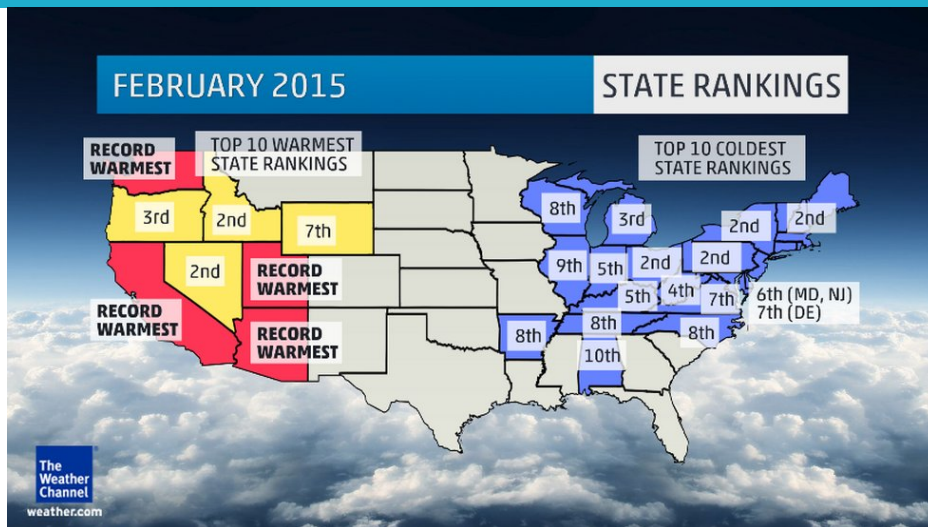


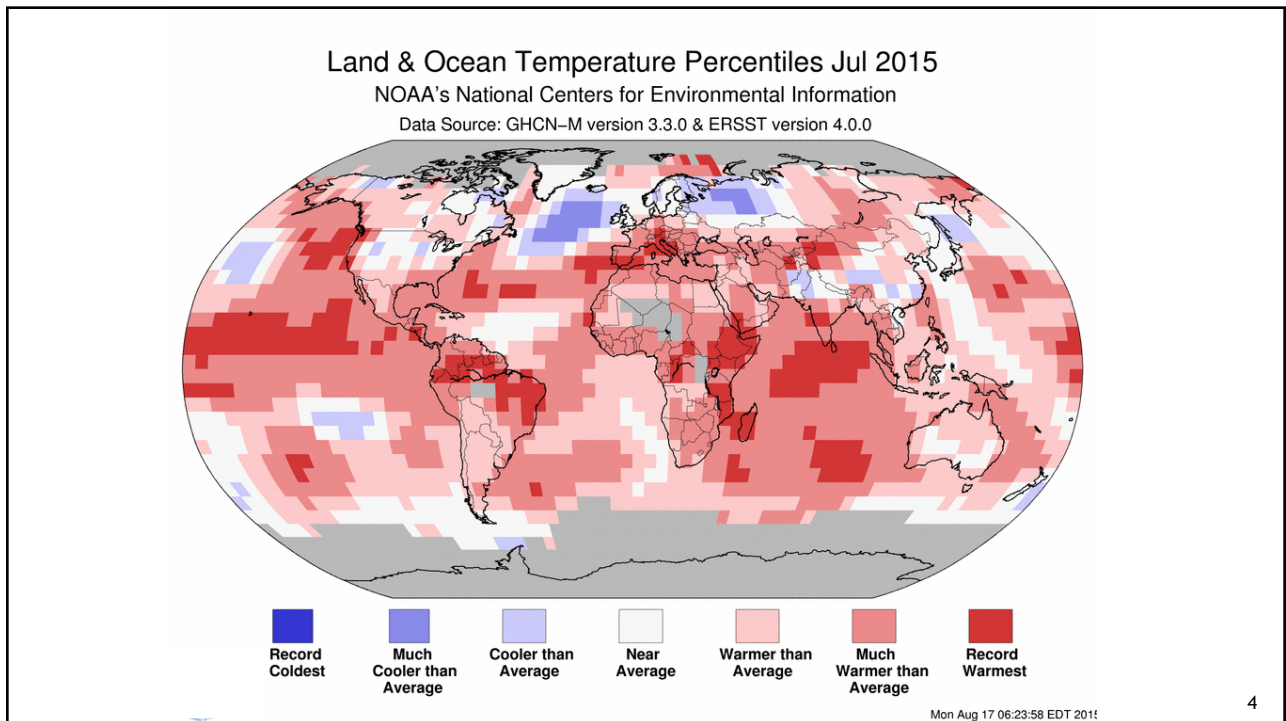
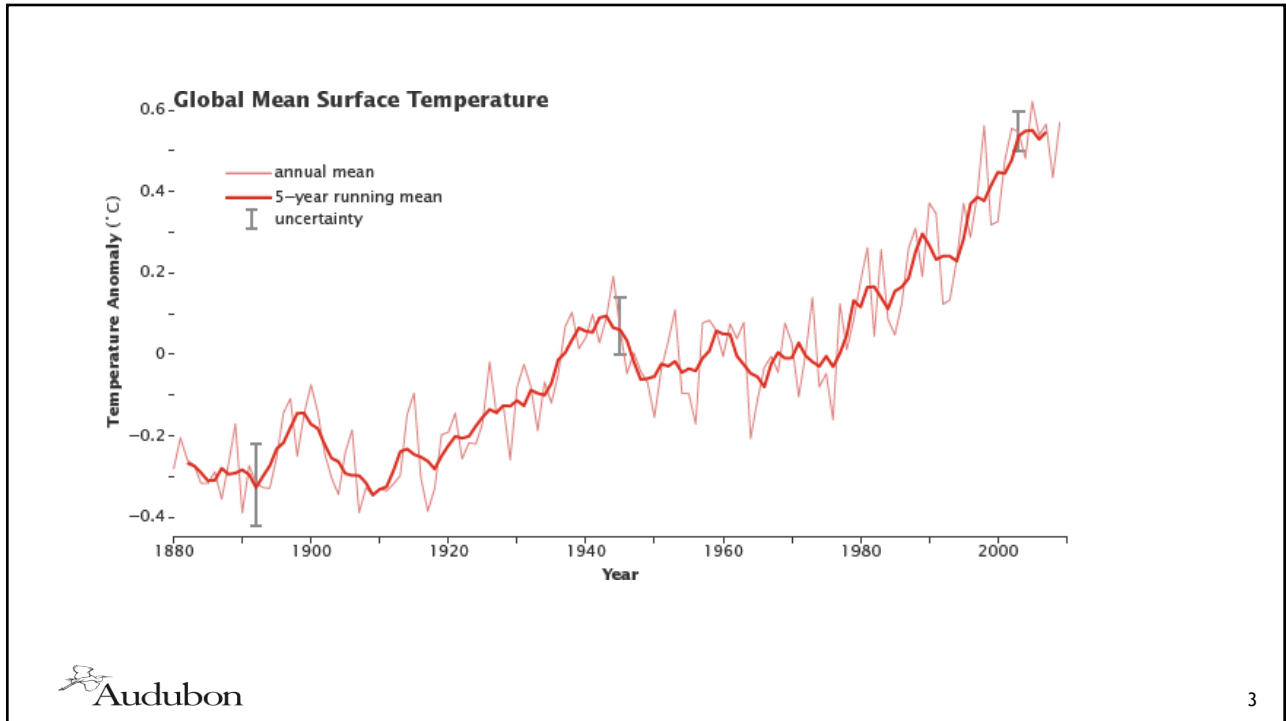


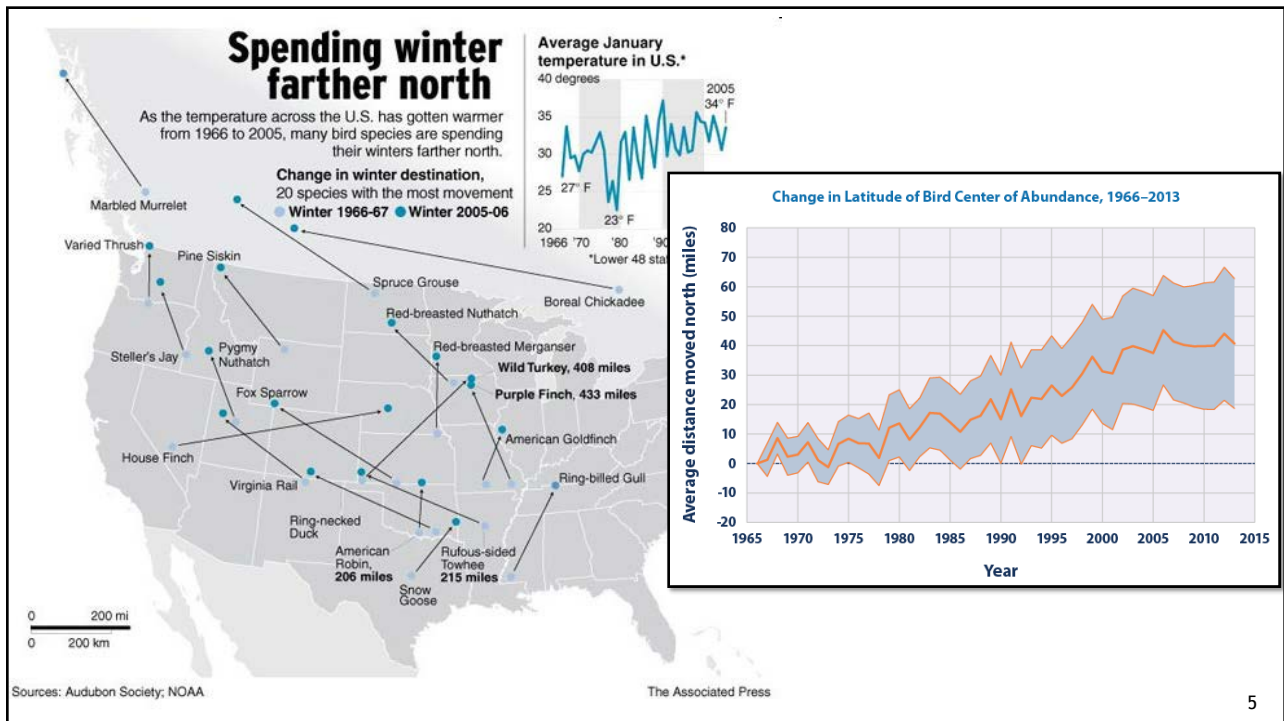
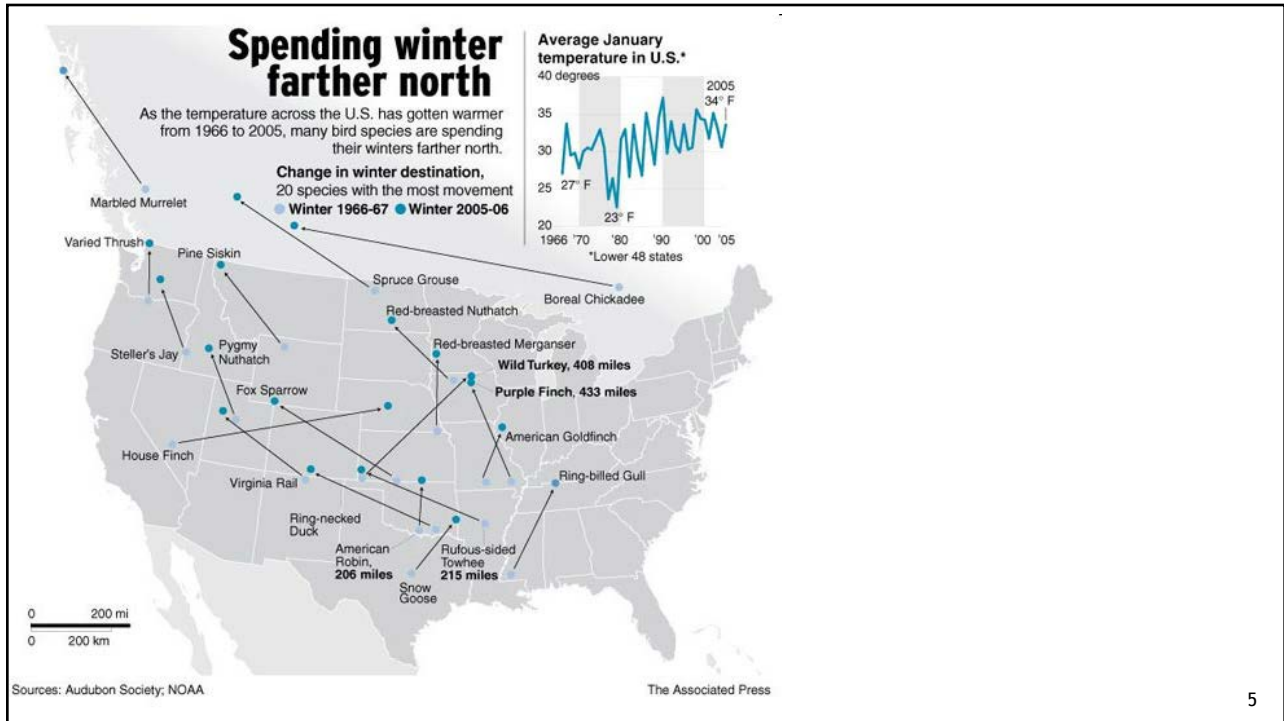
# Birds and Climate Change

Conservation Science  
National Audubon Society

## Climate change isn't always warming



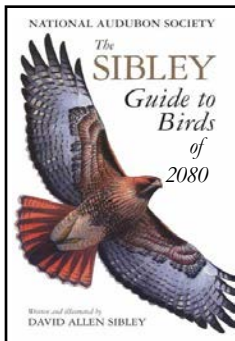




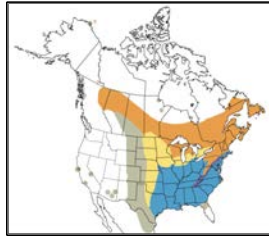
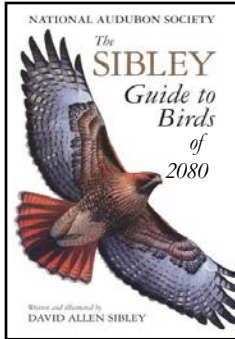
# Conservation for the future



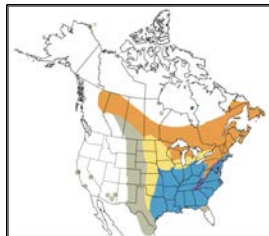
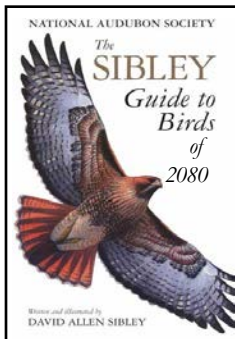
# Conservation for the future



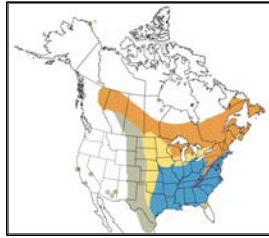
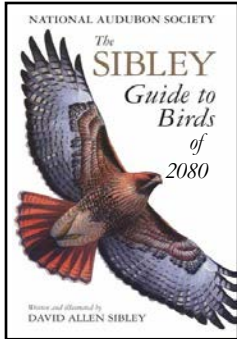
# Conservation for the future



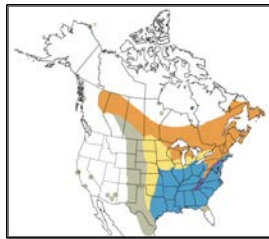
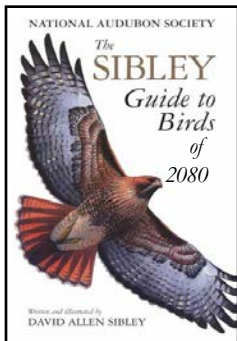
# Conservation for the future



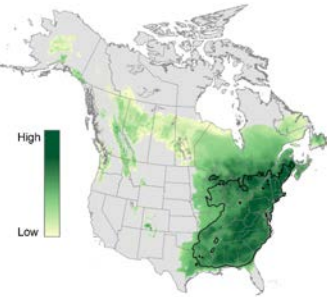
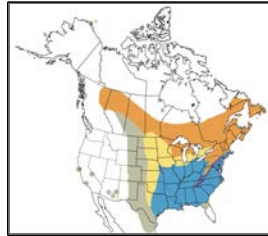
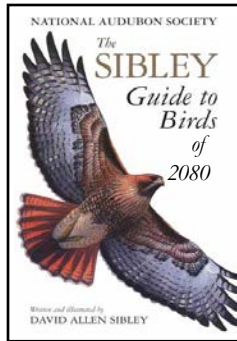
# Conservation for the future



# Conservation for the future



# Conservation for the future



# Tools for conservation

## Tools for conservation

Modeled Future  
Climatic  
Suitability  
Maps

## Tools for conservation

Modeled Future  
Climatic  
Suitability  
Maps

Climate  
Sensitivity Lists

## Tools for conservation

Modeled Future  
Climatic  
Suitability  
Maps

Climate  
Sensitivity Lists

Climate  
Prioritizations

Reality



## Abstraction



 Audubon

## Mathematical Abstraction

$$\log(\lambda_{i,j,t}) = S_i + \omega_j + \gamma_{i,t} + \beta_i(t - t^*) + \frac{B_i(\xi_{i,j,t}^{p_i} - 1)}{p_i} + \varepsilon_{i,j,t}$$

 Audubon

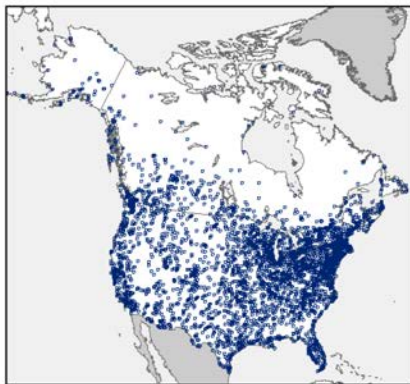


Citizen science

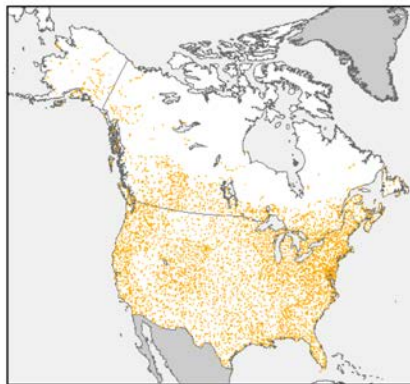


## Winter and summer observations

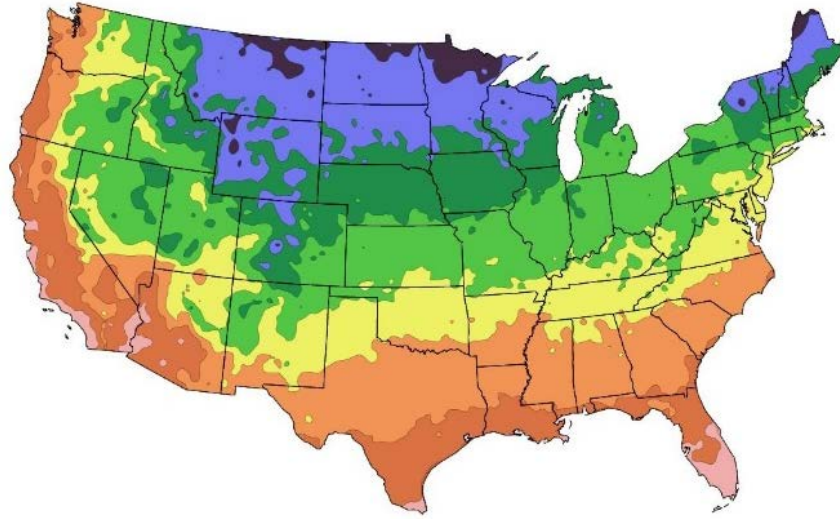
**WINTER**  
Audubon Christmas Bird Count



**SUMMER**  
North American Breeding Bird Survey



# Climate



Audubon

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# Bioclimatic Variables



# Bioclimatic Variables



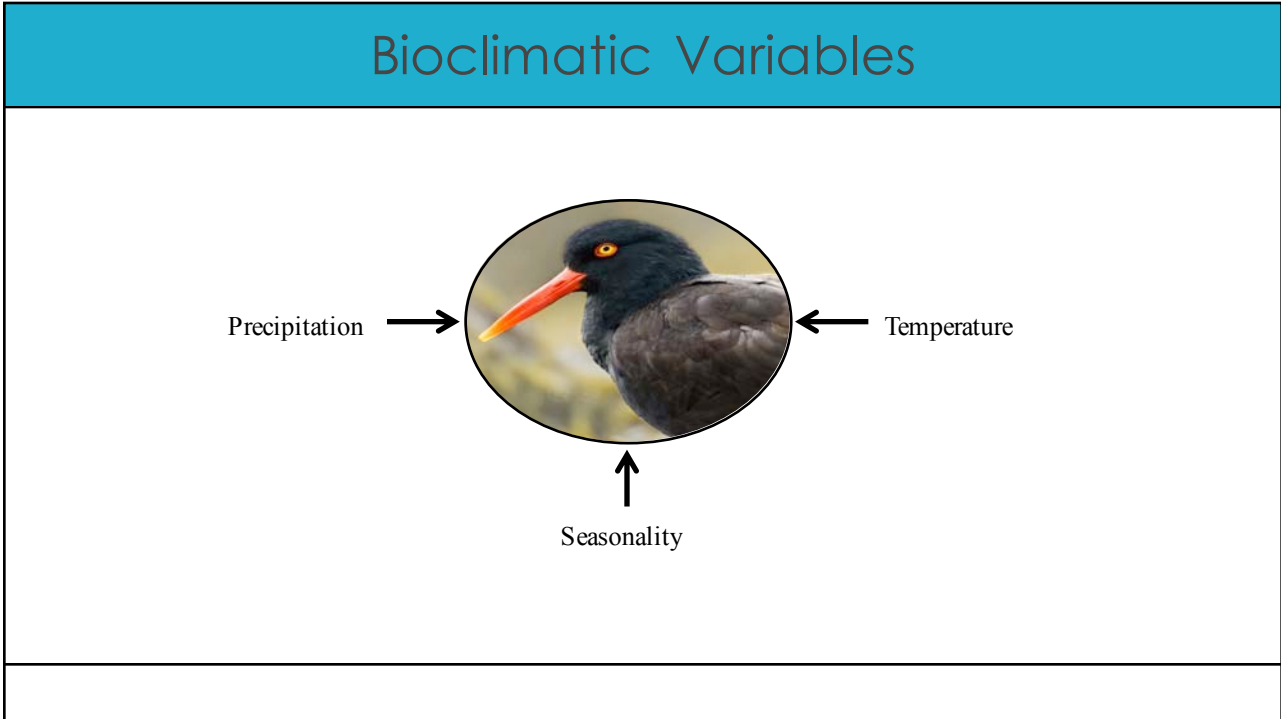
← Temperature

# Bioclimatic Variables




Precipitation →

← Temperature



## Bioclimatic variables

<b>Precipitation (mm)</b>	<b>Temperature (°C)</b>
Annual Total	Annual Mean
Wettest Month	Annual Range
Driest Month	Mean Diurnal Range
Wettest Quarter	Isothermality
Driest Quarter	Mean of Wettest Quarter
Warmest Quarter	Mean of Driest Quarter
Coldest Quarter	Mean of Warmest Quarter
	Mean of Coldest Quarter
	Maximum of Warmest Month
	Minimum of Coldest Month



# Methods

Bird Observations + Historical climate

A diagram illustrating the combination of two data sources. It features a teal header with the word "Methods". Below it, two light blue ovals are connected by a plus sign. The left oval contains the text "Bird Observations" and the right oval contains "Historical climate".

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# Methods

Bird Observations + Historical climate = Bioclimatic Models

A diagram illustrating the combination of two data sources to create a model. It features a teal header with the word "Methods". Below it, three light blue ovals are arranged in a sequence: "Bird Observations", a plus sign, "Historical climate", an equals sign, and "Bioclimatic Models".

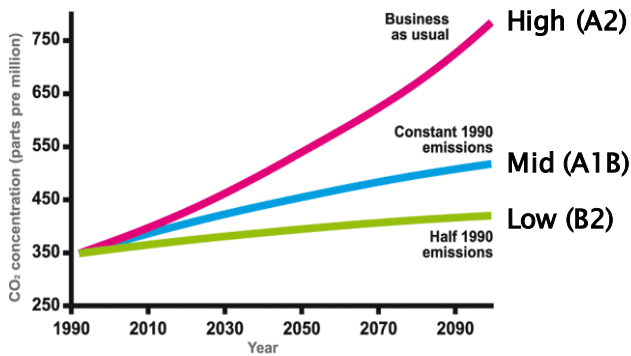
Audubon

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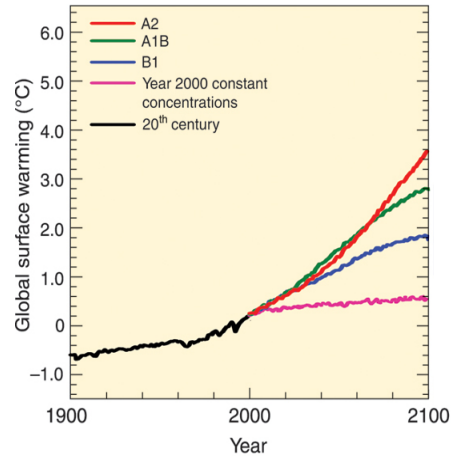
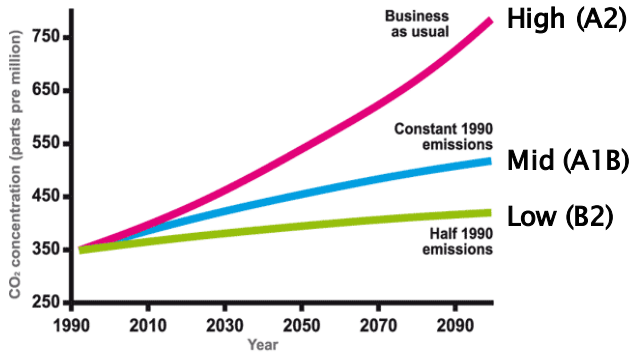
# Methods



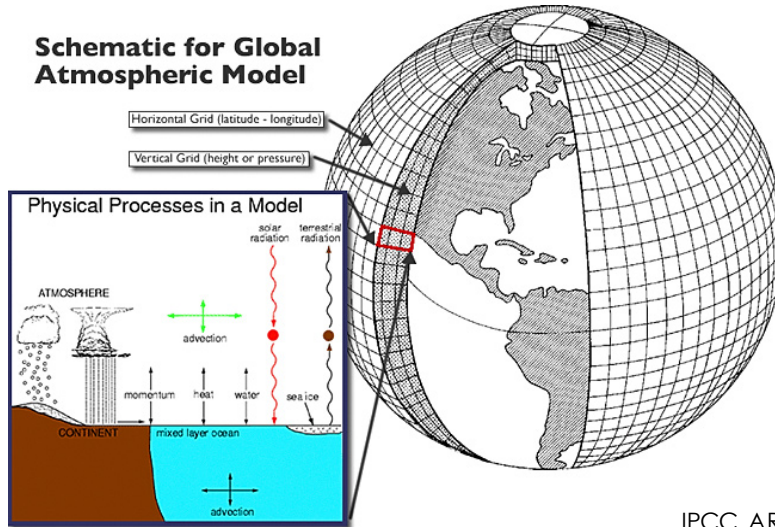
# The future is uncertain



# The future is uncertain

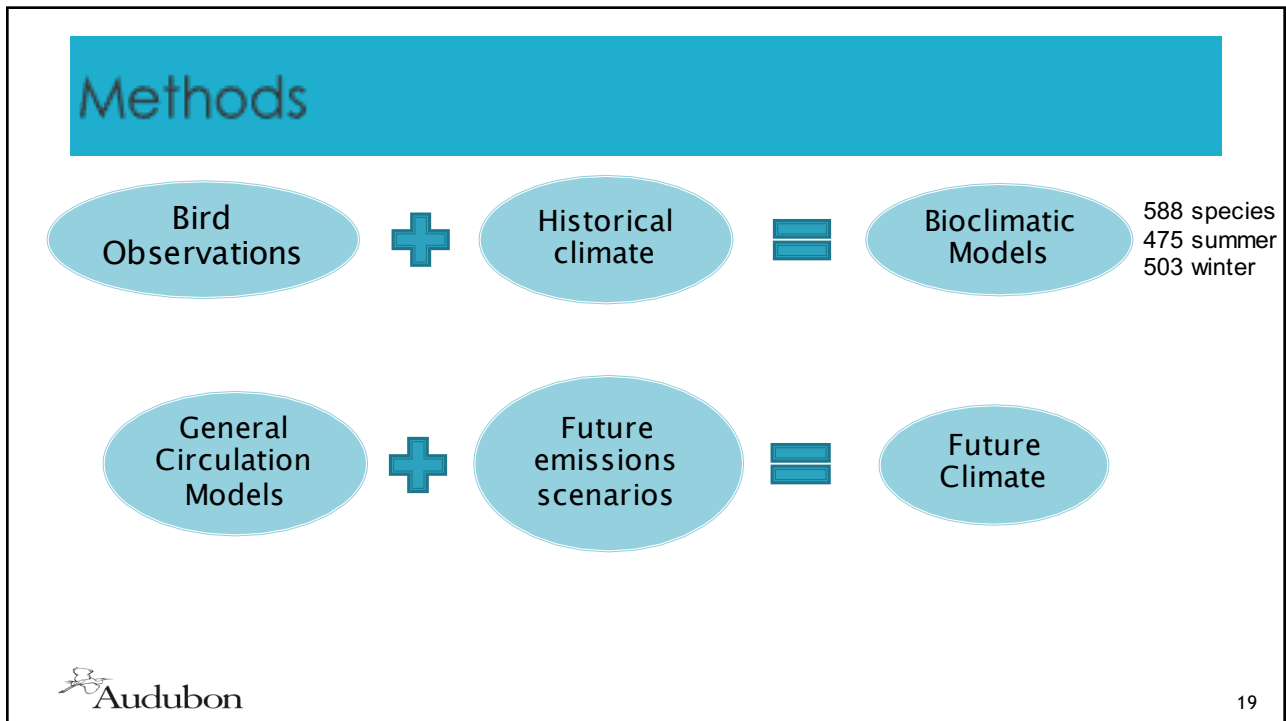
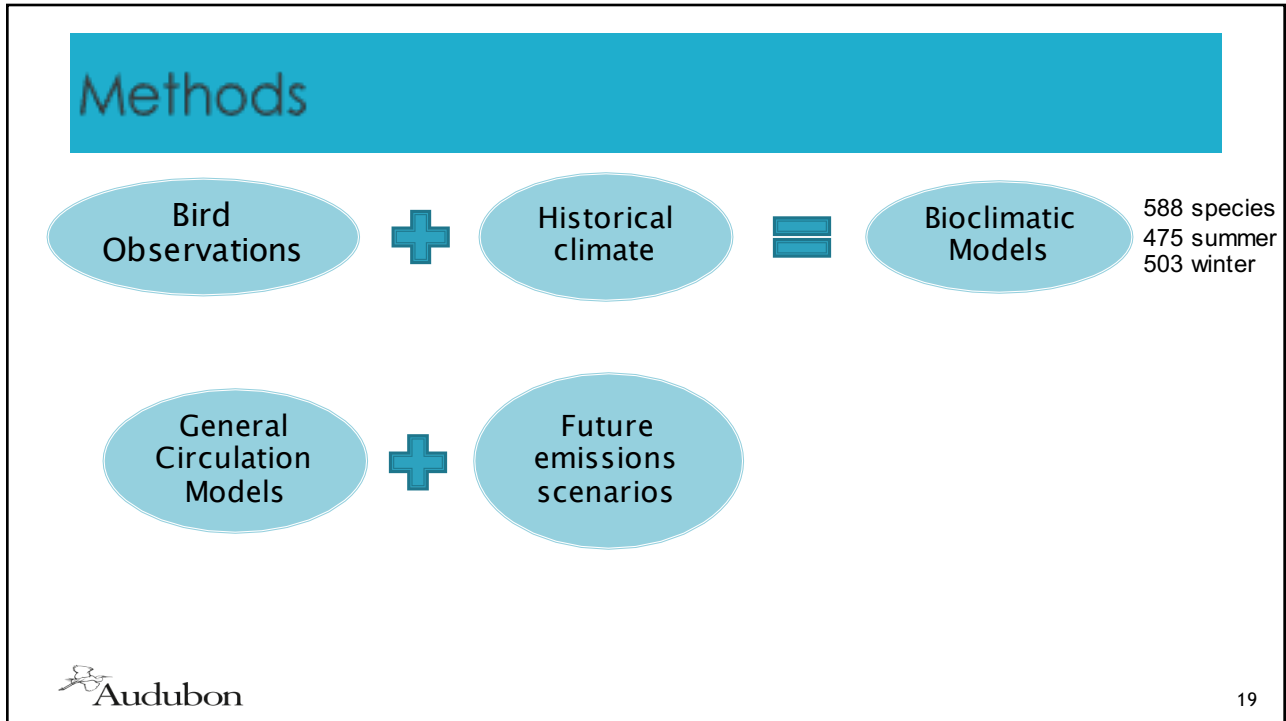


## Schematic for Global Atmospheric Model

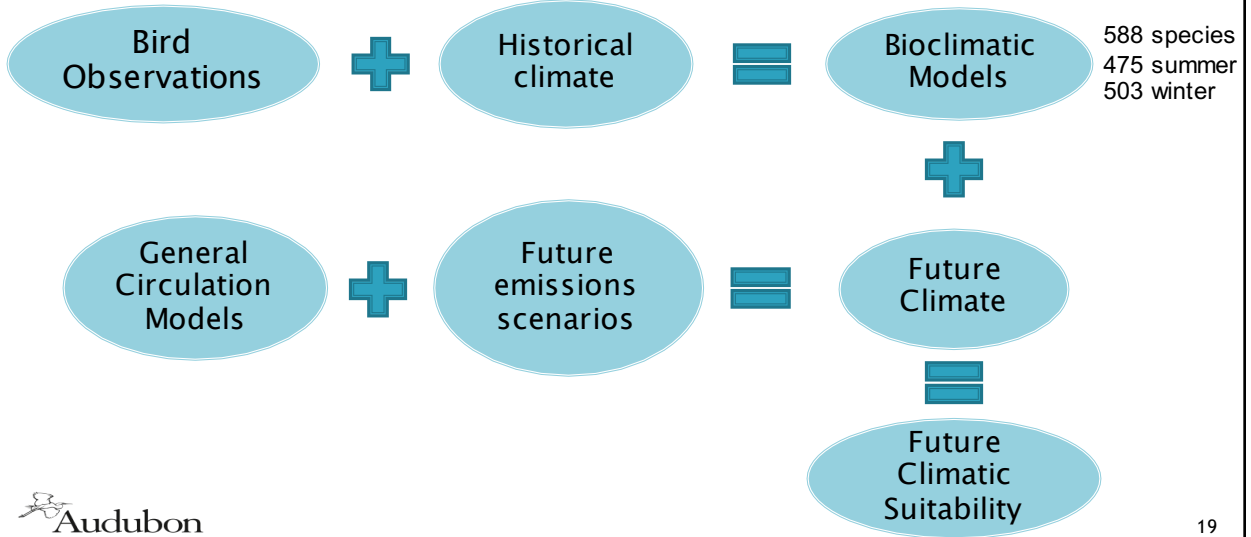


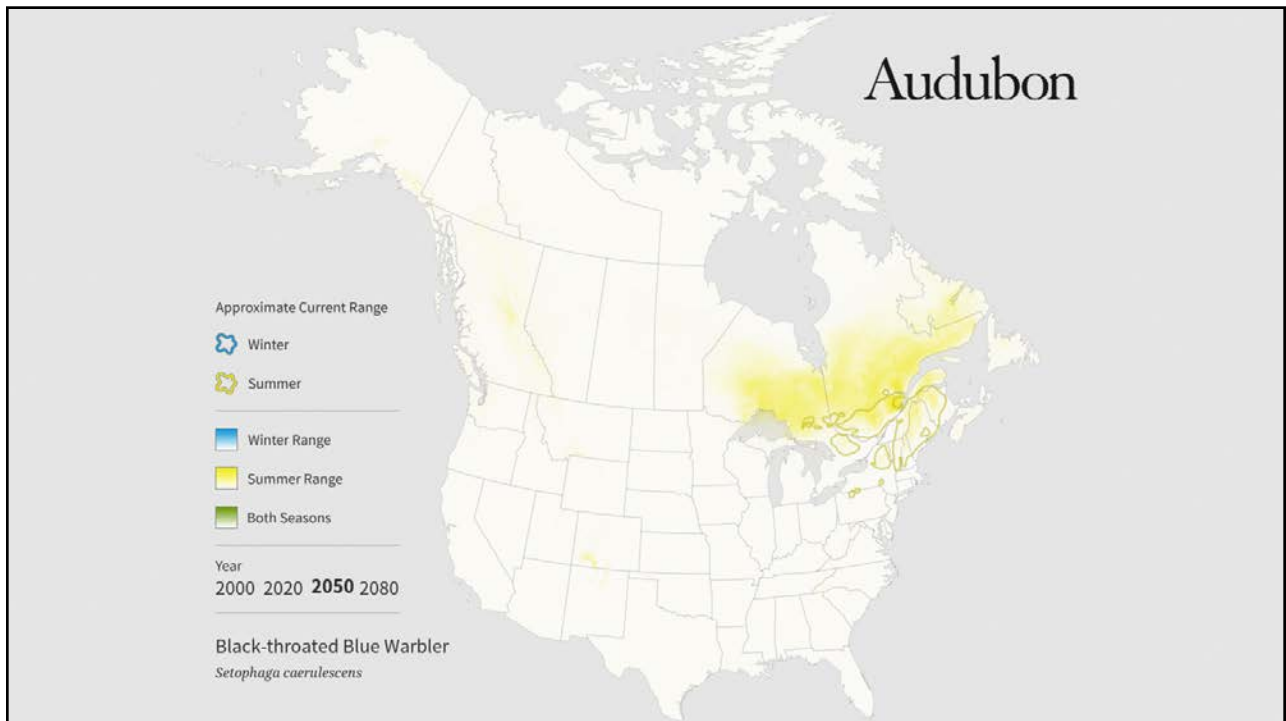
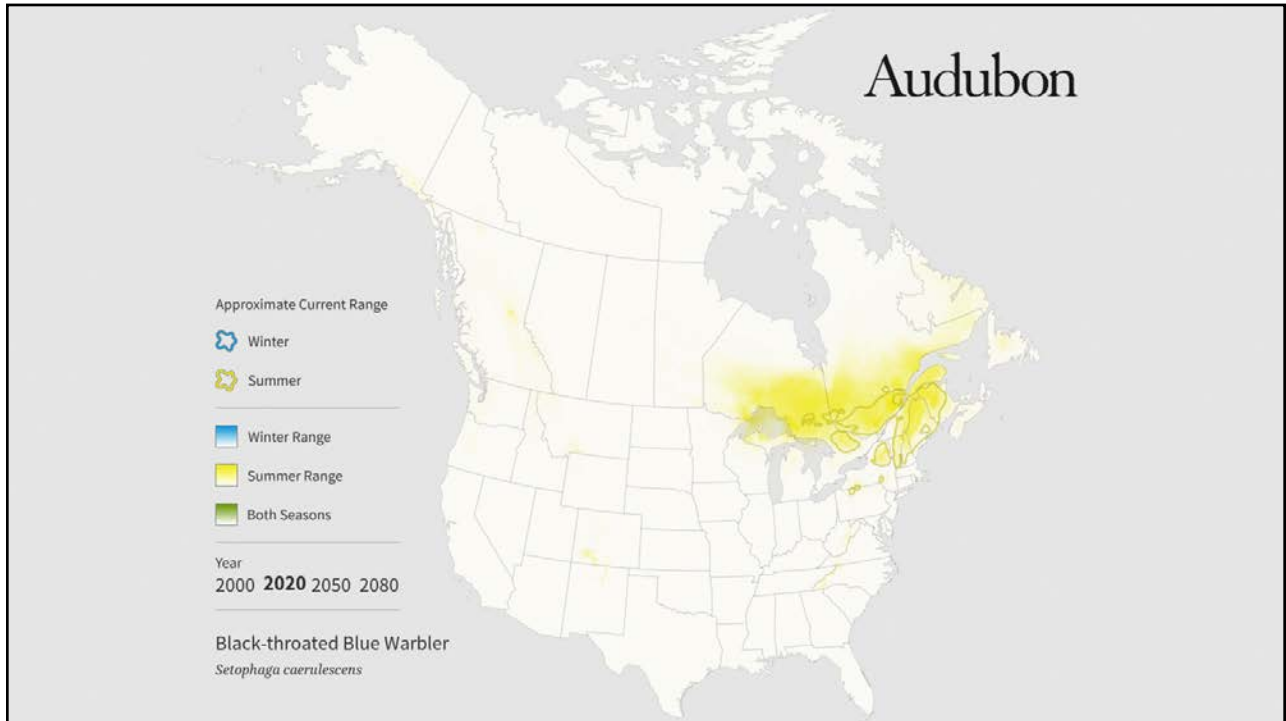
IPCC AR4 WGI

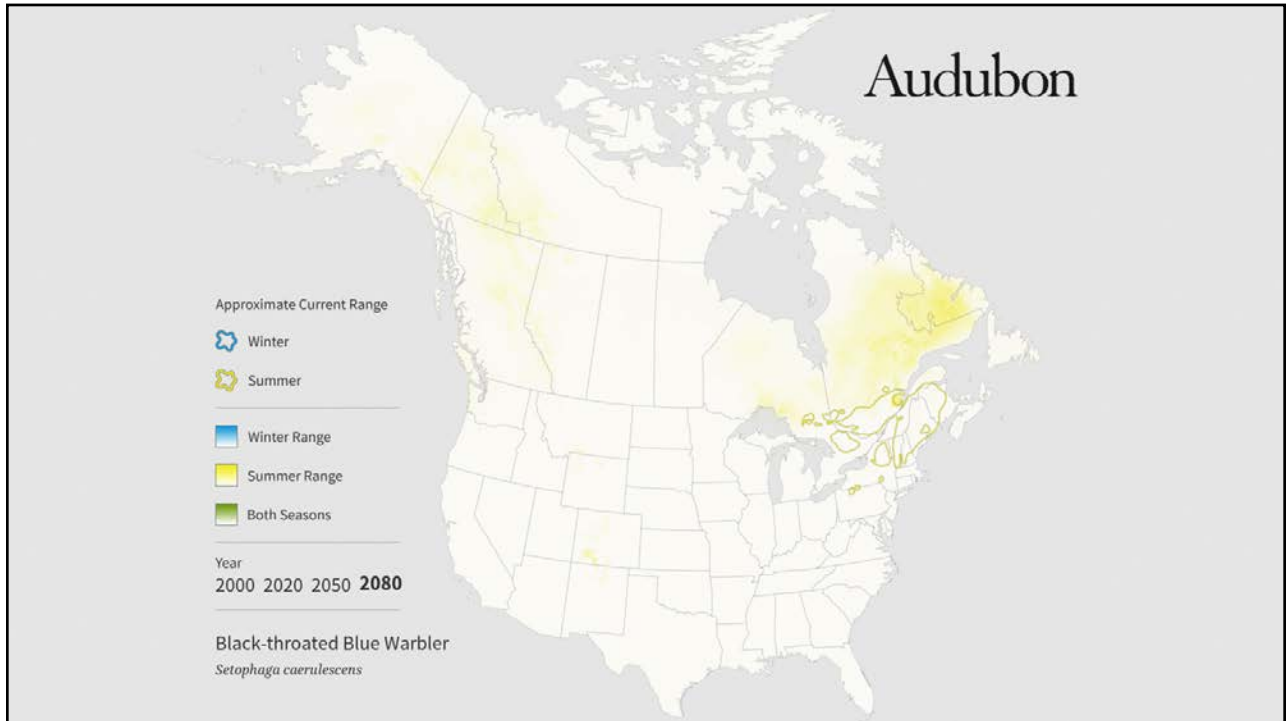
## General circulation models (GCMs)



# Methods







# Tools

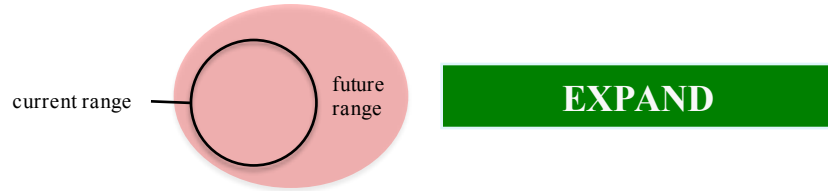
- Modeled Future Climatic Suitability Maps
- Climate Sensitivity Lists
- Climate Prioritizations

NATIONAL AUDUBON SOCIETY  
The SIBLEY  
Guide to  
Birds  
of  
2080  
Photos and Illustrations by  
DAVID ALLEN SIBLEY

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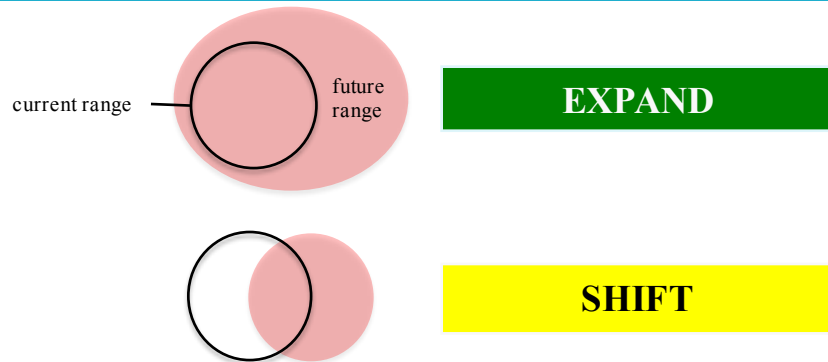
The 'Tools' section features a teal header with the word 'Tools' in white. Below the header are three teal circles containing the text 'Modeled Future Climatic Suitability Maps', 'Climate Sensitivity Lists', and 'Climate Prioritizations'. In the bottom left corner is the Audubon logo. In the bottom center is the cover of the book 'The Sibley Guide to Birds of 2080', which features an illustration of a bird in flight. The page number '21' is in the bottom right corner.

## Current vs future ranges



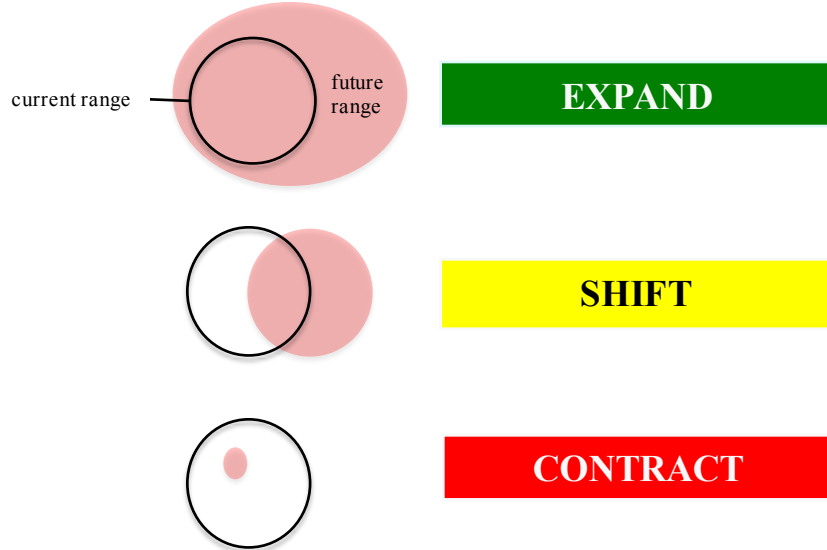
 Audubon

## Current vs future ranges

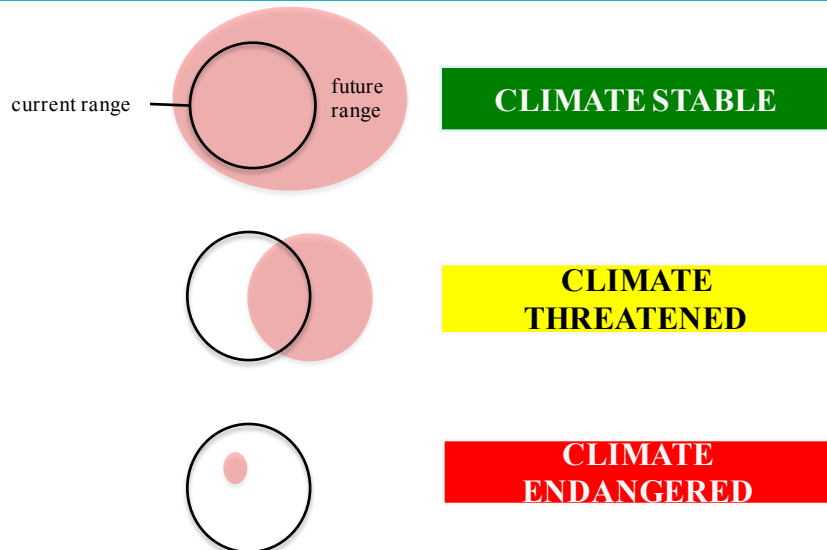


 Audubon

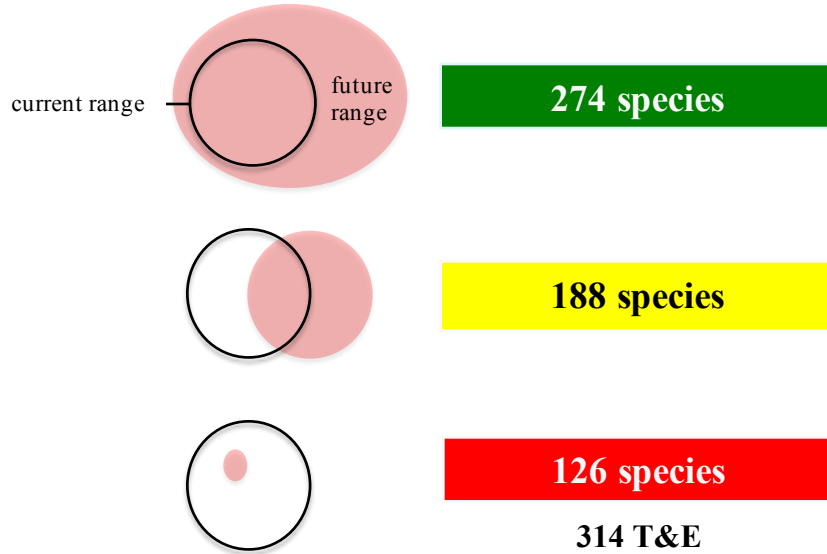
## Current vs future ranges



## Climate sensitivity



# Climate sensitivity



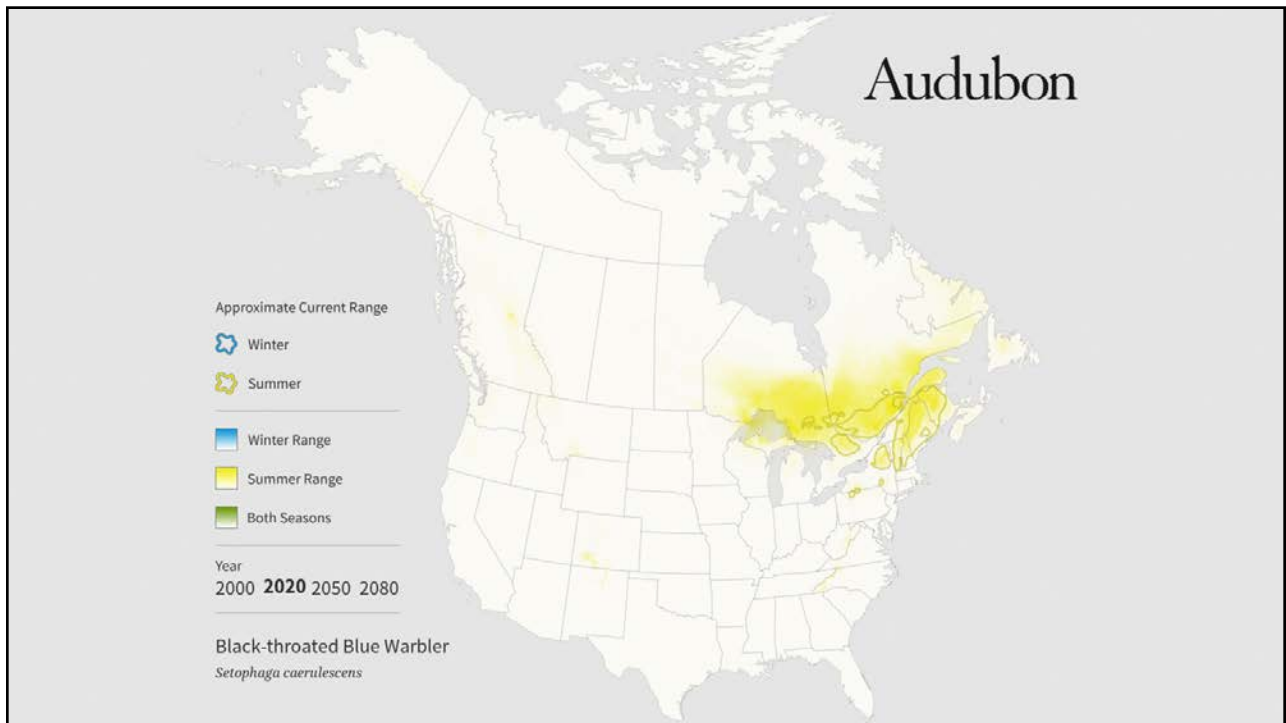
Audubon

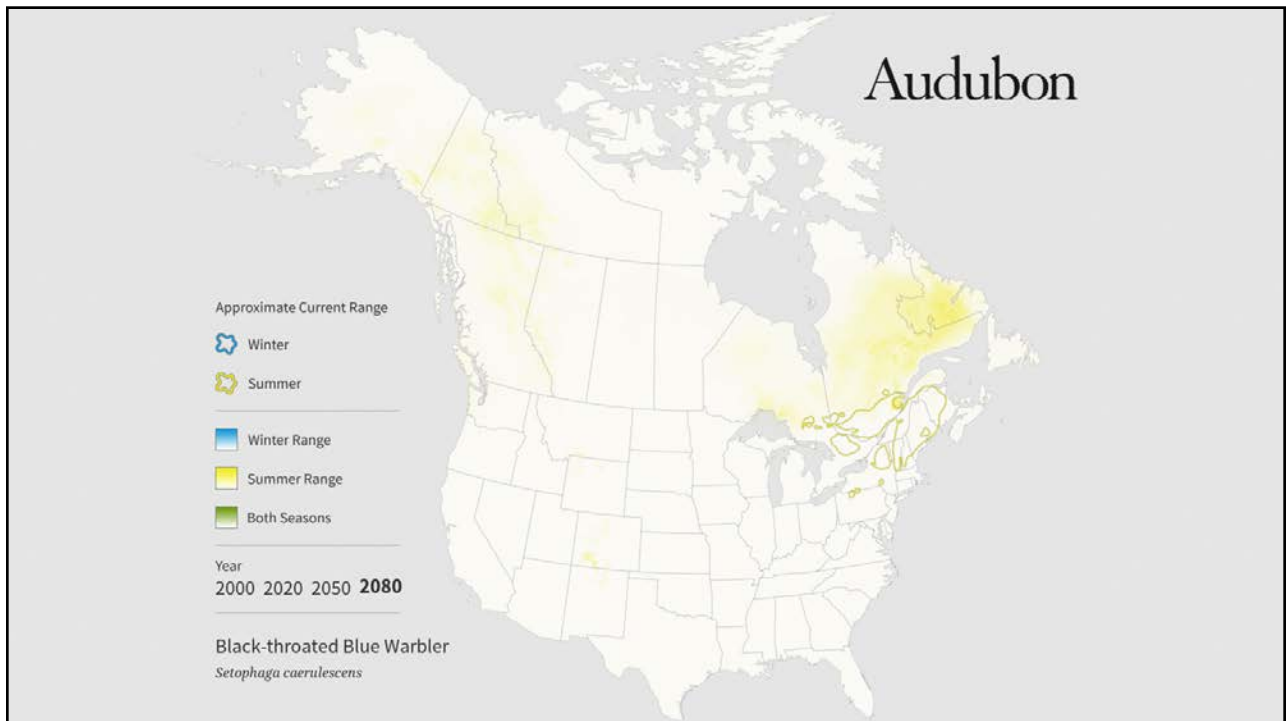
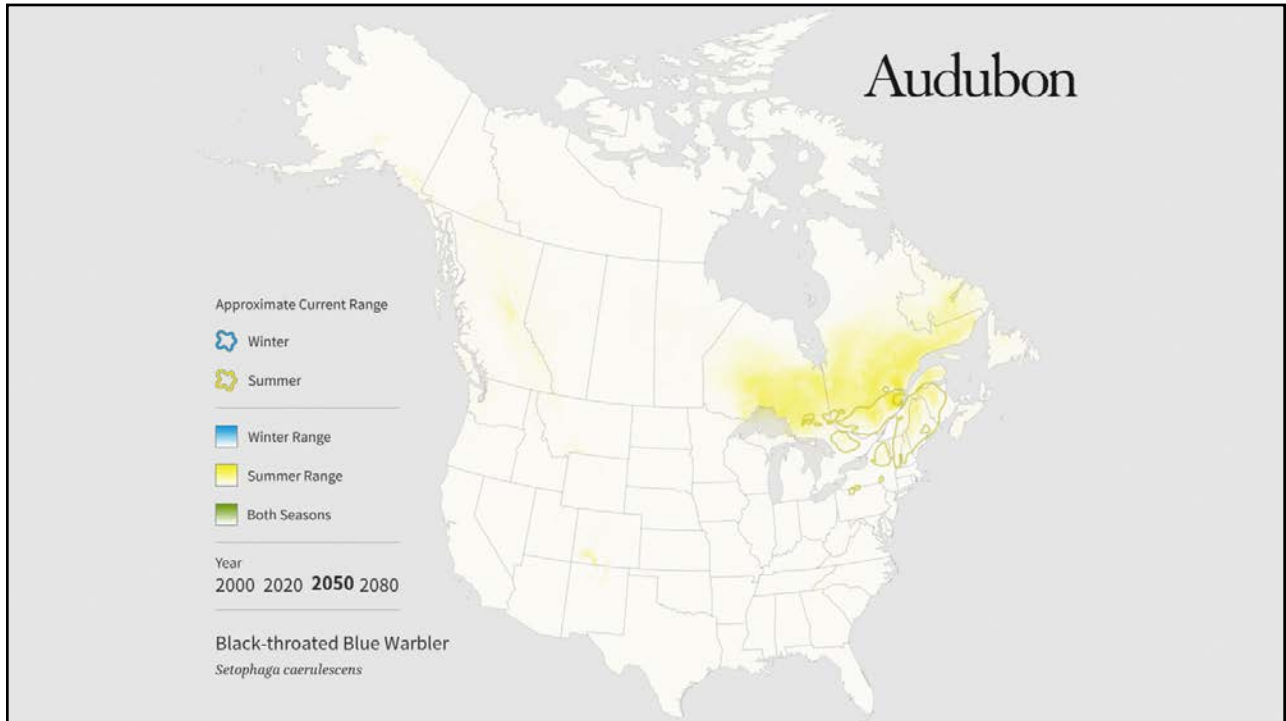


Black-throated Blue Warbler

© Kenneth Cole Schneider

Audubon






## Other Wood Warblers



Audubon

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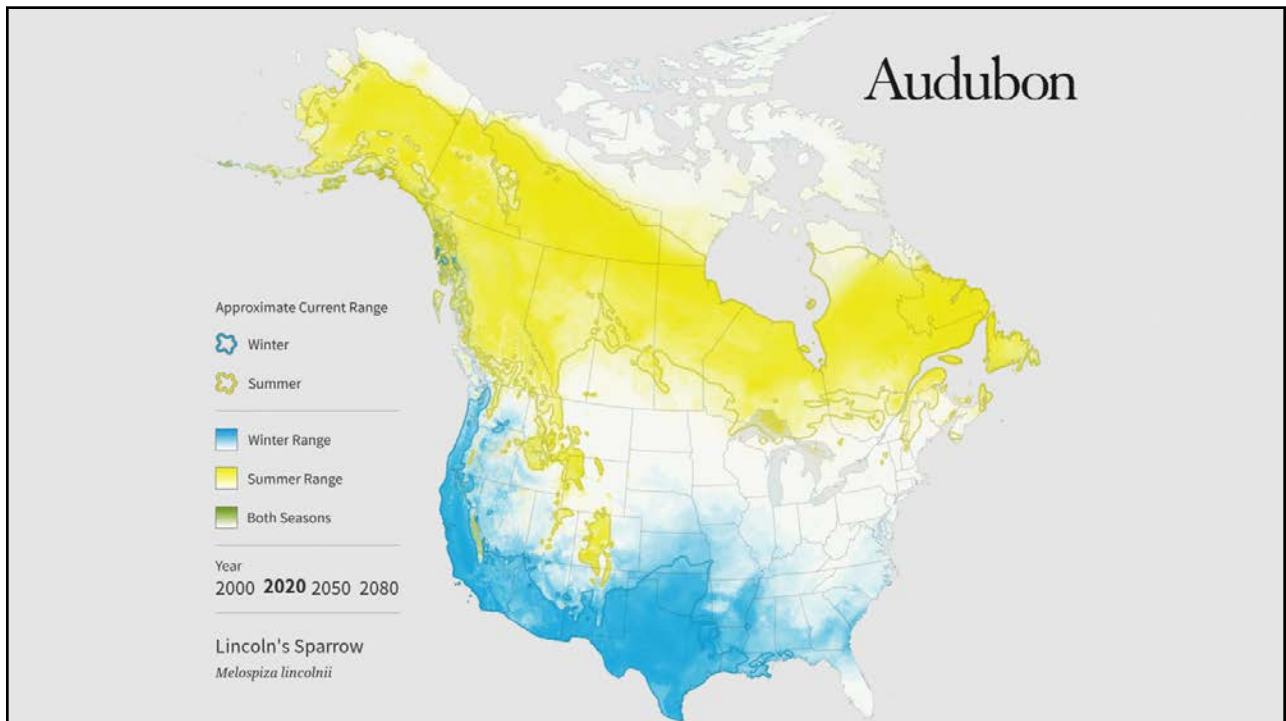
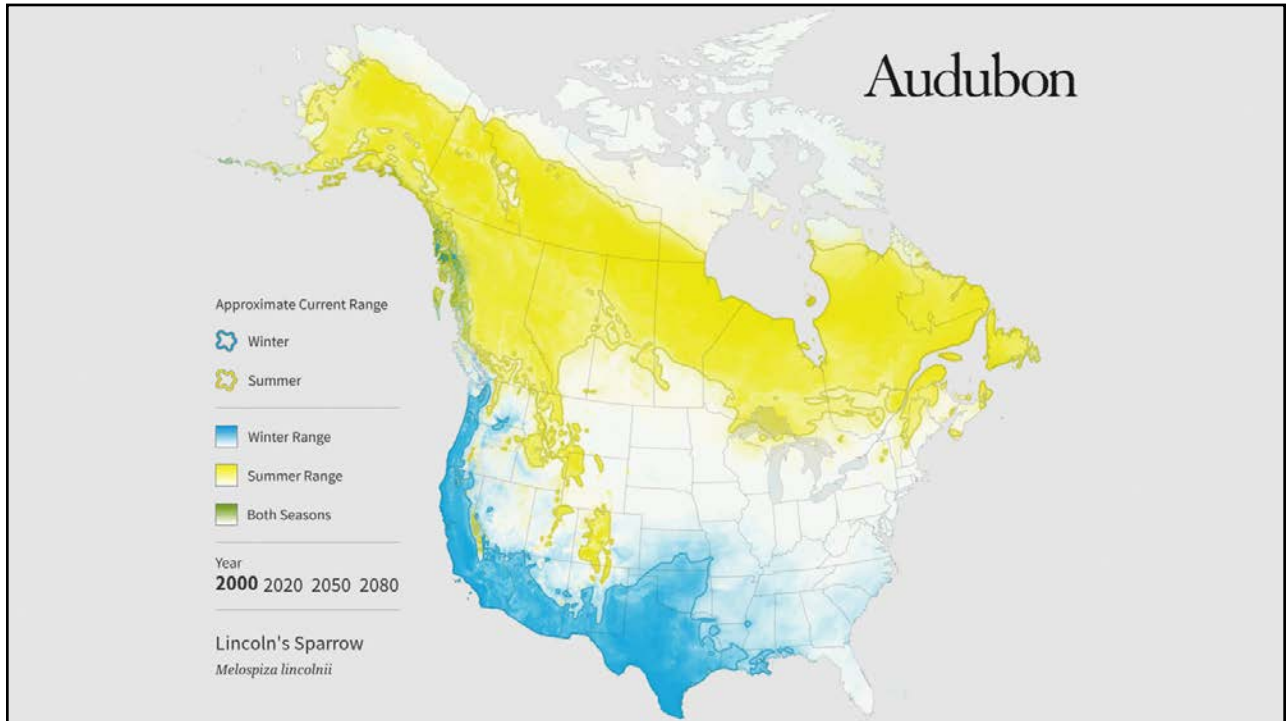
**CLIMATE STABLE**

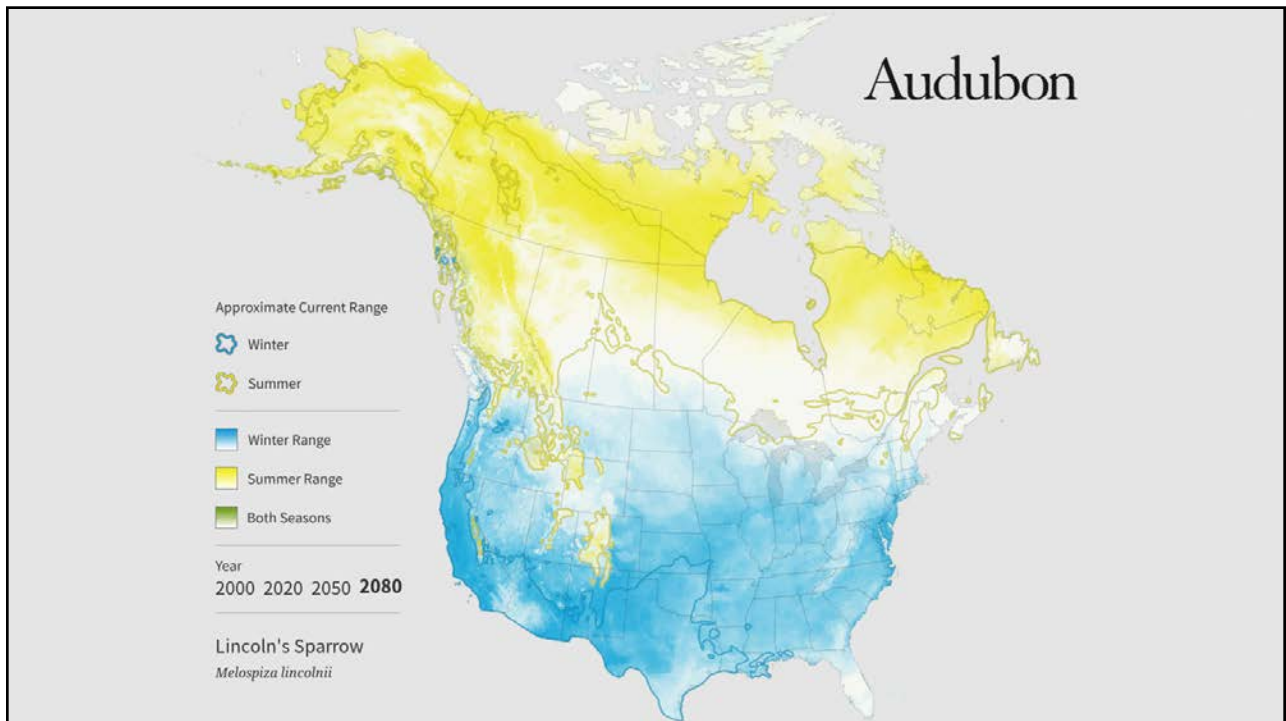
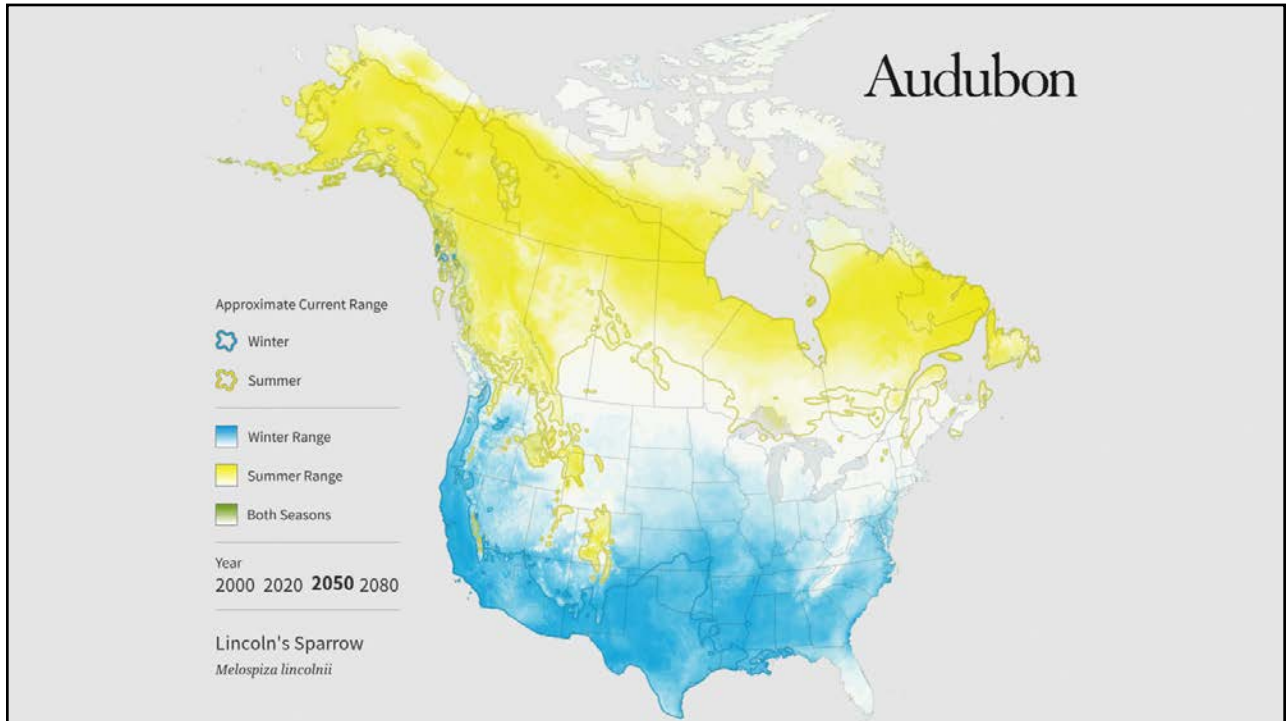
Lincoln's Sparrow

© Glenn Bartley

Audubon

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**CLIMATE THREATENED**

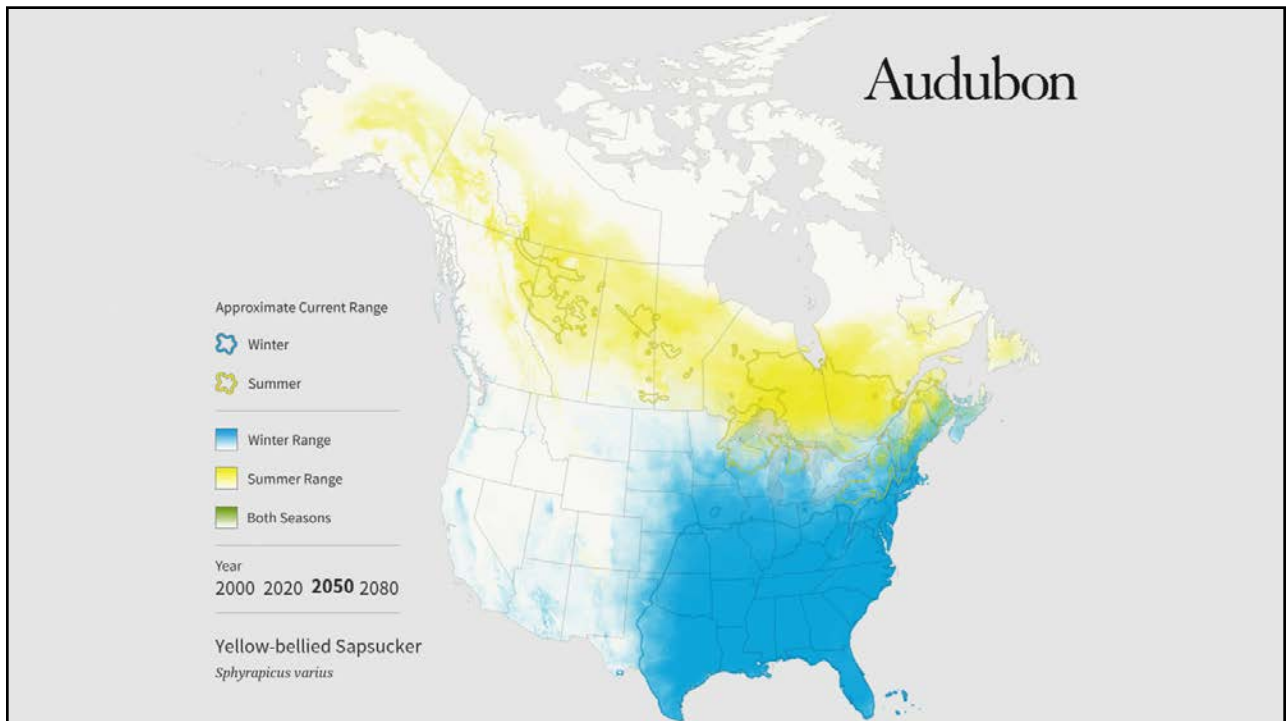
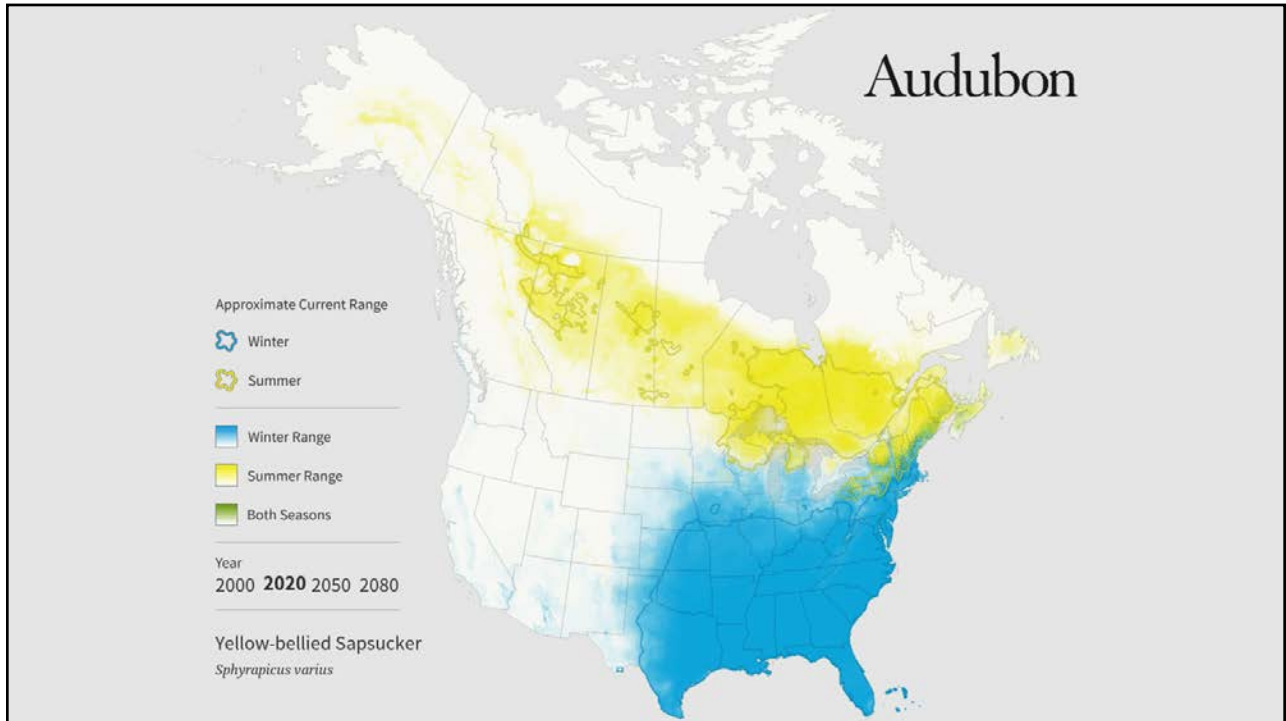
Yellow-bellied Sapsucker

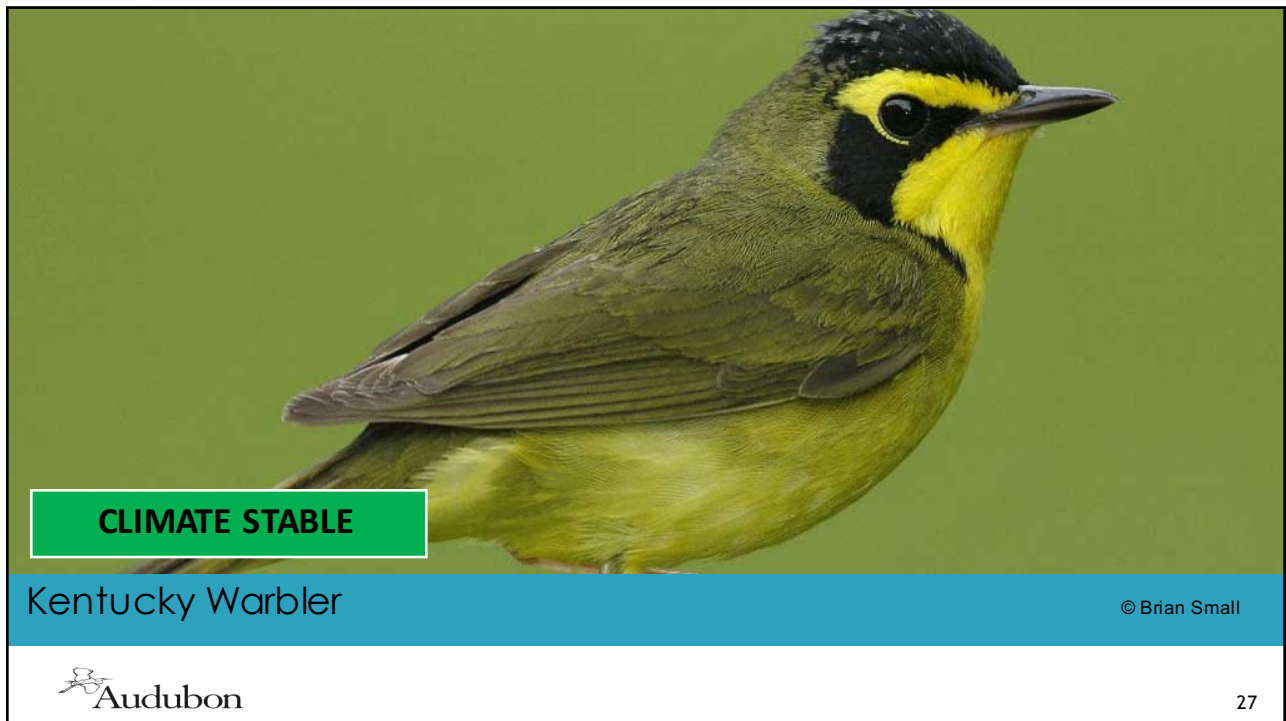
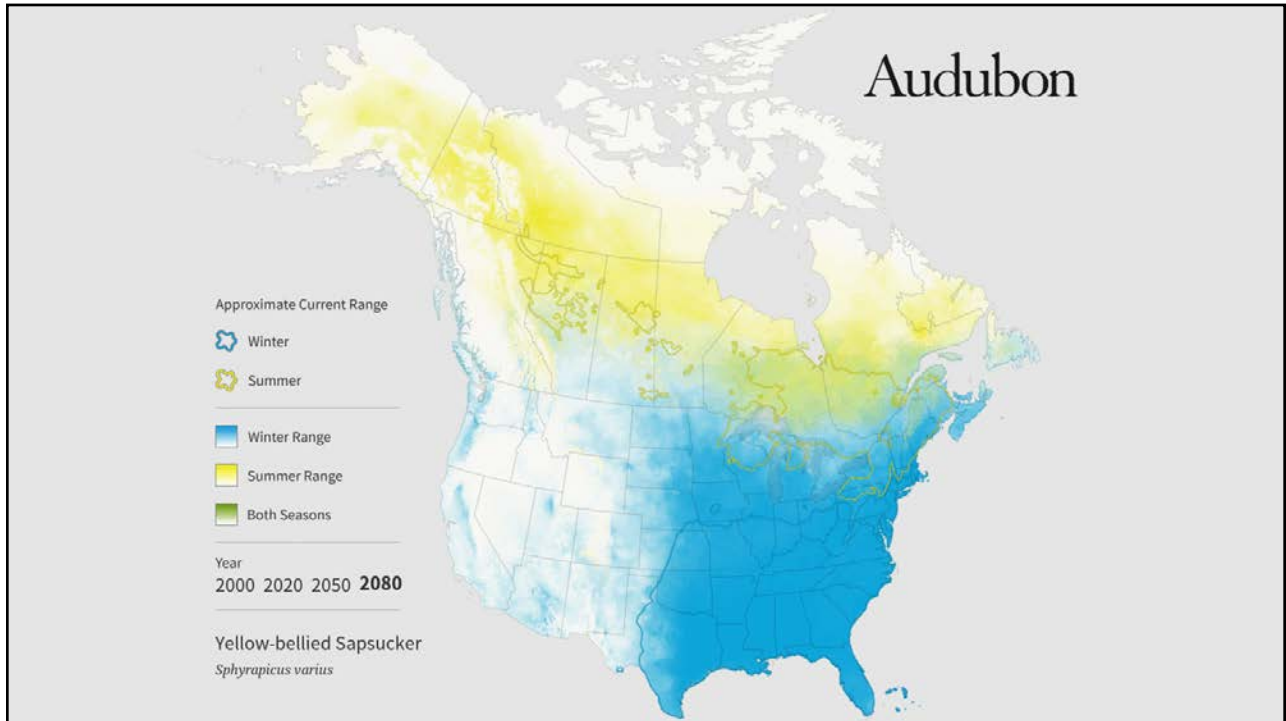
© Terry Loranc

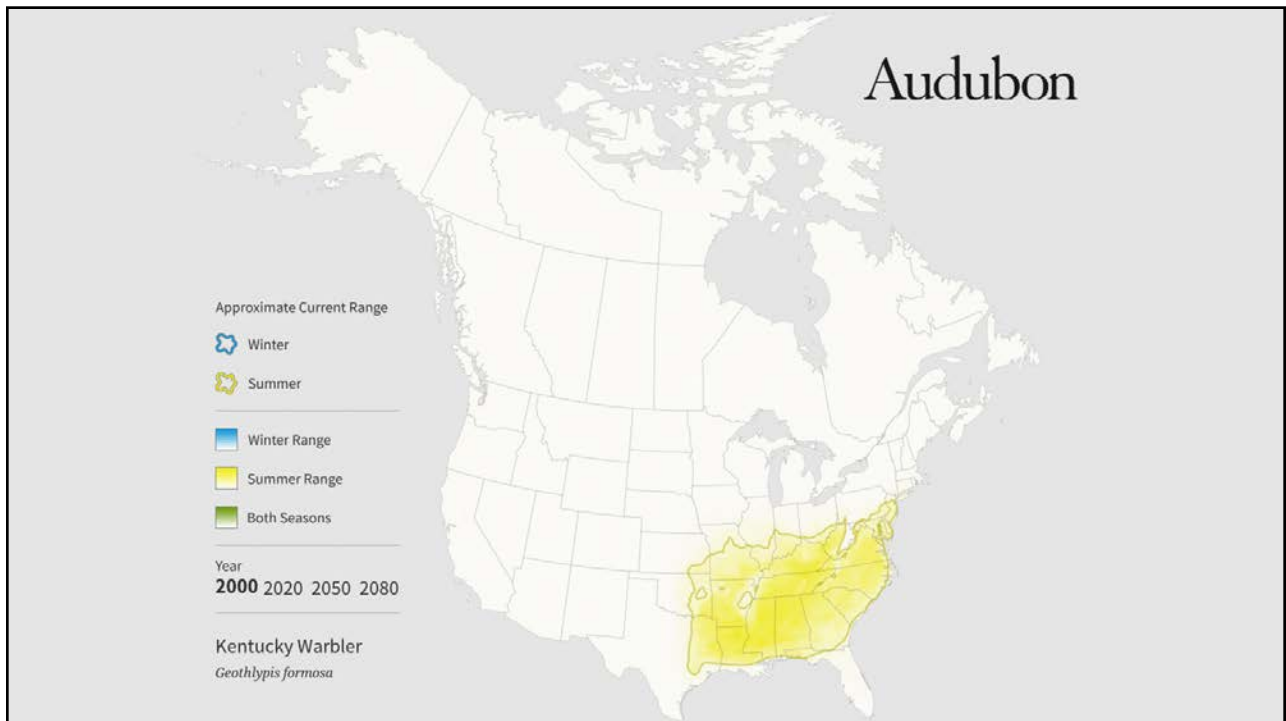
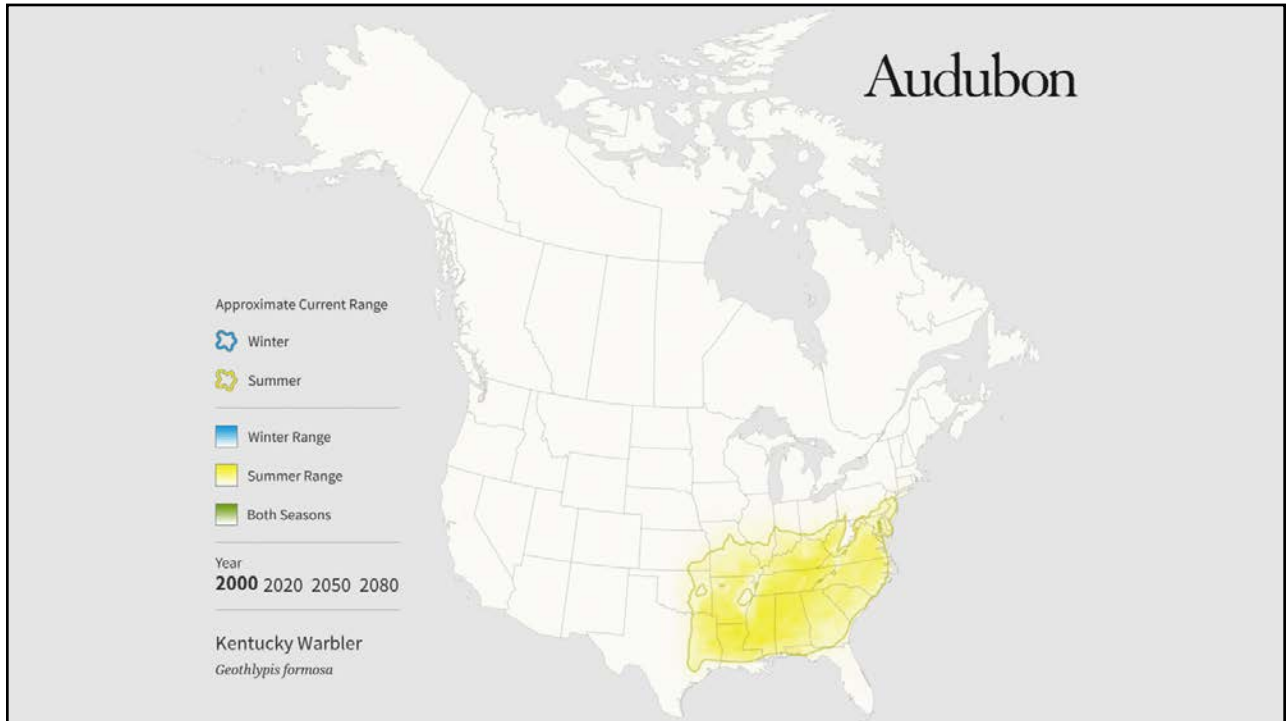
 Audubon

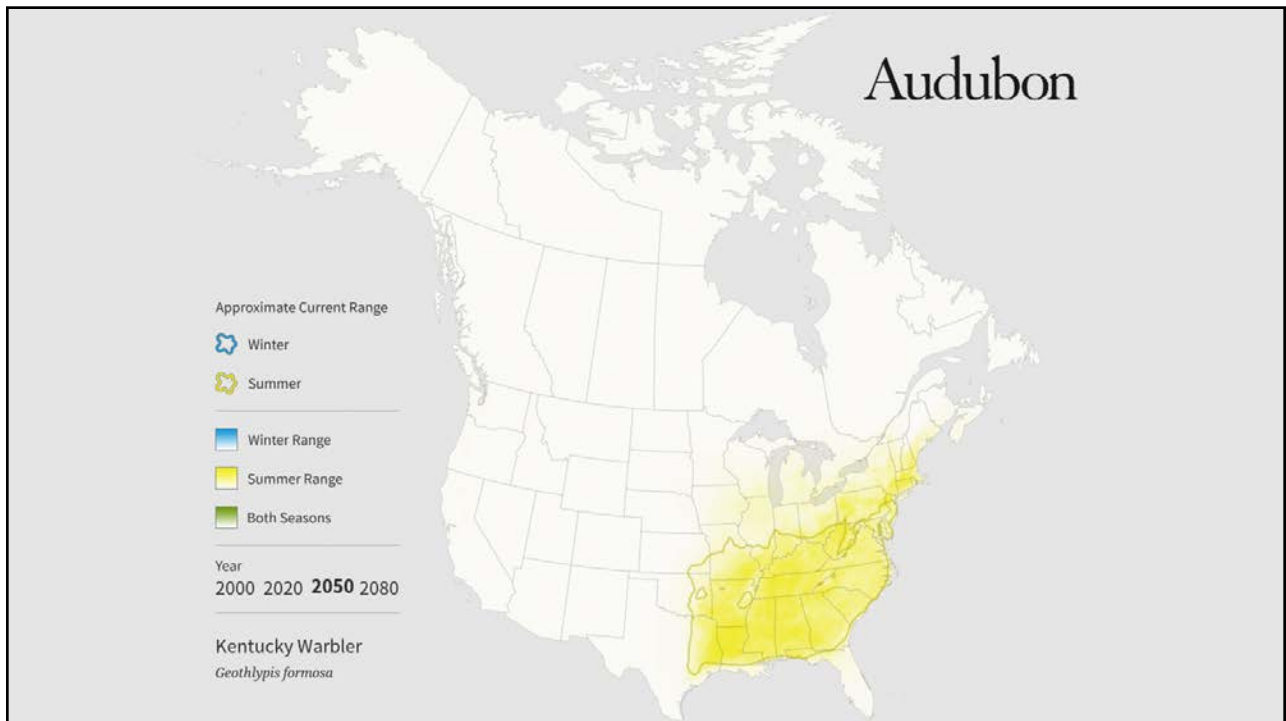
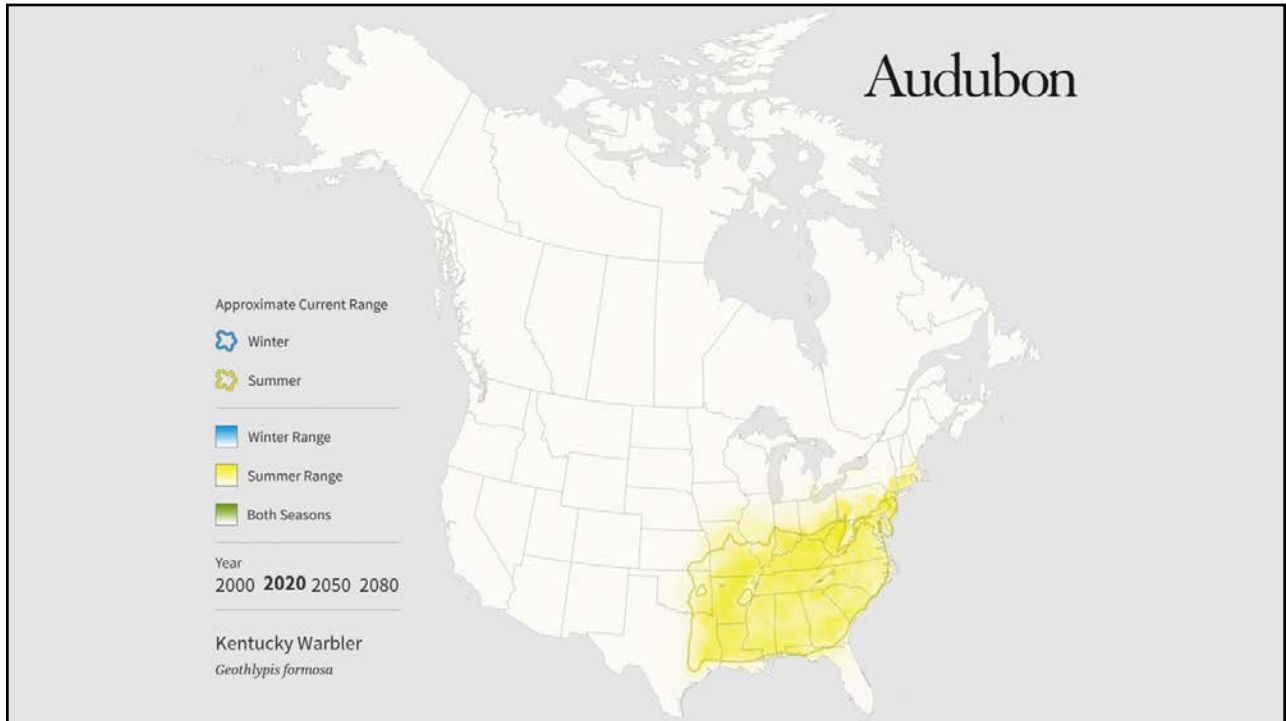
27

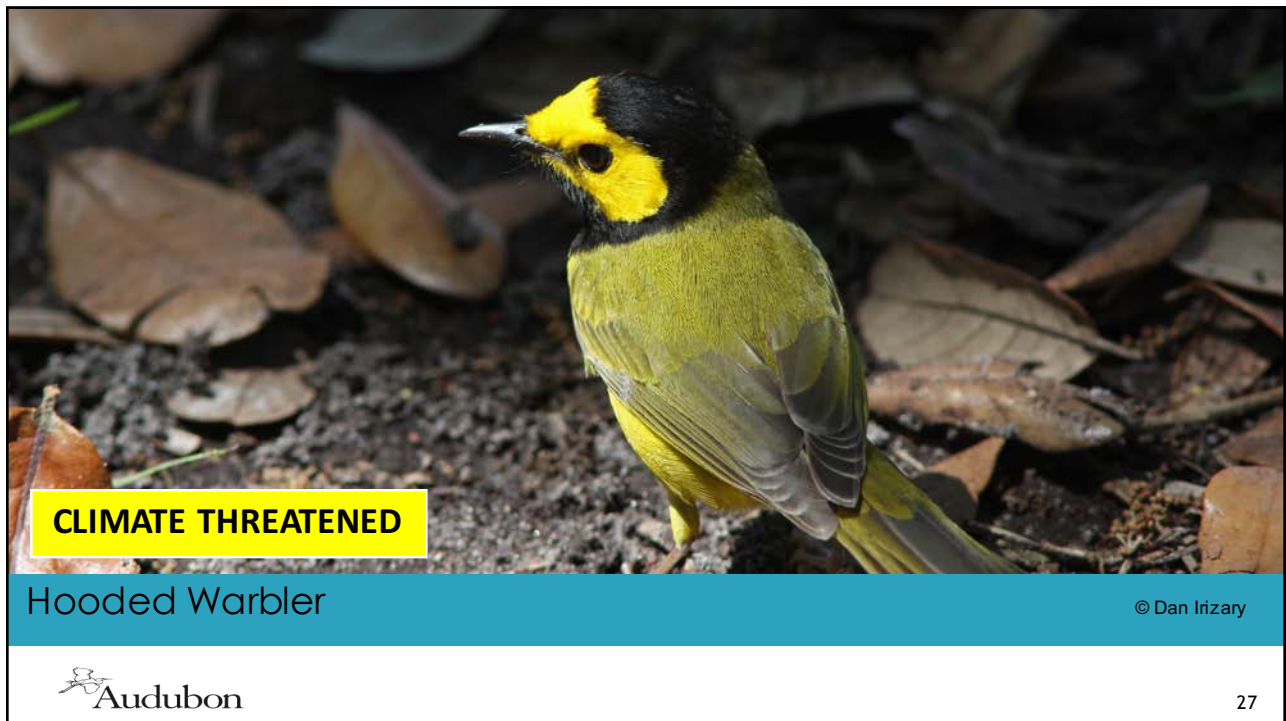
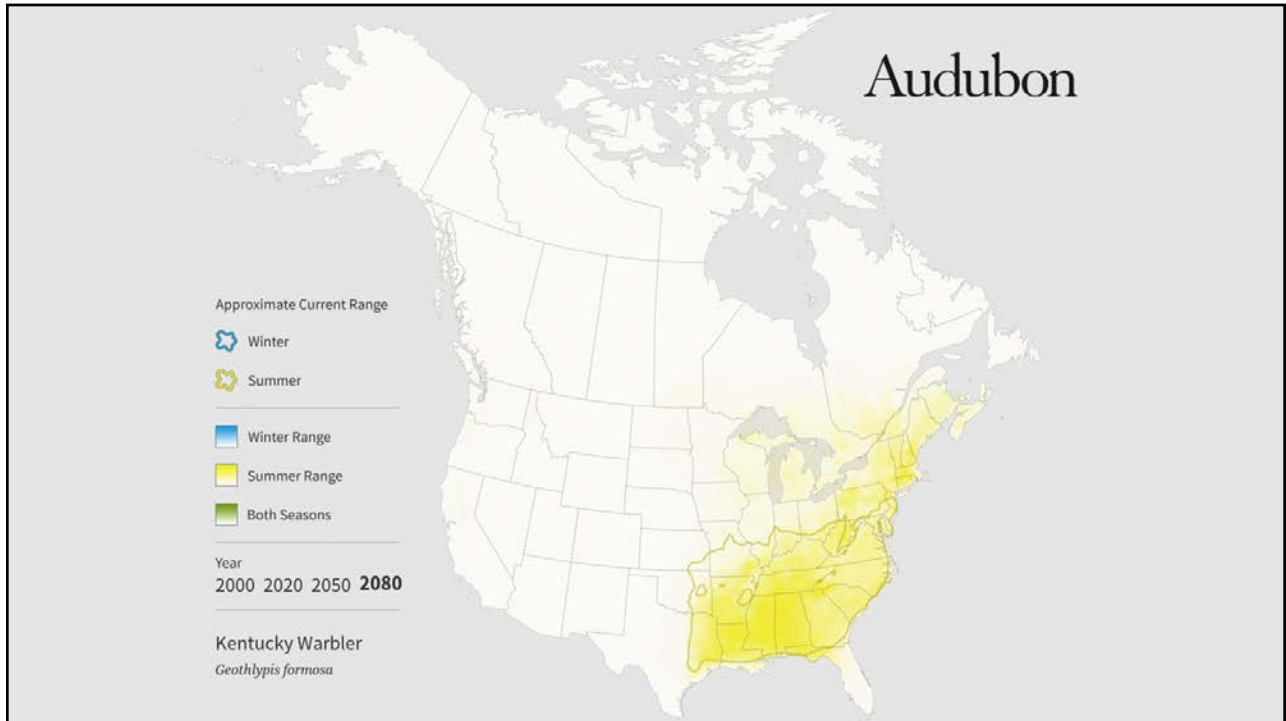


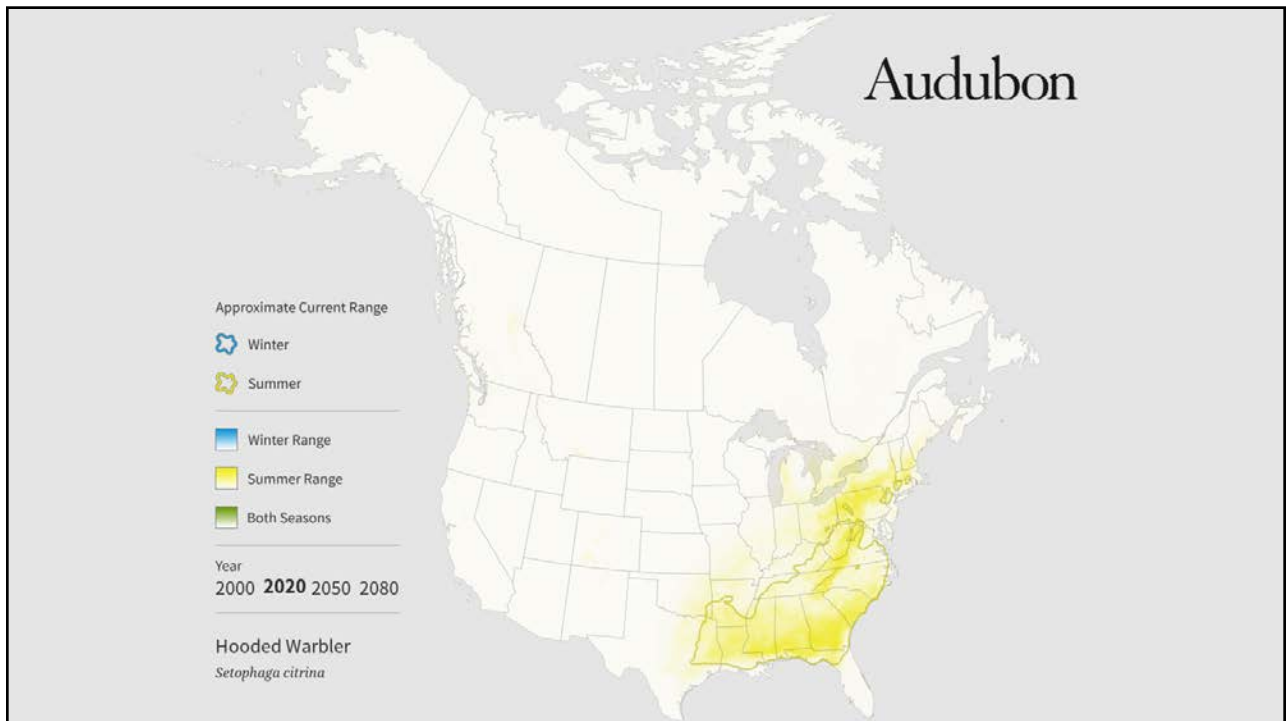
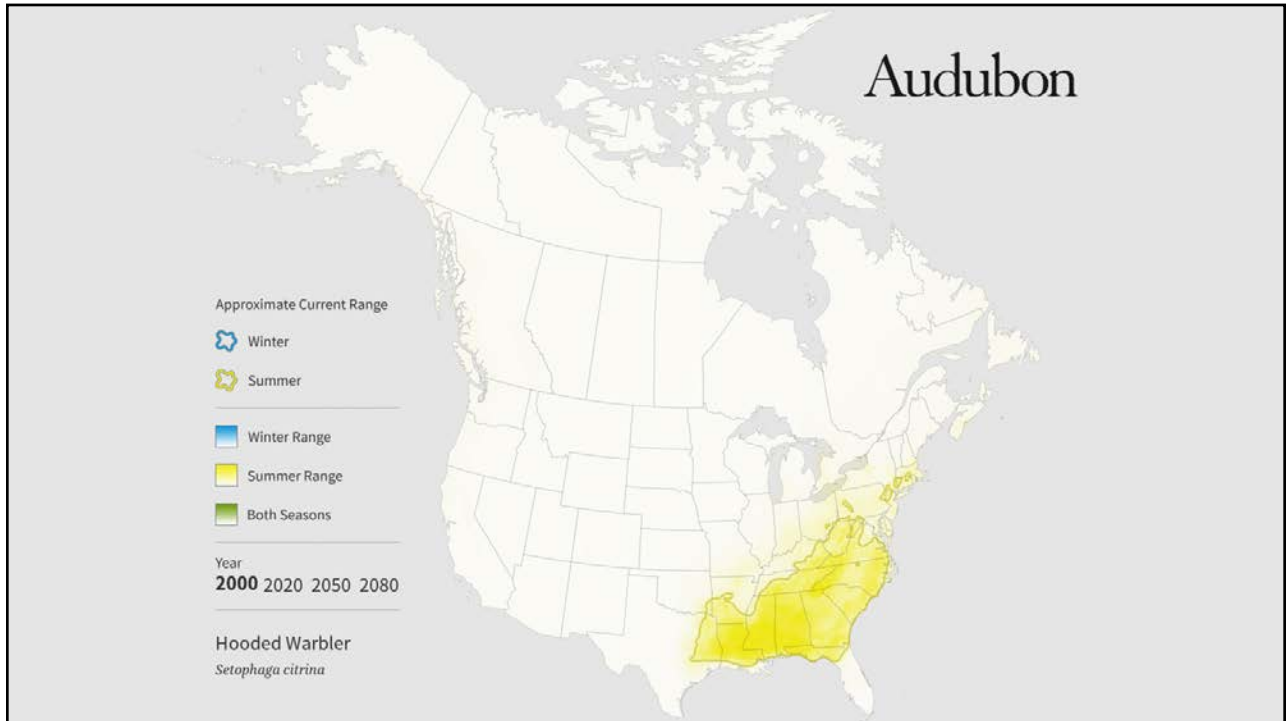


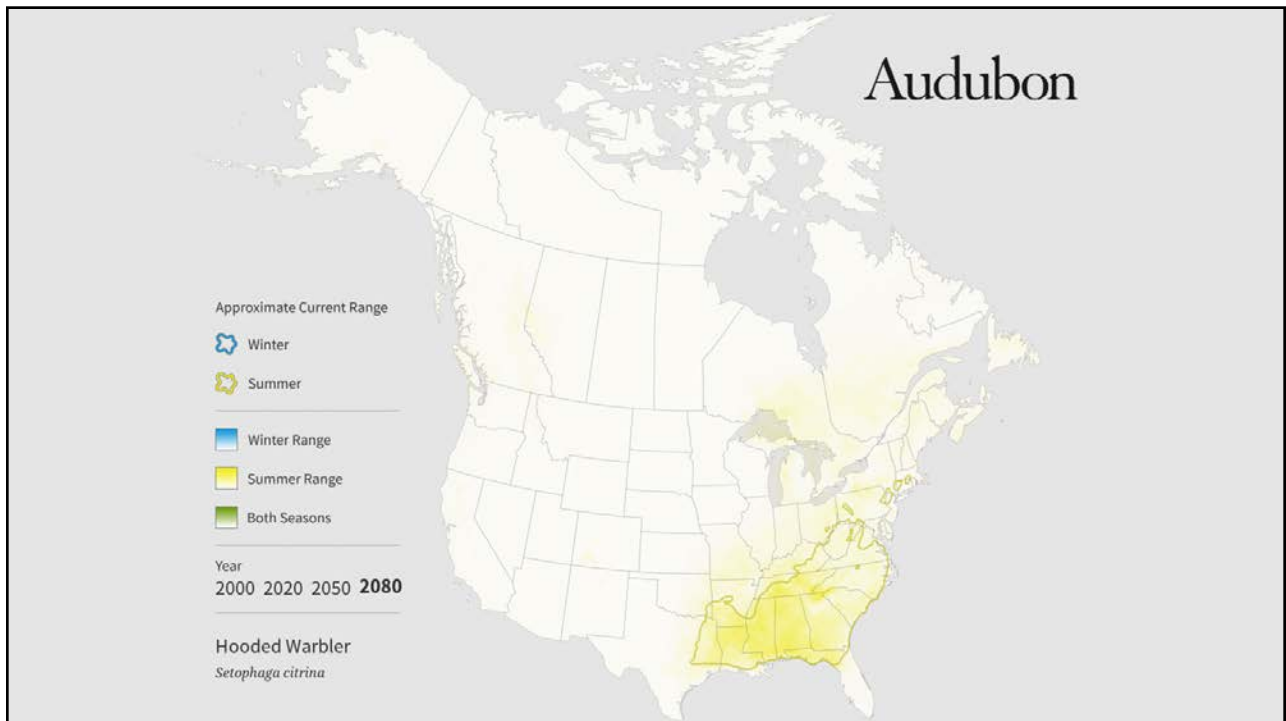
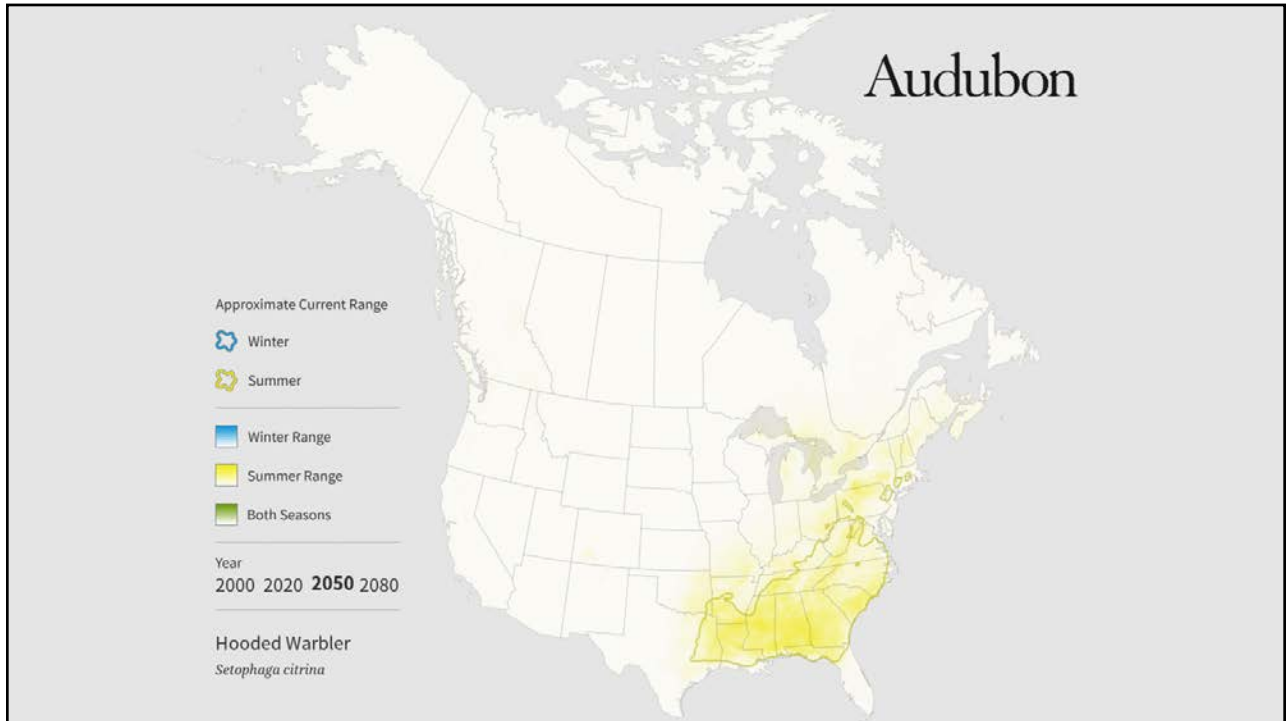


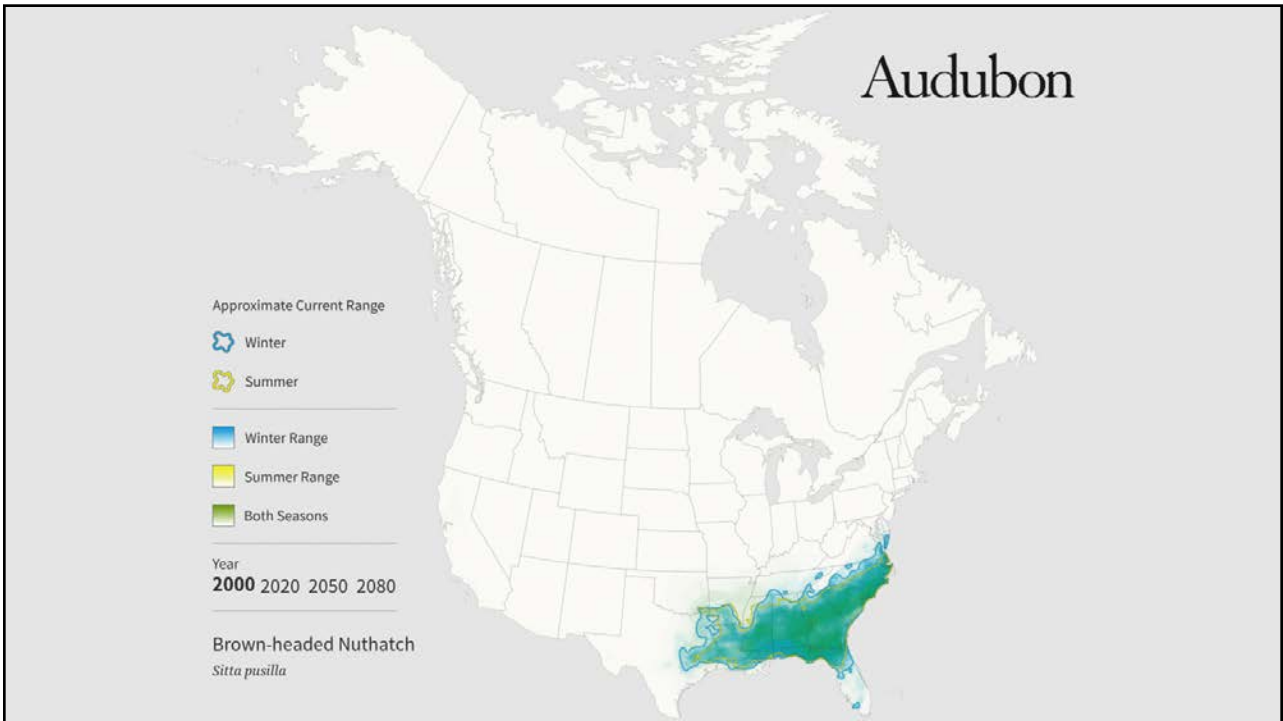


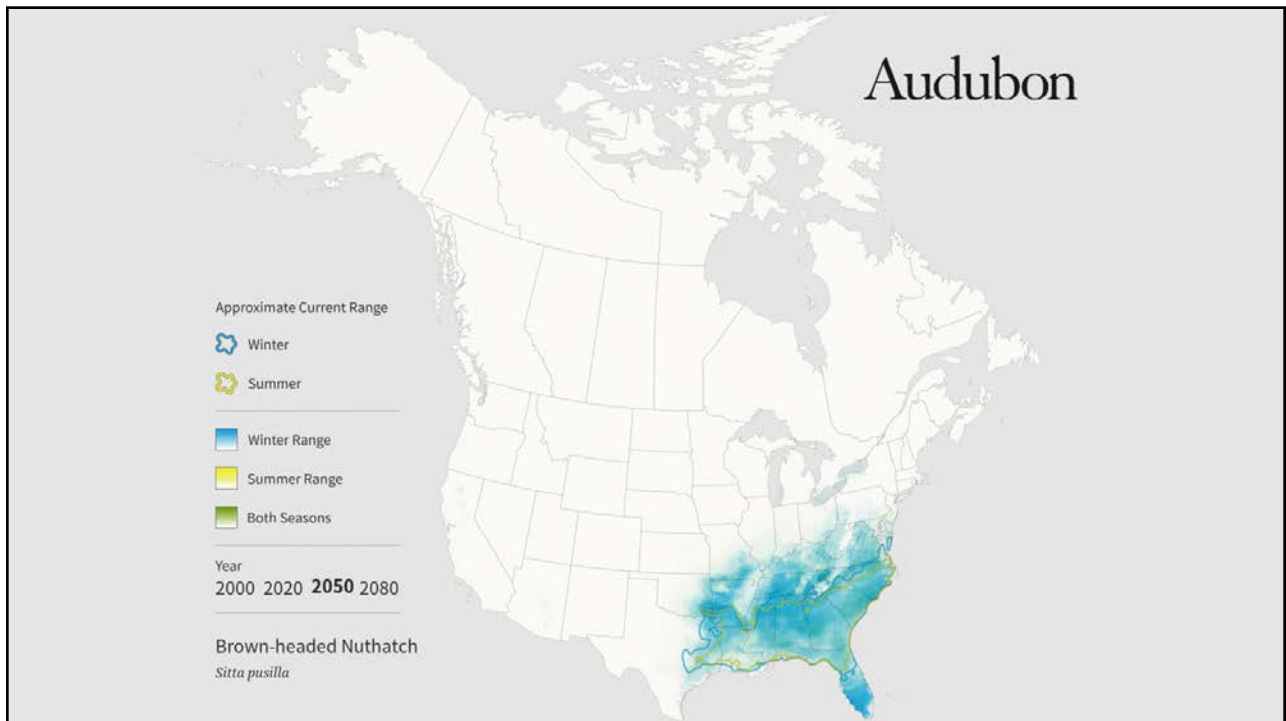
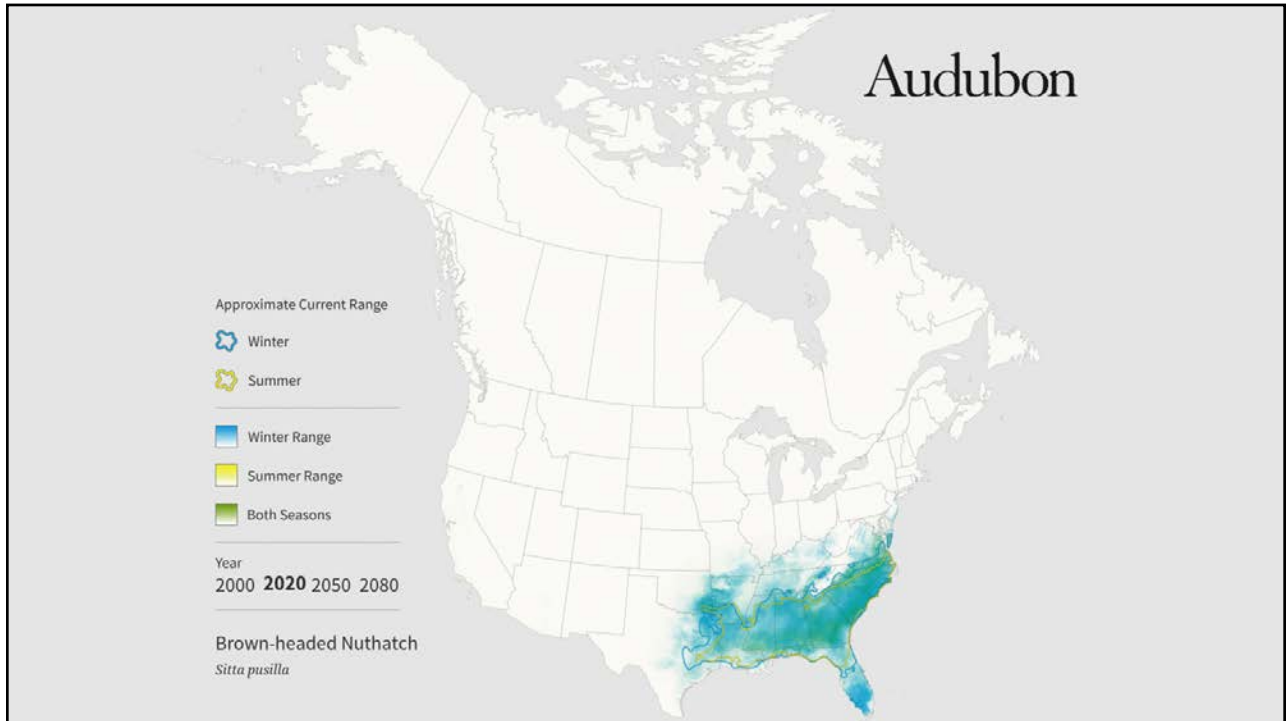












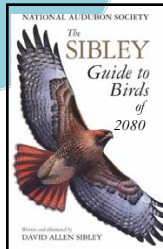


## Tools for climate impacts assessment

Modeled Future Climatic Suitability Maps

Climate Sensitivity Lists

Climate Prioritizations

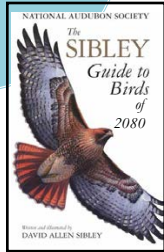


# Tools for climate impacts assessment

Modeled Future Climatic Suitability Maps

Climate Sensitivity Lists

Climate Prioritizations

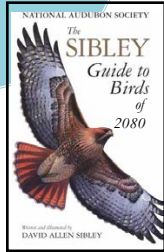


# Tools for climate impacts assessment

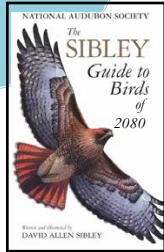
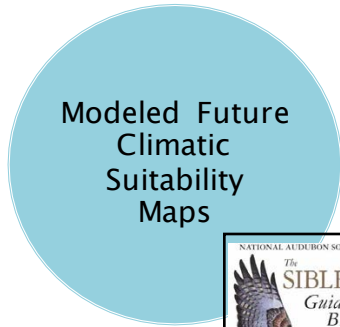
Modeled Future Climatic Suitability Maps

Climate Sensitivity Lists

Climate Prioritizations

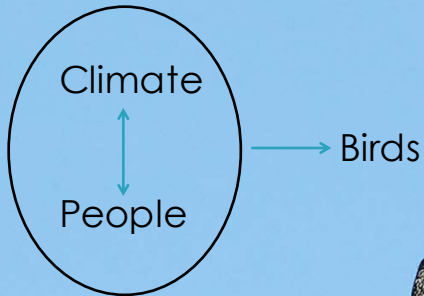


# Tools for climate impacts assessment



# What are the challenges?

- ▶ The future is uncertain



# Biological responses to climate change

<b>Ability to colonize new areas</b>	High	"track and move"	unpredictable
	Low	"suffer in place"	"adapt in place"
		Low	High
		<b>Tolerance of new climates</b>	



# Biological responses to climate change

<b>Ability to colonize new areas</b>	High	"track and move"	unpredictable
	Low	"suffer in place"	"adapt in place"
		Low	High
		<b>Tolerance of new climates</b>	



# Biological responses to climate change

<b>Ability to colonize new areas</b>	High	"track and move"	unpredictable
	Low	"suffer in place"	"adapt in place"
		Low	High
		<b>Tolerance of new climates</b>	



# Biological responses to climate change

<b>Ability to colonize new areas</b>	High	"track and move"	unpredictable
	Low	"suffer in place"	"adapt in place"
		Low	High
		<b>Tolerance of new climates</b>	



# Methods


# Methods

Current  
Climatic  
Suitability Map

# Methods

Current Climatic Suitability Map

Future Climatic Suitability Maps



48


This slide illustrates the methodology for generating future climatic suitability maps. It features a teal header with the word 'Methods'. Below the header, a light blue oval contains the text 'Current Climatic Suitability Map'. Underneath this, a stack of several overlapping, semi-transparent teal ovals is shown, with the text 'Future Climatic Suitability Maps' centered within them. The Audubon logo is positioned in the bottom left corner, and the number '48' is in the bottom right corner.

# Methods

Current Climatic Suitability Map

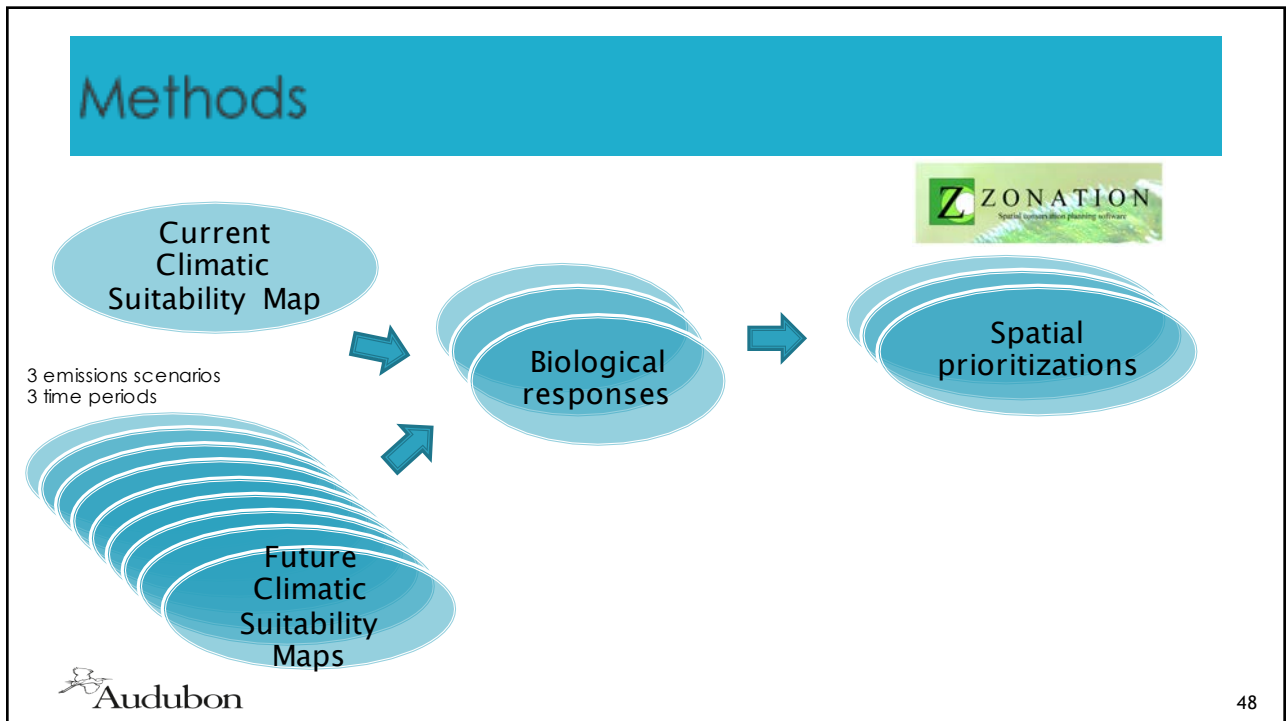
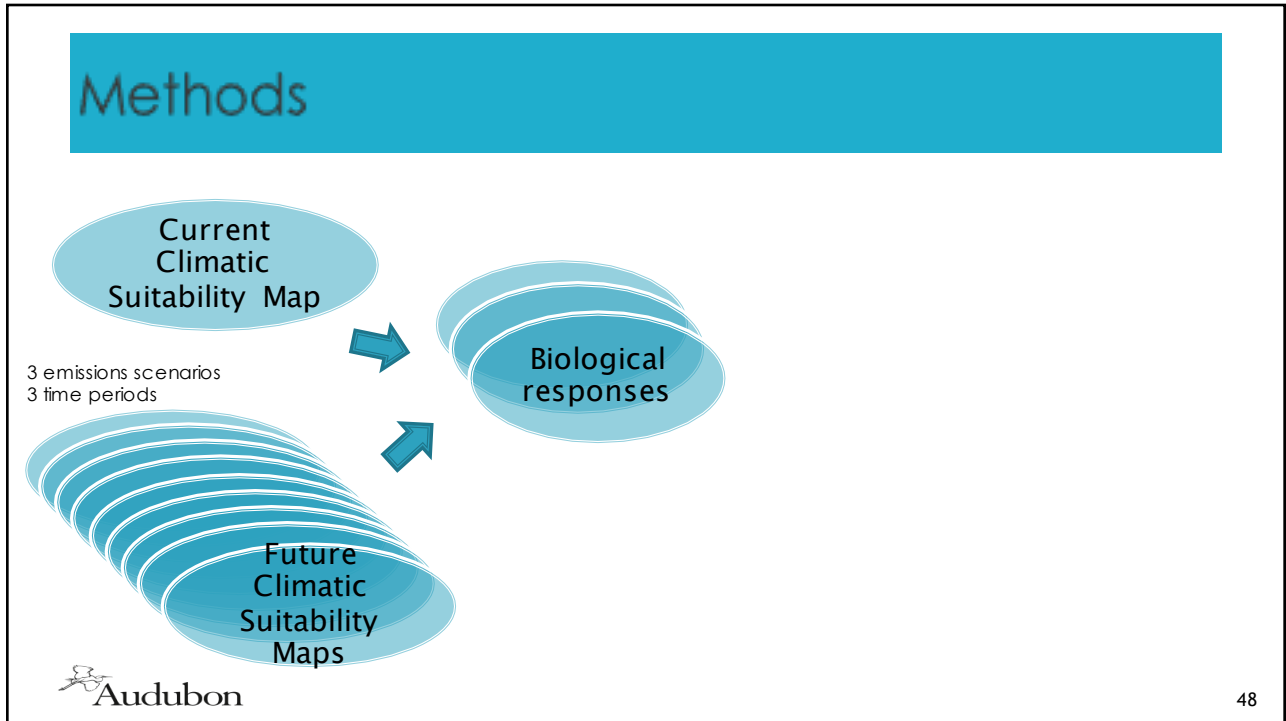
3 emissions scenarios  
3 time periods

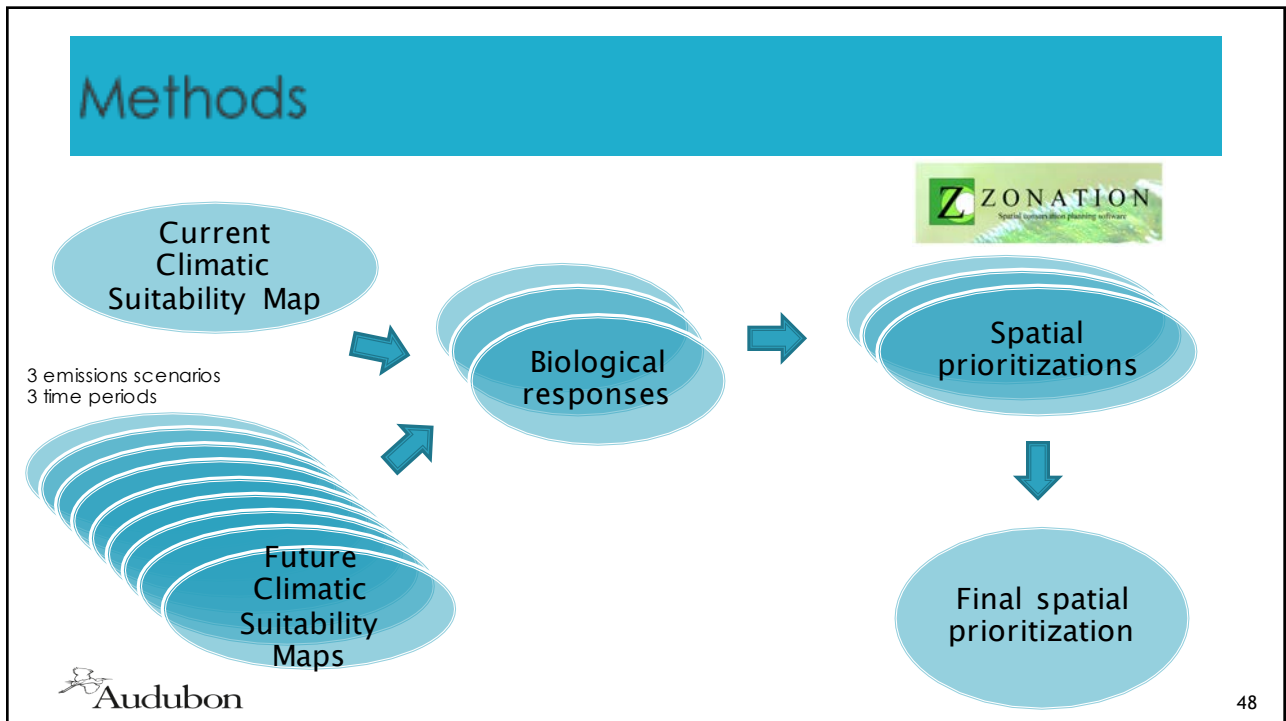
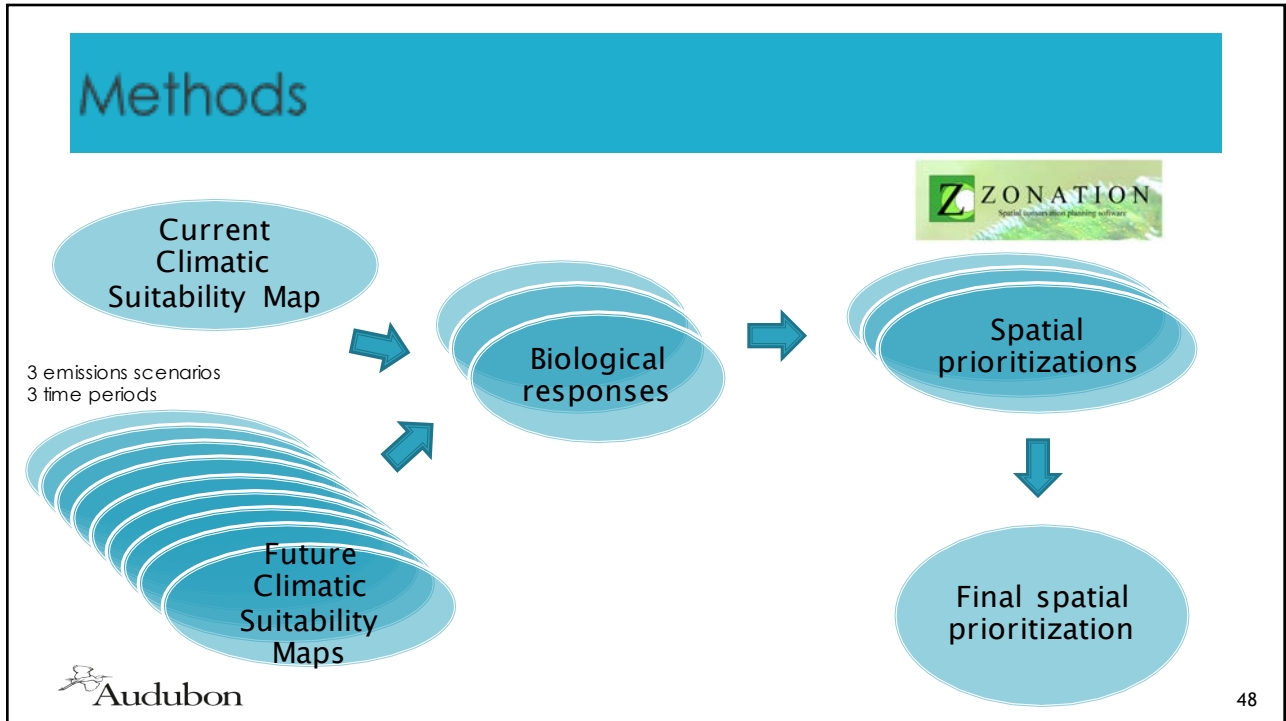
Future Climatic Suitability Maps



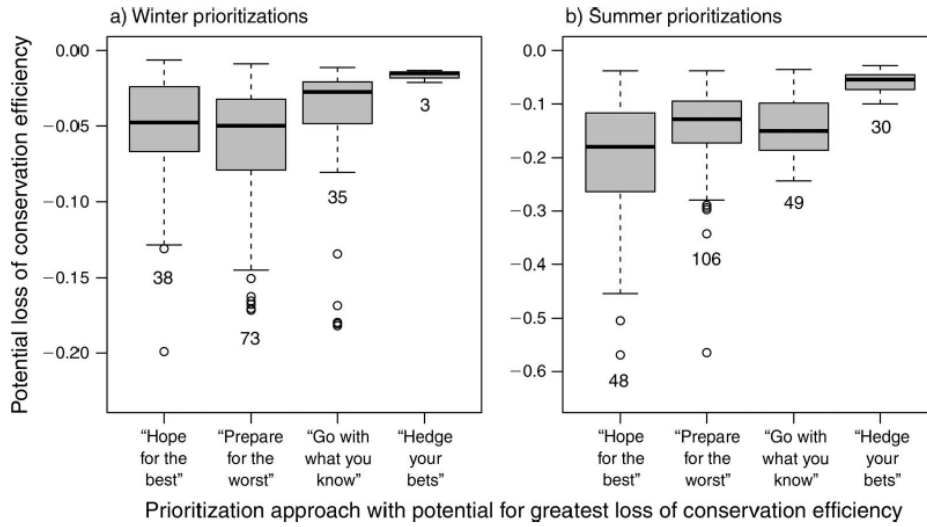
48

This slide is similar to the one above but includes additional details. It features a teal header with the word 'Methods'. Below the header, a light blue oval contains the text 'Current Climatic Suitability Map'. Underneath this, the text '3 emissions scenarios' and '3 time periods' is displayed. Below that, a stack of several overlapping, semi-transparent teal ovals is shown, with the text 'Future Climatic Suitability Maps' centered within them. The Audubon logo is positioned in the bottom left corner, and the number '48' is in the bottom right corner.

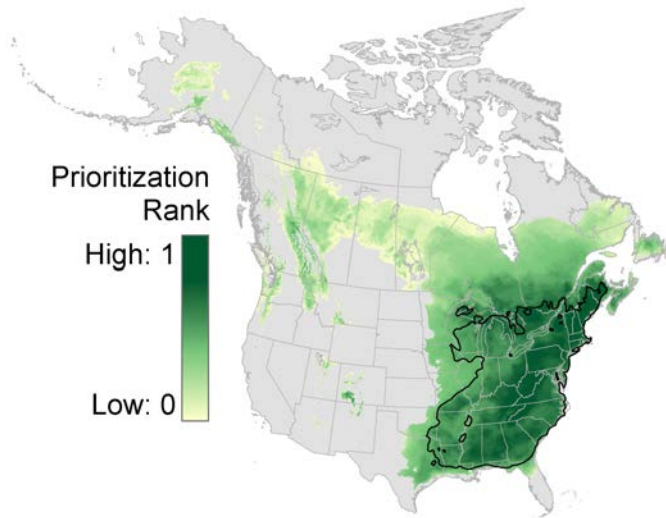




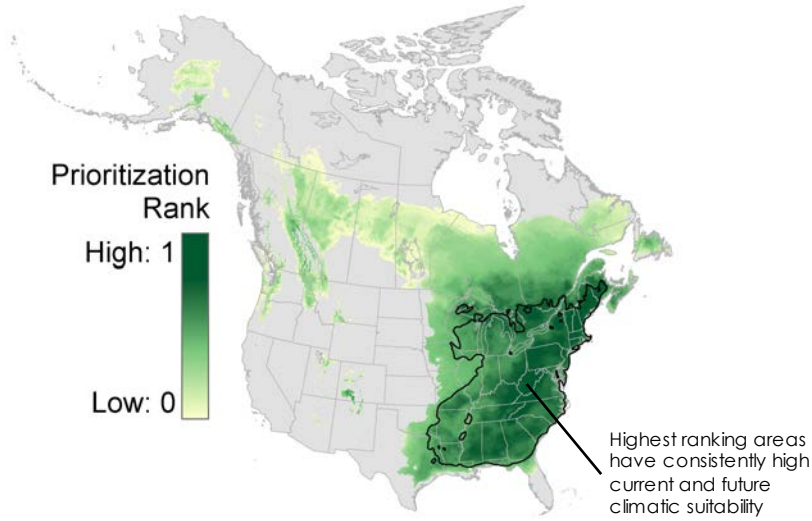
# Increased conservation efficiency



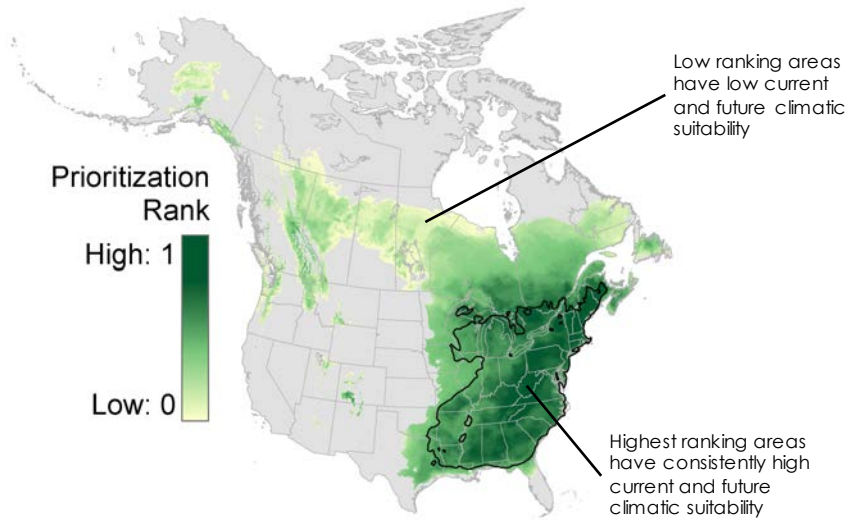
# Anatomy of a spatial prioritization



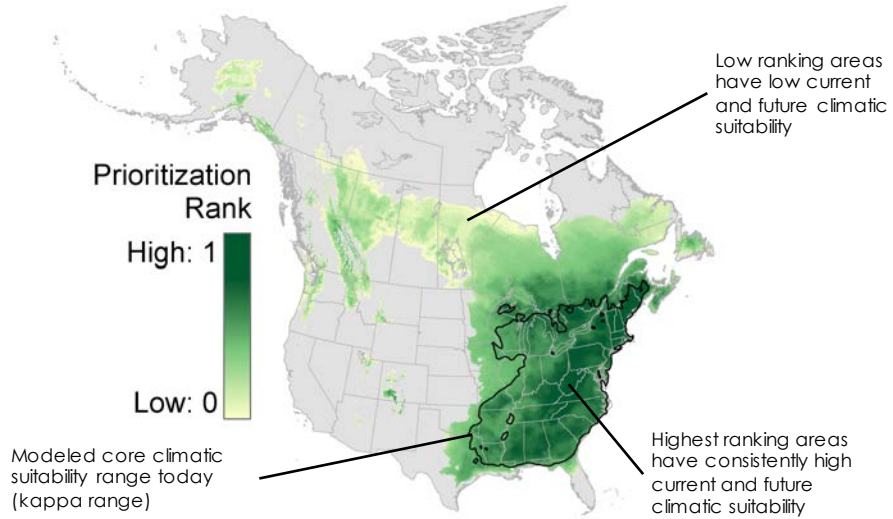
# Anatomy of a spatial prioritization



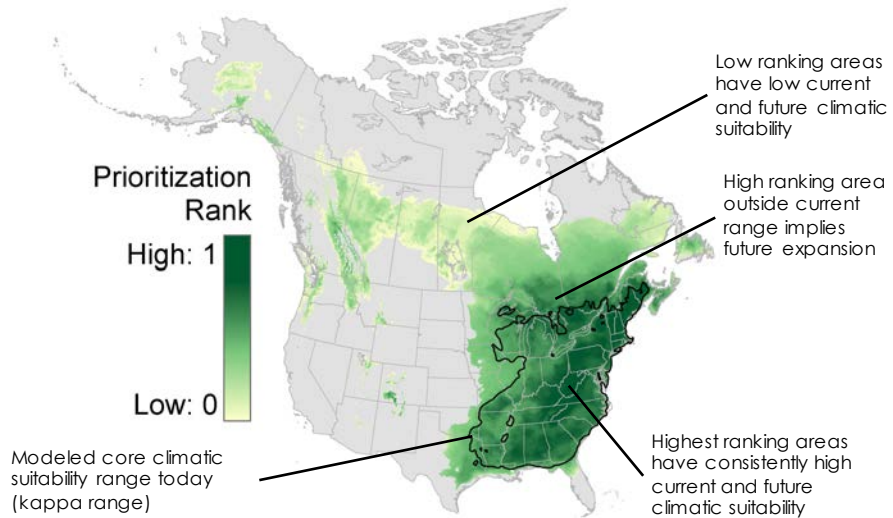
# Anatomy of a spatial prioritization



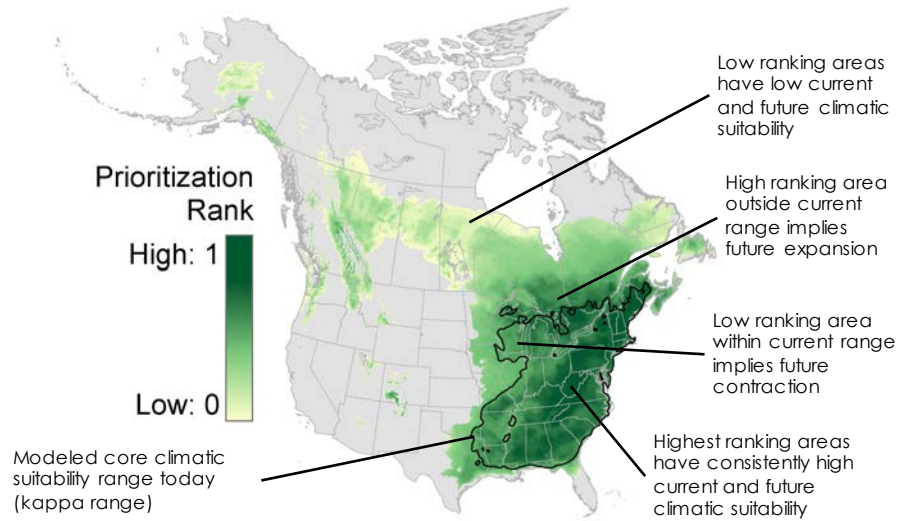
# Anatomy of a spatial prioritization



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## Anatomy of a spatial prioritization



## What are prioritizations used for?

- ▶ Conservation planning

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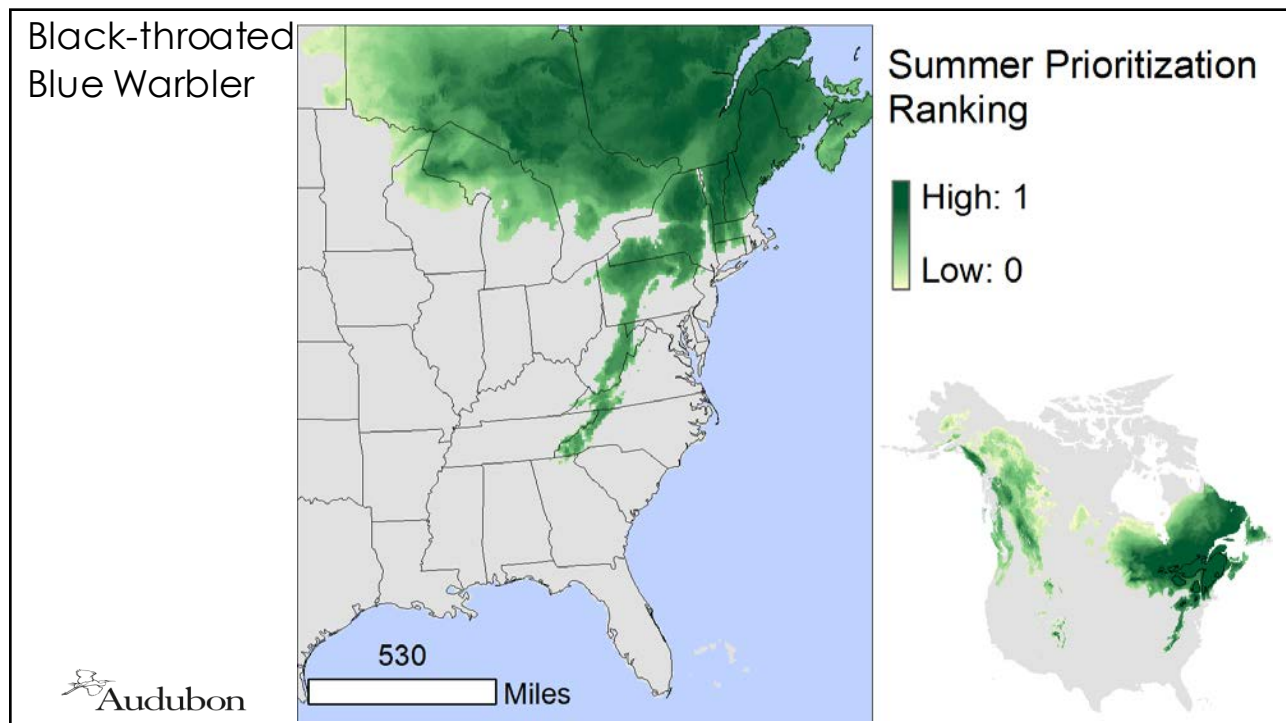
- ▶ Conservation planning
- ▶ Identifying climate strongholds

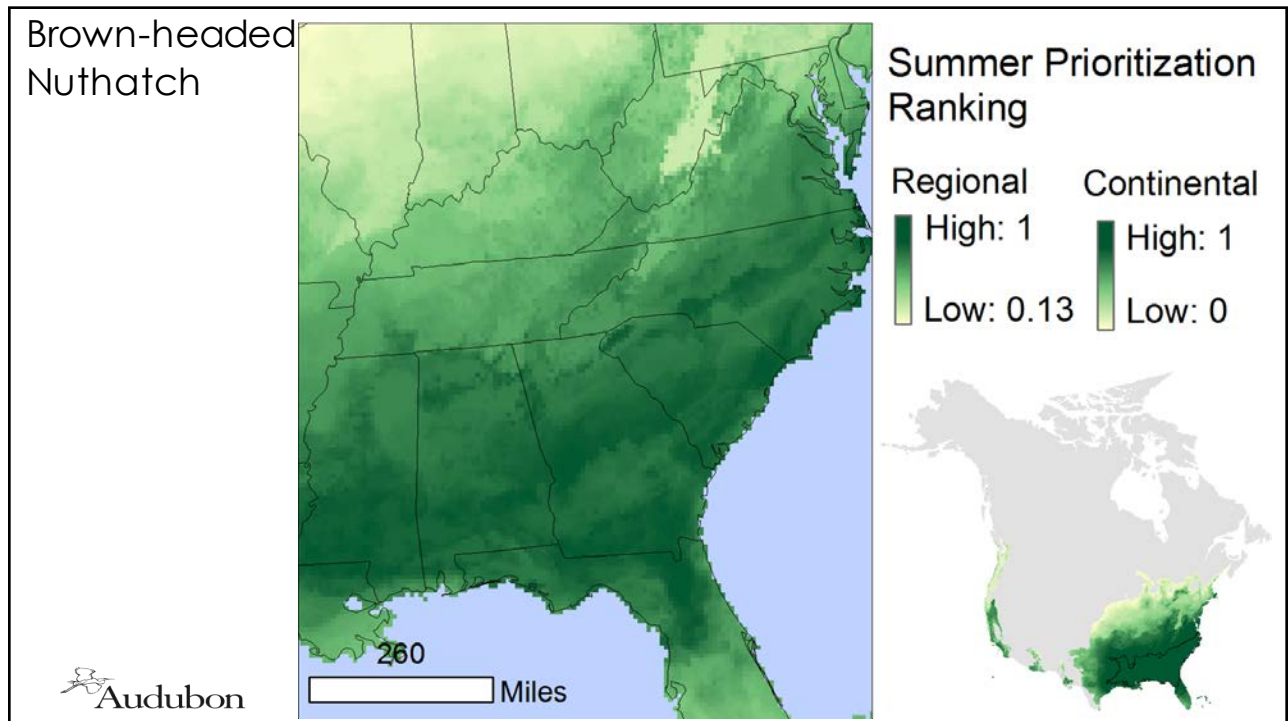
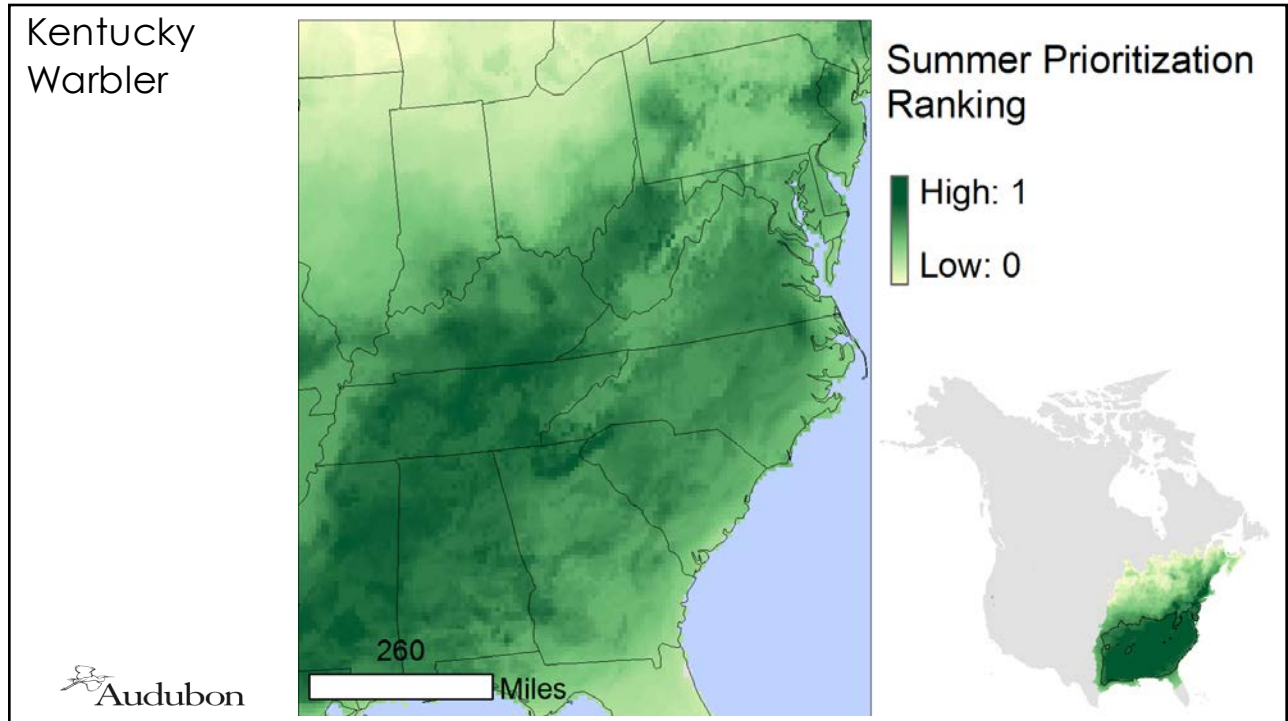
## What are prioritizations used for?

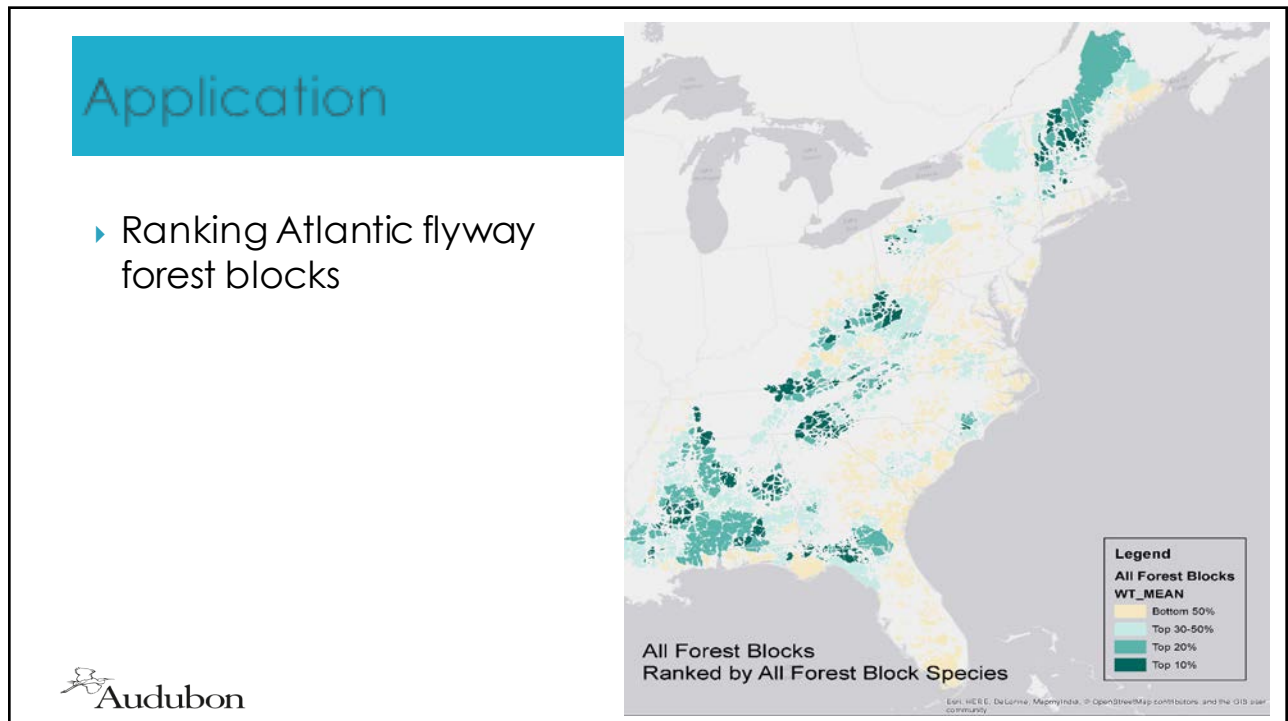
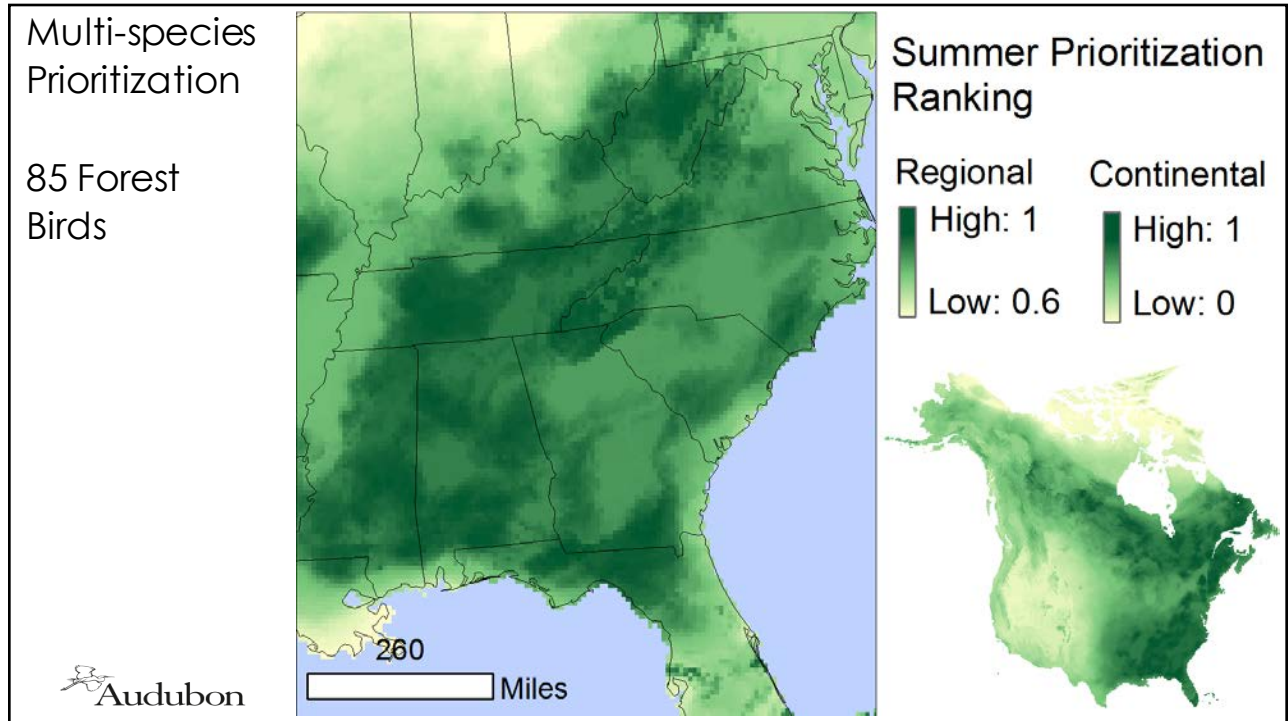
- ▶ Conservation planning
- ▶ Identifying climate strongholds
  - An area that is relatively valuable for retaining one or more bird species while accounting for the potential effects of future climates on their distribution.

## What are prioritizations used for?

- ▶ Conservation planning
- ▶ Identifying climate strongholds
  - An area that is relatively valuable for retaining one or more bird species while accounting for the potential effects of future climates on their distribution.
  - Examples:
    - the top 10% of ranked grid cells within a state or flyway
    - the top ranking existing protected areas within a state or flyway

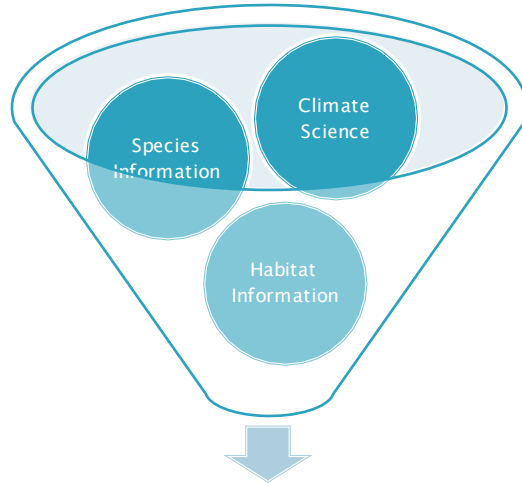






# Conservation framework

- ▶ Incorporate spatial prioritizations into conservation planning



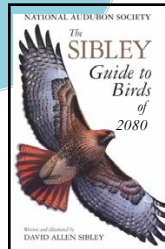
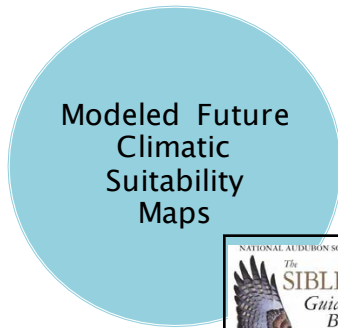
Climate Strongholds



# Tools for climate impacts assessment

At-risk species

Identify climate strongholds



## Future directions for Audubon climate science

- ▶ New partnerships around birds and climate
- ▶ Updating distribution models with additional data and modeling approaches
- ▶ Incorporating the latest generation of climate change scenarios and projections

Audubon's Birds and Climate Change Report

# 314 Species on the Brink

Shrinking and shifting ranges could imperil nearly half of U.S. birds within this century



Burrowing Owl

*By 2080, this diurnal owl species could lose 77 percent of its breeding*

[climate.audubon.org](http://climate.audubon.org)

## Peer-reviewed references

- ▶ Langham GM, et al. (2015) Conservation Status of North American Birds in the Face of Future Climate Change. *PLoS ONE* 10(9): e0135350.
- ▶ Schuetz et al. (2015) Making Spatial Prioritizations Robust to Climate Change Uncertainties: A Case Study with North American Birds, *Ecological Applications*.
- ▶ Distler et al., (2015) Stacked Species Distribution Models and Macroecological Models Provide Congruent Projections of Avian Species Richness Under Climate Change, *Journal of Biogeography* 42(5): 976-988.

## Questions...

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