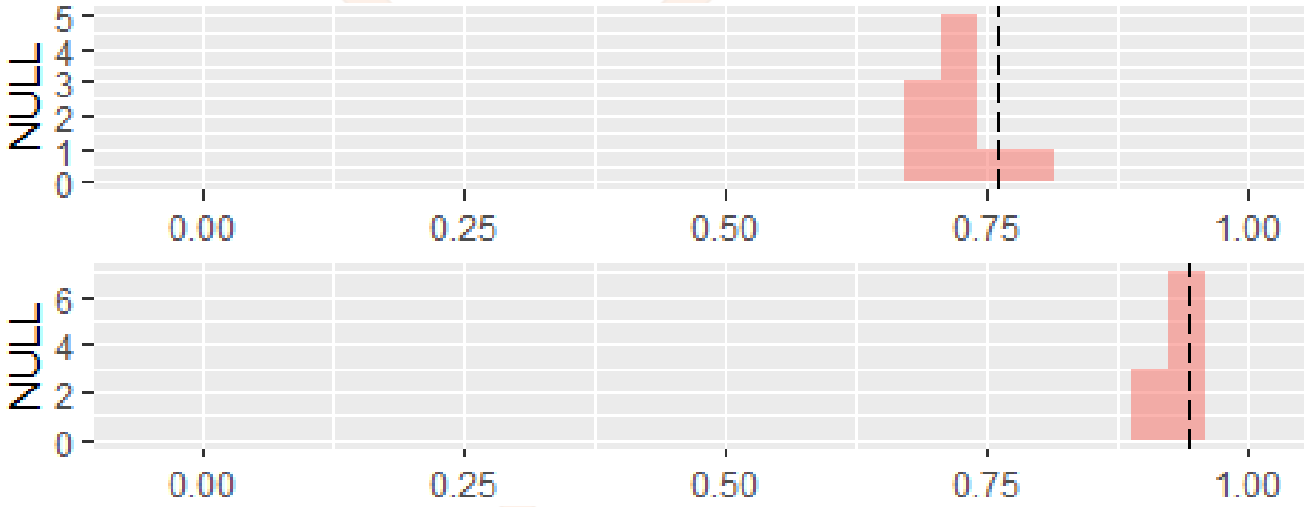
Test on two examples

- Max niche overlap: cushingiana vs glandulosa
  - Schoener's D :0.74123
  - I statisctis:0.93482
  - Expect to accept the hypothesis of identity/background similarity
- Min niche overlap: crassifoila vs gabrielensis
  - Schoener's D:0.077019
  - I statistics:0.215718
  - Expect to reject the hypothesis of identity/background similarity

Q2: Do these subspecies differ in their ecological niche?

- Statistical test on significance (ENMtools):
  - Identity test
  - Background Test

Accept the hypothesis of no significant difference in Background Test: cushingiana vs glandulosa



# of replicates = 10
Schoener's D

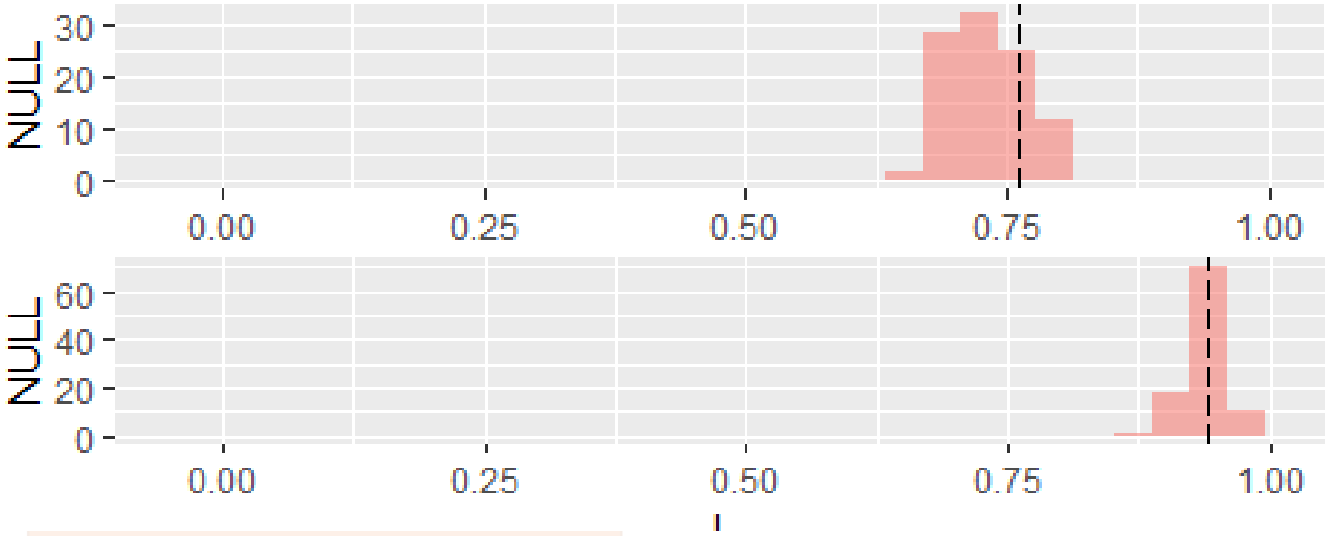
# of replicates = 10
I statistics

- Maximum calculated niche overlap
- Real calculated value fall into the distribution
- ~ 30min. What if we increase the # of replicates?

Q2: Do these subspecies differ in their ecological niche?

- Statistical test on significance (ENMtools):
  - Identity test
  - Background Test

Accept the hypothesis of no significant difference in Background Test: cushingiana vs glandulosa



# of replicates = 100
Schoener's D

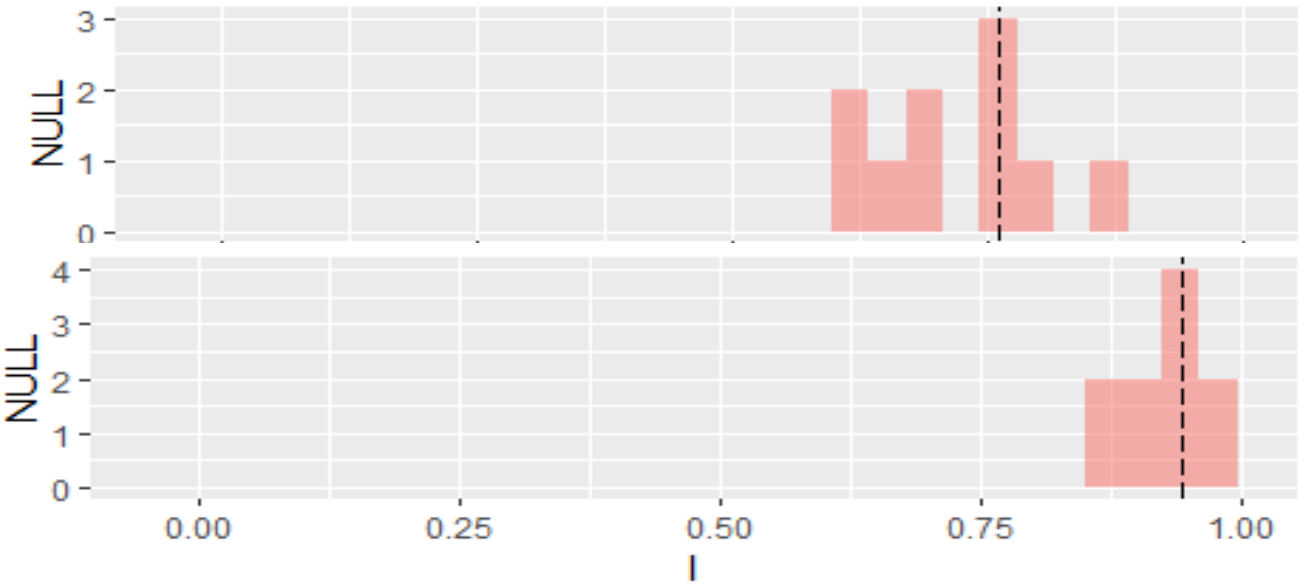
# of replicates = 100
I statistics

- Distribution changed
- Conclusion did not change: Real calculated value still fall into the distribution

Q2: Do these subspecies differ in their ecological niche?

- Statistical test on significance (ENMtools):
  - Identity test
  - Background Test

Accept the hypothesis of no significant difference in Identity Test: cushingiana vs glandulosa



# of replicates = 10
Schoener's D

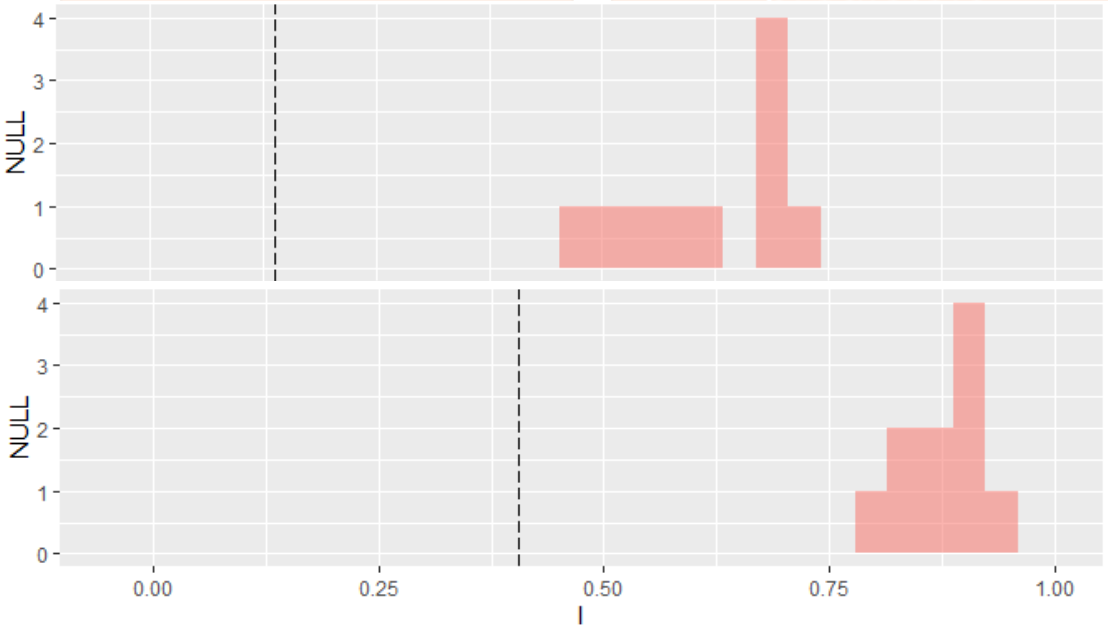
# of replicates = 10
I statistics

- Real calculated value fall into the distribution
- These two subspecies share identical niche

Q2: Do these subspecies differ in their ecological niche?

- Statistical test on significance (ENMtools):
  - Identity test
  - Background Test

Reject the hypothesis of no significant difference in Background Test: crassifolia vs gabrielensis



# of replicates = 10
Schoener's D

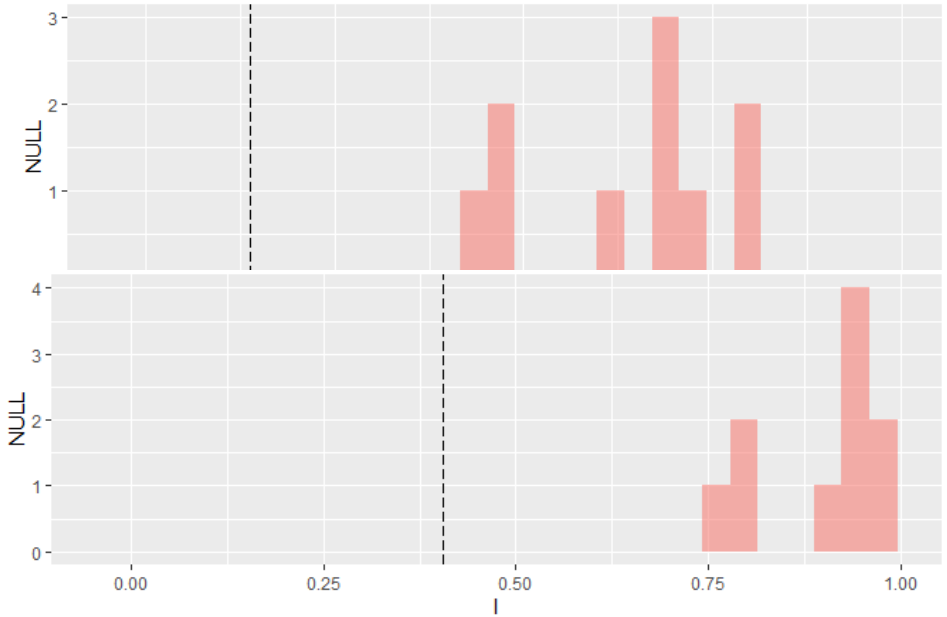
# of replicates = 10
I statistics

- Minimum calculated niche overlap
- Real calculated value did not fall into the distribution

Q2: Do these subspecies differ in their ecological niche?

- Statistical test on significance (ENMtools):
  - Identity test
  - Background Test

Reject the hypothesis of no significant difference in Identity Test: crassifolia vs gabrielensis



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Schoener's D

# of replicates = 10
I statistics

- Minimum calculated niche overlap
- Real calculated value did not fall into the distribution

Q2: Do these subspecies differ in their ecological niche?

- Statistical test on significance (ENMtools):
  - Identity test
  - Background Test

Conclusion

- The contribution of predictors to narrow contribution differ between these two rare subspecies.
- Subspecies cushingiana & glandulosa are NOT ecologically different based on background test, and share **identical** ecological niche.
- Subspecies crassifolia & gabrielensis are significantly different in their ecological niche based on the identity and background test.

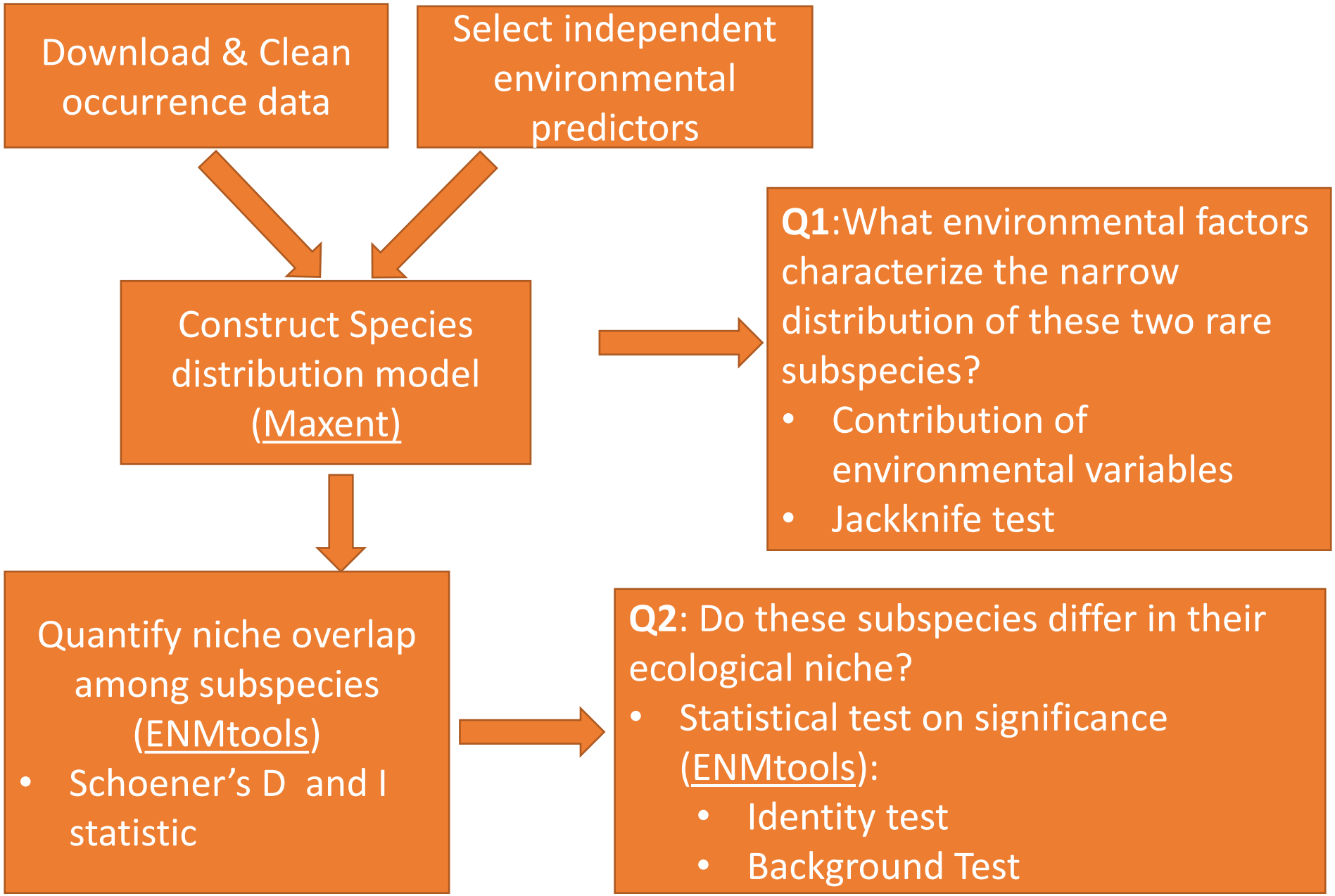
Take-home message

- ENMtools is very useful in estimating niche overlap/similarity and breadth. (R package available)
- Identity test and background is time-consuming and depends on the # of reps
  - half hour for every pair of subspecies, nrep =10
  - 5~6 hours for every pair of subspecies, nrep =100
- Niche shift will be a different topic:

Null modeling software for ecologists

http://garyentsminger.com/ecosim/index.htm

Thank you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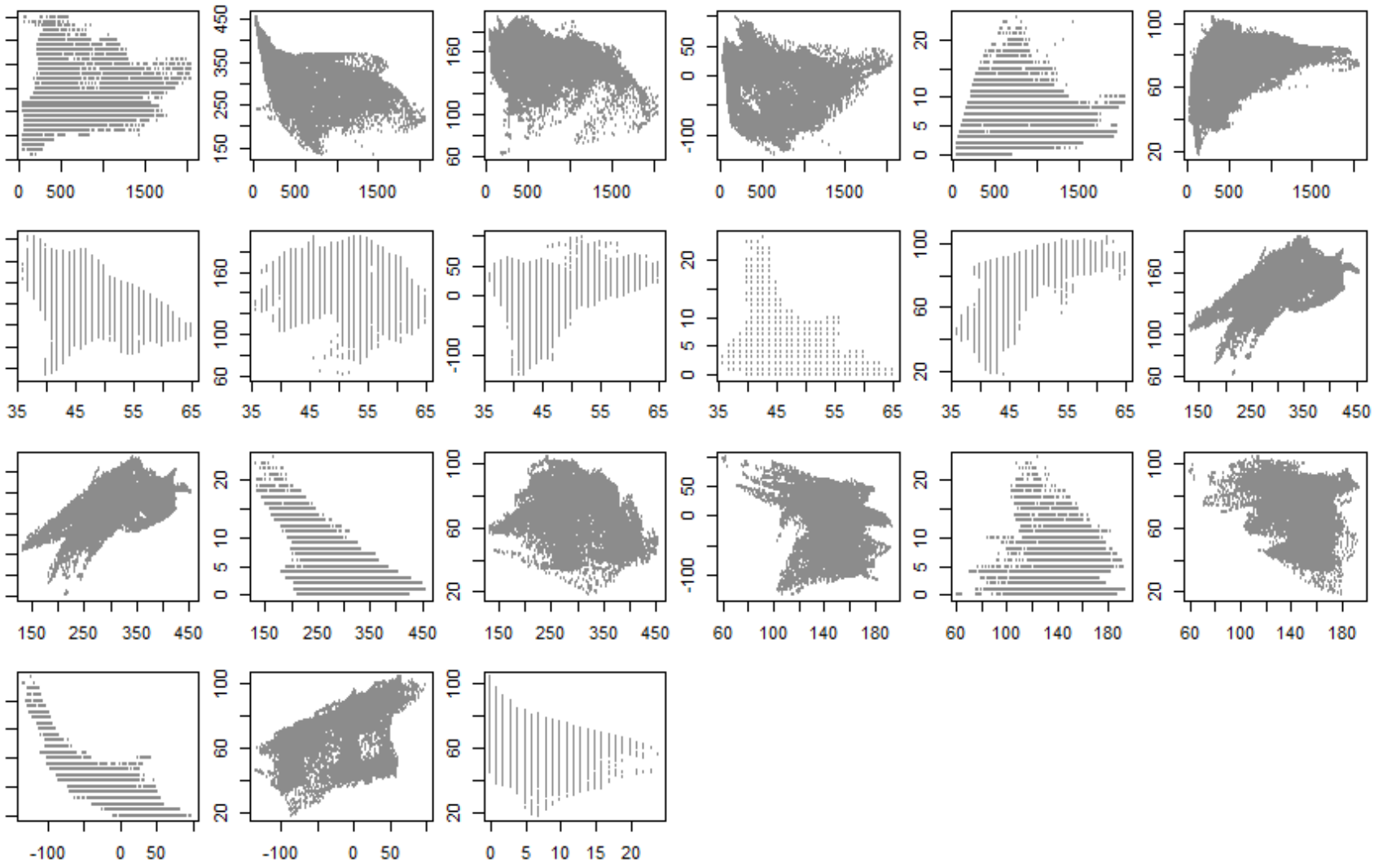
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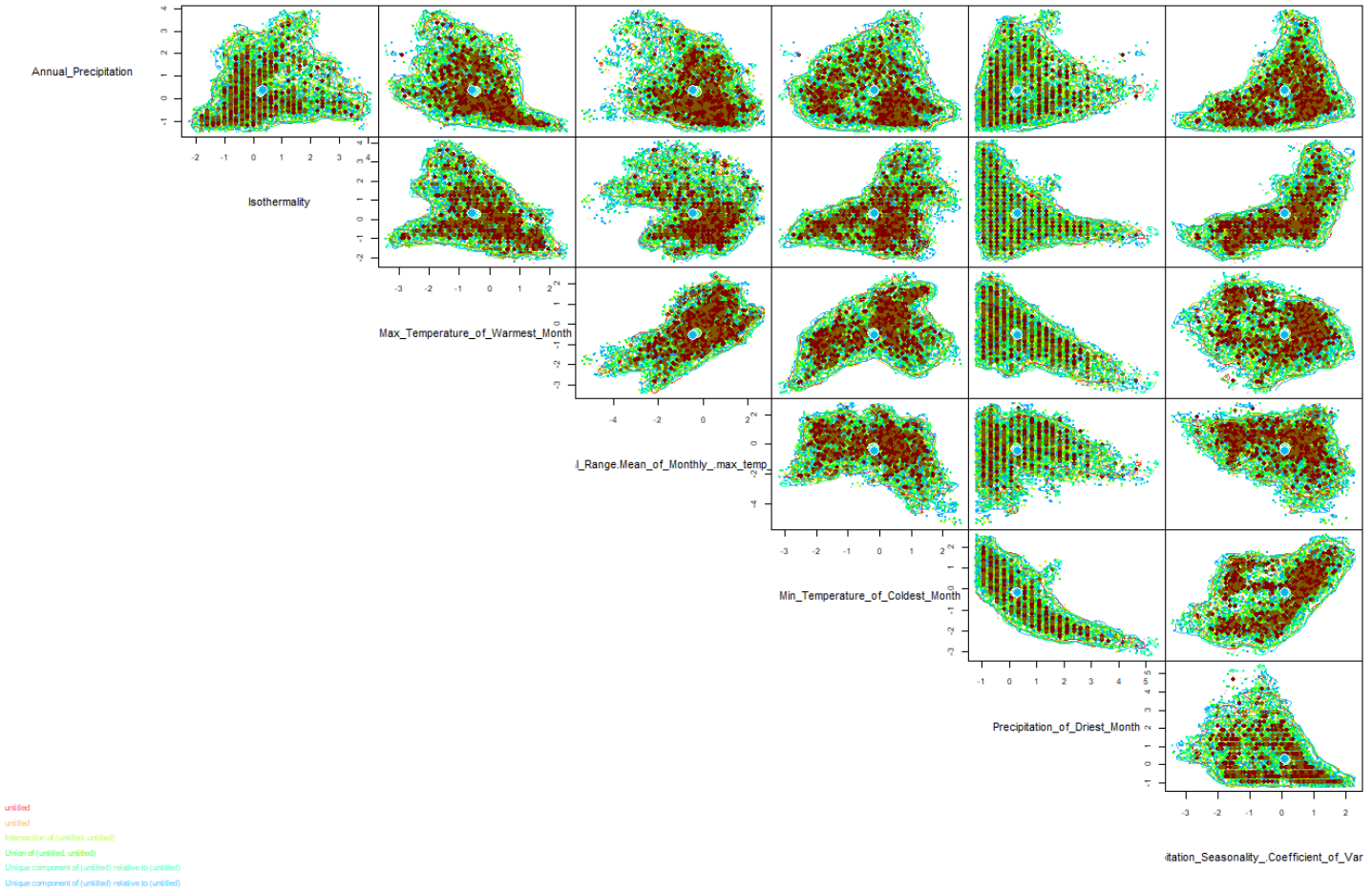
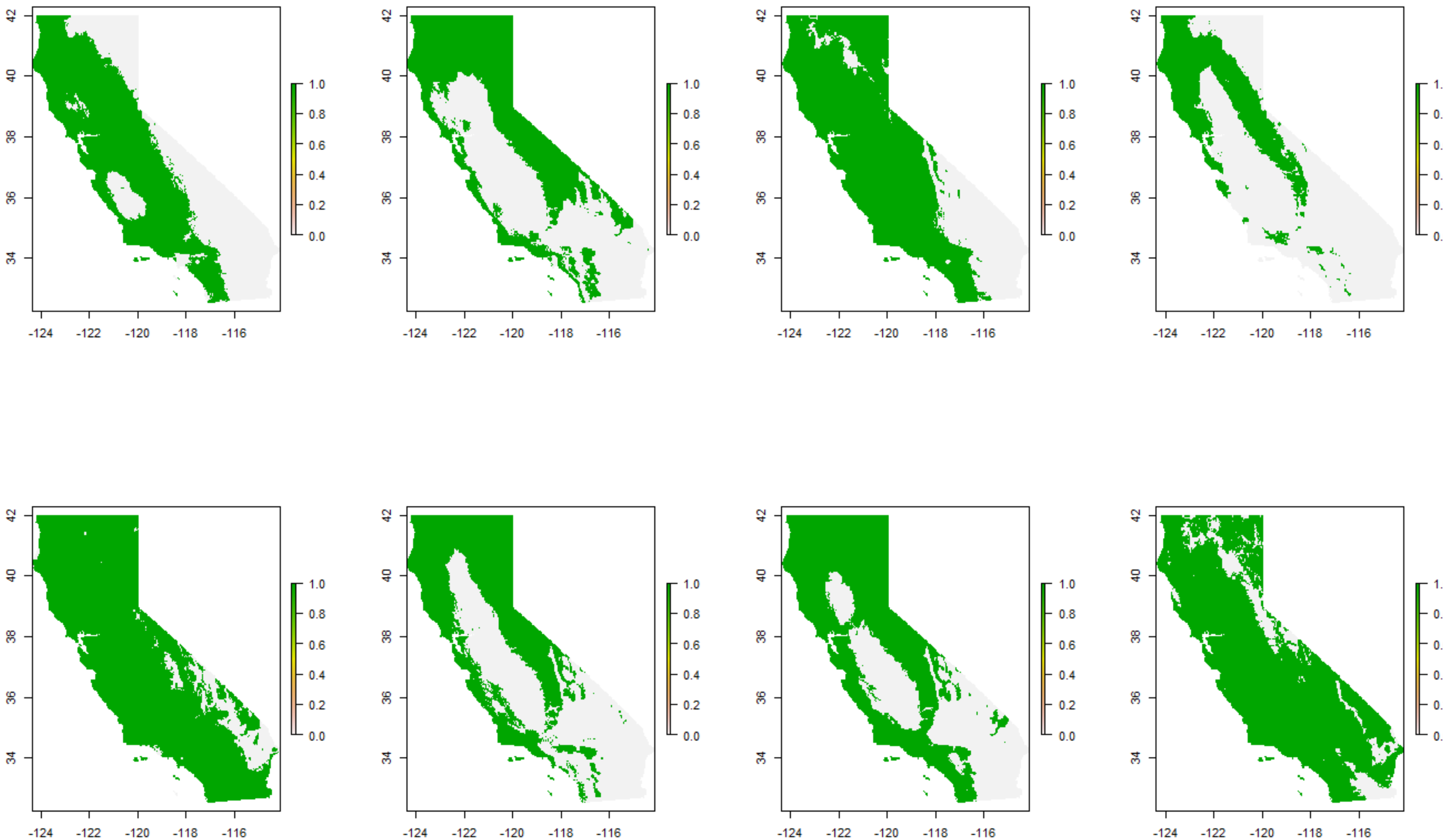
60 100 160
-100 0 50
0 5 10 20
20 60 100
35 45 55 65
150 250 350 450
60 100 140 180
-100 0 50
0 5 10 15 20

Crassifolia vs gabrielensis

```
> hypervolume_overlap_statistics(hv_set)
      jaccard      sorensen frac_unique_1 frac_unique_2
    0.7470702     0.8552263     0.1446826     0.1448647
```

Crassifolia vs gabrielensis





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34
-124
-122
-120
-118
-116
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0.6
0.4
0.2
0.0