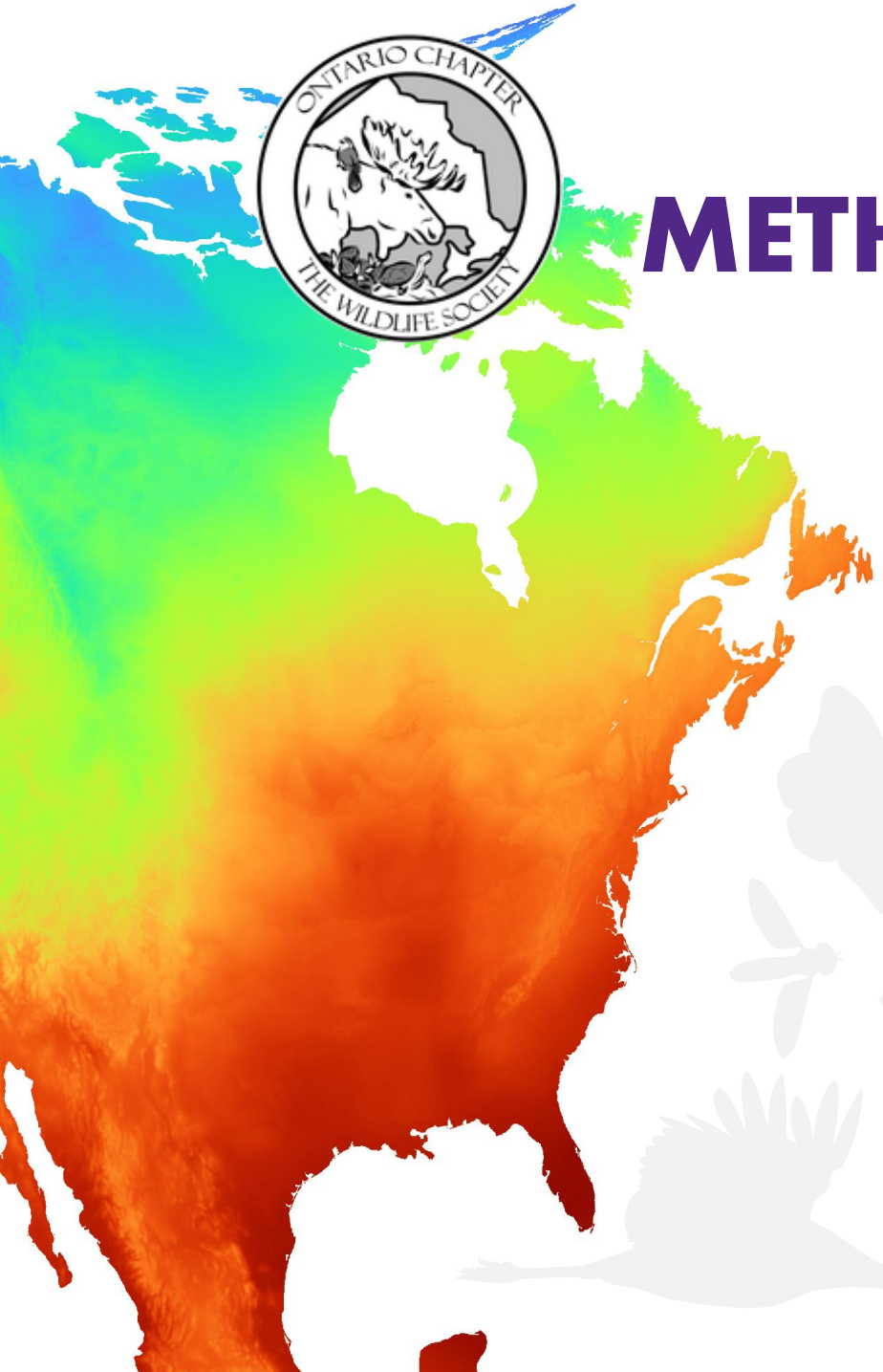


Ontario Chapter of the Wildlife Society

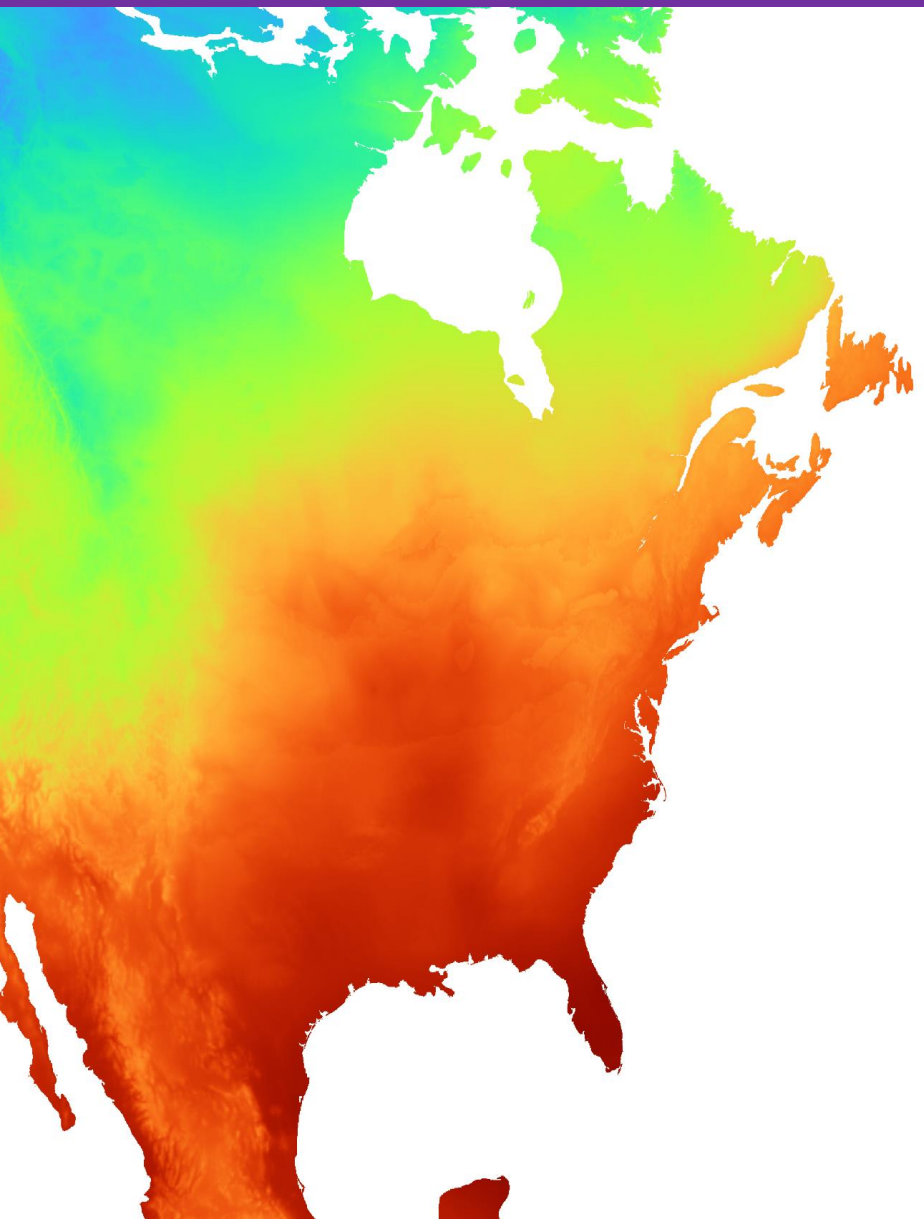
# METHODS IN WILDLIFE RESEARCH

## Introduction to Stable Isotope Assignment in R

Jackson W. Kusack (He/Him)
PhD Candidate
Western
Centre for Animals on the Move

# Overview





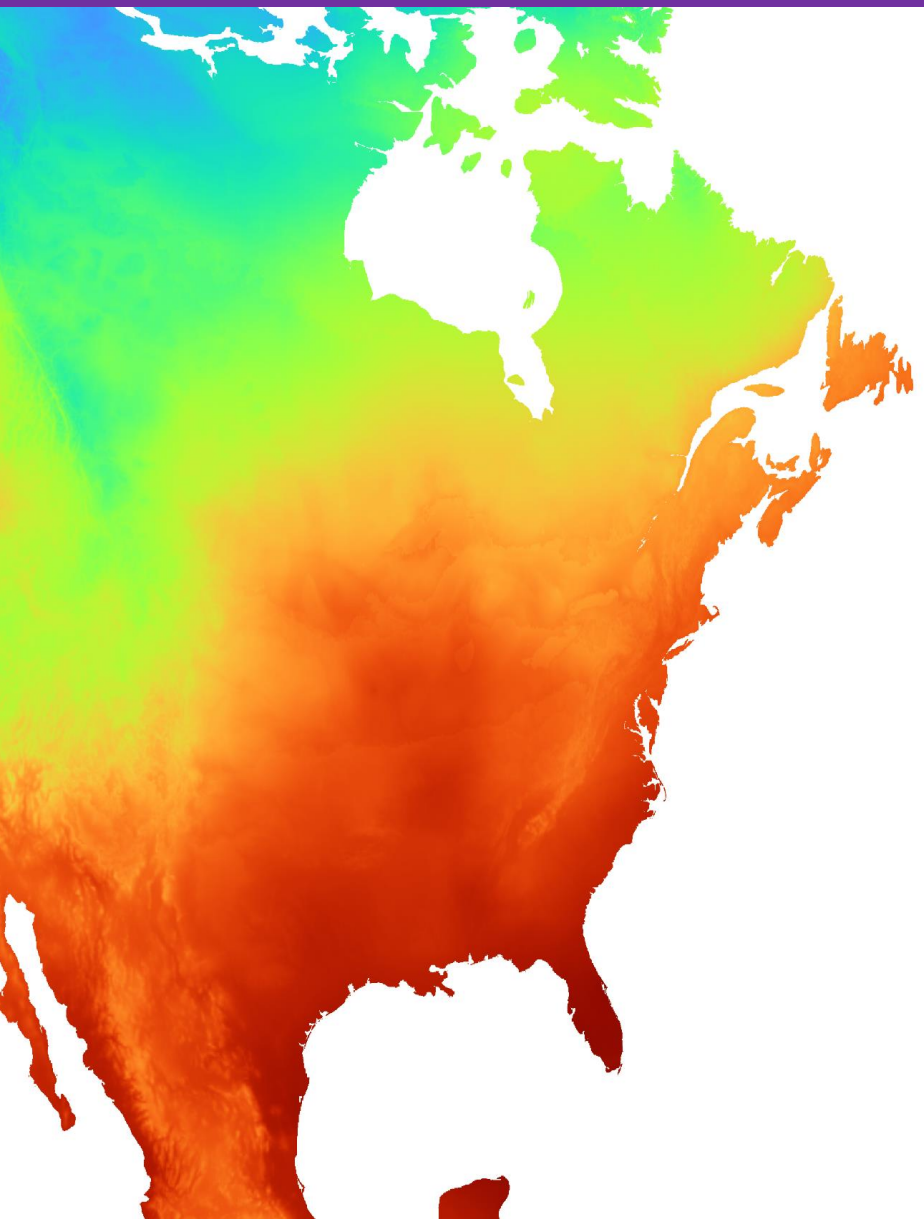
**Can stable isotopes determine where my study species originates?**

**What data do I need?**

**How do I do the data analysis?**

# Overview





**Can stable isotopes determine where my study species originates?**

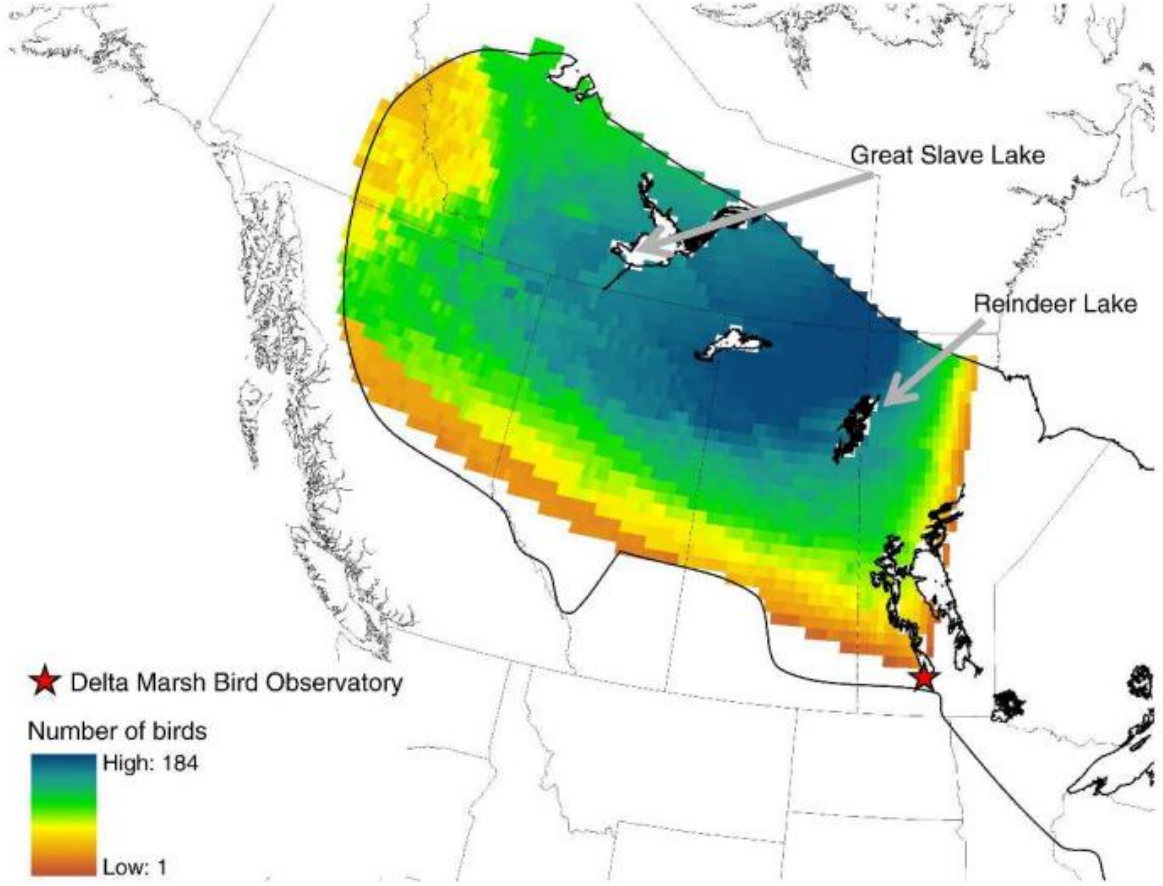
- Background on stable isotopes
- Depends on life-history

**What data do I need?**

**How do I do the data analysis?**

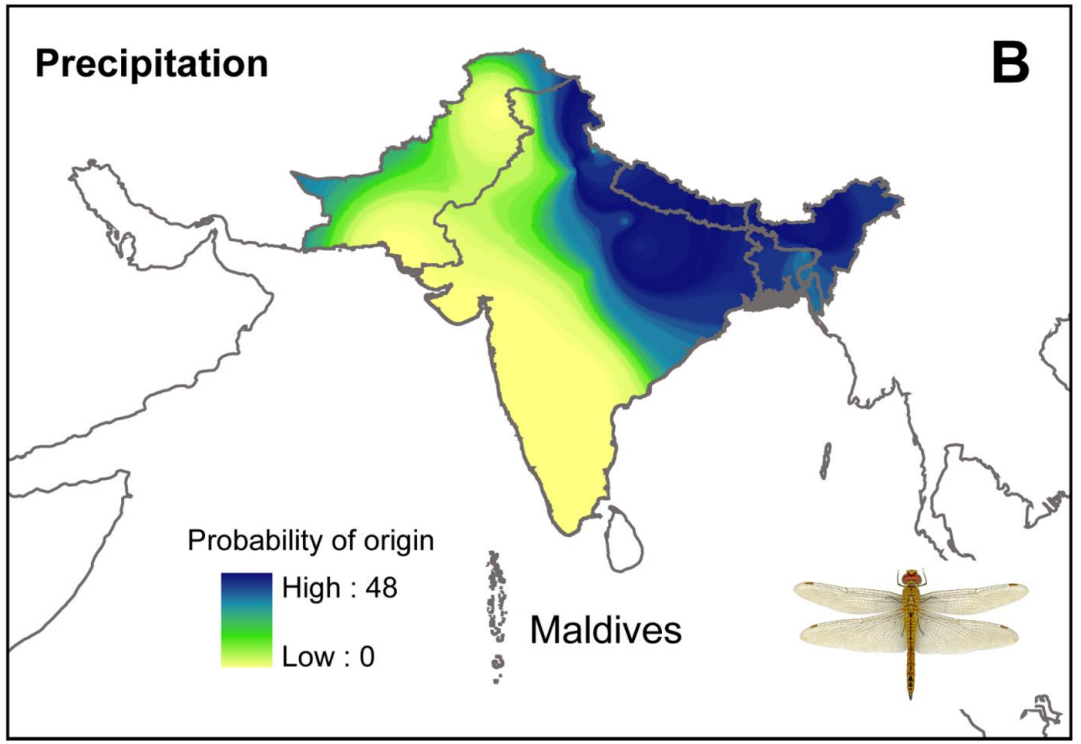
# Likelihood-based Assignment






White-throated Sparrow

(van Wilgenburg and Hobson 2011)

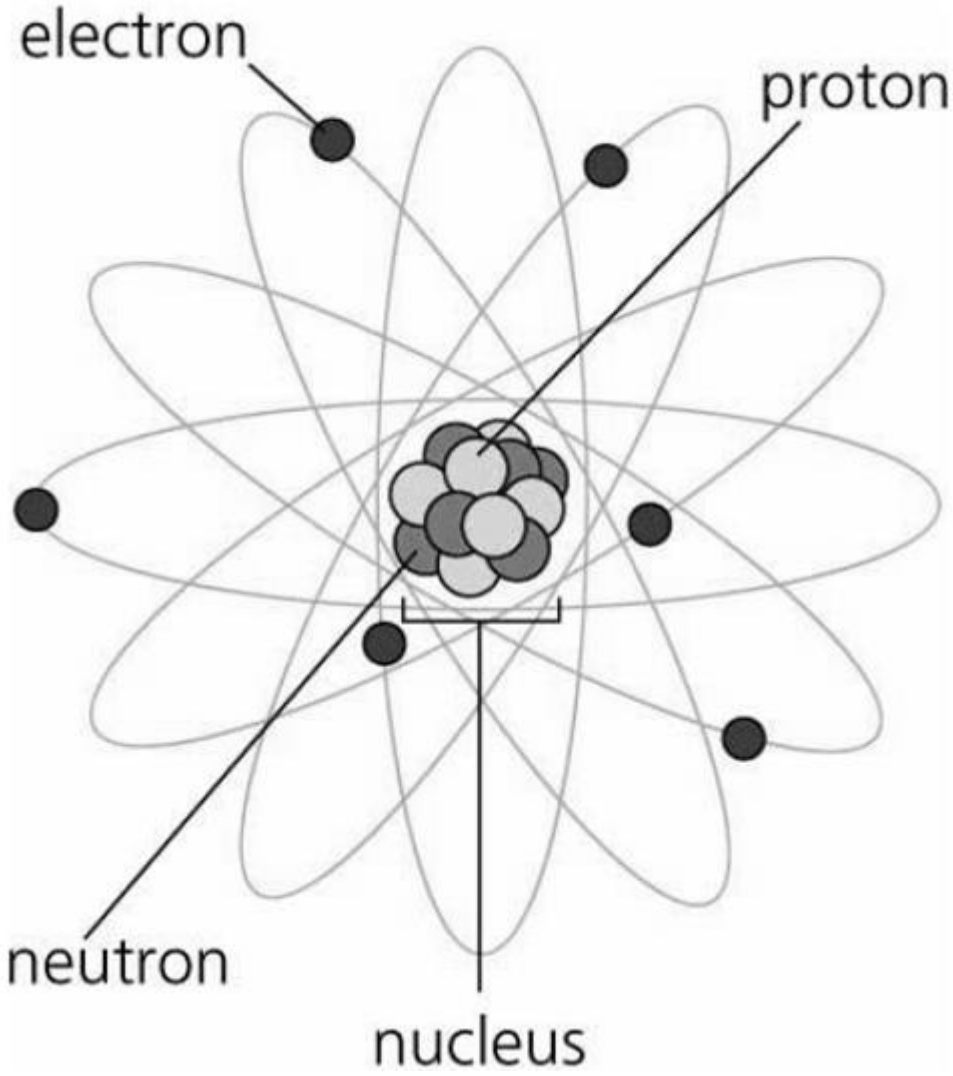



*Pantala flavesens*

(Hobson et al. 2012)

# Stable Isotopes






## Stable

- Not radioactive – does not spontaneously change to another nuclide

## Isotope

- Atoms of the same element, having different atomic weights (additional neutrons) but the same number of protons

# Stable Isotopes



Ratio of **heavy** to **light** stable isotopes

$$^{H}R = \frac{^{H}X \leftarrow \text{Less common}}{^{L}X \leftarrow \text{Common}}$$

$$\delta^{H}X = \left(\frac{R\ sample}{R\ standard} - 1\right) * 1000$$

# Stable Isotopes



'Light' stable-isotopes

$$^{2}H = \frac{^{2}H}{^{1}H}$$

$$^{13}C = \frac{^{13}C}{^{12}C}$$

$$^{15}N = \frac{^{15}N}{^{14}N}$$

$$^{18}O = \frac{^{18}O}{^{16}O}$$

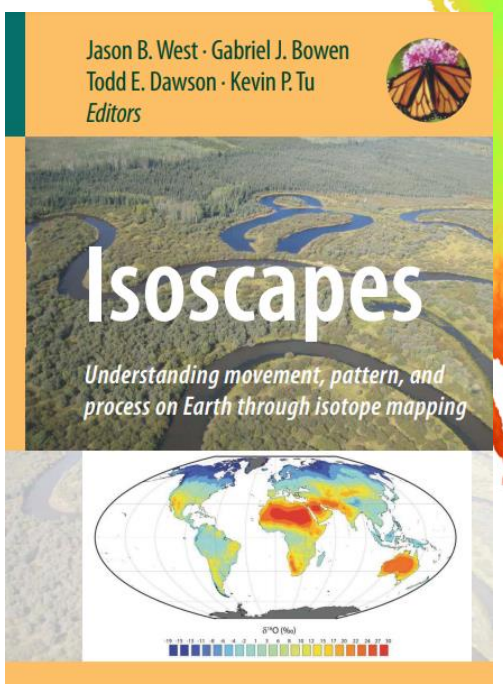
$$^{34}S = \frac{^{34}S}{^{32}S}$$

# Isoscapes



## Isoscape

- **‘iso’**tope land‘**scape’**
- Geospatial representation of predicted stable-isotope values
  - Plant, animal tissue
  - Precipitation, surface, and tap water
  - Bedrock







(Bowen et al. 2005)

# Precipitation isotopes



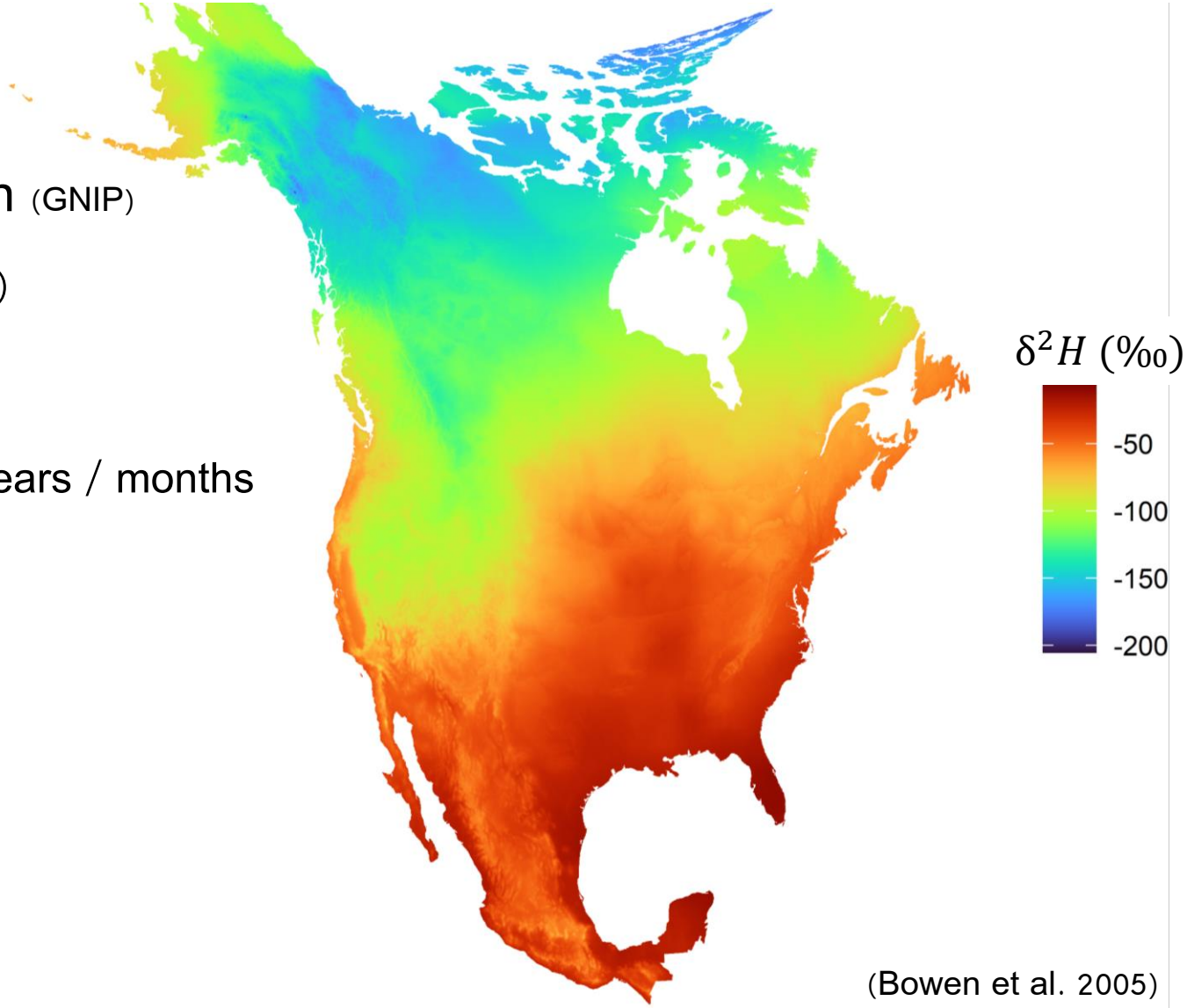
## Hydrogen ($\delta^2$H)

Global Network of Isotopes in Precipitation (GNIP)

- Established 1961 (900 stations / 100 countries)

## Precipitation isoscape

- Amount-weighted average values over many years / months
- Predictable latitudinal and altitudinal gradient
- $\delta^2$H Incorporated into food web




(Bowen et al. 2005)

IAEA International Atomic Energy Agency

# Can stable isotopes determine where my study species originates?

# Life-history



## Distribution

- Breeding/non-breeding

## Movement patterns

- Migration
- Dispersal
- Nomadism
- Human-mediated
  - Trafficking

## Diet

Isotopes within consumer tissues are derived from diet

- What are they eating?
- Where are they eating?

## Development

- Where/when/how are hair/feather/chitin/claw replaced?

# Tissues



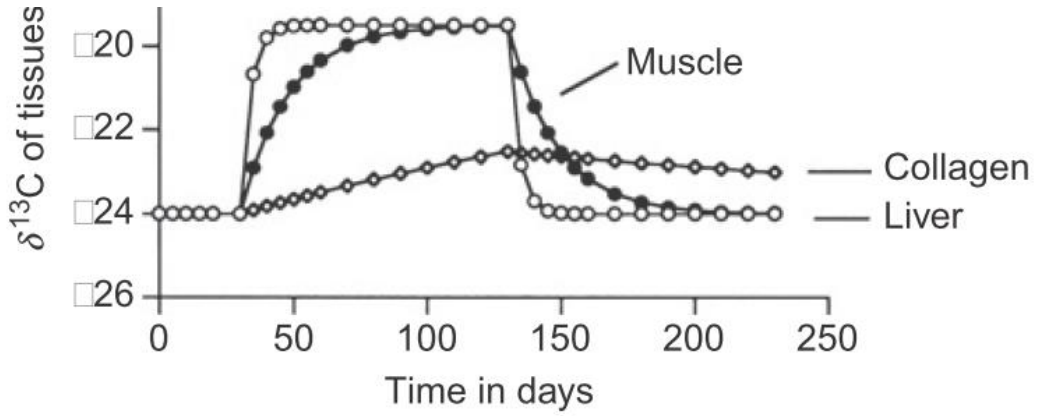
## Isotopic turnover

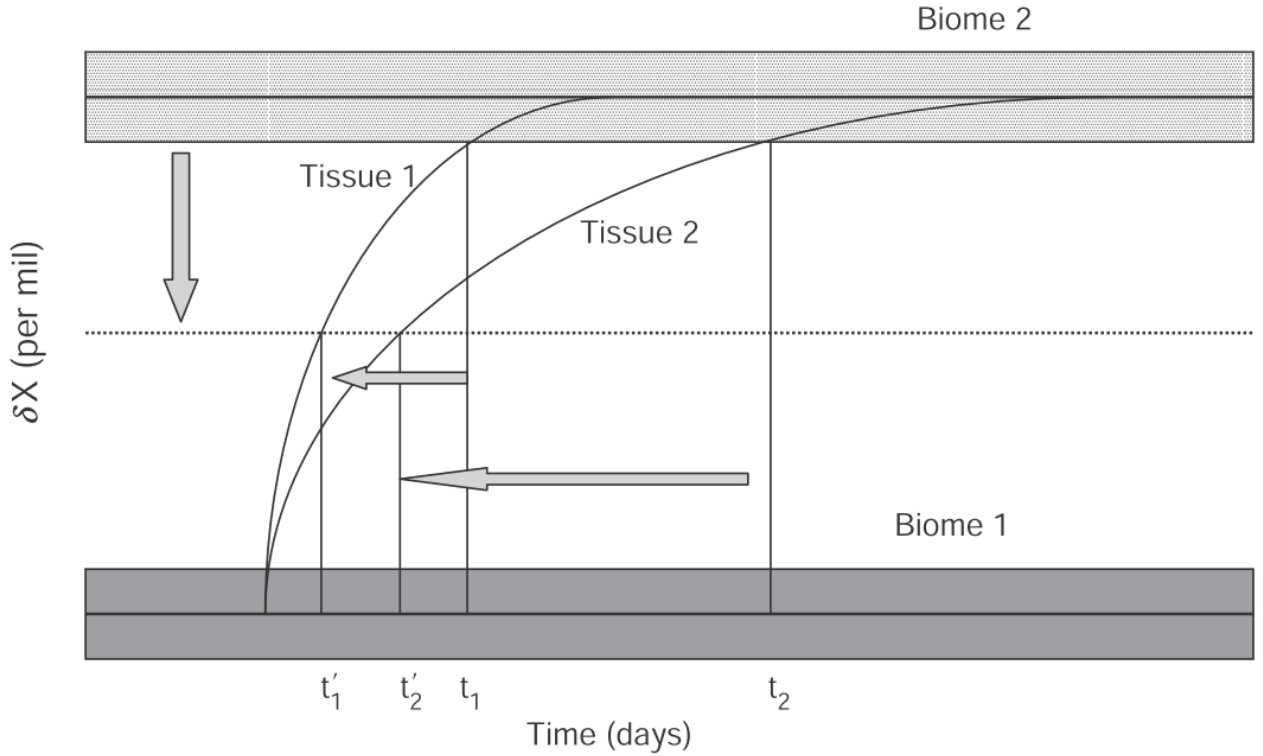
Tissues with constantly changing values:

- Half-life: Liver < Blood < Muscle < Bone

Tissues with fixed values:

- Keratin – Hair, Claw, Feathers, Chitin



# Tissues



## Inert tissue

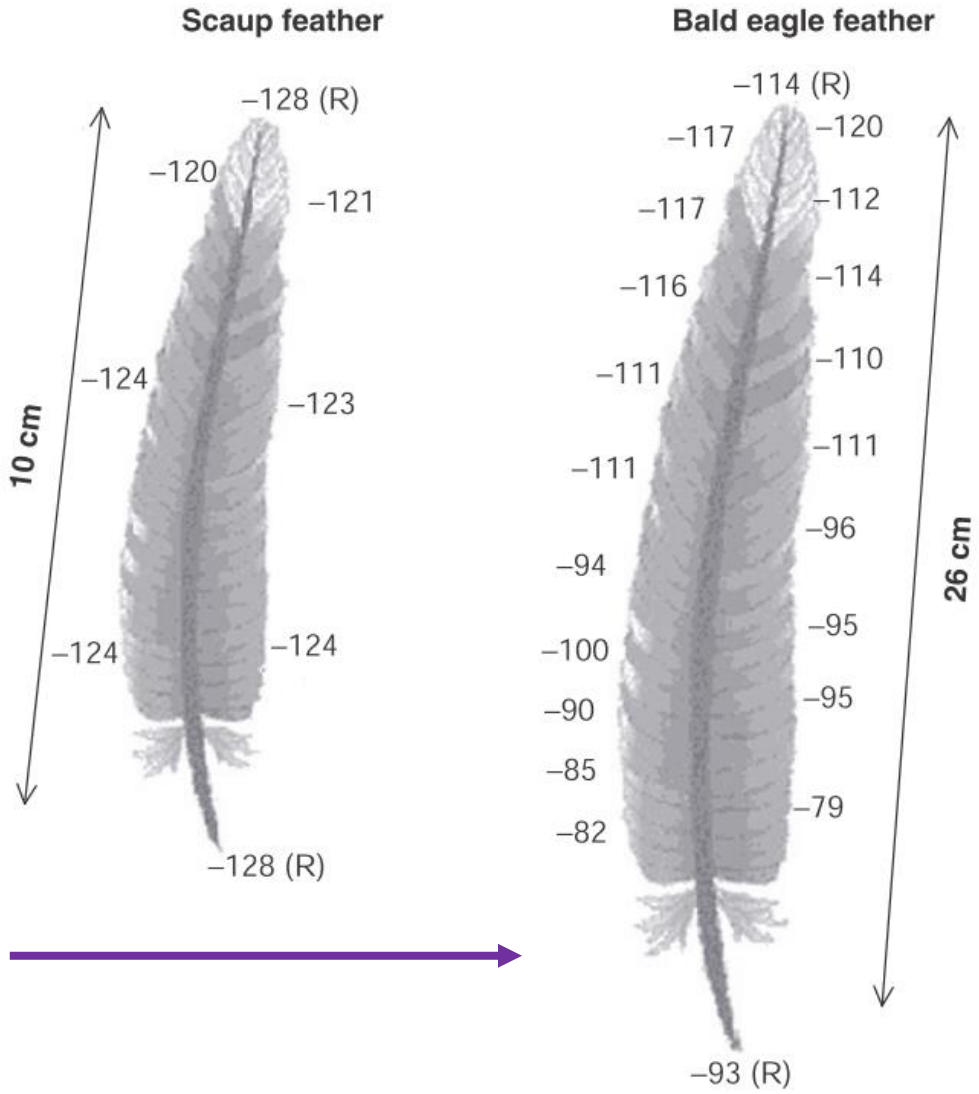
- Representative of diet during growth

**Synchronous moult**: all feathers are replaced simultaneously

- **Immature** – natal site
- **Adult** – moulting site

**Asynchronous moult:** feathers are replaced at different times

- **Adult** – initial moulting site + stopovers



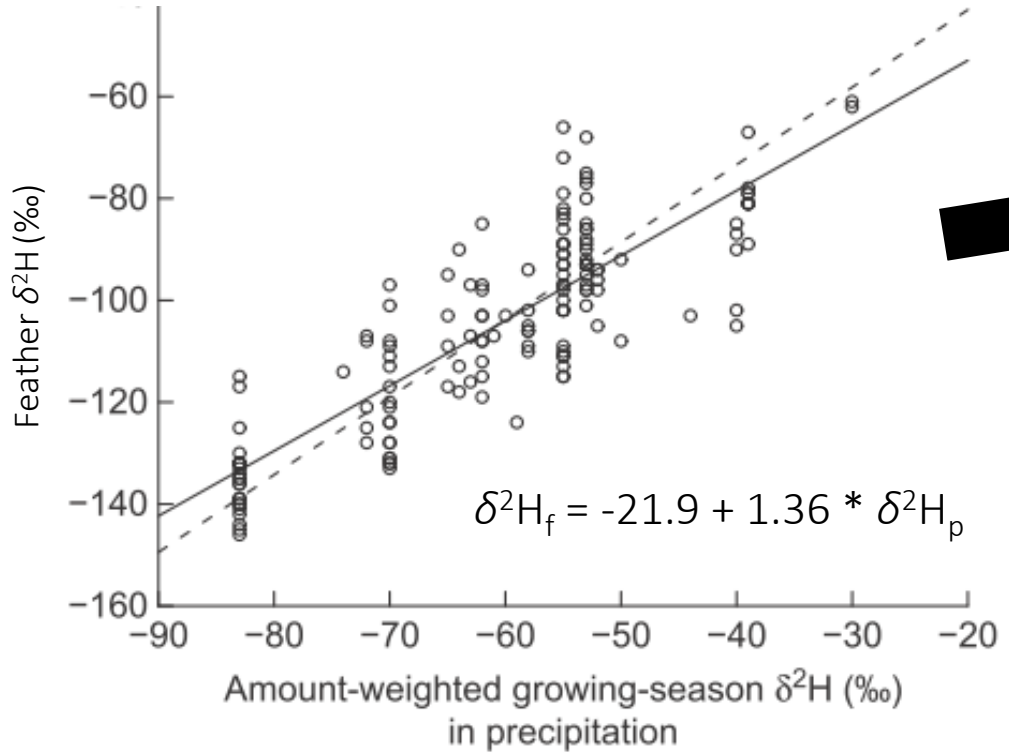
# Calibration

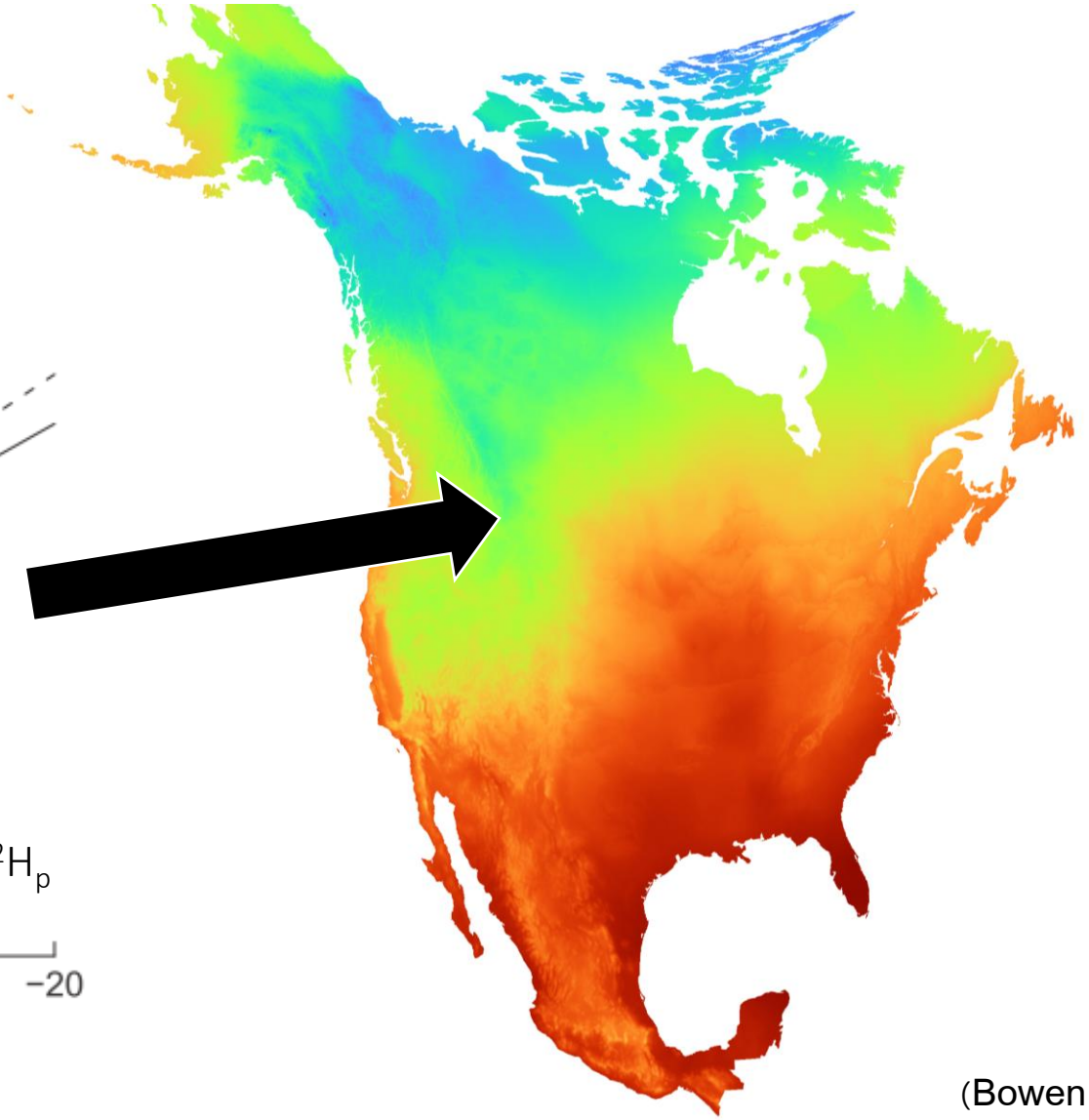


## Calibration equation

Relationship between $\delta^2H_p + \delta^2H_f$

- Tissues grown at known locations

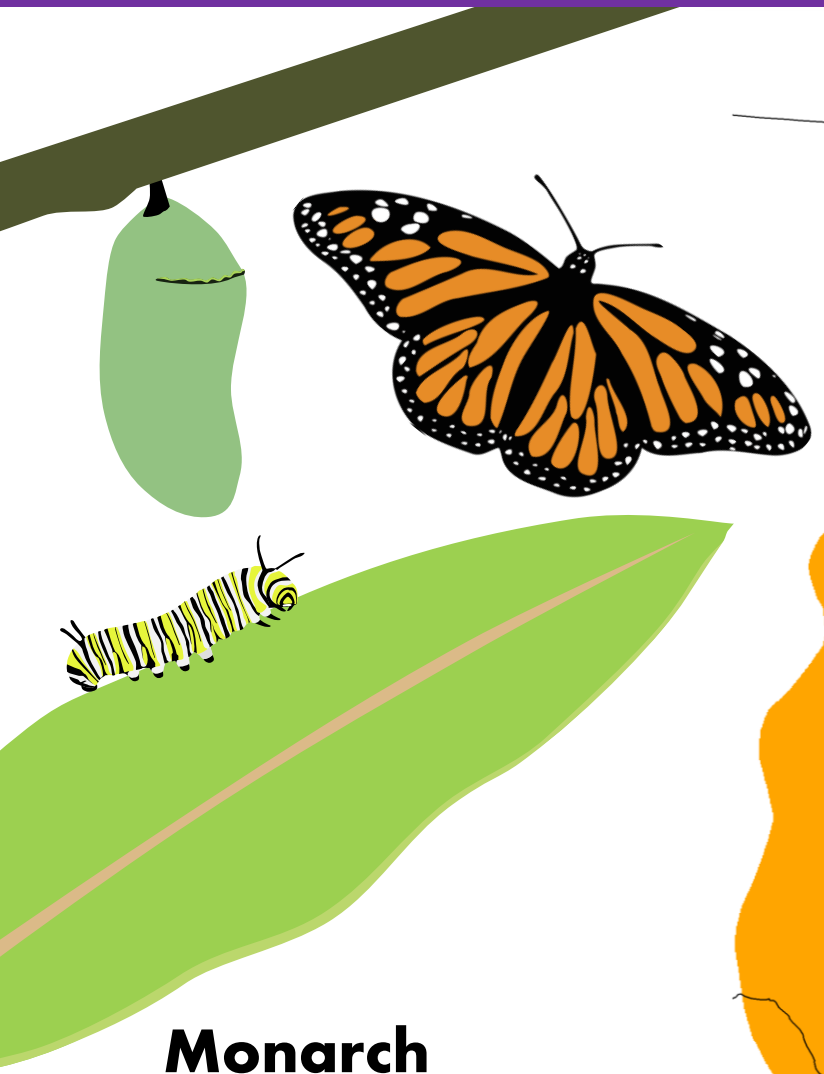


(Bowen et al. 2005)

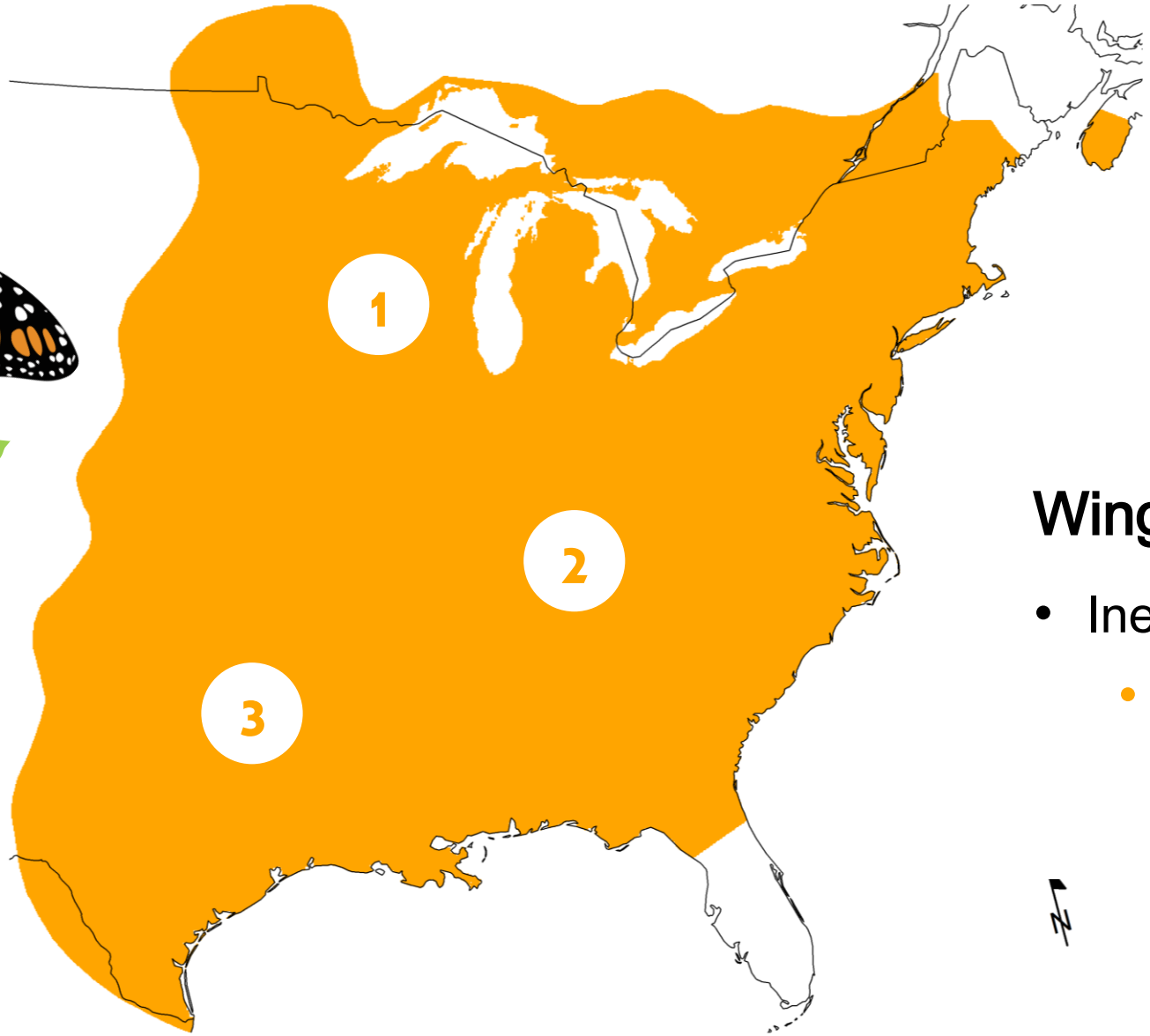
# Example





**Monarch**

*Danaus plexipplus*

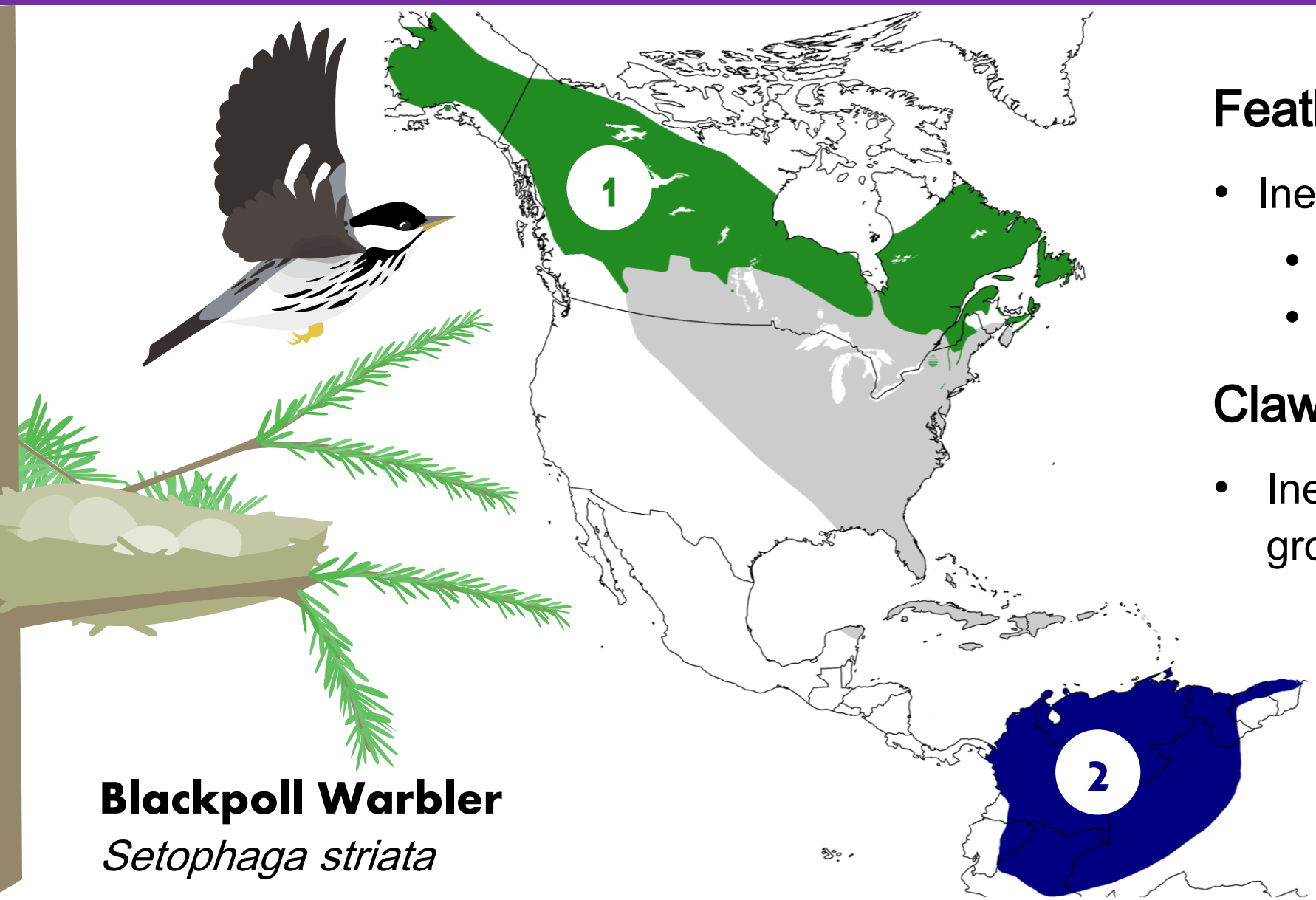



## Wing Chitin $\delta^2H$

- Inert tissue
  - Natal site

# Example






**Blackpoll Warbler**
*Setophaga striata*

## Feather $\delta^2$H

- Inert tissue
  - 1. Head – Non-breeding
  - 2. Primary – Breeding

## Claw $\delta^2$H

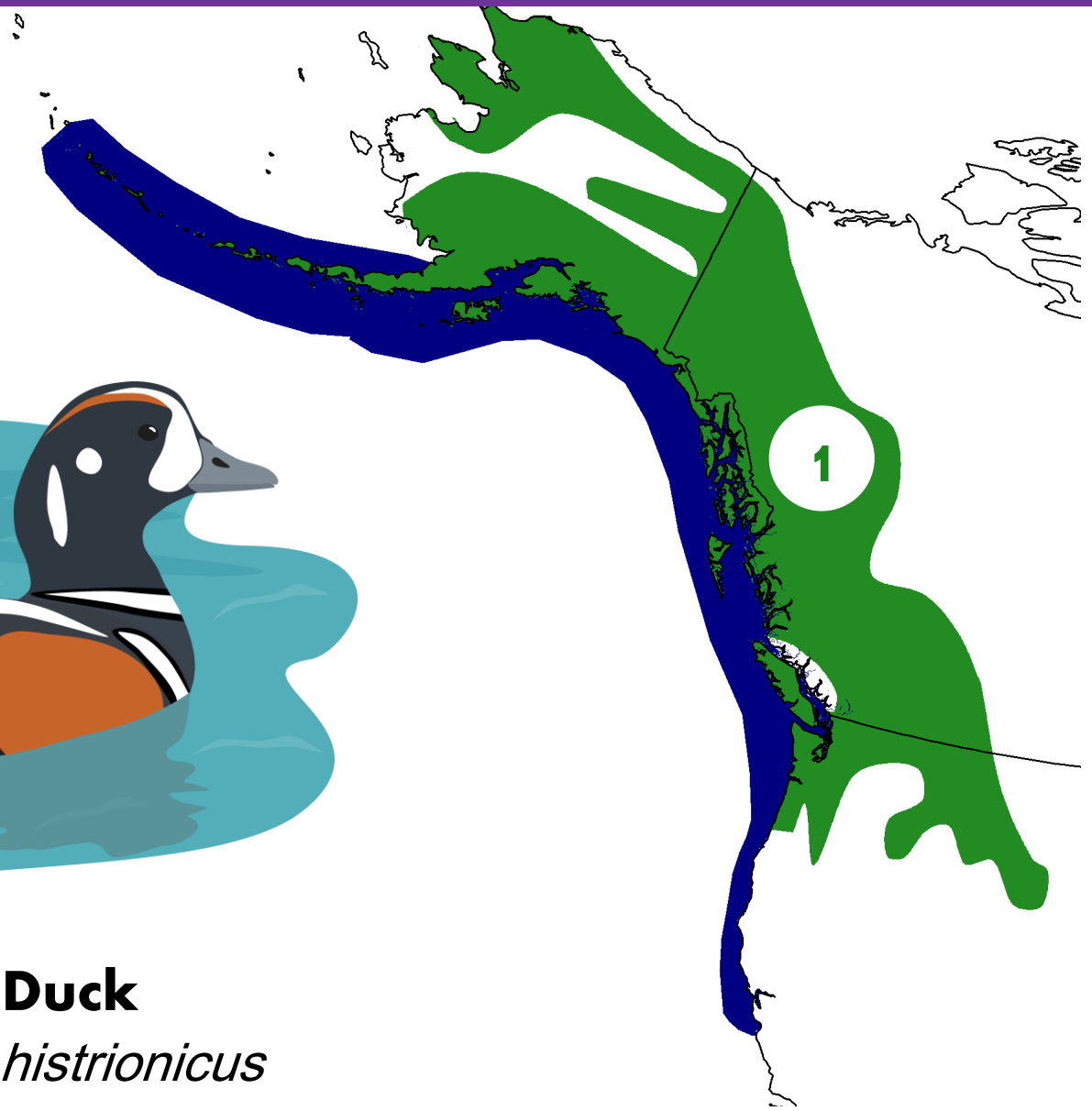
- Inert tissue but continuously grows, depends on timing

# Example



**Harlequin Duck**

*Histrionicus histrionicus*




## Feather $\delta^2$H

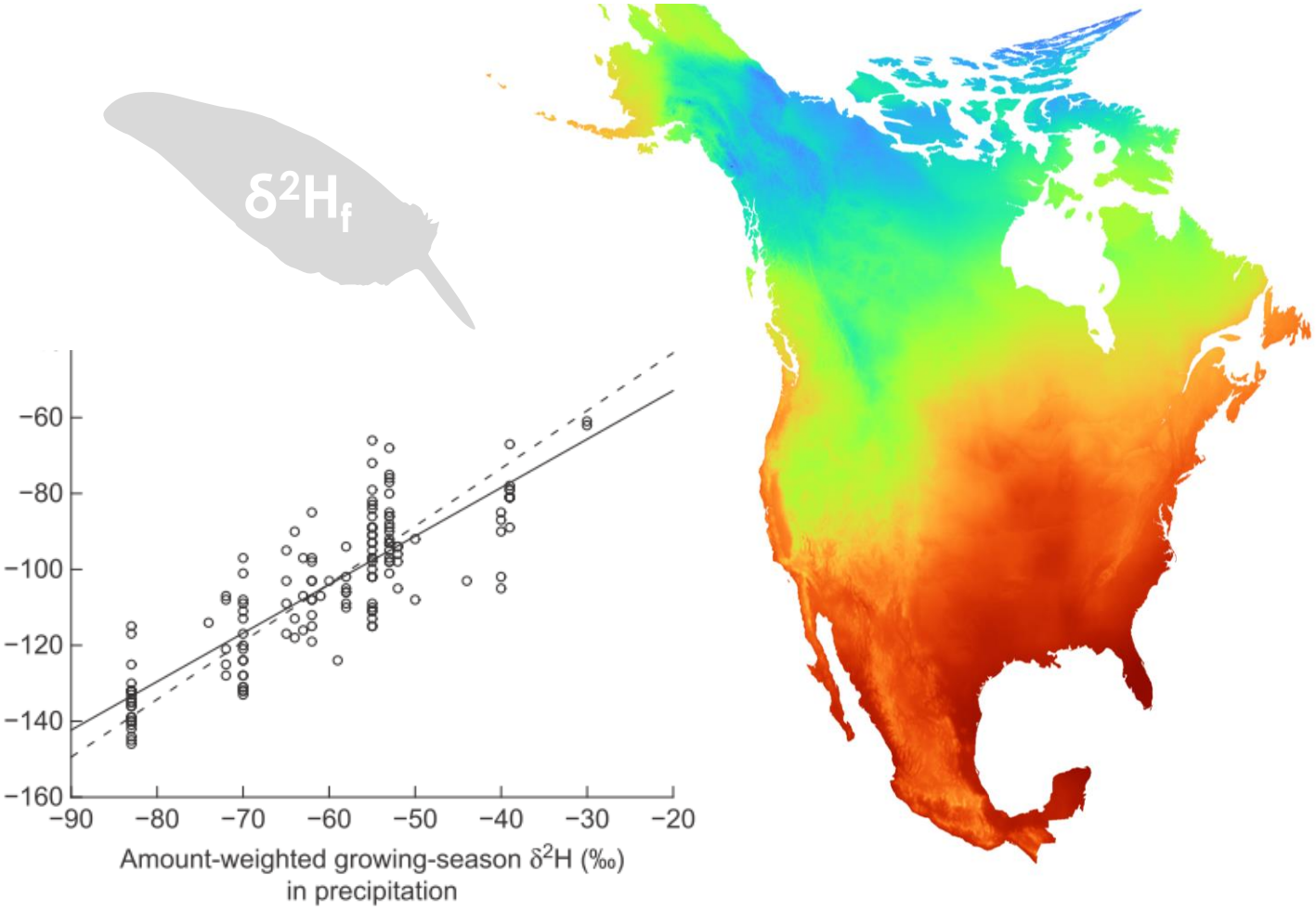
- Inert tissue
  - 1. Primary (Adult) – Non-breeding (Marine)
  - 2. Primary (Juvenile) – Breeding

# What data do I need?

# Stable Isotopes



- Tissue $\delta^2H$
- Isoscape
- Calibration
- *Priors

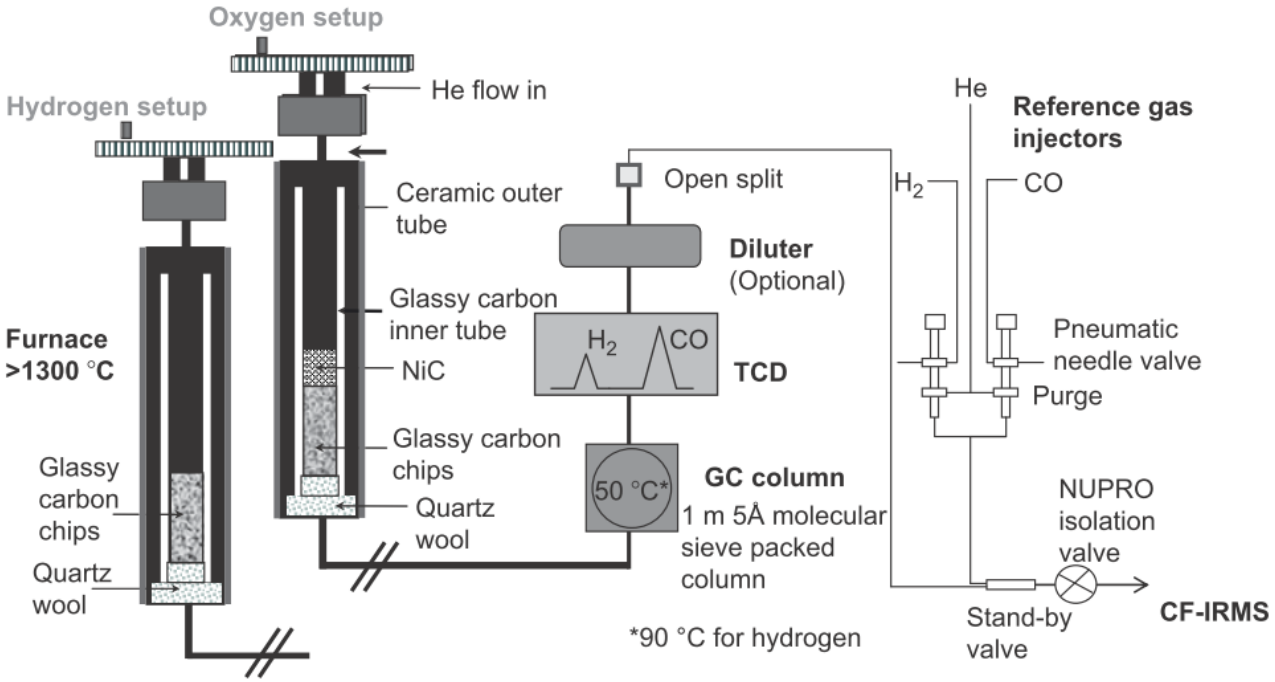


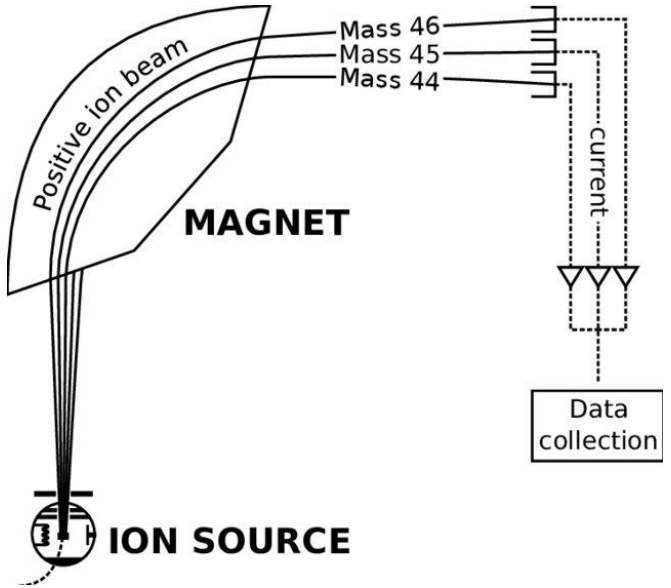
# Tissue $\delta^2H$



## Continuous-flow isotope-ratio mass spectrometry (CF-IRMS)

- Measure small differences in the abundances of isotopes

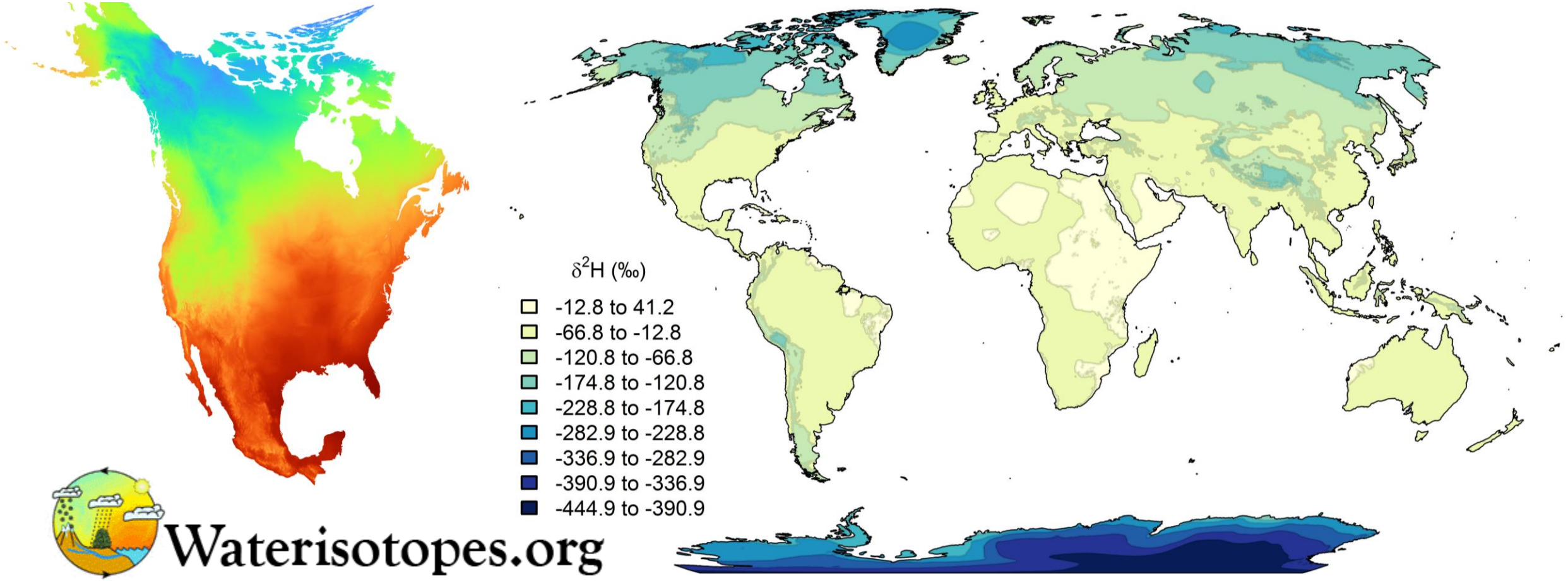


# Isoscapes



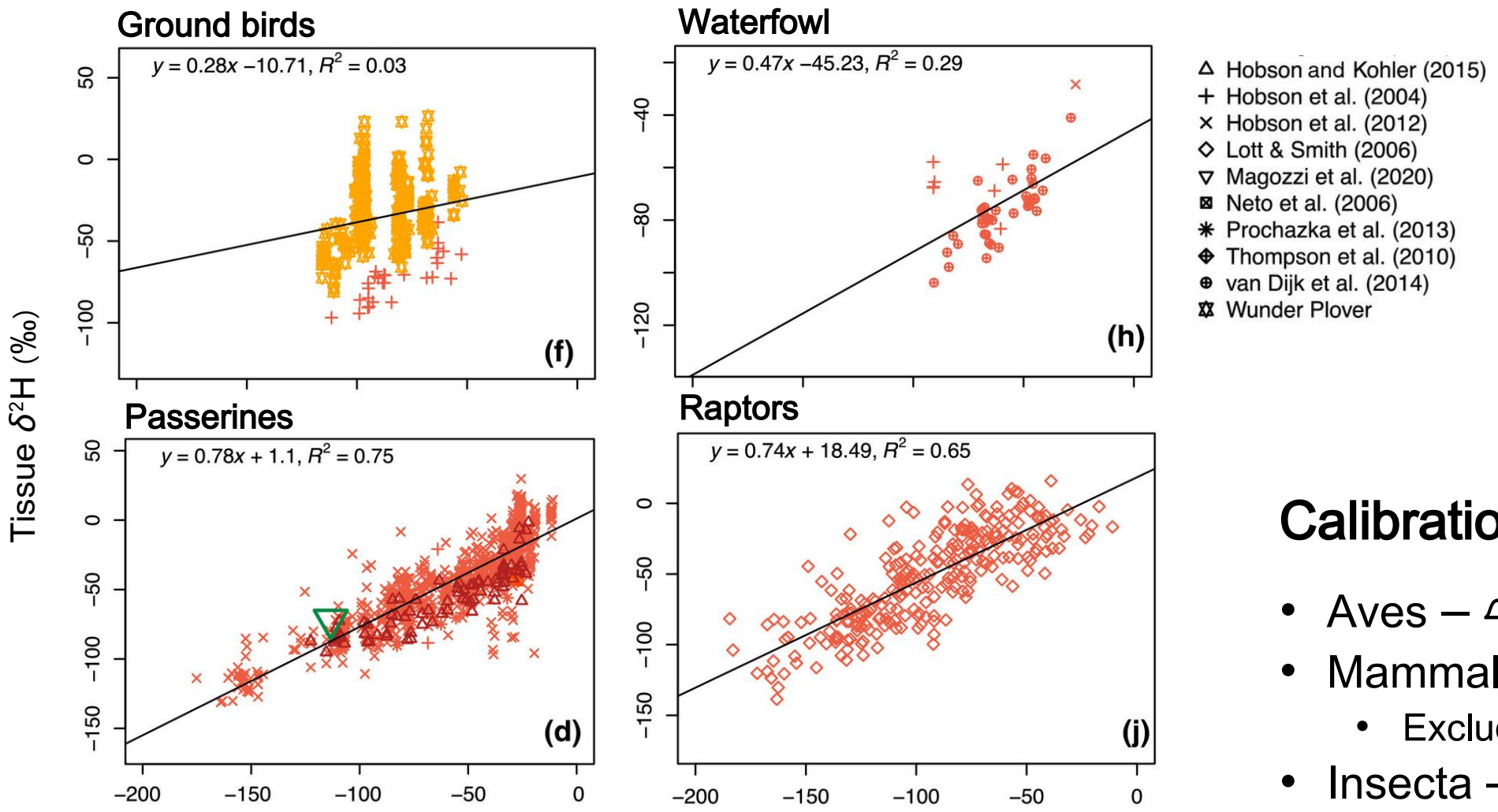
## Hydrogen ($\delta^2$H) Isoscapes




(Bowen et al. 2005)

# Calibration data






(Magozzi et al. 2021)

## Calibration Studies:

- Aves – 42
- Mammalia – 5
  - Excluding humans
- Insecta – 10

# Priors

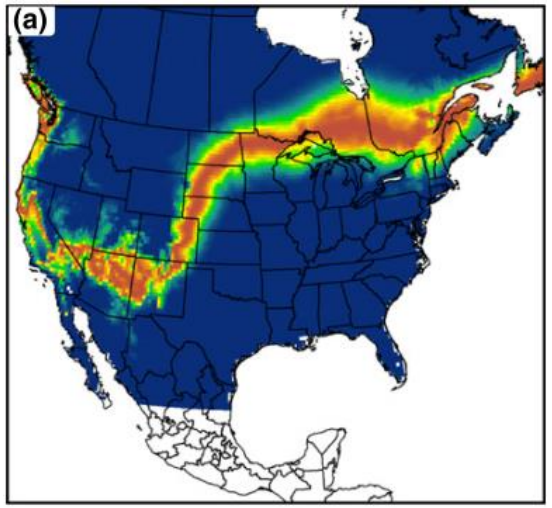


## Prior probability of origin

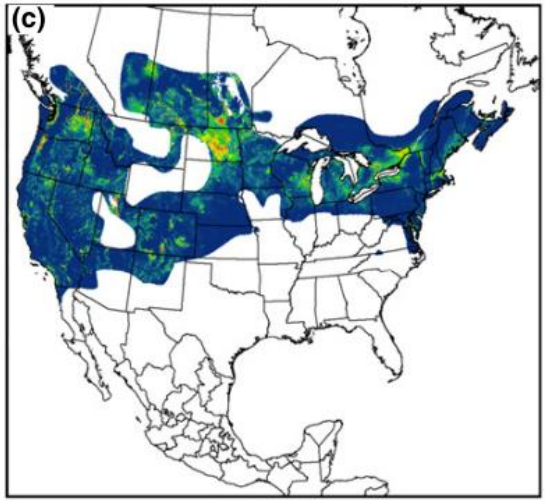
Refine assignment to origin using other sources of information

- **Banding data** (Palumbo et al. 2019)
- **Genetics** (Chabot et al. 2012)
- **Habitat composition** (Ruegg et al. 2017)
- **Relative abundance** (Fournier et al. 2017)

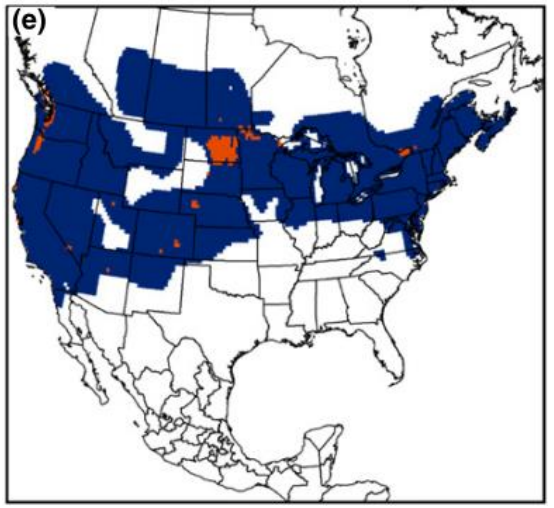
Stable-hydrogen isotopes




Relative abundance




Combined




(Modified from Fournier et al. 2017)

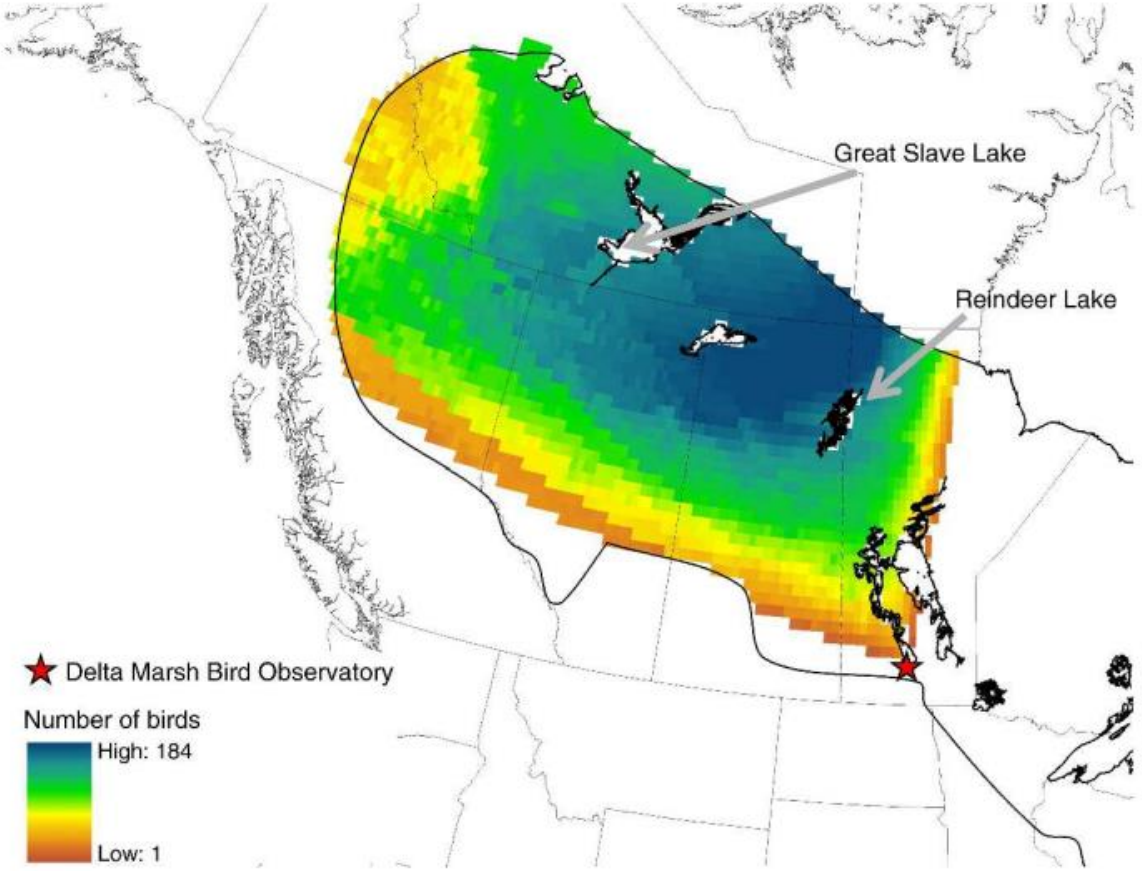
# How do I do the data analysis?

# Assignment



## Likelihood-based assignment

- Compare stable isotope values within feathers to isoscapes to determine likely origins
- Color scale represents the number of individuals that were likely assigned at any pixel

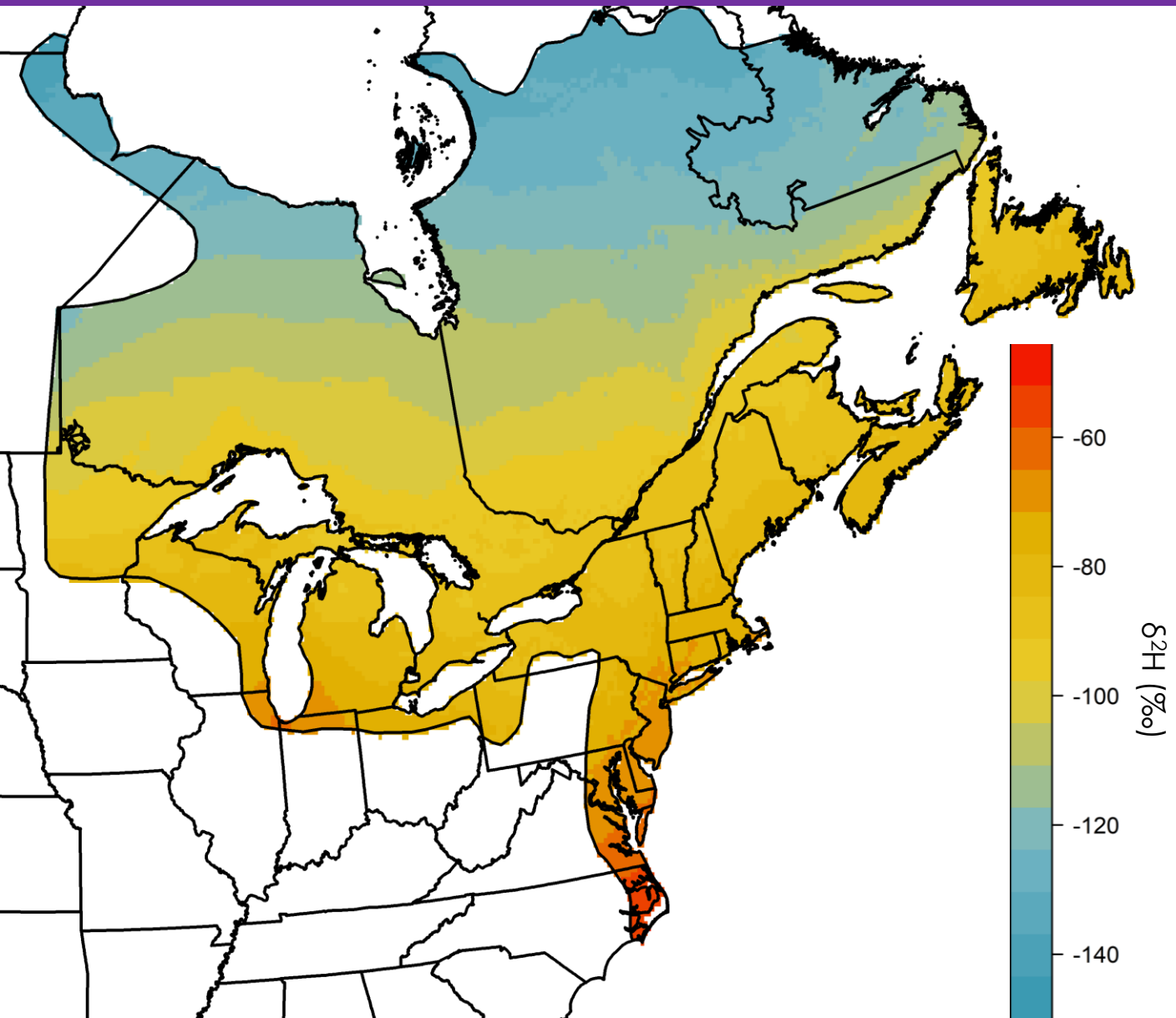



White-throated Sparrow

(van Wilgenburg and Hobson 2011)

# Assignment



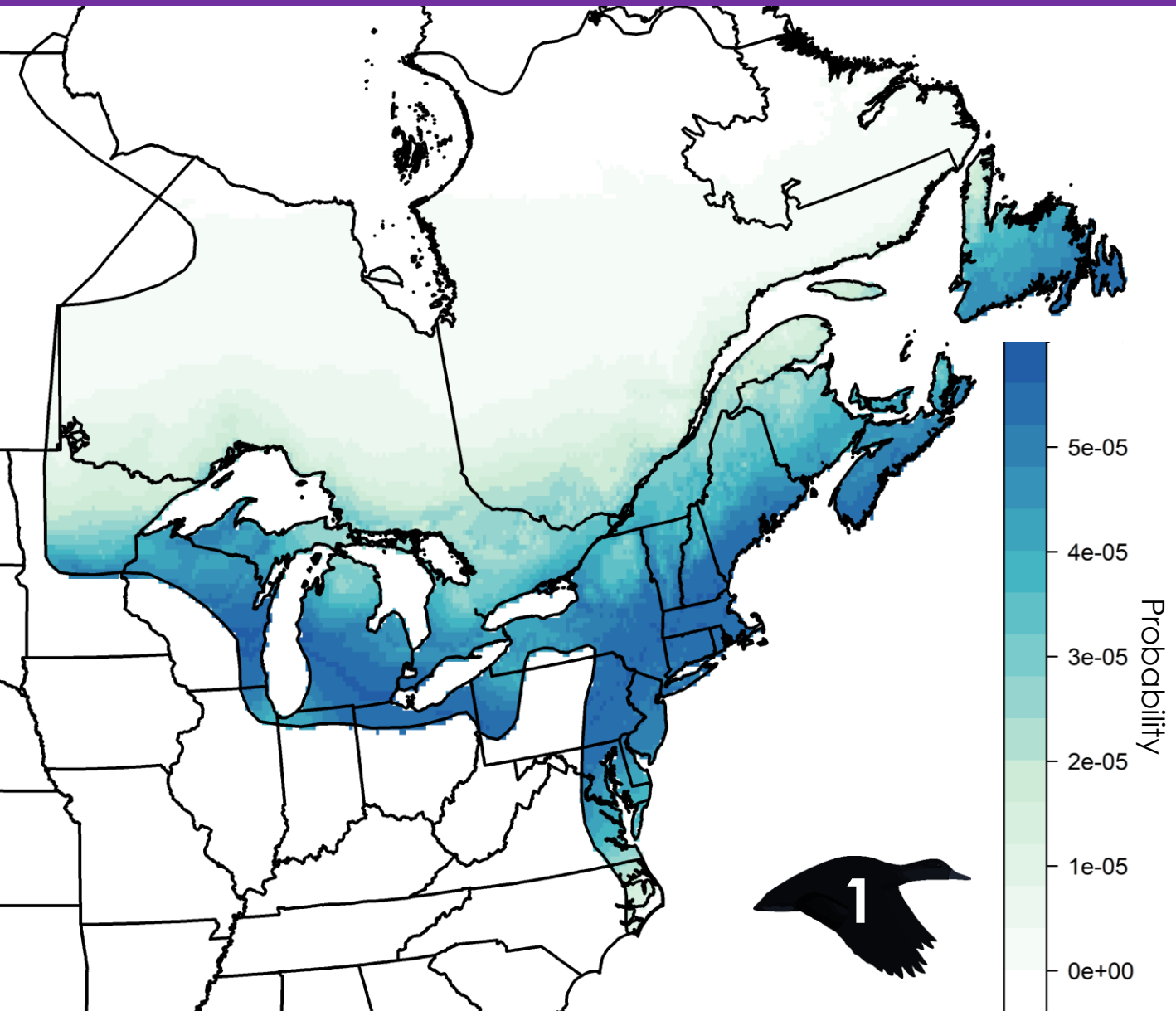



## Likelihood-based Assignment

1. Restrict isoscape to breeding range
   - Only interested in the area where the individual could have originated from

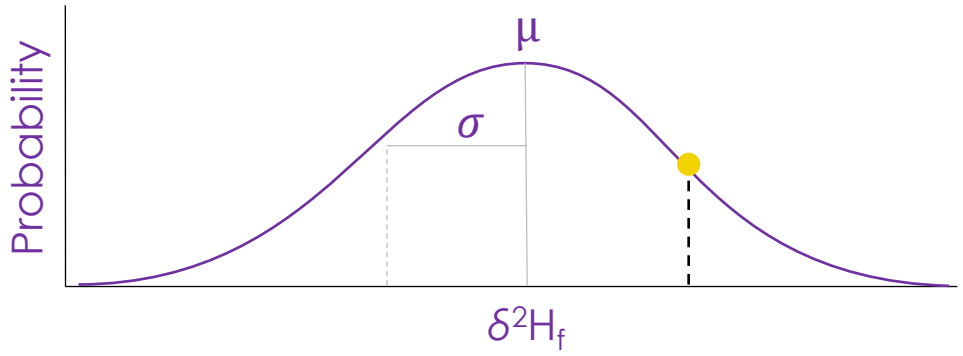
# Assignment






## Likelihood-based Assignment

2. For every pixel, estimate probability that it is the origin, based on the ducks $\delta^2H_f$ and the pixel's $\delta^2H_f$

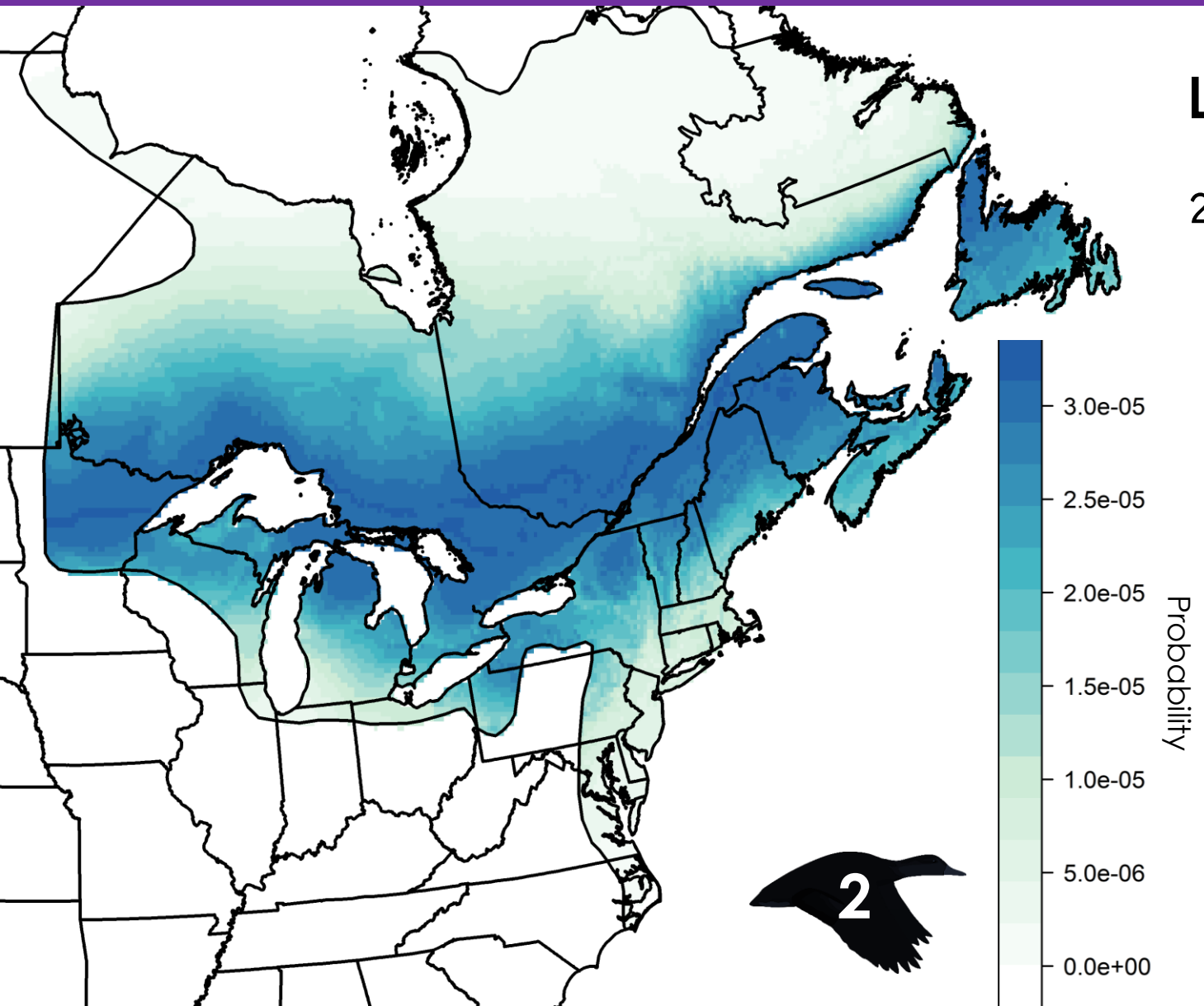



$$f(y|\mu_c,\sigma_c) = \left(\frac{1}{\sigma_c\sqrt{2\pi}}\right) e\left[-\frac{(y-\mu_c)^2}{2{\sigma_c}^2}\right]$$

Normal probability density function

# Assignment



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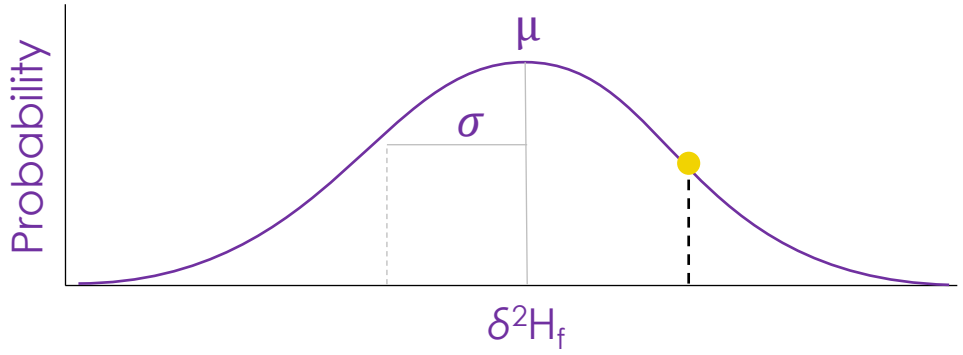


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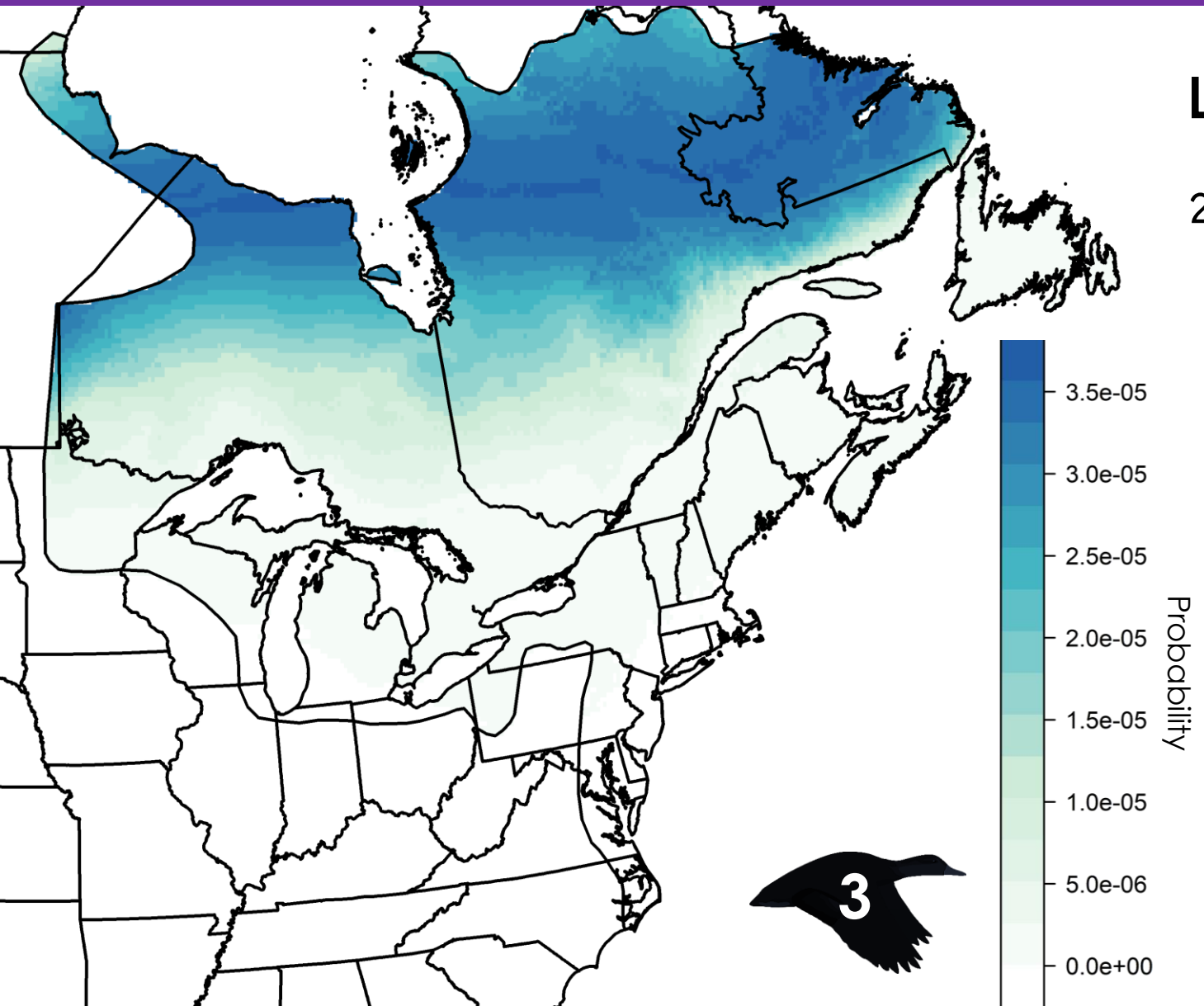
Normal probability density function

# Assignment






## Likelihood-based Assignment

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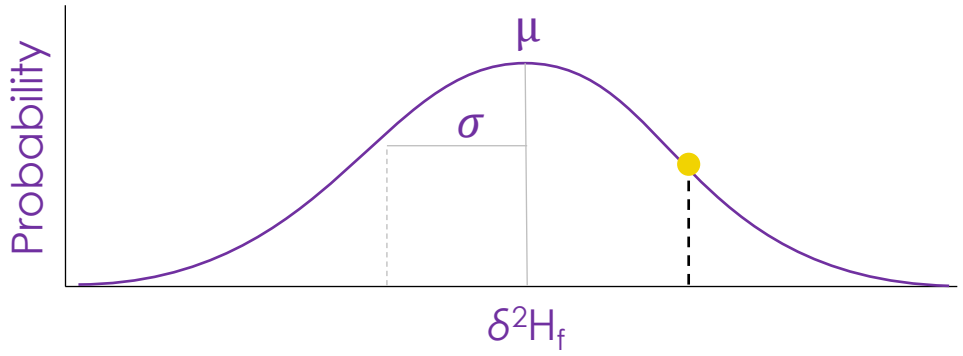
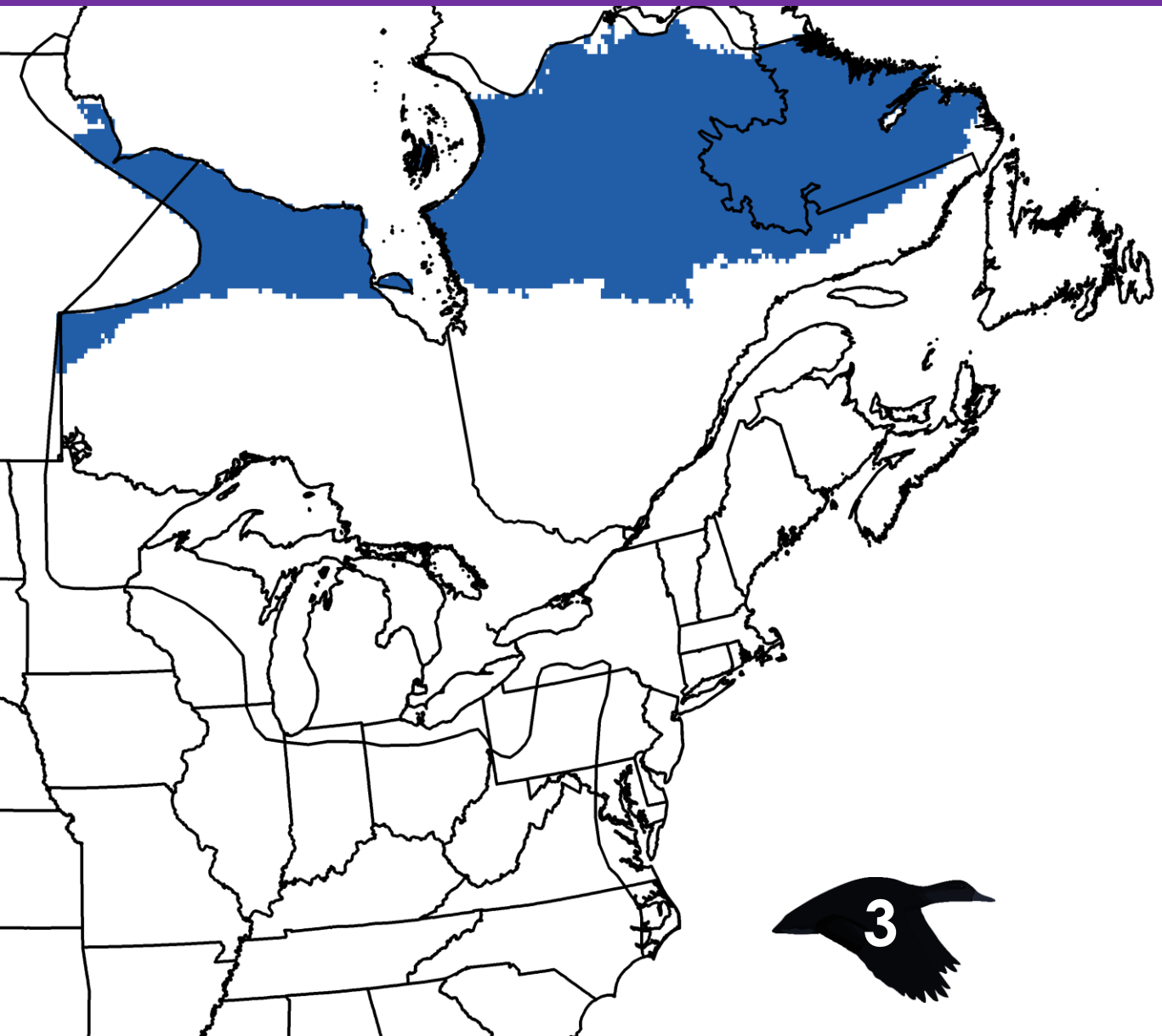



$$f(y|\mu_c,\sigma_c) = \left(\frac{1}{\sigma_c\sqrt{2\pi}}\right) e\left[-\frac{(y-\mu_c)^2}{2{\sigma_c}^2}\right]$$

Normal probability density function

# Assignment





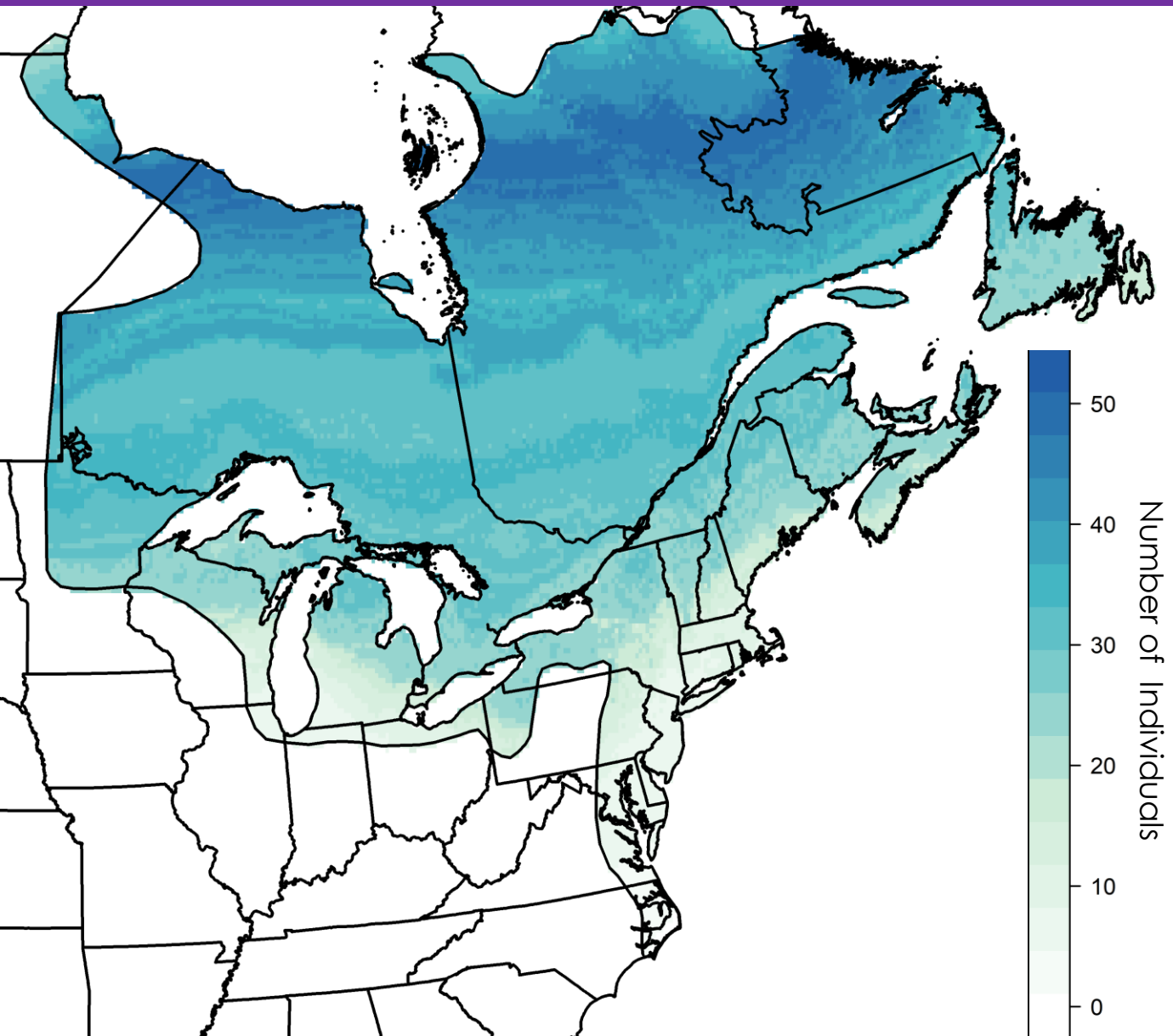



## Likelihood-based Assignment

3. Simplify the region into a binary ‘likely’ origins region
   - **Odds ratio** - Odds (2:1 here) that a given bird had truly originated from within the simplified range

# Assignment



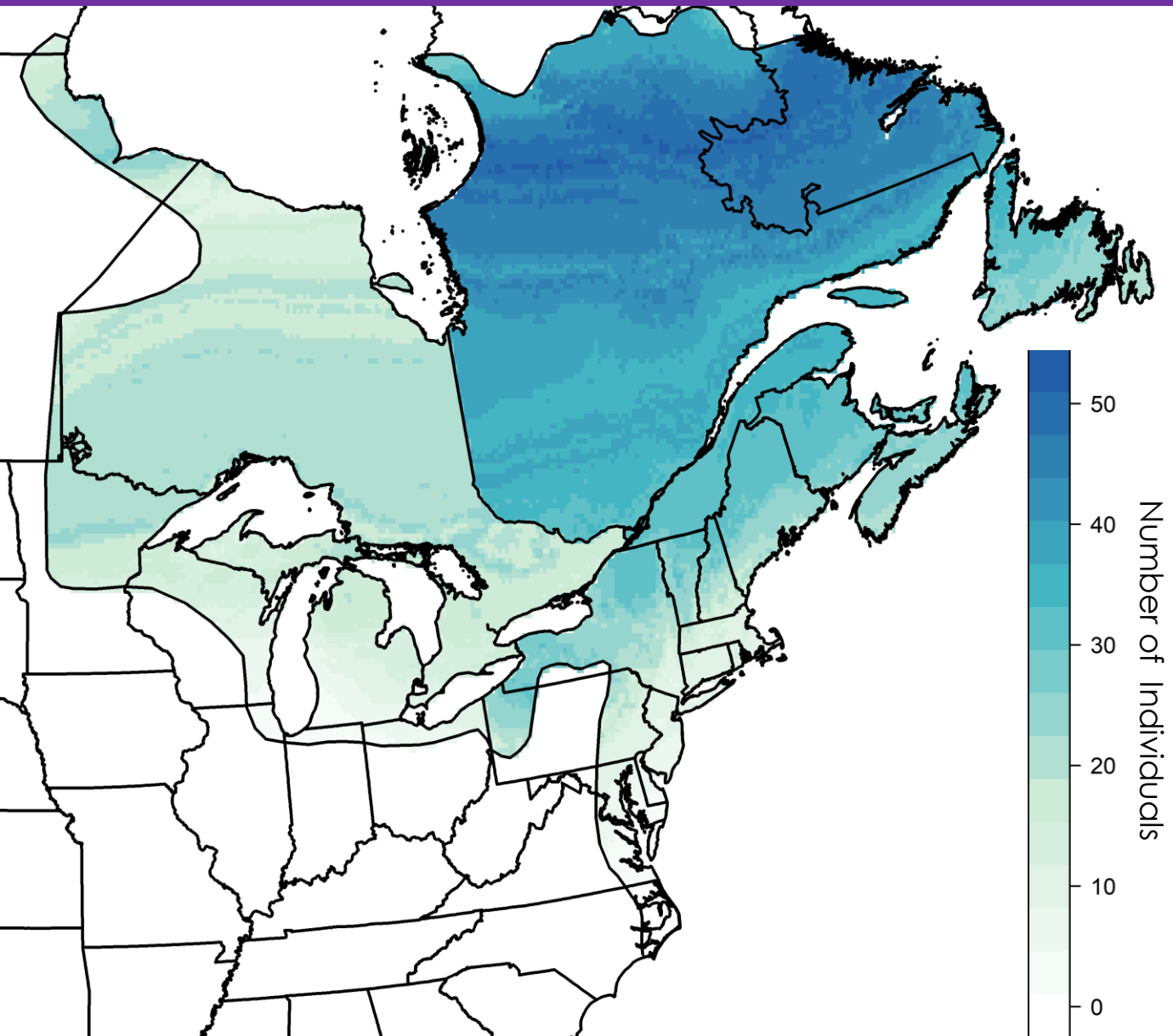



## Likelihood-based Assignment

4. Sum the surfaces across all individuals
   - The scale represents the number of individuals assigned to any pixel

# Assignment






## Likelihood-based assignment

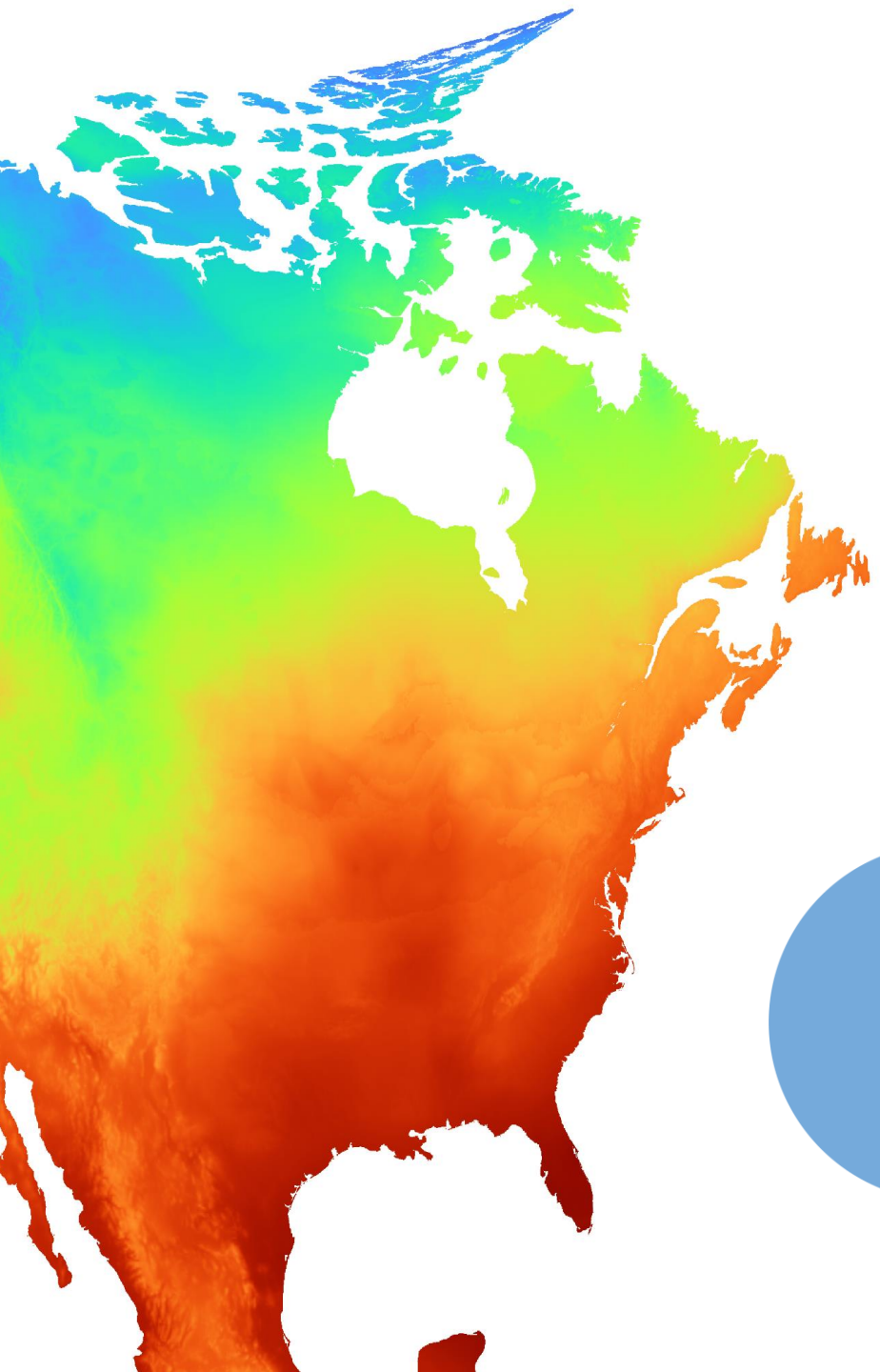
Posterior Probability - $f_x$

Prior Probability - $f_b$

- Prior probability of origin: band returns by flyway

## Baye's Rule

$$f_x = \frac{f(y|\mu_c, \sigma_c) f_b}{\Sigma f(y|\mu_c, \sigma_c) f_b}$$



# ANY QUESTIONS?

# ON TO R!

RStudio®

R

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van Dijk, J. G., W. Meissner, and M. Klaassen. 2014. Improving provenance studies in migratory birds when using feather hydrogen stable isotopes. Journal of Avian Biology 45:103–108.

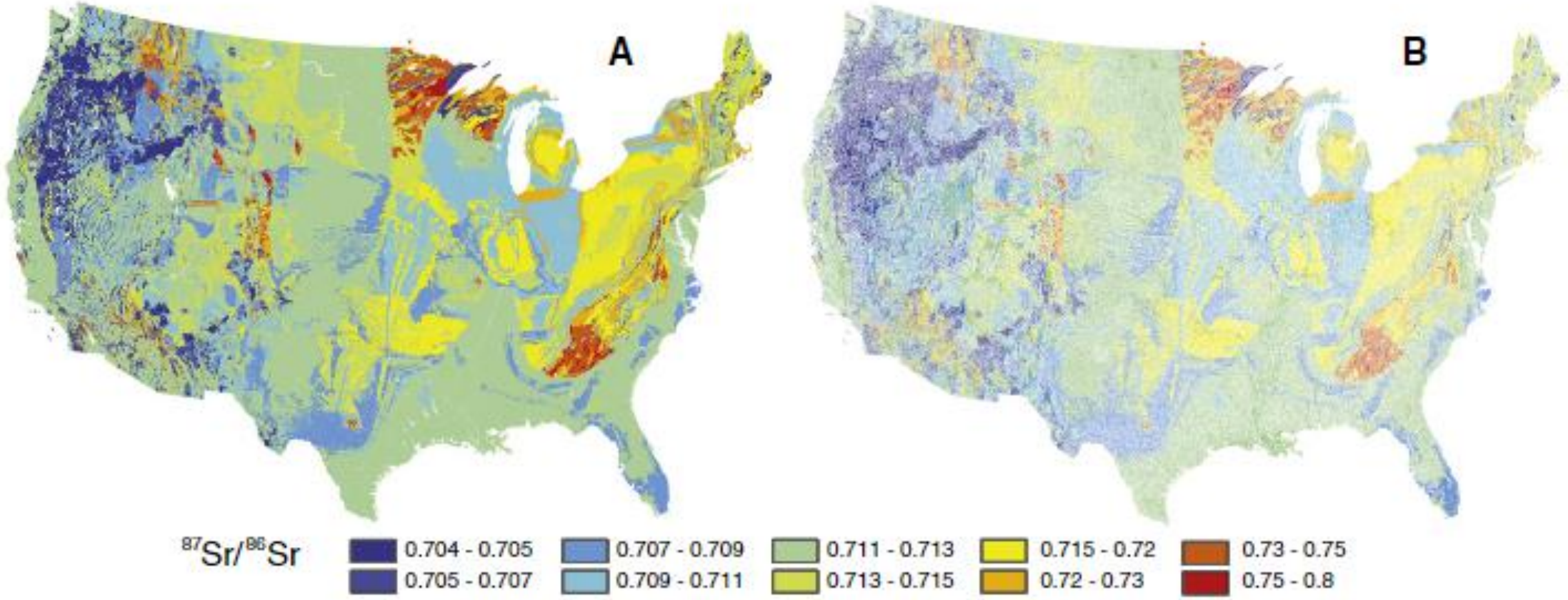
van Wilgenburg, S. L., and K. A. Hobson. 2011. Combining stable-isotope (δD) and band recovery data to improve probabilistic assignment of migratory birds to origin. Ecological Applications 21:1340–1351.

# Extra Slides

# Isoscapes



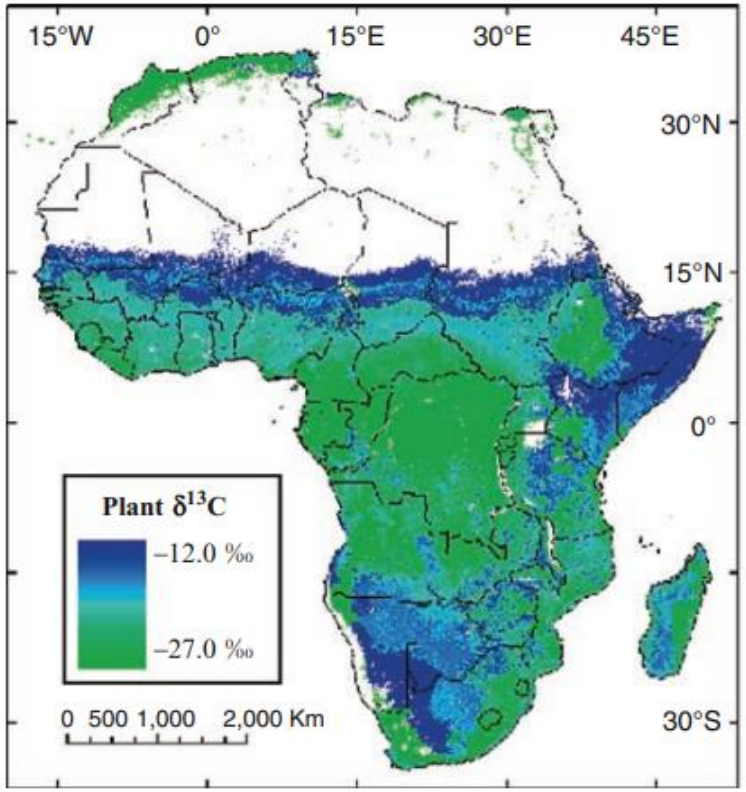
## Strontium ($\delta^{87}Sr$) Isoscapes



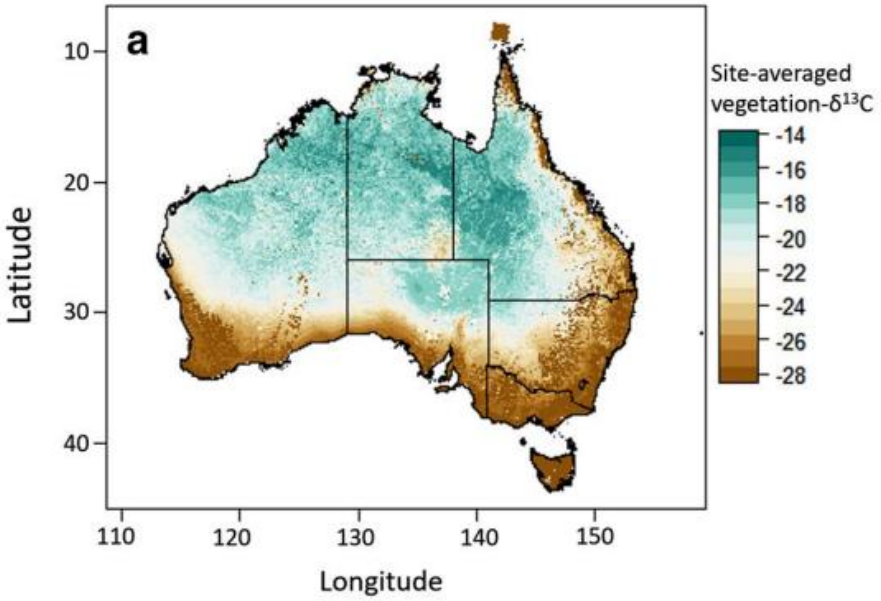
# Isoscapes



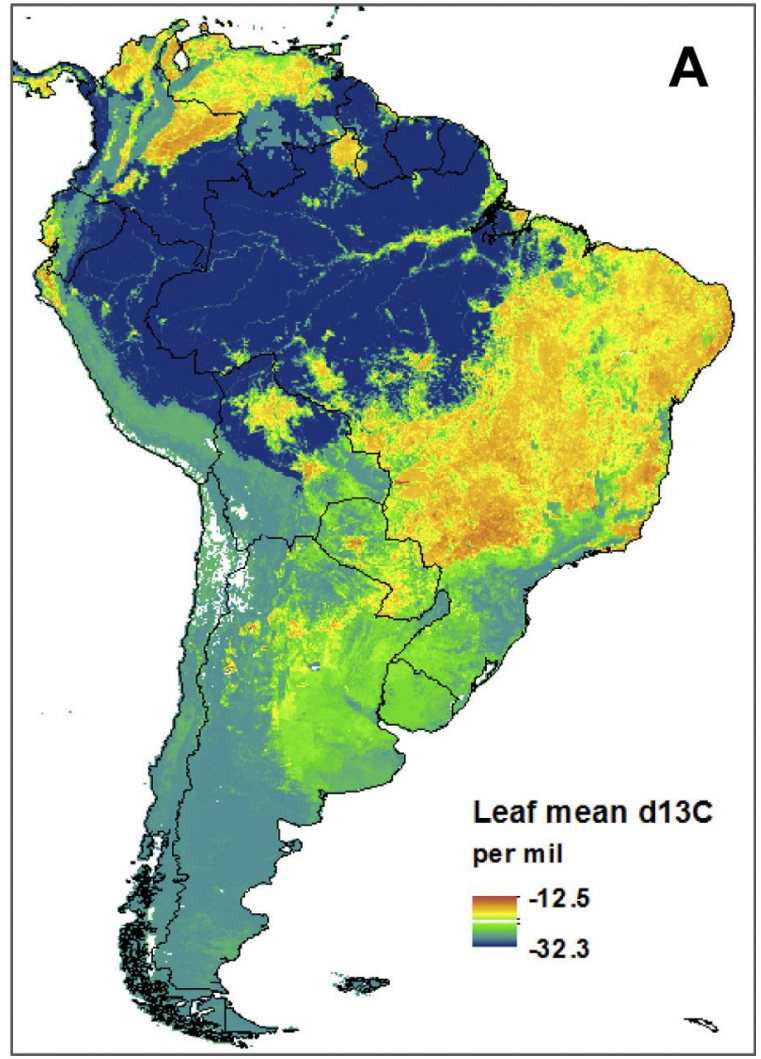
## Carbon ($\delta^{13}C$) Isoscapes




(Still and Powel 2010)




(Munroe et al. 2022)




(Powel et al. 2012)