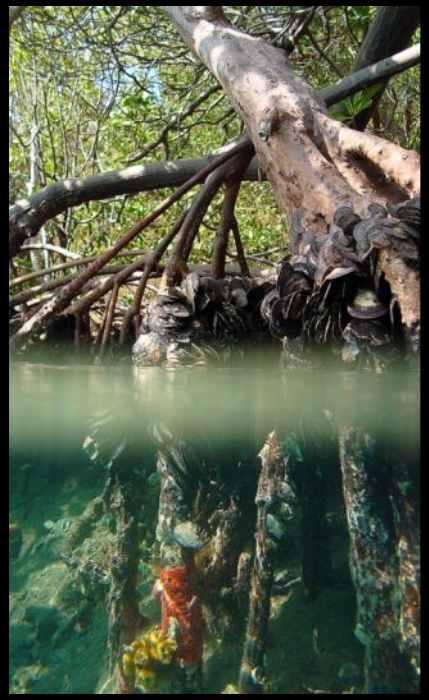
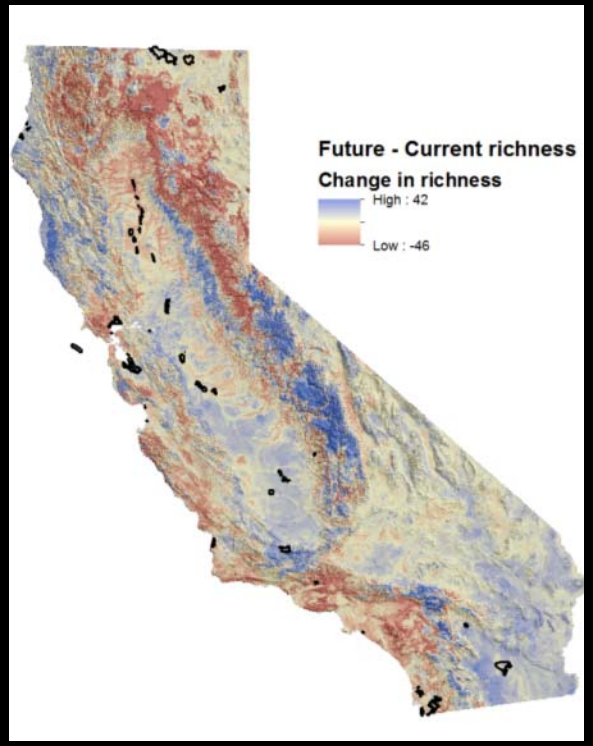
Distribution Modeling
&
Species Indices





A rose by any other name...

- Ecological niche modeling
- Element distribution modeling
- Predictive range mapping
- Habitat suitability modeling
- Climate envelope modeling

A rose by any other name…

- Ecological niche modeling
- Element distribution modeling
- Predictive range mapping
- Habitat suitability modeling
- Climate envelope modeling

THE GOAL: capture species-environment relationships that characterize where the species can occur on the landscape

A rose by any other name…

- Ecological niche modeling
- Element distribution modeling
- Predictive range mapping
- Habitat suitability modeling
- Climate envelope modeling

The assumption being that species/habitat distributions are not uniform, and depend on suitable habitats/climates. If the preferences for such habitats/climates are identified, and then the distribution of these factors mapped…something can be inferred regarding the distribution of elements of interest

Common uses

- Discovery of new populations
- Risk of species invasions
- Reserve selection and design
- Restoration, translocation, reintroductions
- Climate change impacts on biodiversity

Methods for modeling species responses to climate change

- Forecasting distribution responses

  Correlative models (PATTERNS):

  - Phenomenological
  - Relate current distributions to environmental variables

  Mechanistic models (PROCESSES):

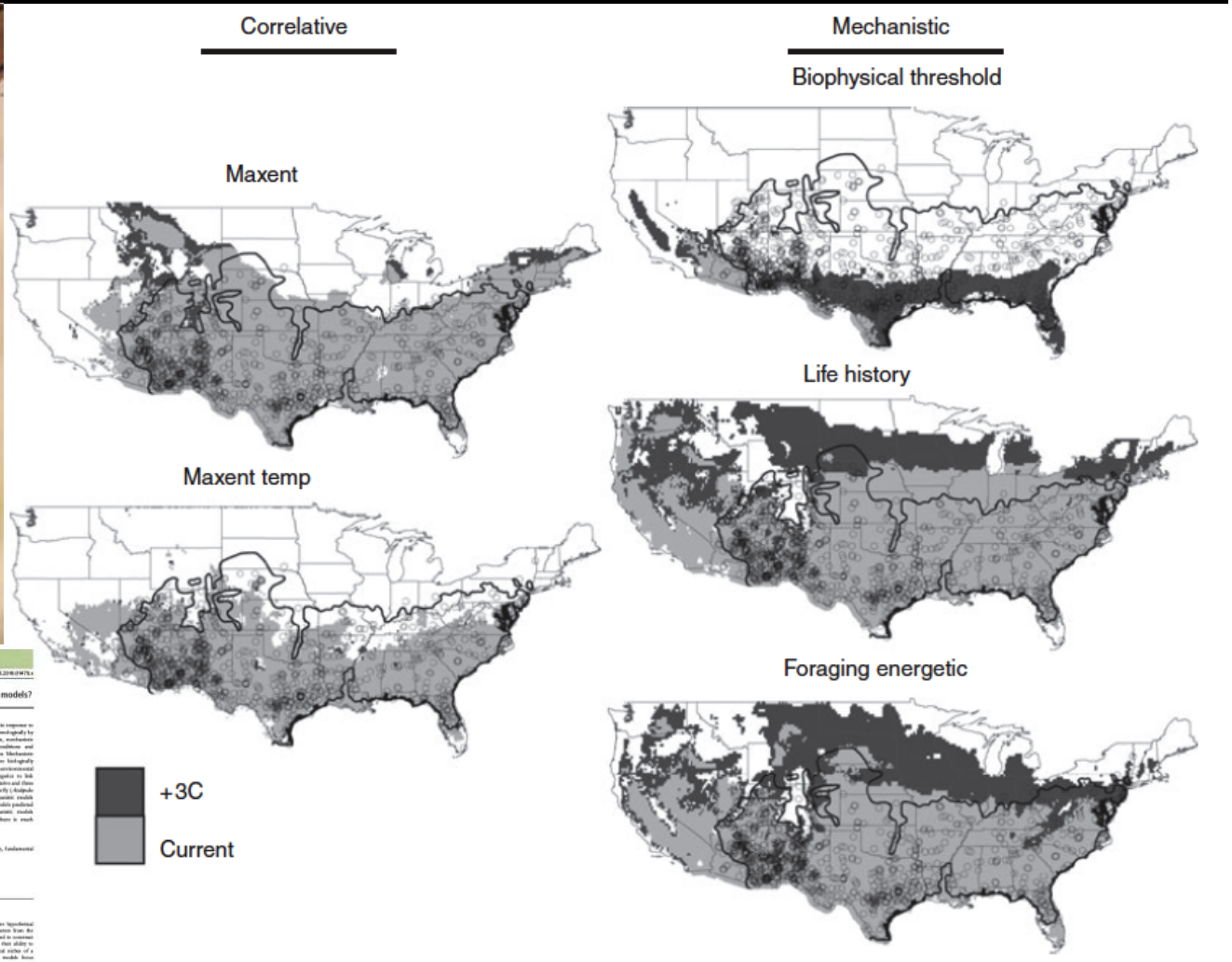
  - Use explicit relationships between environmental variables and organismal performance
  - Estimated independently of species current distribution

Methods for modeling species responses to climate change

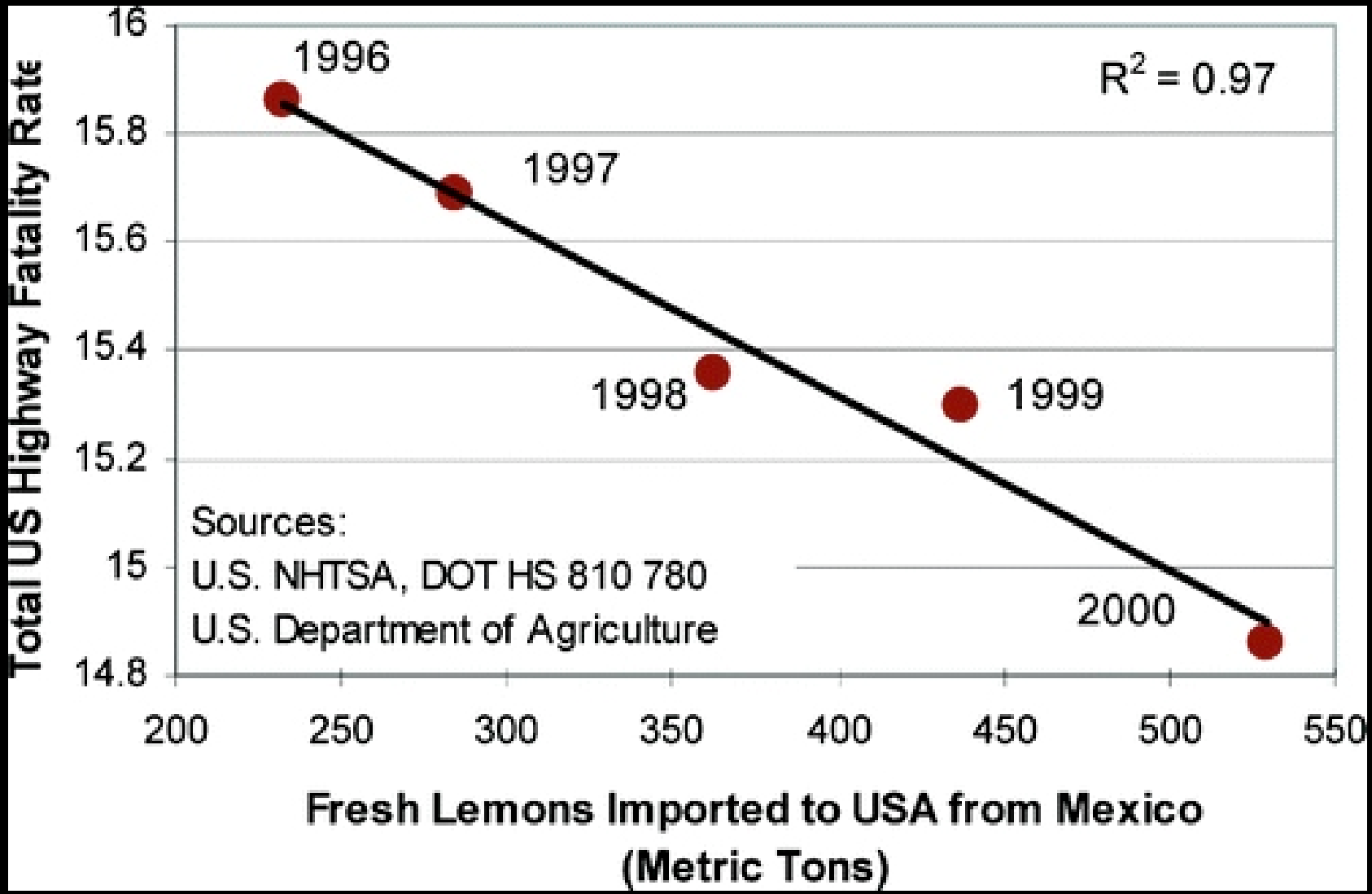
ECOLOGY LETTERS

REVIEW AND SYNTHESIS

Can mechanism inform species' distribution models?



re 1 Range predictions for *Sceloporus undulatus* in current climates (light gray) and predicted range expansions following a uniform 3 °C
perature increase (dark gray). Localities (o) and the atlas range polygon are shown.


Total US Highway Fatality Rate
16
15.8
15.6
15.4
15.2
15
14.8
1996
1997
1998
1999
2000
R^2 = 0.97
Sources:
U.S. NHTSA, DOT HS 810 780
U.S. Department of Agriculture
200
250
300
350
400
450
500
550
Fresh Lemons Imported to USA from Mexico
(Metric Tons)

- **75 percent of people prefer scooped ice cream over soft serve. But among those who would only drink Tang under duress, 88 percent prefer scooped ice cream.**

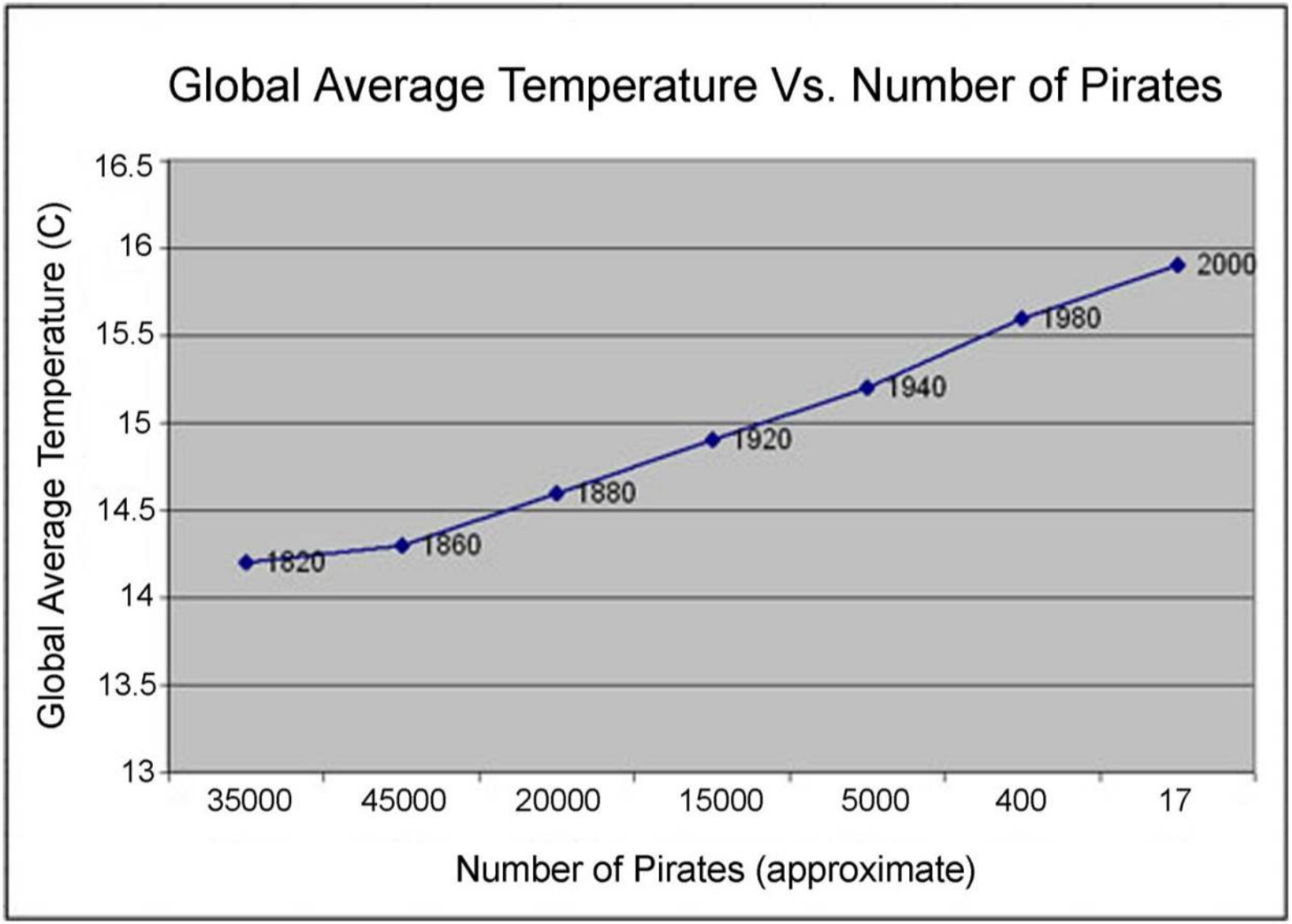
  Based on a survey of 165 people who would only drink Tang under duress and 413 people total.

- **58 percent of people describe their temperament as unflappable. But among those who would rather fight one horse-sized duck than 100 duck-sized horses, 77 percent describe their temperament as unflappable.**

  Based on a survey of 189 people who would rather fight one horse-sized duck than 100 duck-sized horses and 464 people total.

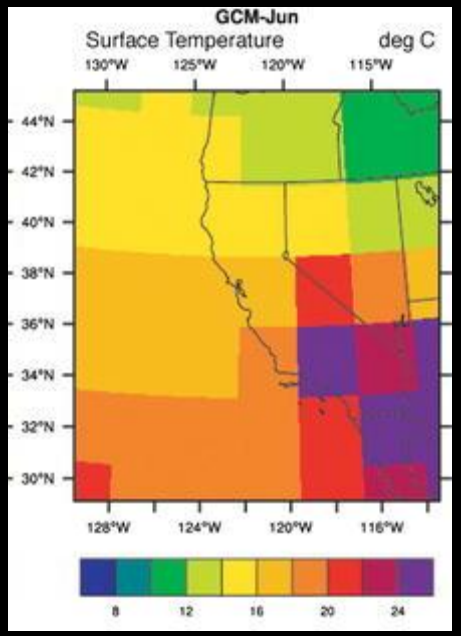
- **62 percent of people say they have at least one sister. But among those who think clowns are more freaky than fun, 75 percent have at least one sister.**

  Based on a survey of 207 people who think clowns are freaky and 422 people total.

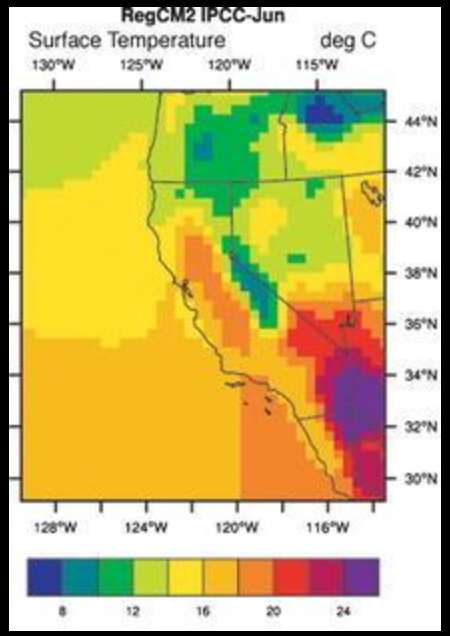

Global Average Temperature Vs. Number of Pirates
Global Average Temperature (C)
16.5
16
15.5
15
14.5
14
13.5
13
1820
1860
1880
1920
1940
1980
2000
35000
45000
20000
15000
5000
400
17
Number of Pirates (approximate)

How can distribution models contribute to a vulnerability assessment?

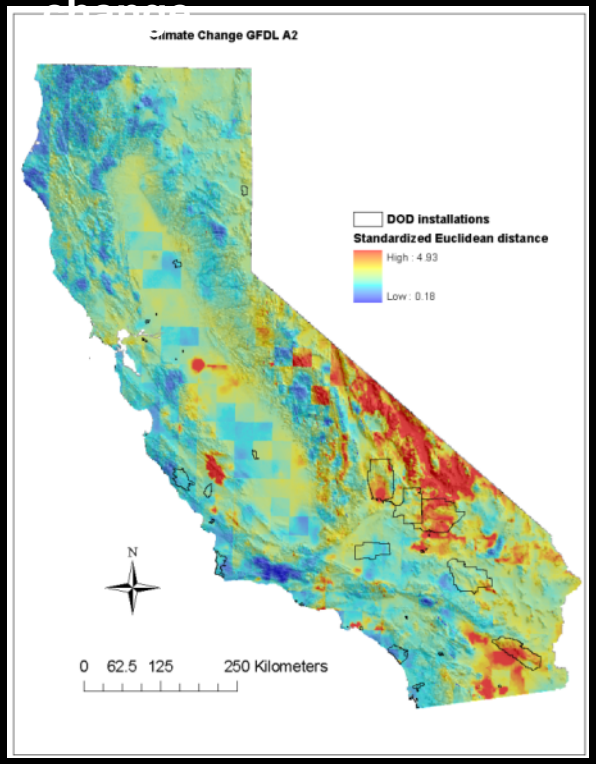
General Circulation Model GCM)



Regional Climate Model (RCM)



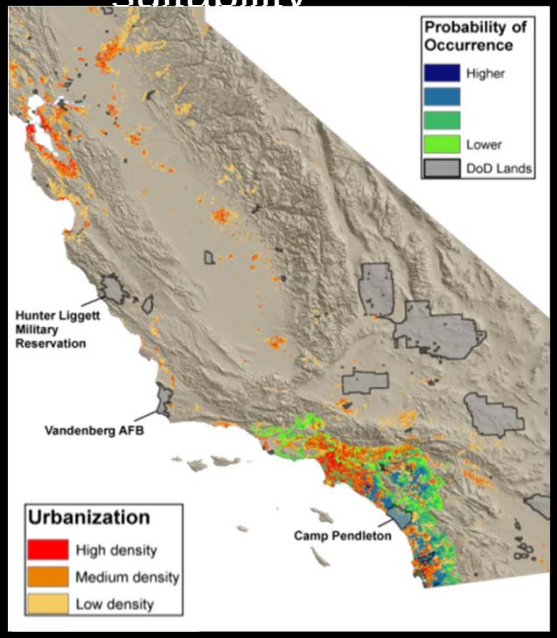
Magnitude of climate change



Qualitative assessment – estimate exposure qualitatively and piecemeal

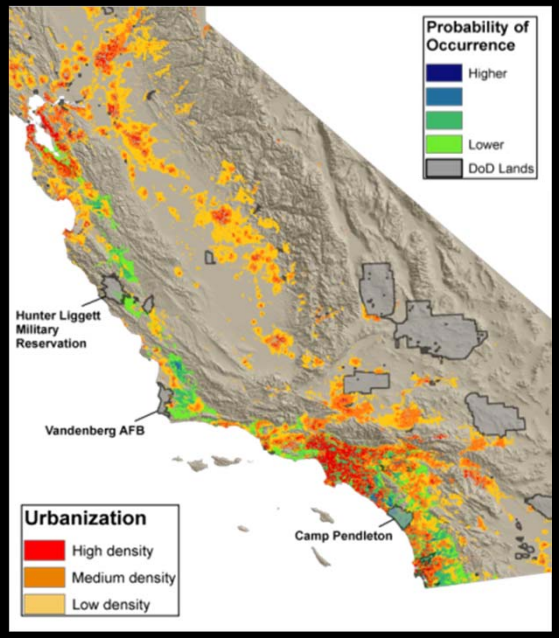
How can distribution models contribute to a vulnerability assessment?

Current suitability



California Gnatcatcher

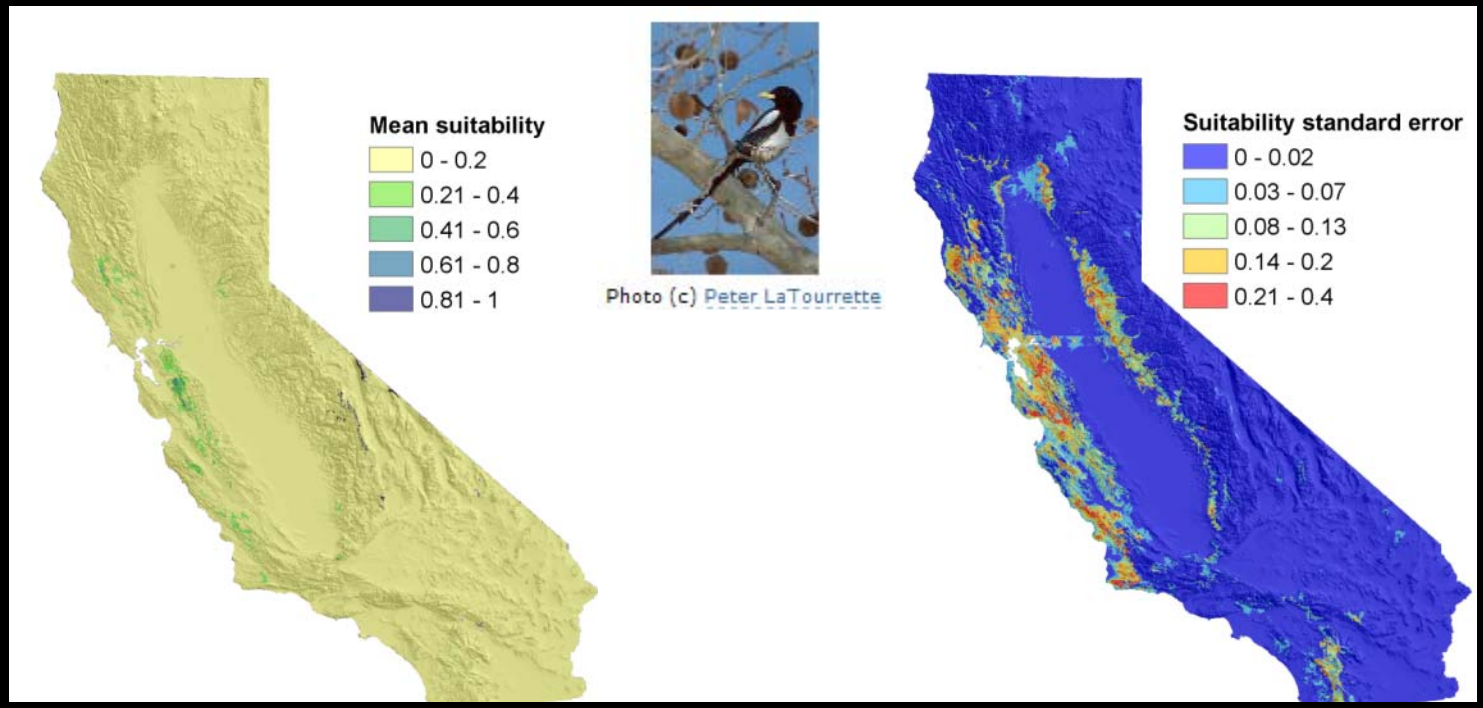
Suitability in 2070



Sensitivity can be assessed in a quantitative and spatially explicit manner

How can distribution models contribute to a vulnerability assessment?

Yellow-billed Magpie

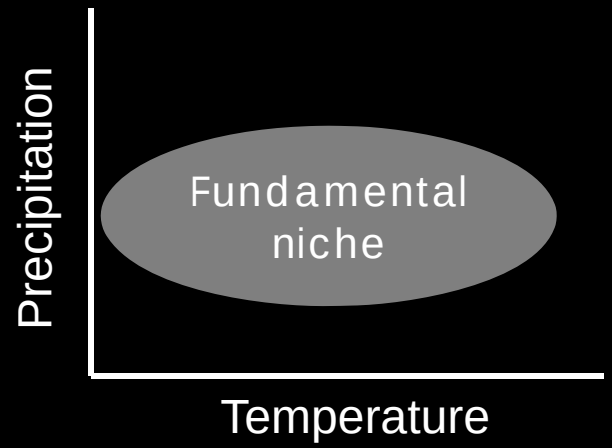


Uncertainty also addressed and conveyed to stakeholders in a clear and spatially explicit way

We should always examine more than one GCM and examine that GCM through the lens of >1 downscaling technique….all of these evaluations can be represented in an overlay to examine regions of common prediction

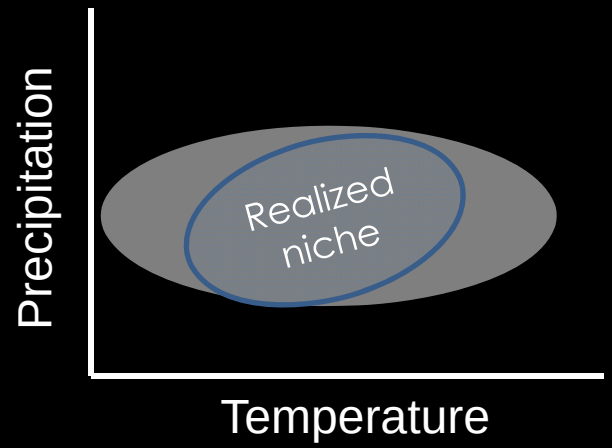
Issues to consider

- In many cases we only know the realized niche of a species



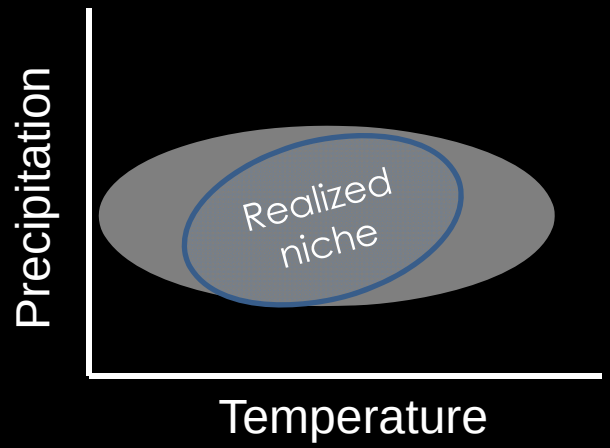
Issues to consider

- In many cases we only know the realized niche of a species

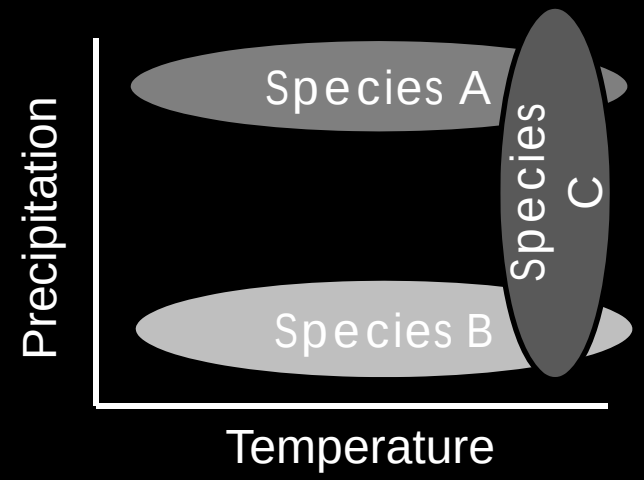


Issues to consider

- In many cases we only know the realized niche of a species

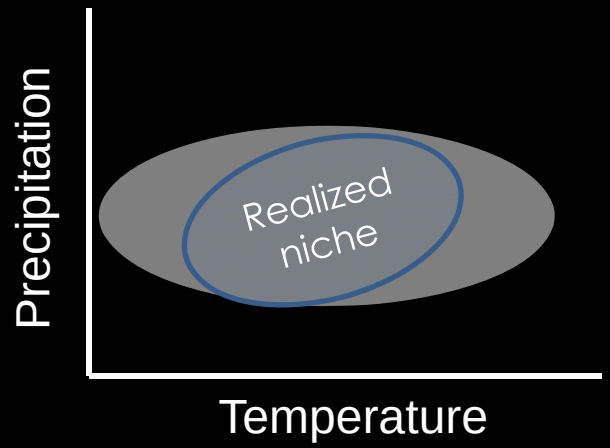


- There may not be current analogs of future climate or future communities

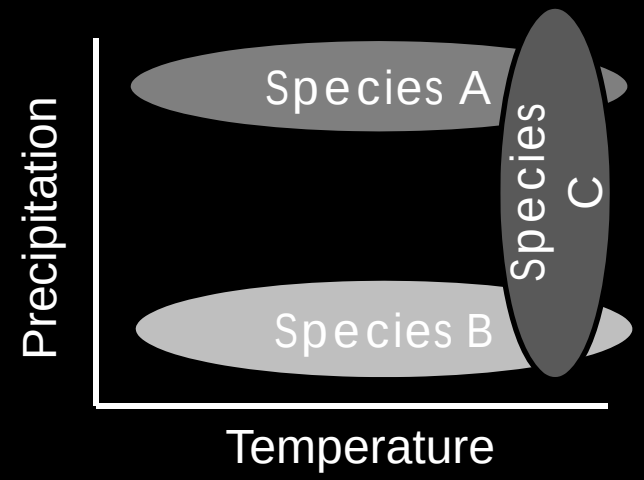


Issues to consider

- In many cases we only know the realized niche of a species

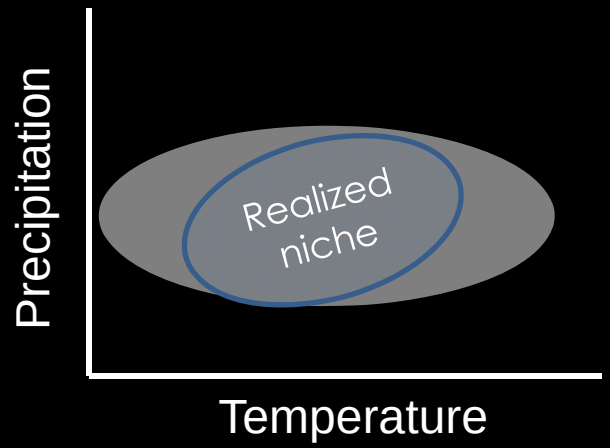


- There may not be current analogs of future climate or future communities

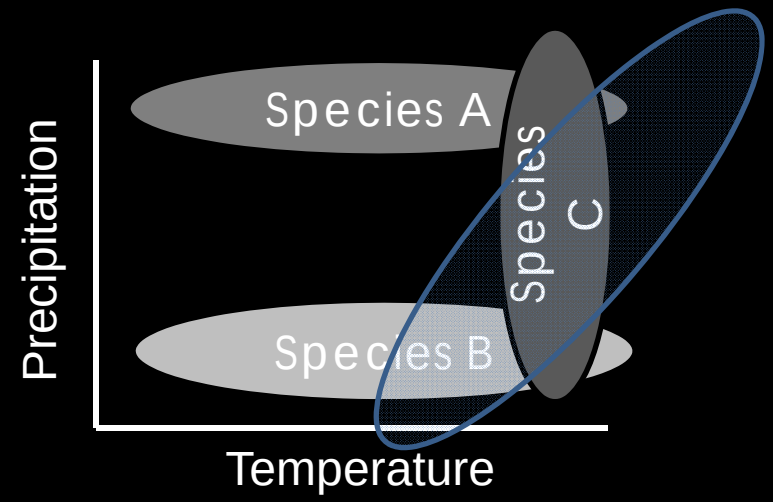


Issues to consider

- In many cases we only know the realized niche of a species

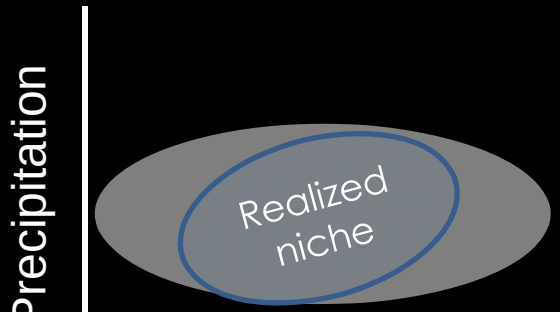


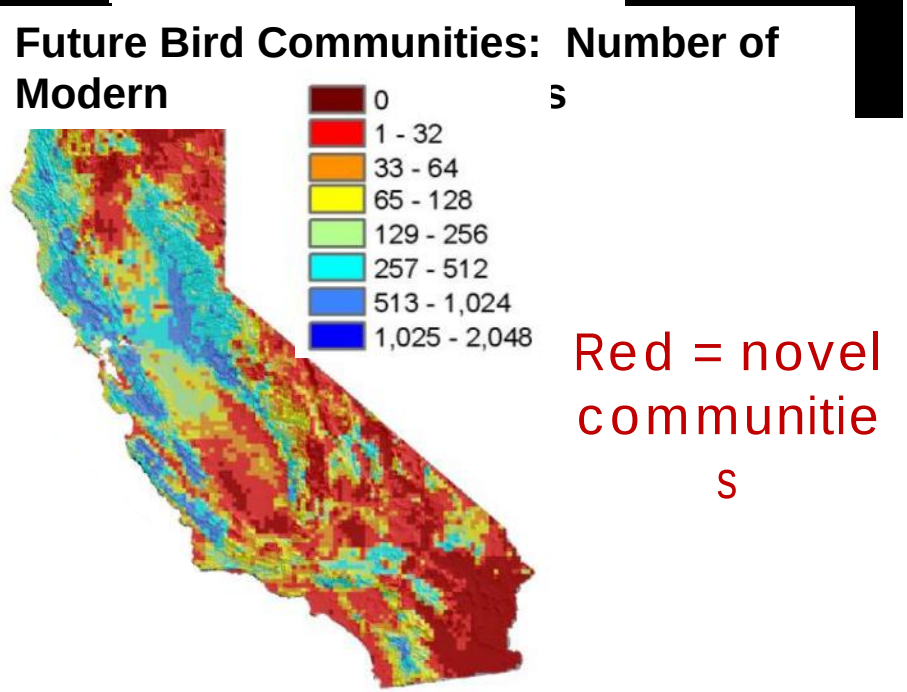
- There may not be current analogs of future climate or future communities



Issues to consider

- In many cases we only know the realized niche of a species
- There may not be current analogs of future climate or future communities





Red = novel communities

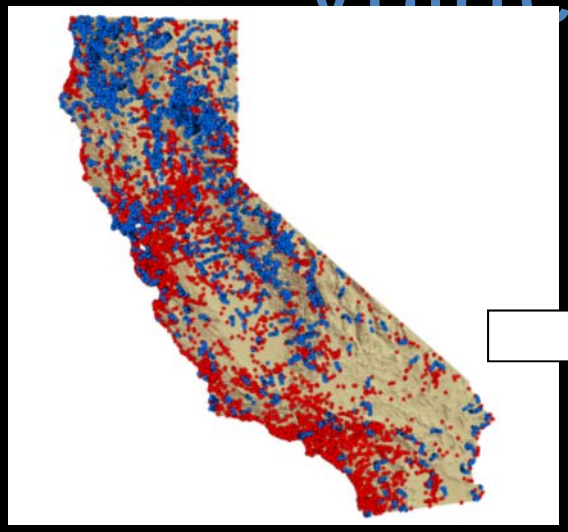
Categories of correlative distribution modeling

- Deductive
  - Typically based on expert knowledge
  - Identify key habitat/environmental requirements and map them
  - National GAP program

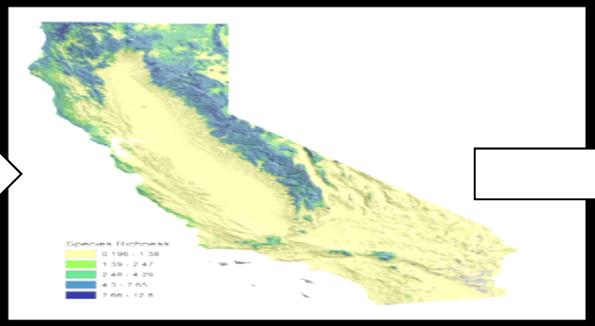
Categories of correlative distribution modeling

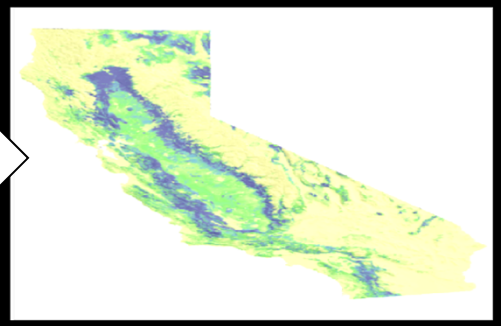
- Deductive
  - Typically based on expert knowledge
  - Identify key habitat/environmental requirements and map them
  - National GAP program
- Inductive
  - Requires knowledge of species occurrence data
  - Uses an algorithm to identify species-environment relationship

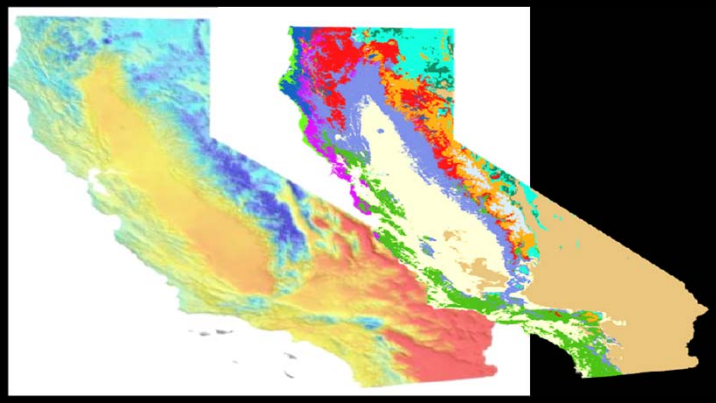
How can correlative distribution models contribute to a vulnerability assessment?



Current distributions **Future distributions**







Current species - environment relationships are projected onto forecasted climate scenarios

Species Vulnerability Indices

Alternatives to “DIY”

Species are Important!

USFWS

Peter La Tourrette
© California Academy of Sciences

Audubon

Vulnerability Indices can...

... save R & D time

... remind you about vulnerability factors

... compare apples and oranges

... promote transparency

Vulnerability Indices cannot...

... turn garbage into gold

... replace in-depth VAs of species

System for Assessing `Vulnerability of Species (SAVS) to Climate Change
(Forest Service)

Framework for categorizing the relative vulnerability of threatened & endangered species to climate change
(EPA)

Climate Change Vulnerability Index
(NatureServe)

Climate Change Sensitivity Index
(University of Washington and TNC)

All:

- are potentially rapid
- score individual factors
- produce categories of relative vulnerability
- address uncertainty

SAVS

www.fs.fed.us/rm/grassland-shrubland-desert/products/species-vulnerability

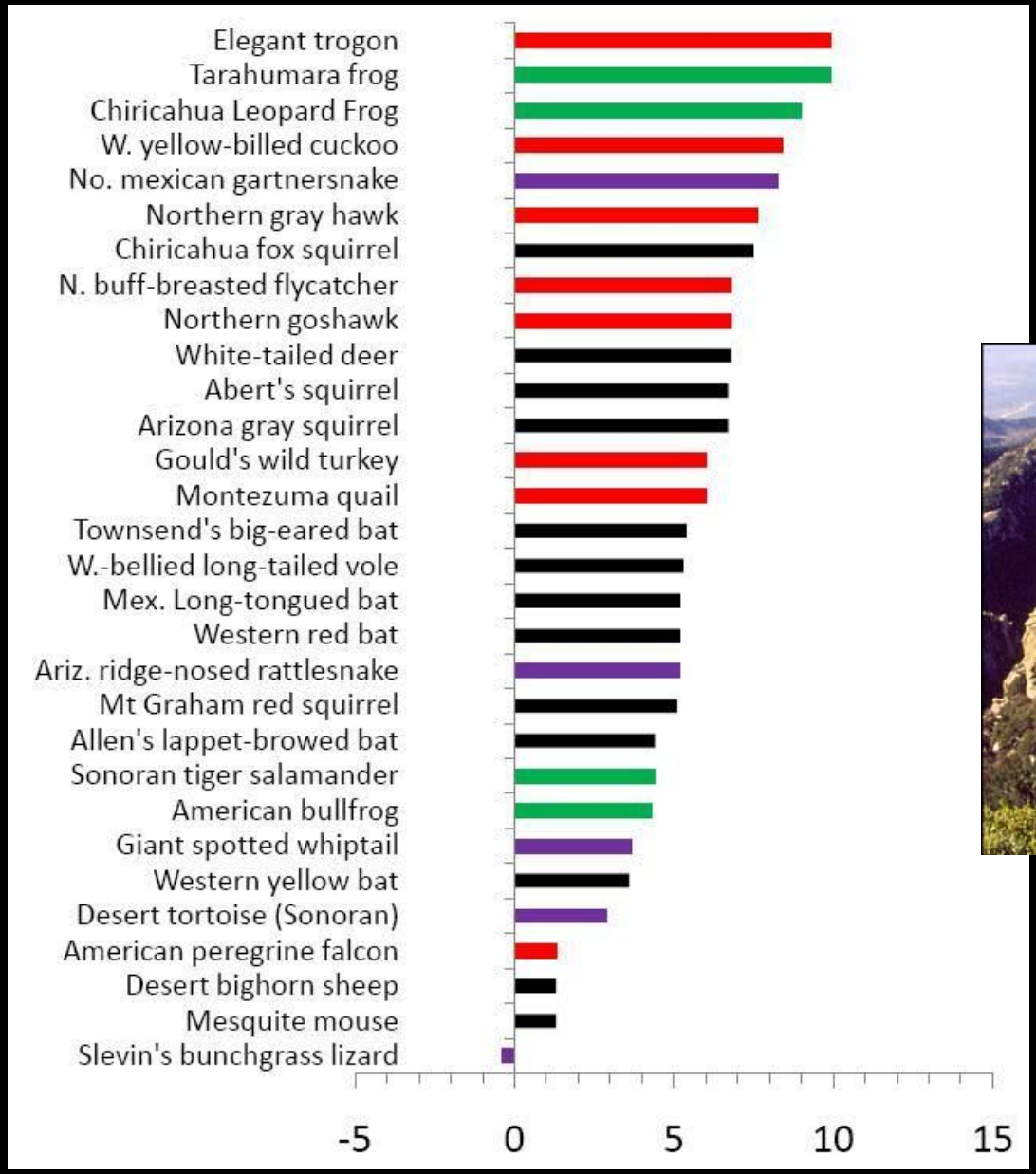
Terrestrial vertebrates

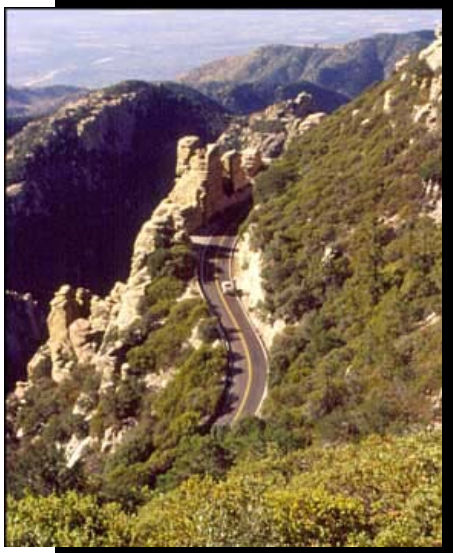
Questionnaire-based tool: Habitat, physiology, phenology, biotic interactions

Abundance, range, demographics considered implicitly

Scale: habitat/management area

Coronado National Forest





Less **Vulnerability** More

Coe et al. 2010

EPA

http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=203743

T&E Vertebrates Only

Baseline & climate change vulnerability

Abundance, range, demographics considered in baseline

Spatial Scale: any

NatureServe

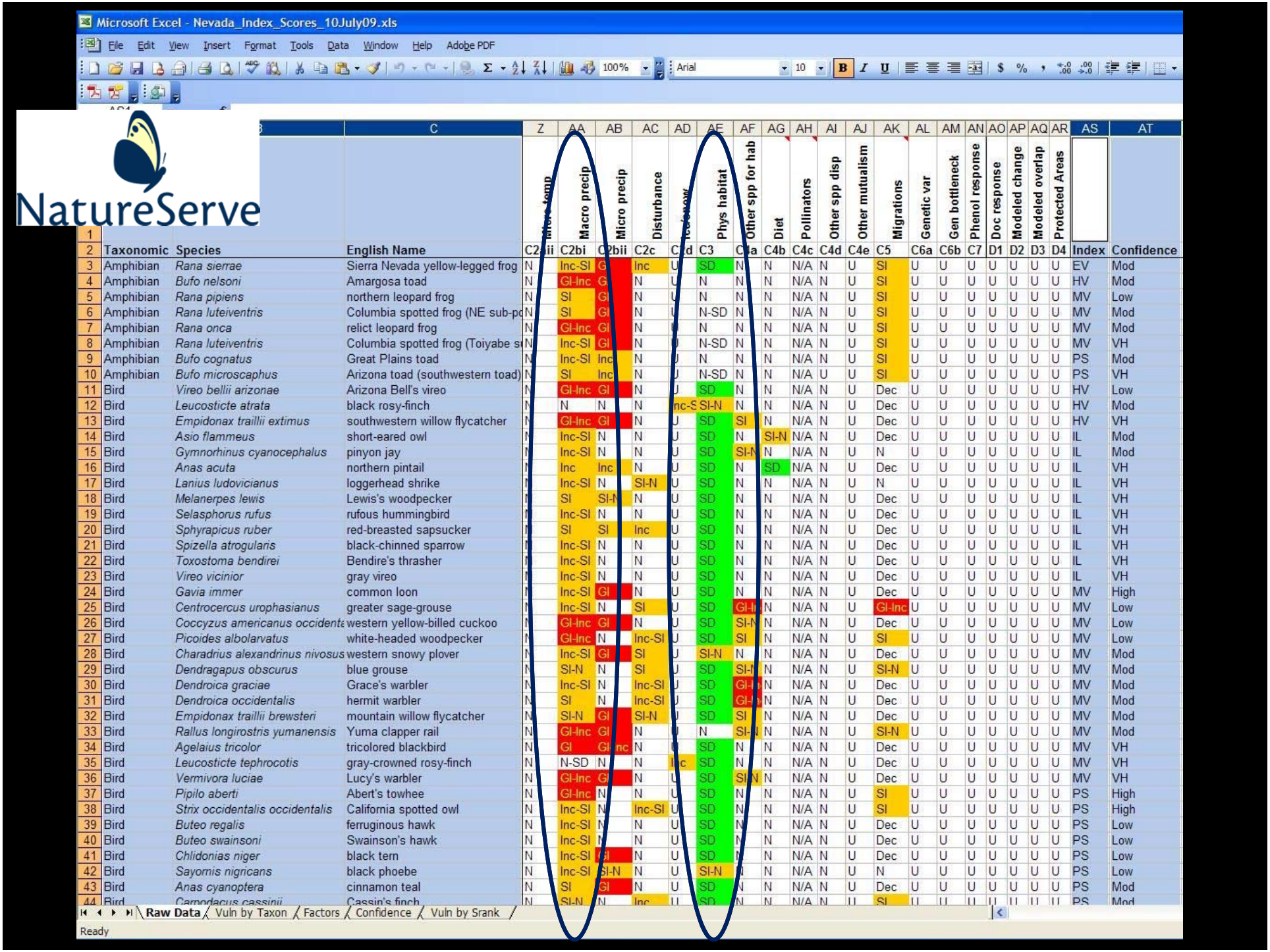
www.natureserve.org/climatechange

Terrestrial/aquatic, plants/animals

Excludes conservation status factors – use in conjunction with G/S-ranks

Exposure and sensitivity sections

Scale: state or large conservation area



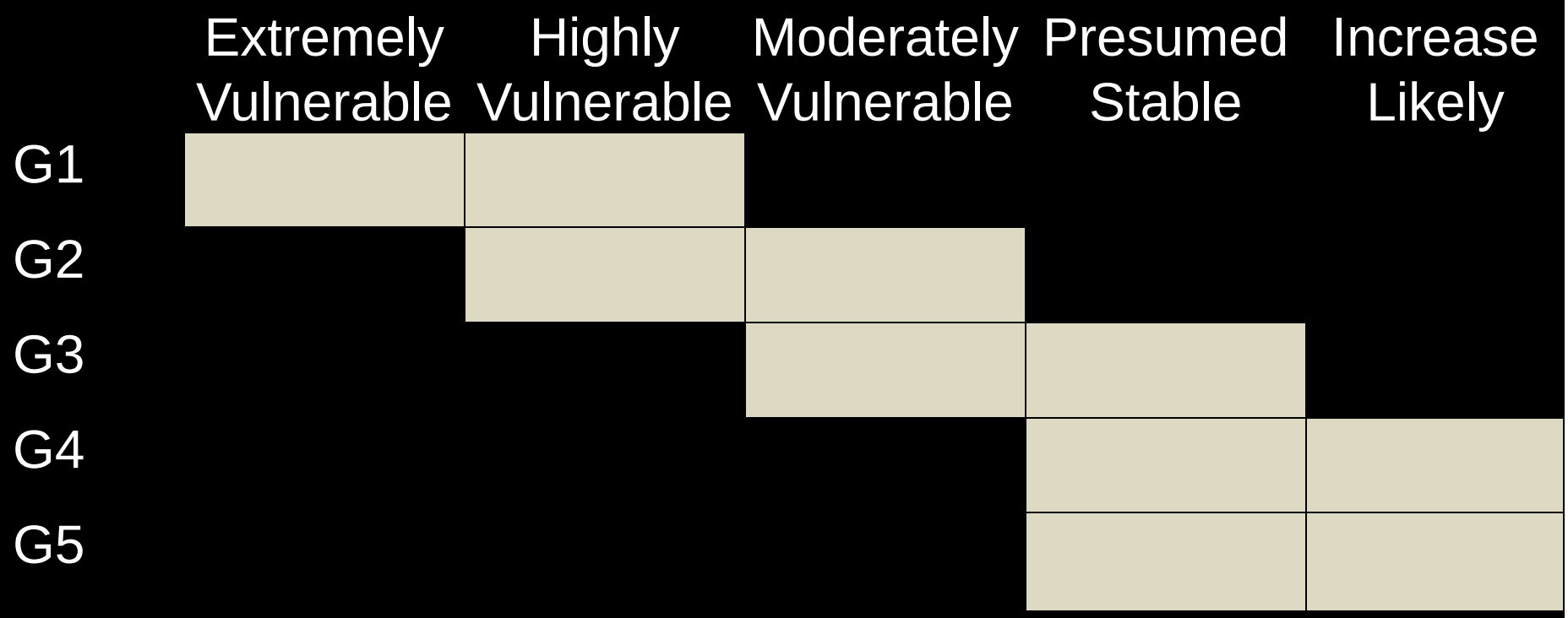
				Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT
1																								
2	Taxonomic	Species	English Name	C2aii	C2bi	C2bii	C2c	C2d	C3	C4a	C4b	C4c	C4d	C4e	C5	C6a	C6b	C7	D1	D2	D3	D4	Index	Confidence
3	Amphibian	*Rana sierrae*	Sierra Nevada yellow-legged frog	N	Inc-SI	GI	Inc	U	SD	N	N	N/A	N	U	SI	U	U	U	U	U	U	U	EV	Mod
4	Amphibian	*Bufo nelsoni*	Amargosa toad	N	GI-Inc	GI	N	U	N	N	N	N/A	N	U	SI	U	U	U	U	U	U	U	HV	Mod
5	Amphibian	*Rana pipiens*	northern leopard frog	N	SI	GI	N	U	N	N	N	N/A	N	U	SI	U	U	U	U	U	U	U	MV	Low
6	Amphibian	*Rana luteiventris*	Columbia spotted frog (NE sub-pc	N	SI	GI	N	U	N-SD	N	N	N/A	N	U	SI	U	U	U	U	U	U	U	MV	Mod
7	Amphibian	*Rana onca*	relict leopard frog	N	GI-Inc	GI	N	U	N	N	N	N/A	N	U	SI	U	U	U	U	U	U	U	MV	Mod
8	Amphibian	*Rana luteiventris*	Columbia spotted frog (Toiyabe s	N	Inc-SI	GI	N	U	N-SD	N	N	N/A	N	U	SI	U	U	U	U	U	U	U	MV	VH
9	Amphibian	*Bufo cognatus*	Great Plains toad	N	Inc-SI	Inc	N	U	N	N	N	N/A	N	U	SI	U	U	U	U	U	U	U	PS	Mod
10	Amphibian	*Bufo microscaphus*	Arizona toad (southwestern toad)	N	SI	Inc	N	U	N-SD	N	N	N/A	U	U	SI	U	U	U	U	U	U	U	PS	VH
11	Bird	*Vireo bellii arizonae*	Arizona Bell's vireo	N	GI-Inc	GI	N	U	SD	N	N	N/A	N	U	Dec	U	U	U	U	U	U	U	HV	Low
12	Bird	*Leucosticte atrata*	black rosy-finch	N	N	N	N	Inc-S	SI-N	N	N	N/A	N	U	Dec	U	U	U	U	U	U	U	HV	Mod
13	Bird	*Empidonax traillii extimus*	southwestern willow flycatcher	N	GI-Inc	GI	N	U	SD	SI	N	N/A	N	U	Dec	U	U	U	U	U	U	U	HV	VH
14	Bird	*Asio flammeus*	short-eared owl	N	Inc-SI	N	N	U	SD	N	SI-N	N/A	N	U	Dec	U	U	U	U	U	U	U	IL	Mod
15	Bird	*Gymnorhinus cyanocephalus*	pinyon jay	N	Inc-SI	N	N	U	SD	SI-N	N	N/A	N	U	N	U	U	U	U	U	U	U	IL	Mod
16	Bird	*Anas acuta*	northern pintail	N	Inc	Inc	N	U	SD	N	SD	N/A	N	U	Dec	U	U	U	U	U	U	U	IL	VH
17	Bird	*Lanius ludovicianus*	loggerhead shrike	N	Inc-SI	N	SI-N	U	SD	N	N	N/A	N	U	N	U	U	U	U	U	U	U	IL	VH
18	Bird	*Melanerpes lewis*	Lewis's woodpecker	N	SI	SI-N	N	U	SD	N	N	N/A	N	U	Dec	U	U	U	U	U	U	U	IL	VH
19	Bird	*Selasphorus rufus*	rufous hummingbird	N	Inc-SI	N	N	U	SD	N	N	N/A	N	U	Dec	U	U	U	U	U	U	U	IL	VH
20	Bird	*Sphyrapicus ruber*	red-breasted sapsucker	N	SI	SI	Inc	U	SD	N	N	N/A	N	U	Dec	U	U	U	U	U	U	U	IL	VH
21	Bird	*Spizella atrogularis*	black-chinned sparrow	N	Inc-SI	N	N	U	SD	N	N	N/A	N	U	Dec	U	U	U	U	U	U	U	IL	VH
22	Bird	*Toxostoma bendirei*	Bendire's thrasher	N	Inc-SI	N	N	U	SD	N	N	N/A	N	U	Dec	U	U	U	U	U	U	U	IL	VH
23	Bird	*Vireo vicinior*	gray vireo	N	Inc-SI	N	N	U	SD	N	N	N/A	N	U	Dec	U	U	U	U	U	U	U	IL	VH
24	Bird	*Gavia immer*	common loon	N	Inc-SI	GI	N	U	SD	N	N	N/A	N	U	Dec	U	U	U	U	U	U	U	MV	High
25	Bird	*Centrocercus urophasianus*	greater sage-grouse	N	Inc-SI	N	SI	U	SD	GI-I	N	N/A	N	U	GI-Inc	U	U	U	U	U	U	U	MV	Low
26	Bird	*Coccyzus americanus occidenta*	western yellow-billed cuckoo	N	GI-Inc	GI	N	U	SD	SI-N	N	N/A	N	U	Dec	U	U	U	U	U	U	U	MV	Low
27	Bird	*Picoides albolarvatus*	white-headed woodpecker	N	GI-Inc	N	Inc-SI	U	SD	SI	N	N/A	N	U	SI	U	U	U	U	U	U	U	MV	Low
28	Bird	*Charadrius alexandrinus nivosus*	western snowy plover	N	Inc-SI	GI	SI	U	SI-N	N	N	N/A	N	U	Dec	U	U	U	U	U	U	U	MV	Mod
29	Bird	*Dendragapus obscurus*	blue grouse	N	SI-N	N	SI	U	SD	SI-N	N	N/A	N	U	SI-N	U	U	U	U	U	U	U	MV	Mod
30	Bird	*Dendroica graciae*	Grace's warbler	N	Inc-SI	N	Inc-SI	U	SD	GI-I	N	N/A	N	U	Dec	U	U	U	U	U	U	U	MV	Mod
31	Bird	*Dendroica occidentalis*	hermit warbler	N	SI	N	Inc-SI	U	SD	GI-I	N	N/A	N	U	Dec	U	U	U	U	U	U	U	MV	Mod
32	Bird	*Empidonax traillii brewsteri*	mountain willow flycatcher	N	SI-N	GI	SI-N	U	SD	SI	N	N/A	N	U	Dec	U	U	U	U	U	U	U	MV	Mod
33	Bird	*Rallus longirostris yumanensis*	Yuma clapper rail	N	GI-Inc	GI	N	U	N	SI-I	N	N/A	N	U	SI-N	U	U	U	U	U	U	U	MV	Mod
34	Bird	*Agelaius tricolor*	tricolored blackbird	N	GI	GI-Inc	N	U	SD	N	N	N/A	N	U	Dec	U	U	U	U	U	U	U	MV	VH
35	Bird	*Leucosticte tephrocotis*	gray-crowned rosy-finch	N	N-SD	N	N	Inc	SD	N	N	N/A	N	U	Dec	U	U	U	U	U	U	U	MV	VH
36	Bird	*Vermivora luciae*	Lucy's warbler	N	GI-Inc	GI	N	U	SD	SI-N	N	N/A	N	U	Dec	U	U	U	U	U	U	U	MV	VH
37	Bird	*Pipilo aberti*	Abert's towhee	N	GI-Inc	N	N	U	SD	N	N	N/A	N	U	SI	U	U	U	U	U	U	U	PS	High
38	Bird	*Strix occidentalis occidentalis*	California spotted owl	N	Inc-SI	N	Inc-SI	U	SD	N	N	N/A	N	U	SI	U	U	U	U	U	U	U	PS	High
39	Bird	*Buteo regalis*	ferruginous hawk	N	Inc-SI	N	N	U	SD	N	N	N/A	N	U	Dec	U	U	U	U	U	U	U	PS	Low
40	Bird	*Buteo swainsoni*	Swainson's hawk	N	Inc-SI	N	N	U	SD	N	N	N/A	N	U	Dec	U	U	U	U	U	U	U	PS	Low
41	Bird	*Chlidonias niger*	black tern	N	Inc-SI	GI	N	U	SD	N	N	N/A	N	U	Dec	U	U	U	U	U	U	U	PS	Low
42	Bird	*Sayornis nigricans*	black phoebe	N	Inc-SI	SI-N	N	U	SI-N	N	N	N/A	N	U	N	U	U	U	U	U	U	U	PS	Low
43	Bird	*Anas cyanoptera*	cinnamon teal	N	SI	GI	N	U	SD	N	N	N/A	N	U	Dec	U	U	U	U	U	U	U	PS	Mod
44	Bird	*Carpodacus cassinii*	Cassin's finch	N	SI-N	N	Inc	U	SD	N	N	N/A	N	U	SI	U	U	U	U	U	U	U	PS	Mod

Duplicate Conservation Status Assessments?

	Extremely Vulnerable	Highly Vulnerable	Moderately Vulnerable	Presumed Stable	Increase Likely
G1					
G2					
G3					
G4					
G5					

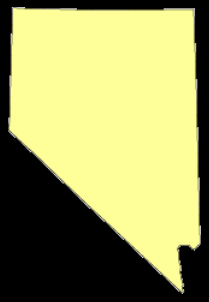
NatureServe

Duplicate Conservation Status Assessments?



NatureServe

209 spp



	Extremely Vulnerable	Highly Vulnerable	Moderately Vulnerable	Presumed Stable	Increase Likely
G1	10	11	25	9	0
G2	2	4	5	3	1
G3	0	4	3	11	1
G4	1	1	6	24	3
G5	0	2	7	61	15

$p<0.001$

NatureServe

Climate Change Sensitivity Index (University of Washington and TNC)

Aegolius funereus

View | Edit | Revisions | Track | Dev load | Dev render

Title: *

Aegolius funereus

Common Name:

Boreal Owl

Enter known common names, one name per line.

This Species is Completed

- Taxonomy
- Dispersal Ability
- Disturbance Regimes
- Generalist/Specialist
- Physiology
- Life History Information
- Habitat
- Ecological Climate Effects
- Subjective ranking
- Menu settings
  Not in menu
- Revision information
  New revision
- Comment settings
  Read/Write
- URL path settings
  Alias: species/aegolius-funereus
- XML sitemap
  Inclusion: Default (included)
  Priority: Default (0.5)

Average annual dispersal distance:

- N/A
- >100 km
- 75-100 km
- 50-75 km
- 25-50km
- 5-25km
- 1-5km
- <1km

Confidence in average annual dispersal distance:

2 Medium-Low

Do barriers to dispersal exist?:

2

Are there landscape elements that would prevent this species from moving in response to climate change? Some examples of such barriers are given in the checklist below.

Confidence in barriers to dispersal exists:

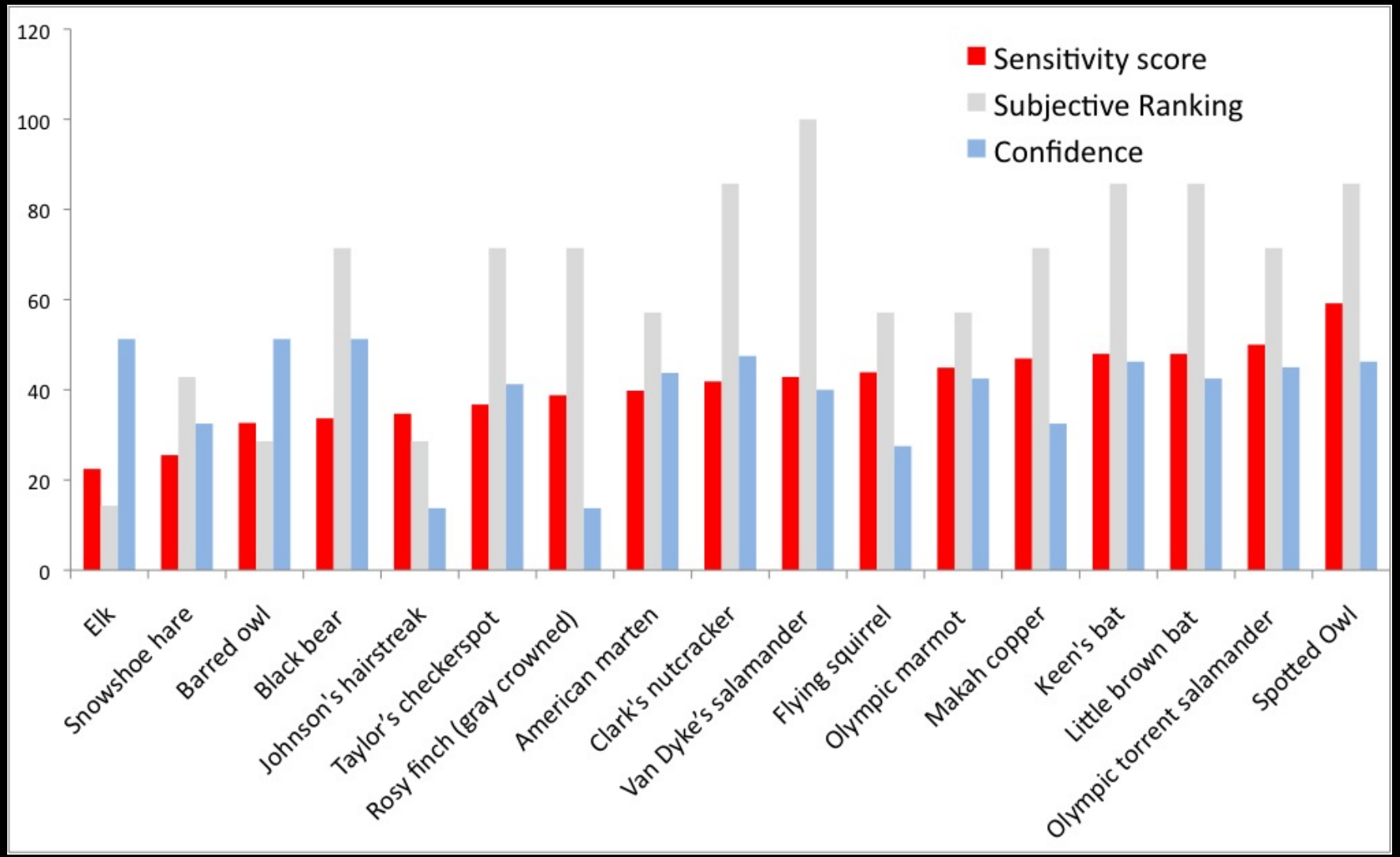
4 Medium-High

Specific dispersal distance, (if known) and dispersal type (juvenile, adult, etc.):

Please select all general types of barriers to dispersal that apply:

http://courses.washington.edu/ccdb/drupal

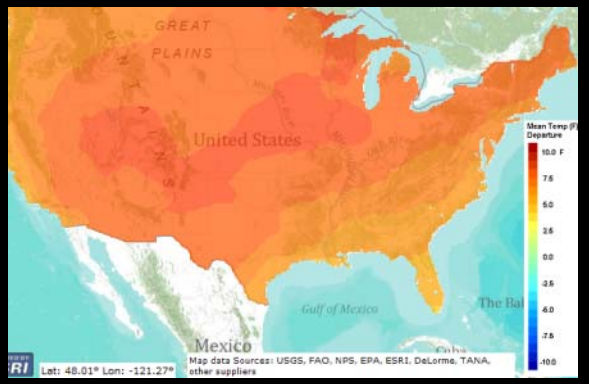
Climate Change Sensitivity Index (University of Washington and TNC)

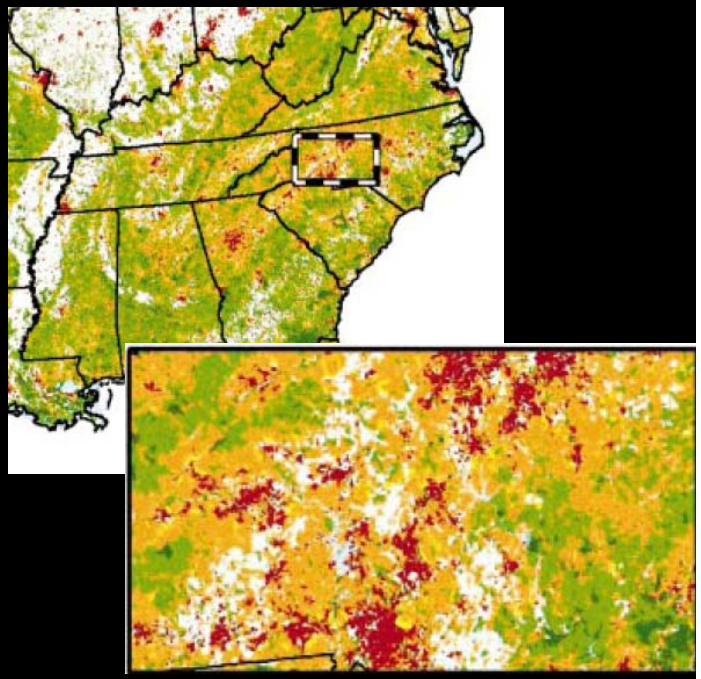


Finding data for the index

- **Exposure:** Climate Wizard; WorldClim
- **Sensitivity/adaptive capacity:** literature reviews and expert elicitation, existing web-based tools (ex: GAP, WUI)

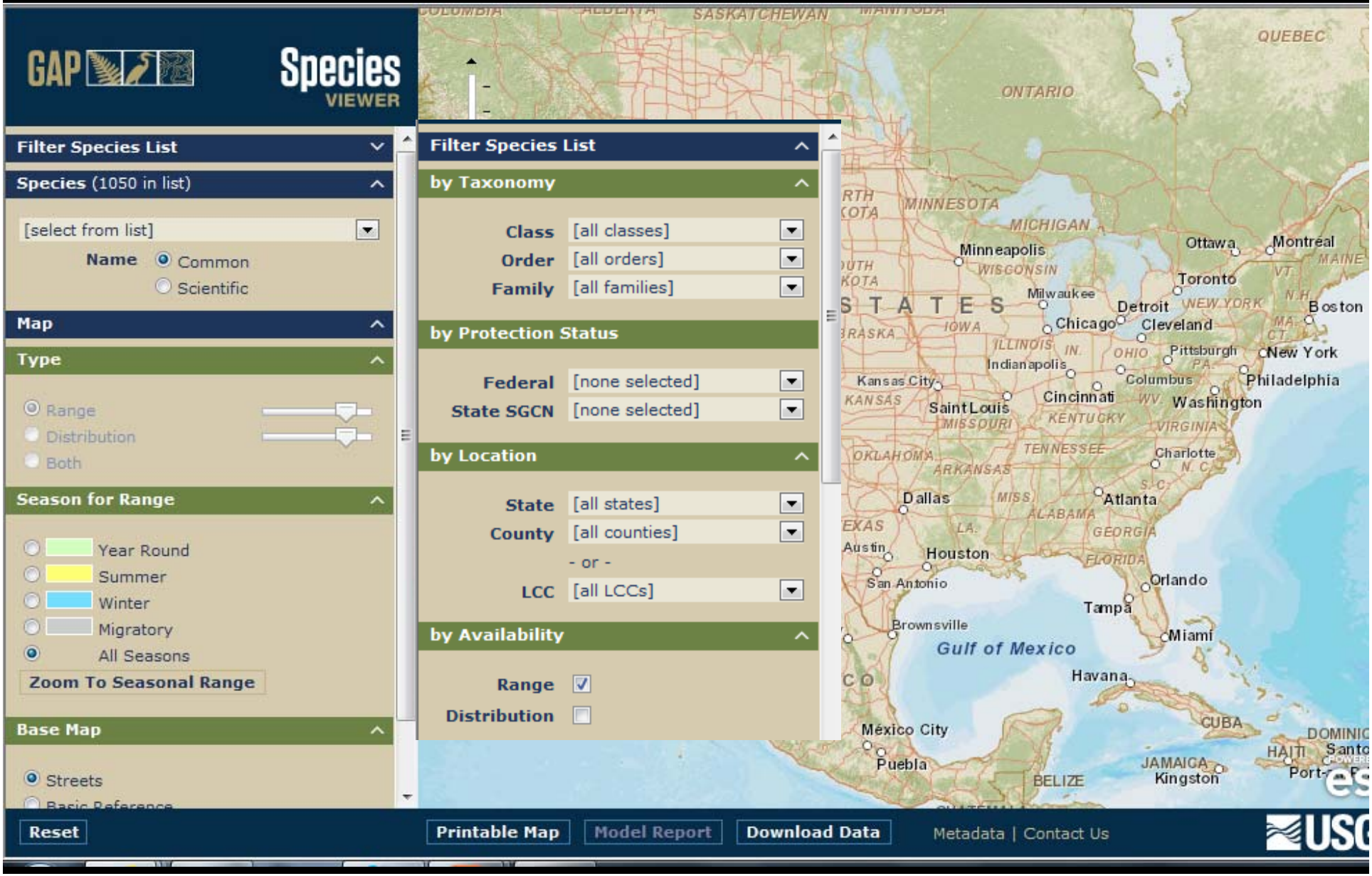
- Uncertainty
  - Explore various climate models
  - Can explicitly address during input by omitting responses or providing multiple responses



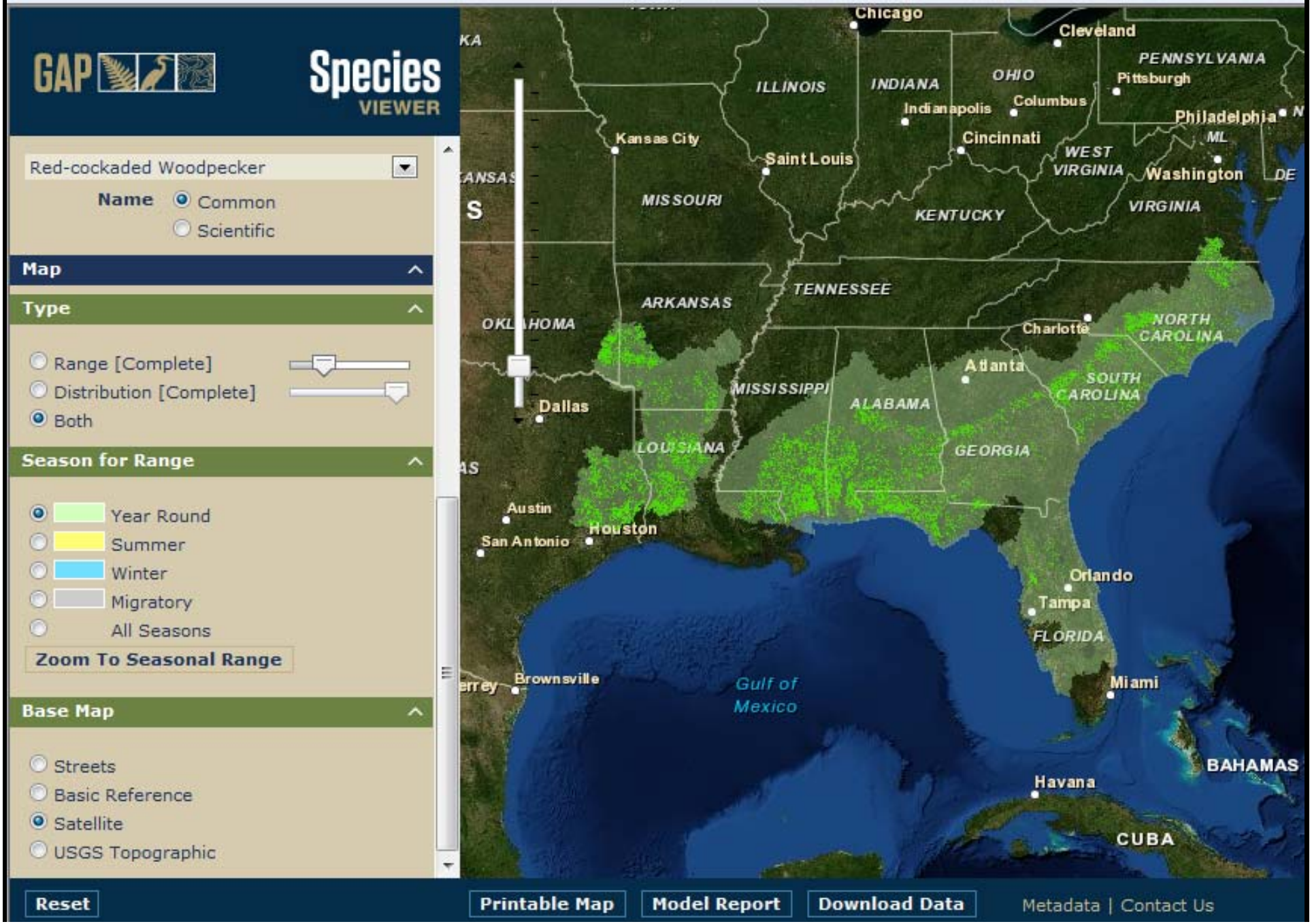


Wildland-Urban Interface
Silvus Lab, U of WI

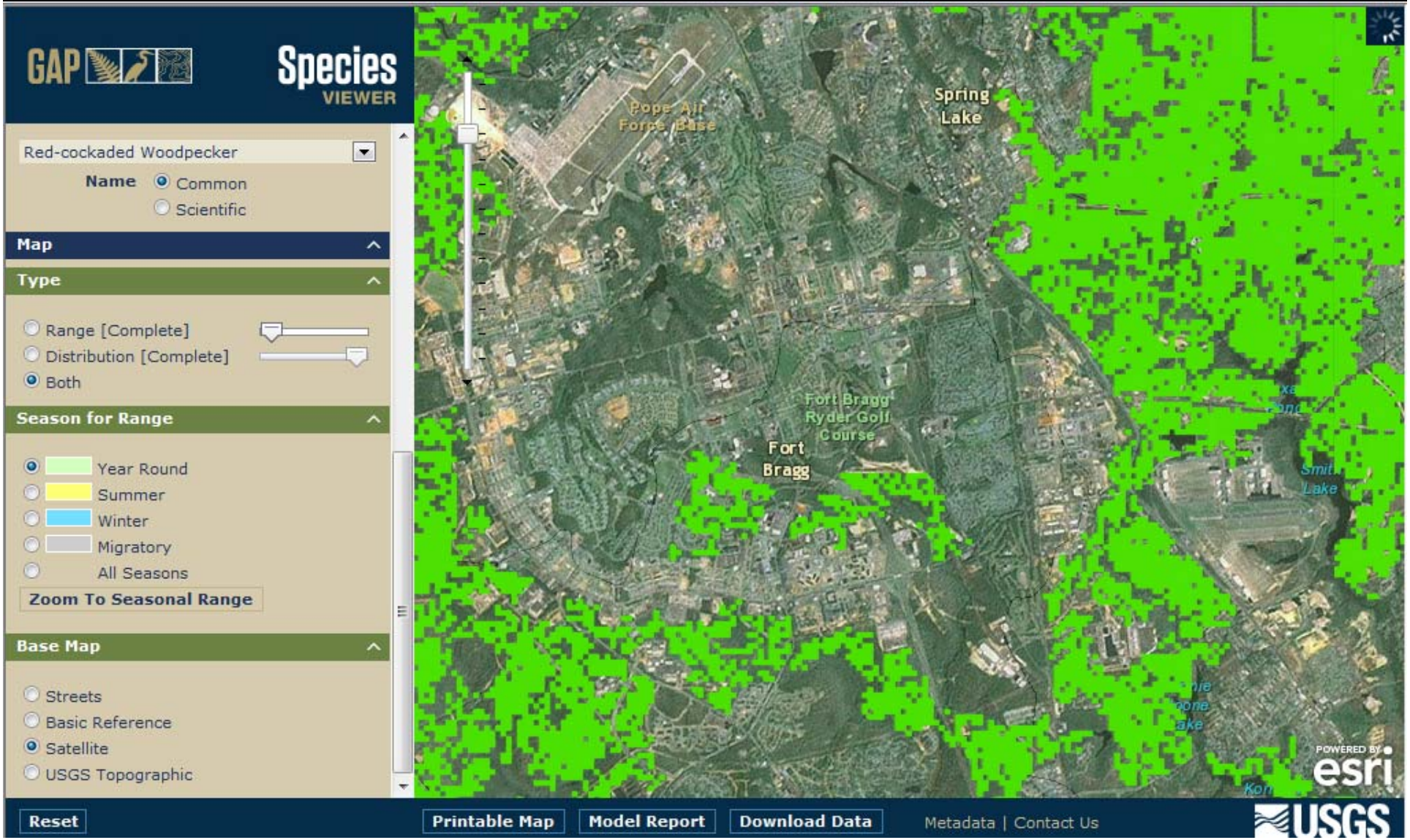
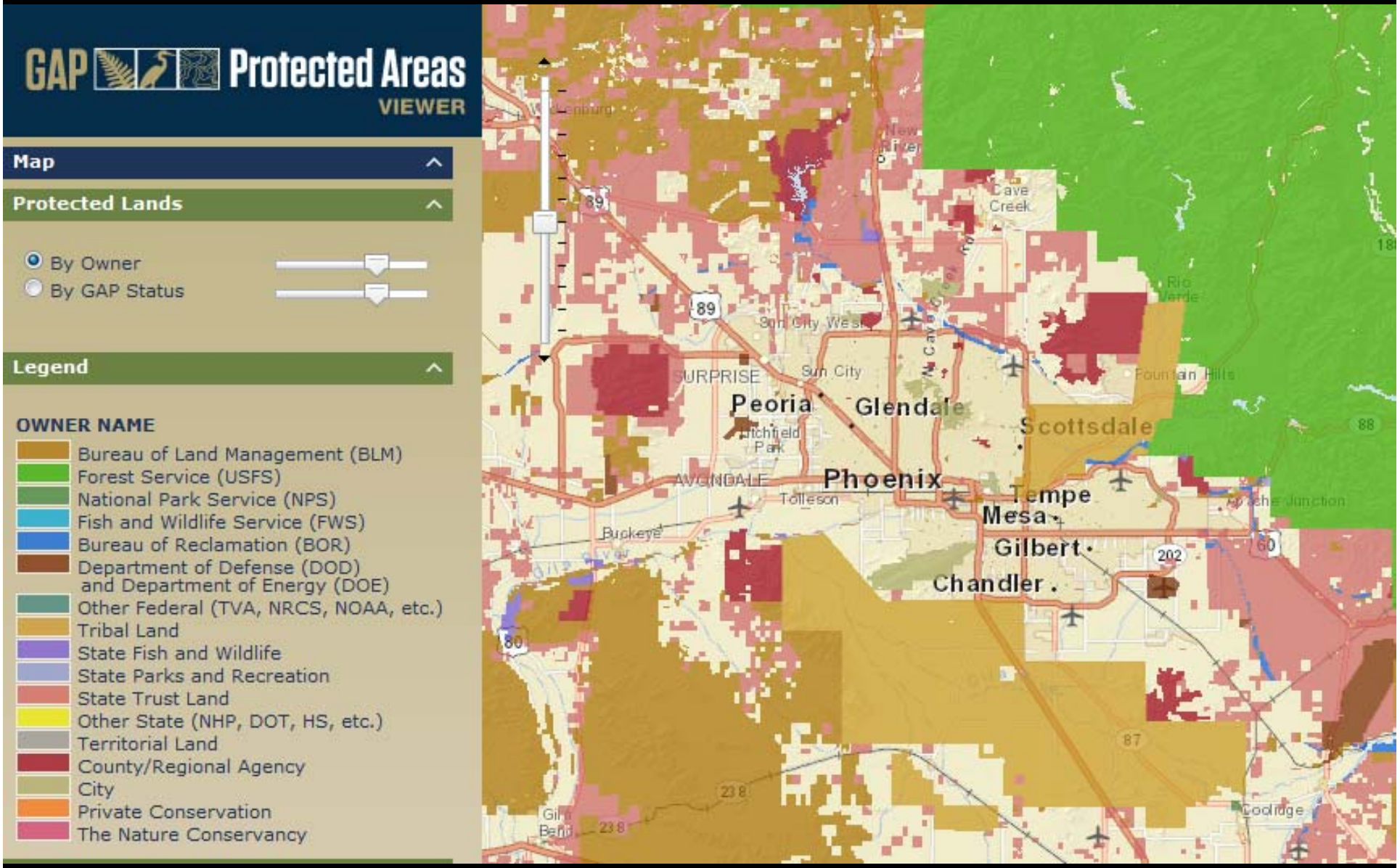
Sources of Species Distribution Data … GAP Species Viewer (http://www.gap.uidaho.edu/species_viewer.html)



Red-cockaded Woodpecker example (range and distribution



Fort Bragg, NC … Red-cockaded Woodpecker Modeled Distribution



Sources of Senstivity/Adaptive Capacity data
GAP PAD Viewer (http://www.gap.uidaho.edu/padusmap.html)