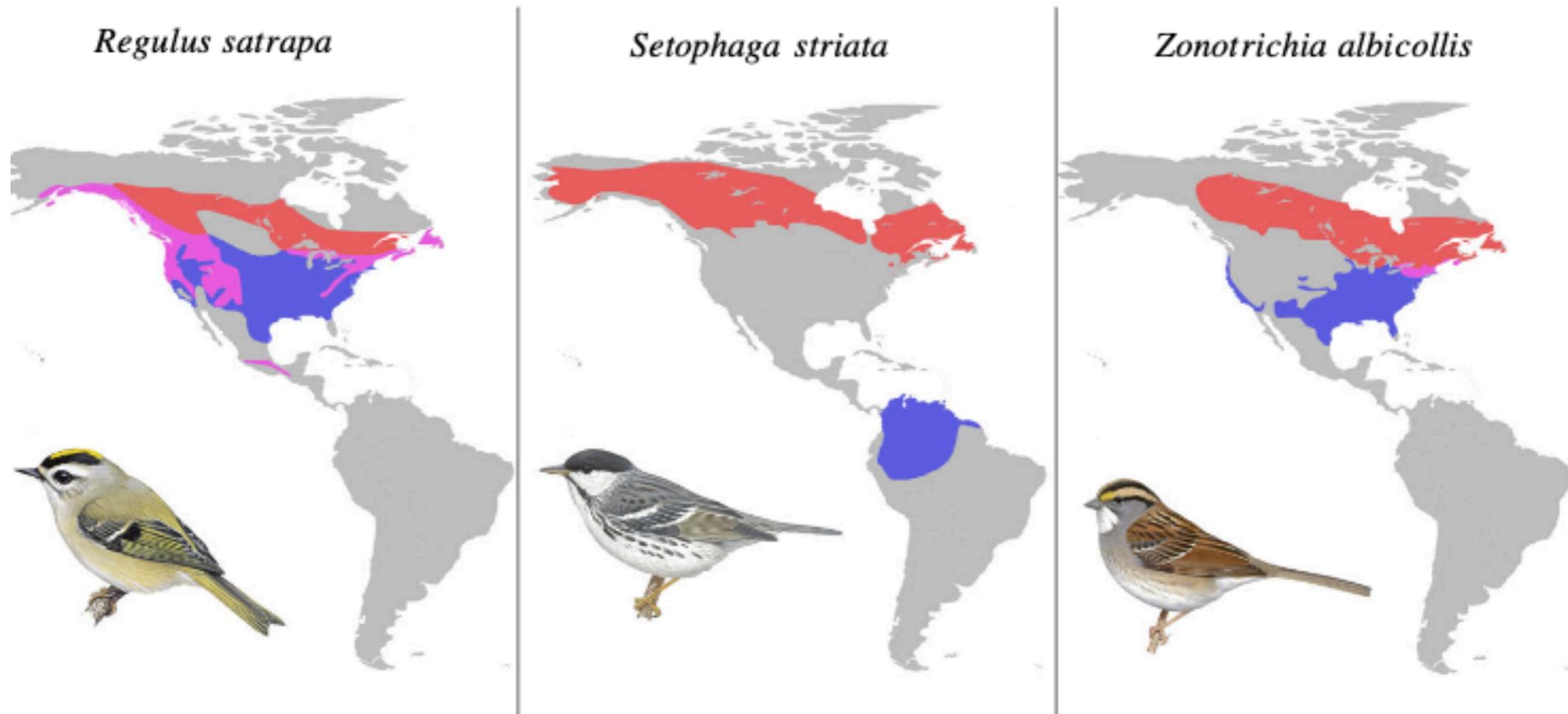


## A long winter for the Red Queen: rethinking the evolution of seasonal migration

Benjamin M. Winger\*, Giorgia G. Auteri, Teresa M. Pegan and Brian C. Weeks

*Museum of Zoology and Department of Ecology and Evolutionary Biology, University of Michigan, Ann Arbor, MI 48109, U.S.A.*



**Turn in your research proposals**

# Migration

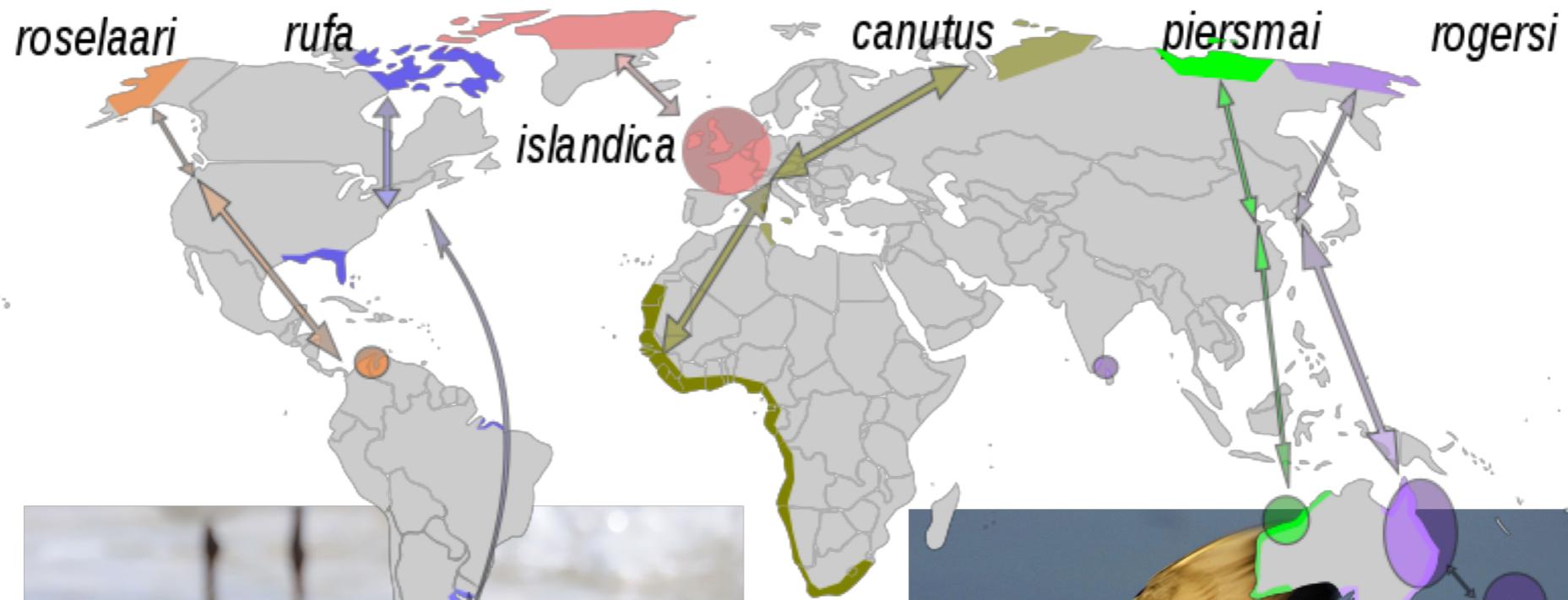
10 billion birds/yr: 187 sp. Europe > Africa, 200 species North > C. and S. America





<https://vimeo.com/58641790>

# Red knots travel nearly 10,000 miles



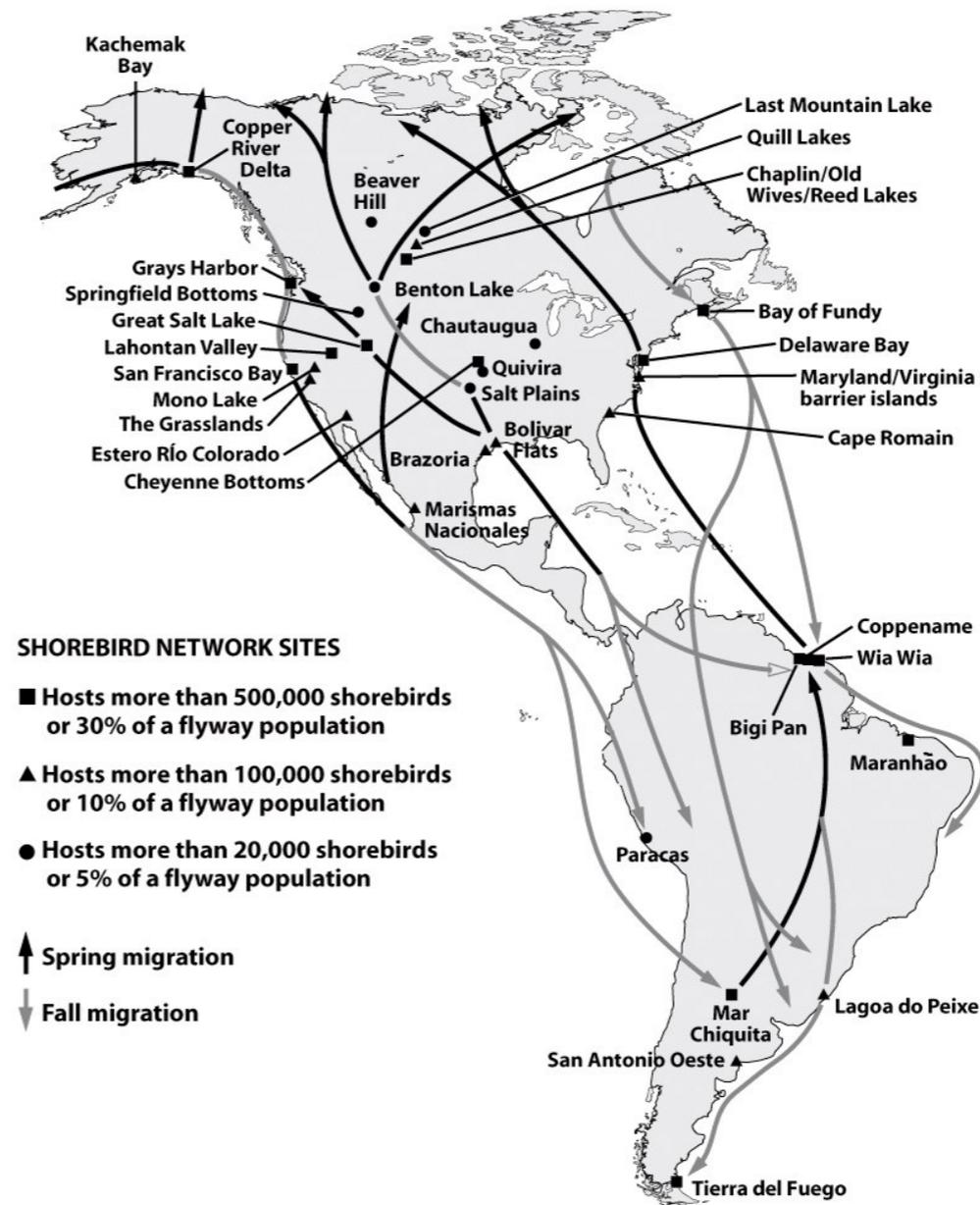
Why migrate?



Wouldn't you?

40% less energy/day spent keeping warm

Migration allows birds to exploit seasonal food sources while remaining active and in favorable climates all year (cf. hibernation)



Routes are highly variable

But follow  
some patterns

Pacific  
flyway



Atlantic  
flyway



Central  
flyway  
(Prairie  
Potholes)



Mississippi  
flyway

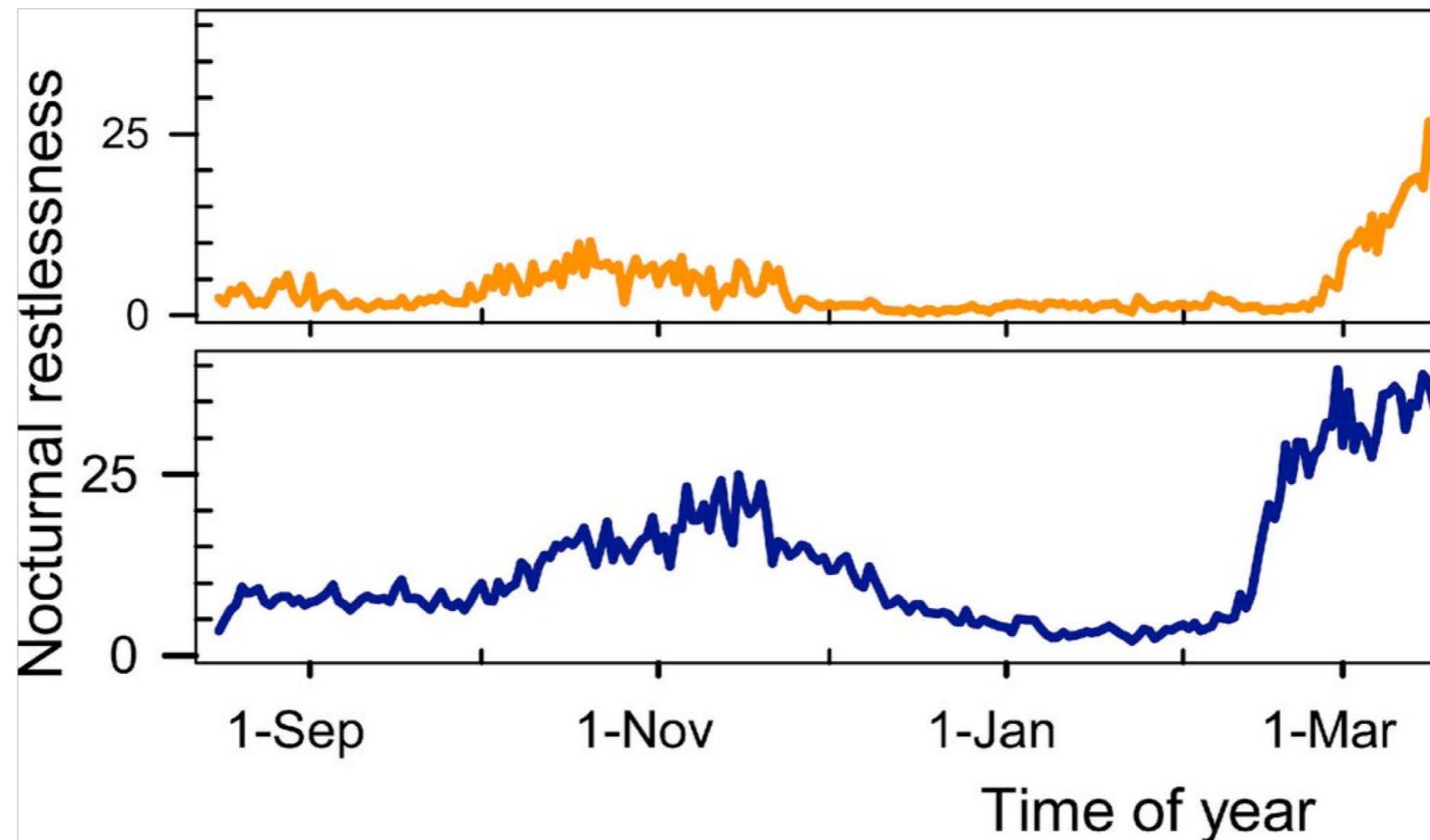


**Adult birds tend to migrate inland, young birds tend to follow the coast**



© Kurt Ongman

## Zugunruhe (migration restlessness)



Seems to be (proximately) caused by prolactin surge

**For a long time it was thought that birds hibernated during the winter**

**-Aristotle thought this**

**-In the middle Ages, it was thought that Barnacle Geese were born out of trees each spring (thus they counted as plants, so they were ok to eat during lent)**

At the [Fourth Council of the Lateran](#) (1215), [Pope Innocent III](#) explicitly prohibited the eating of these geese during Lent, arguing that despite their unusual reproduction, they lived and fed like ducks and so were of the same nature as other birds.<sup>[14]</sup>



**Bewick (of Bewick's Wren fame) was the first to observe large numbers of Swallows moving in the spring and posit that maybe they moved seasonally**

# The Pfielstorch!

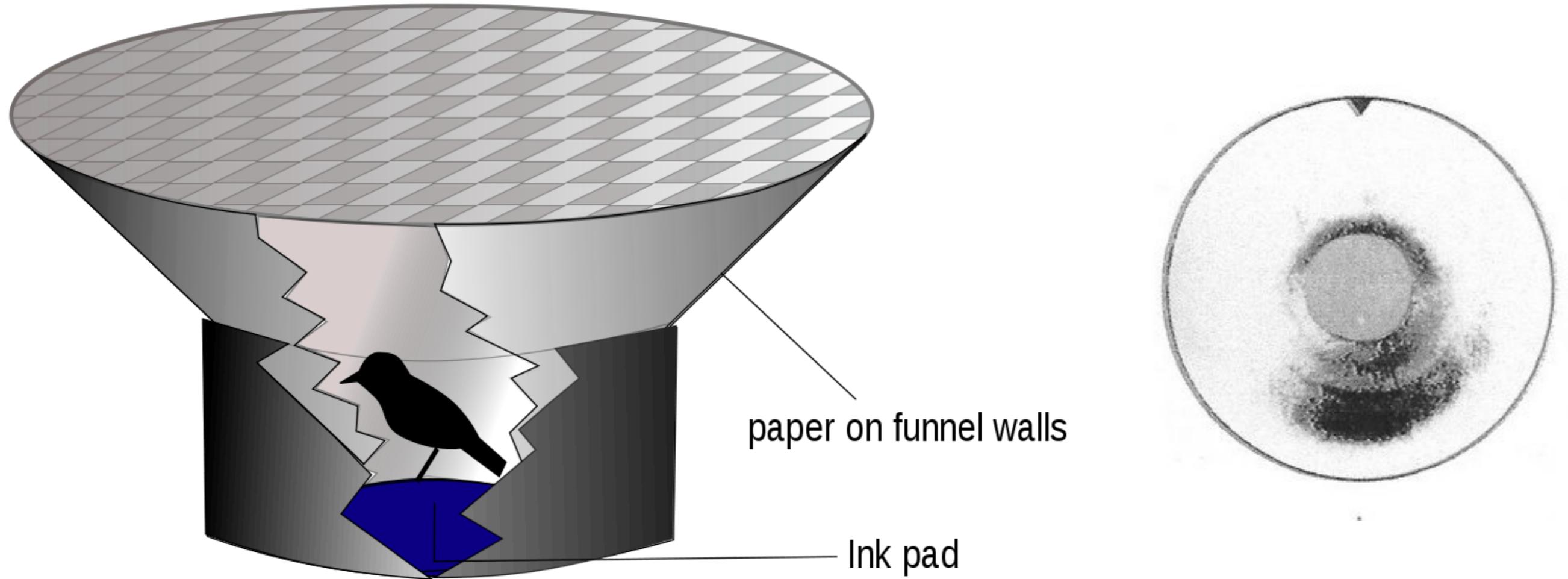
1822



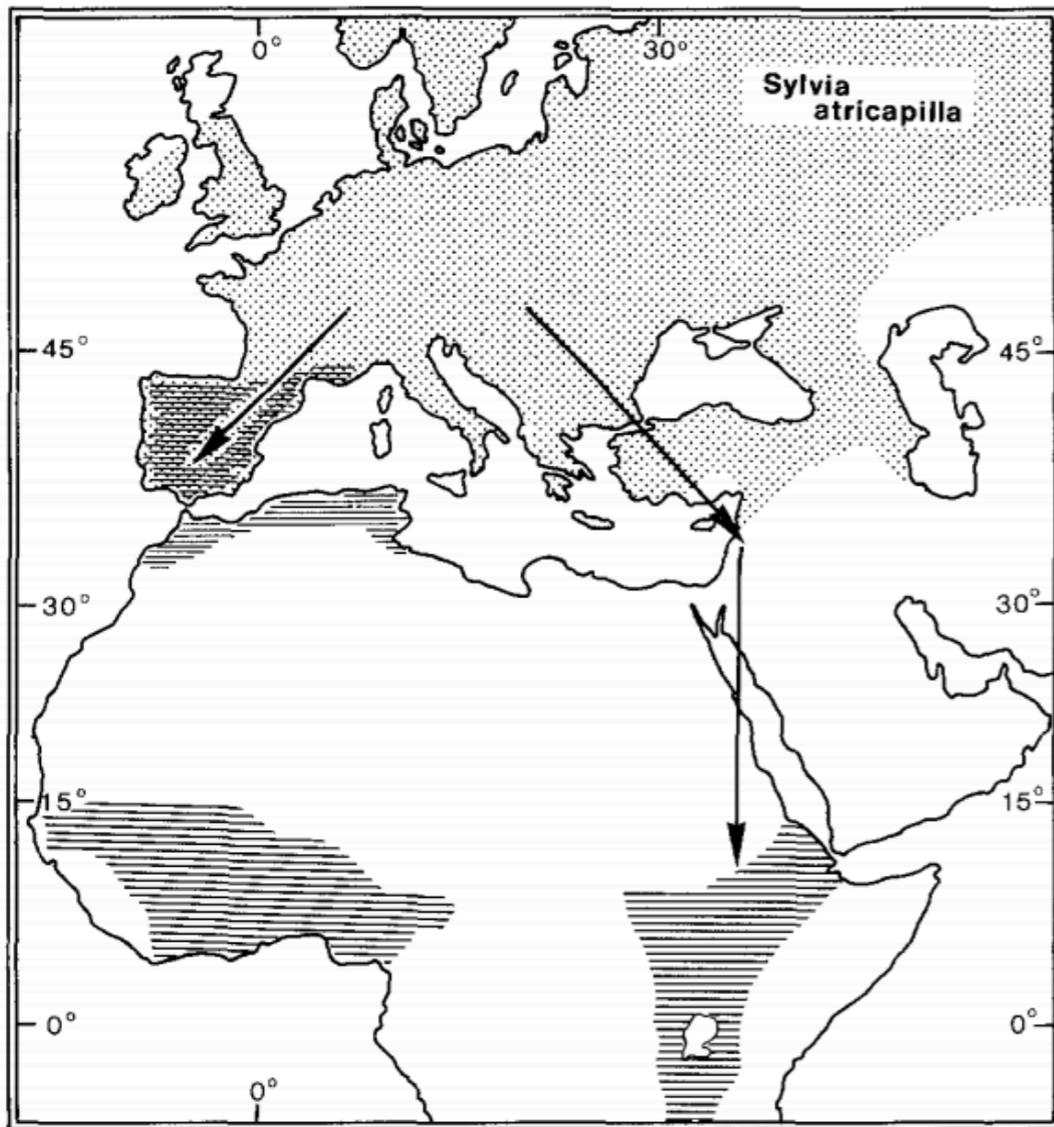
# How is migration studied?

## Emlen Funnels

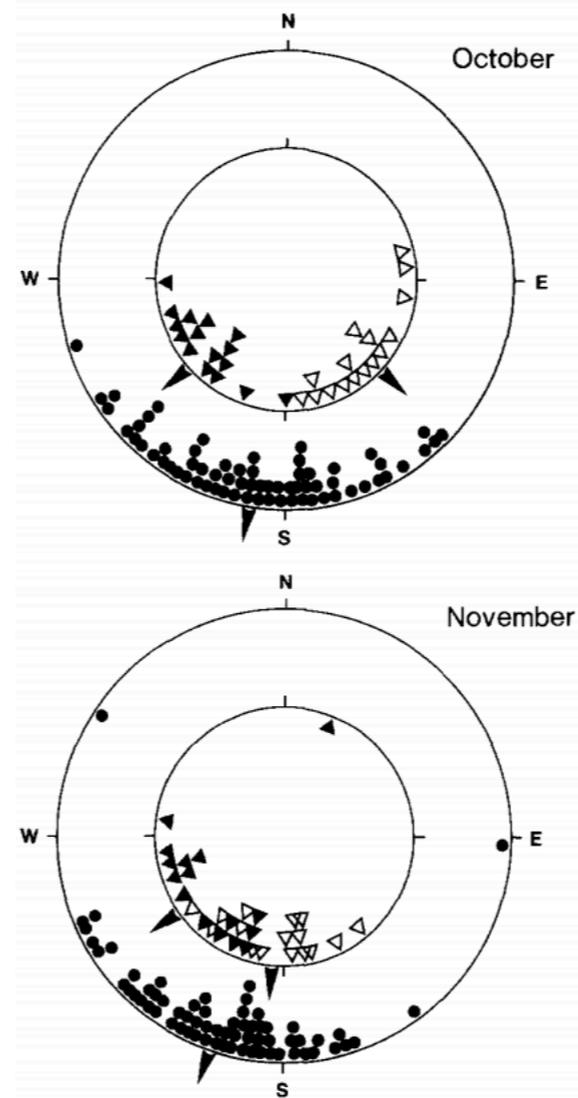
<https://www.youtube.com/watch?v=sWZWonIJzSQ>



**Migration is inherent - Blackcap hybrids**



**Fig. 1.** Breeding (*stippled*) and main over wintering (*hatched*) areas of the blackcap. *Arrows* show schematically the autumn migratory directions of central European SW- and SE-migrating populations (after Klein et al. 1973) which were the subjects of this study

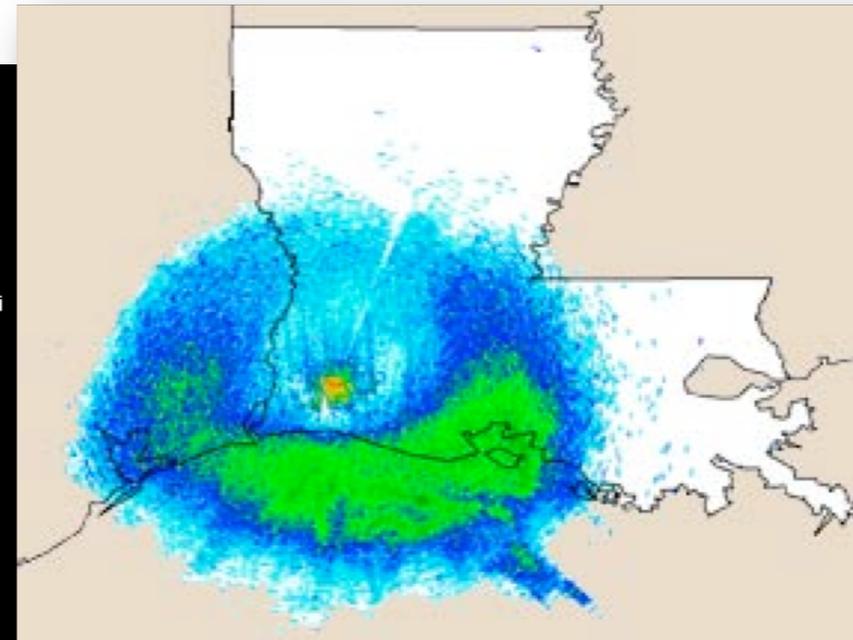
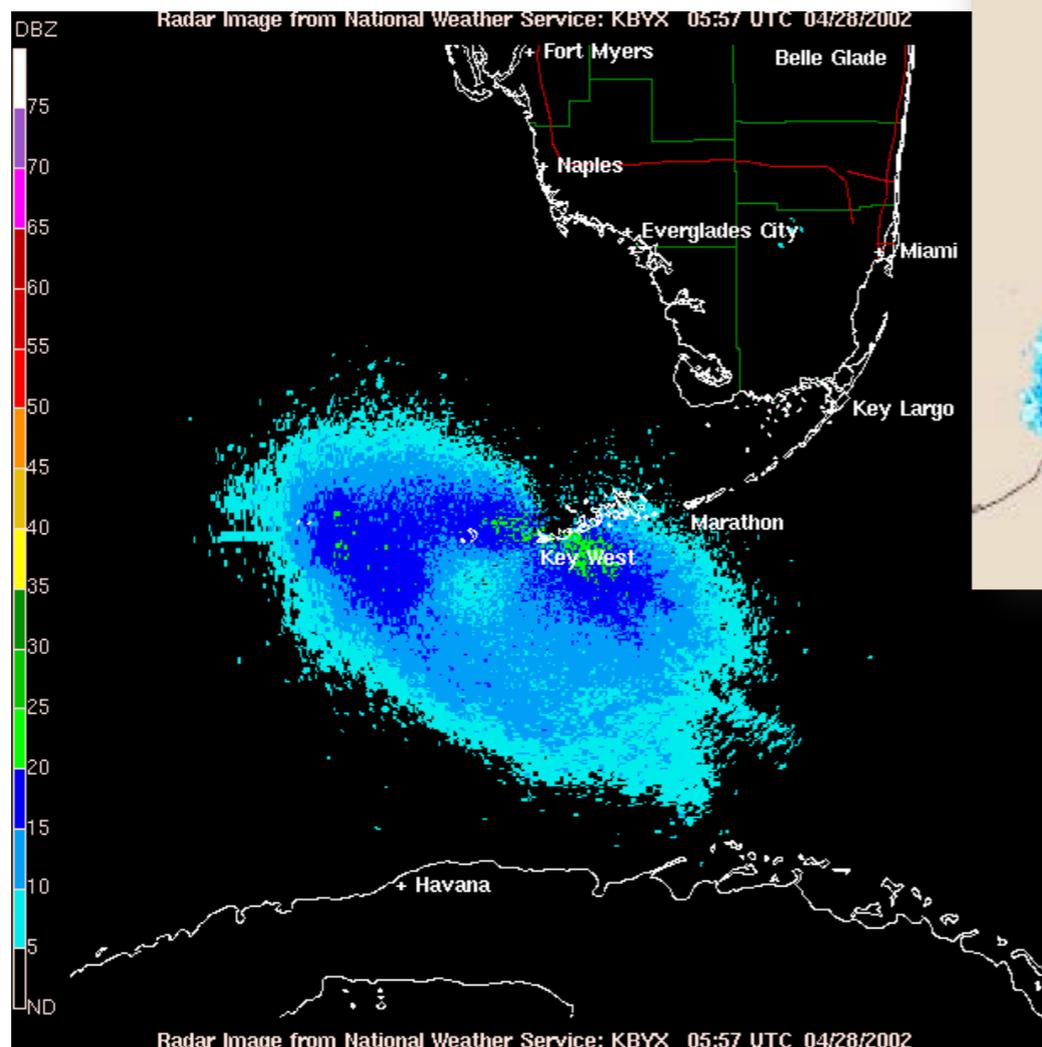


**Fig. 2.** Individual means of directional choices of hand-raised blackcaps during the early and late part of the autumn migration season. *Inner circle*, parental generation; *solid triangles*, birds from the FRG; *open triangles*, birds from eastern Austria. *Outer circles (full dots)*, F1 generation. *Arrowheads*, group mean directions.

## Watching the moon, or using a big spotlight

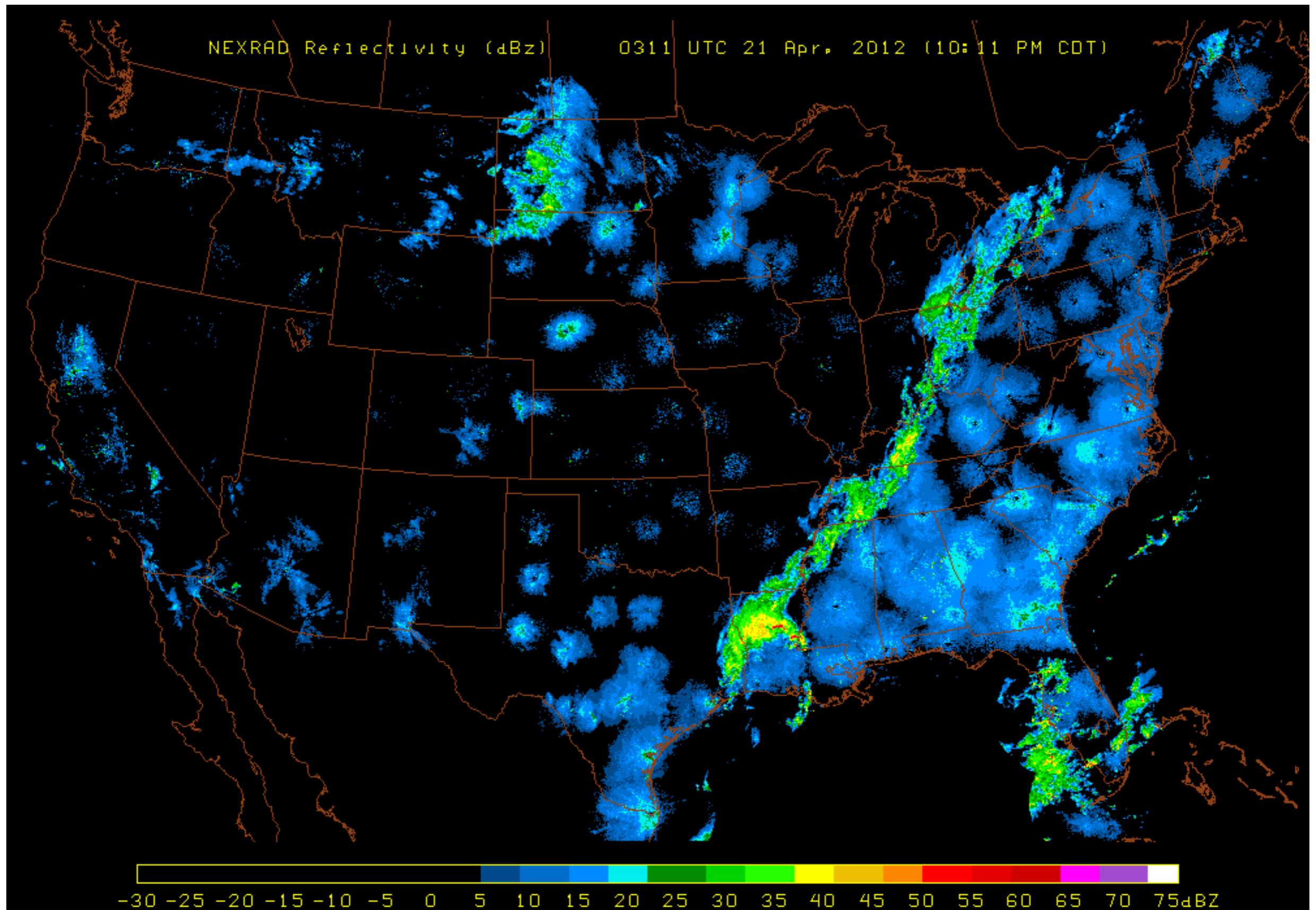


# Recent methods include Doppler radar



1960s to 1980s:  
50% decline in  
migratory activity  
on peak days

<http://birdcast.info/live-migration-maps/>



<https://www.youtube.com/watch?v=uPff1t4pXil&feature=youtu.be>

**Most migration happens at night - but raptors migrate during the day**

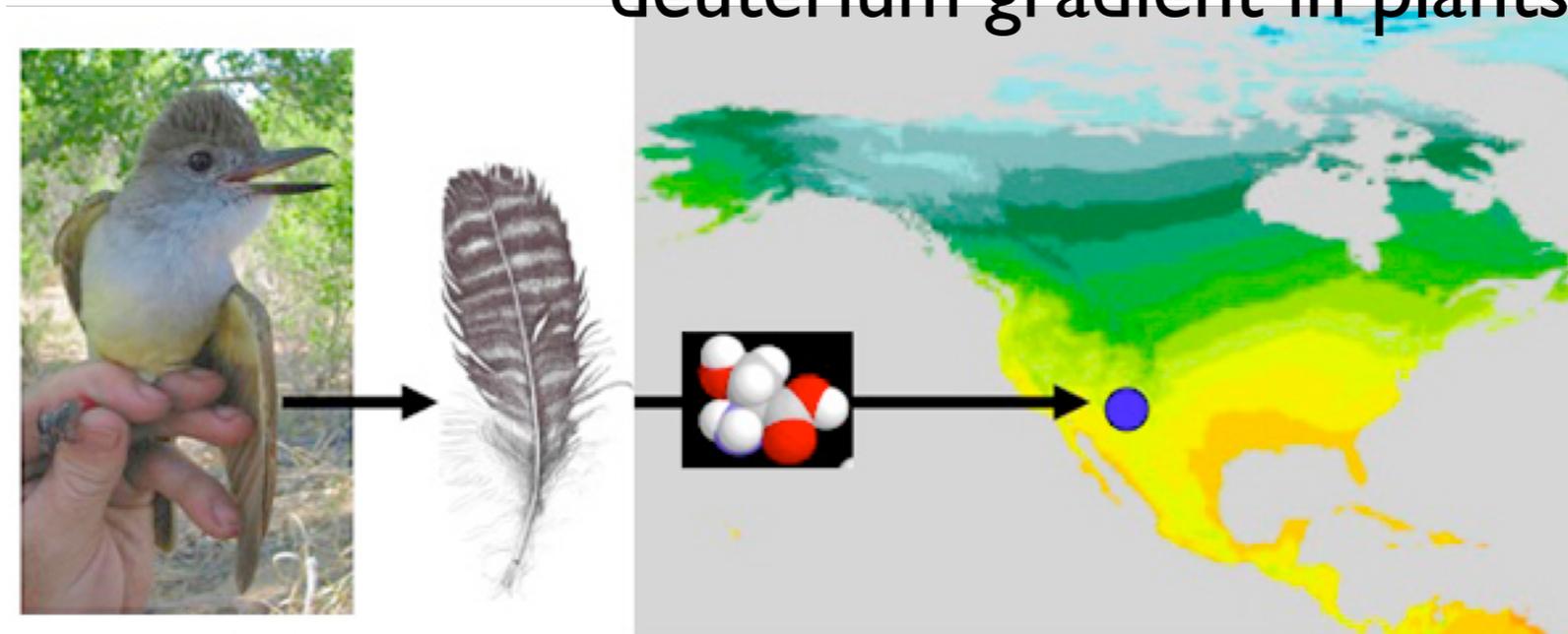
**Why?**



# Why do we want to know where birds are going for the winter?

## Stable isotopes

Deuterium has an extra neutron compared to hydrogen & falls out of rain faster, creating a deuterium gradient in plants, etc.



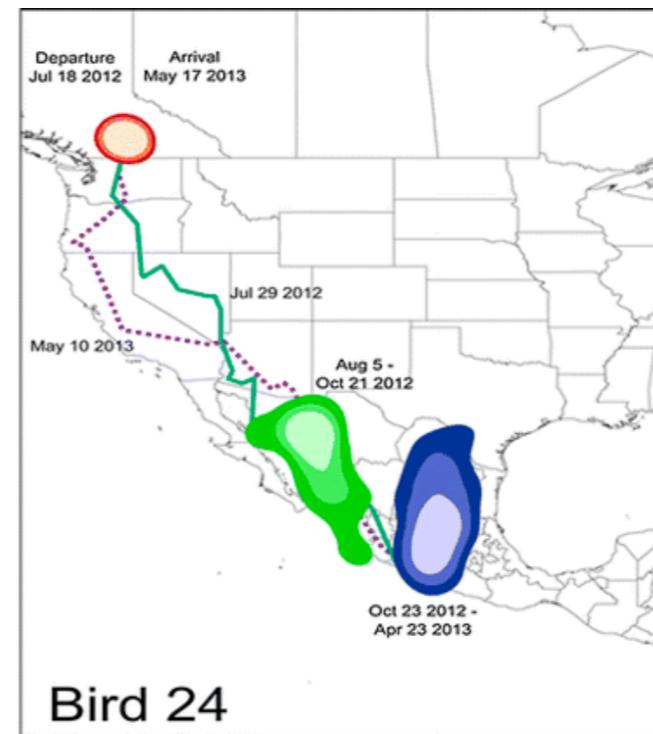
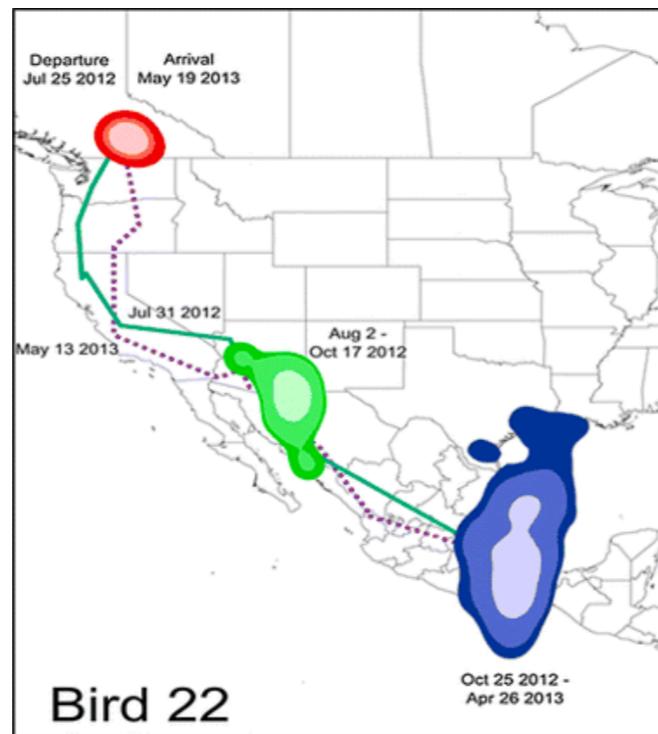
Match the deuterium levels in a feather with maps of isotope ratio to see roughly where the feather was grown (breeding grounds)

# Moult migration in Bullock's orioles (*Icterus bullockii*) confirmed by geolocators and stable isotope analysis

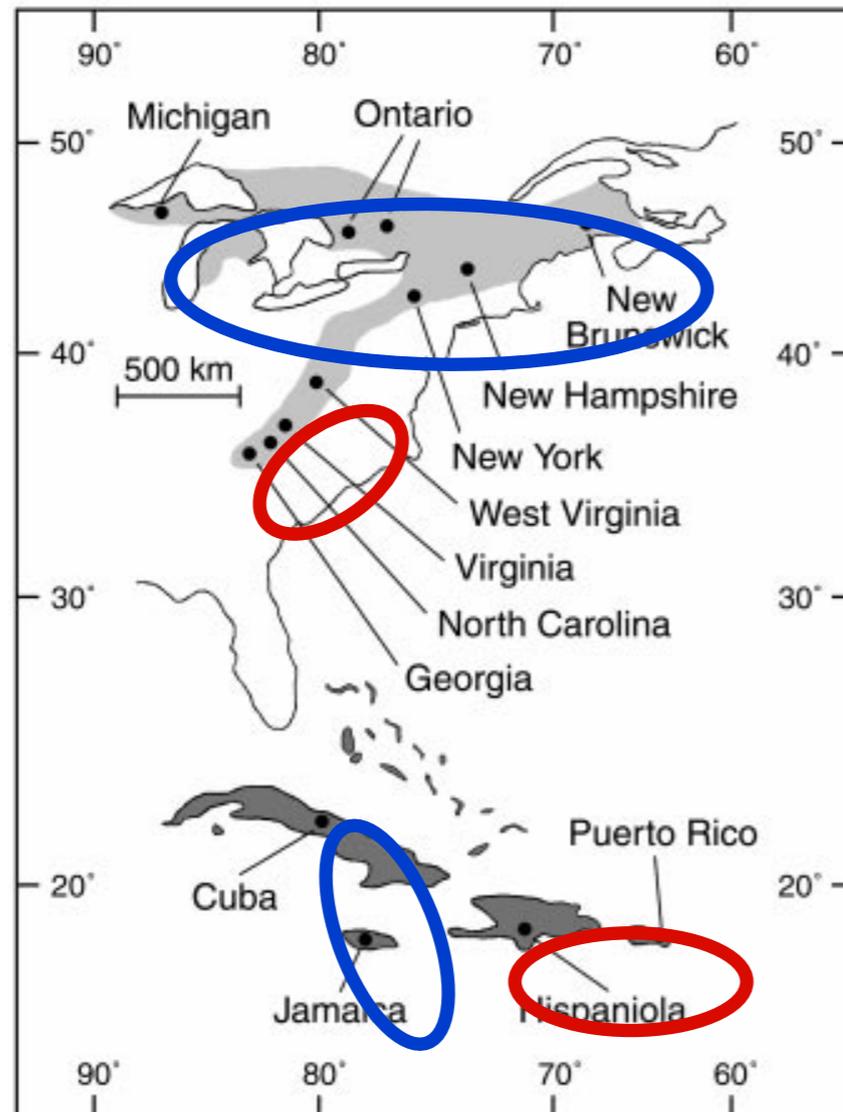
Authors

[Authors and affiliations](#)

Andrew G. Pillar, Peter P. Marra, Nancy J. Flood, Matthew W. Reudink 



## Black-throated Blue Warbler: Stable Isotopes

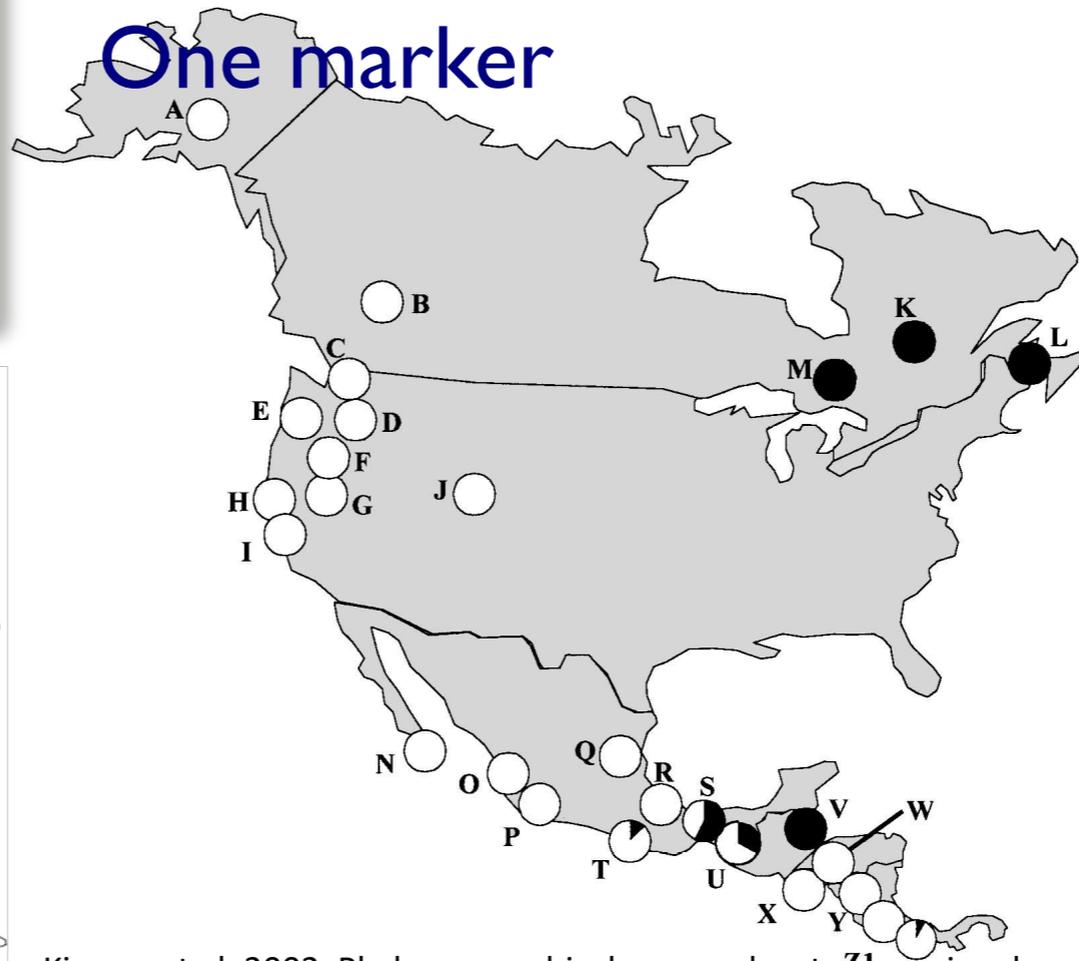
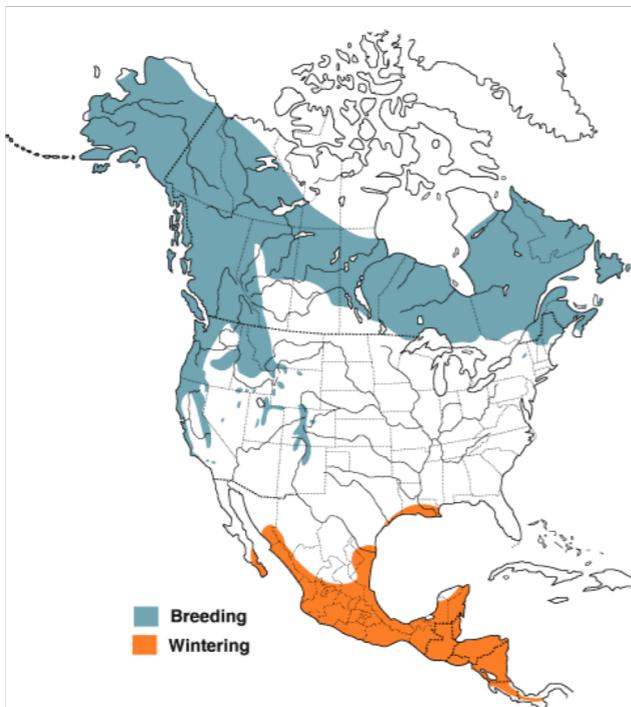


Rubenstein et al. 2002. Linking breeding and wintering ranges of a migratory songbird using stable isotopes. **Science** 295: 1062-1065.



# “DNA tracking”: Wilson's Warbler – mtDNA

One marker



Kimura et al. 2002. Phylogeographical approaches to assessing demographic connectivity between breeding and overwintering regions in a Nearctic–Neotropical warbler (*Wilsonia pusilla*). **Molecular Ecology** 11: 1605-1616.

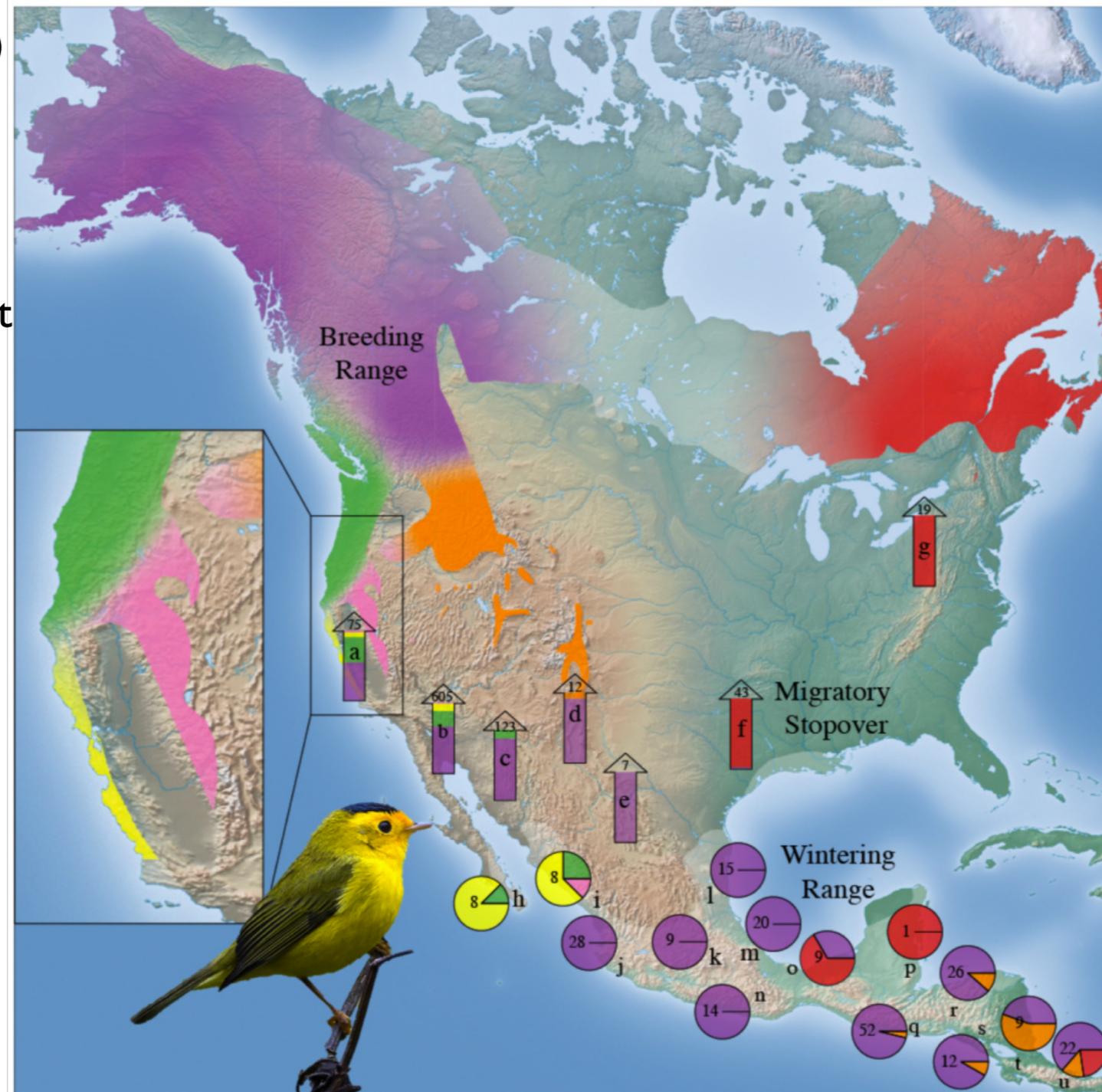
Ruegg et al. (2013)

100 markers

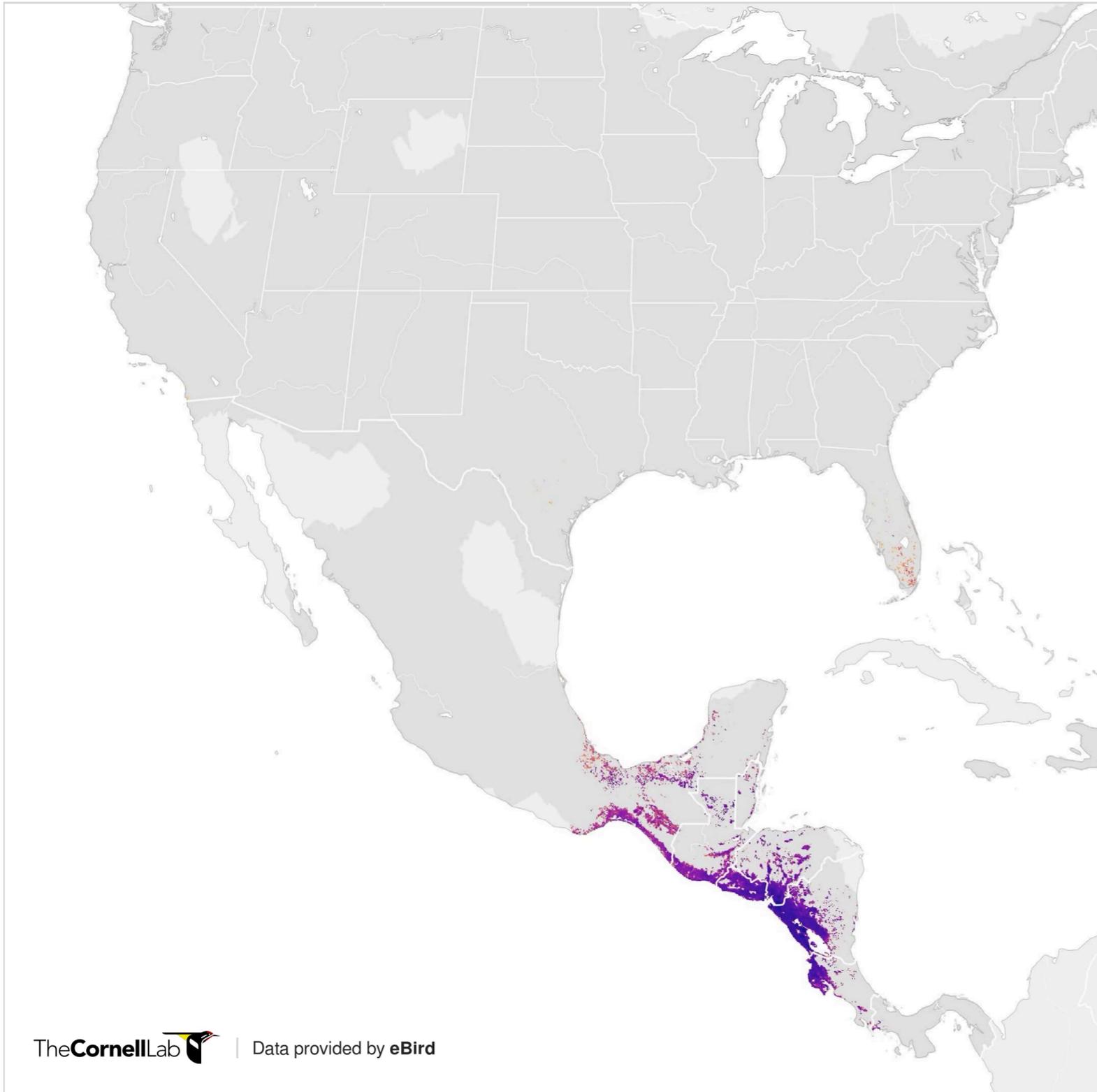
UCLA

Genoscape Project

Ruegg et al. 2014.  
Mapping migration  
in a songbird using  
high-resolution  
genetic markers.  
**Molecular Ecology**  
23: 5726-5739.



# eBird data



## Scissor-tailed Flycatcher

*Tyrannus forficatus*

### Abundance

This map animates weekly estimated relative abundance, defined as the expected count on a one-hour, one kilometer eBird Traveling Count conducted at the ideal time of day for detection of that species in a region.

**RELATIVE ABUNDANCE** birds per km/hr



**WEEK OF THE YEAR** January 4



- Modeled area (0 abundance)
- No prediction

eBird data from 2004-2016. Estimated for 2016.

Fink, D., T. Auer, A. Johnston, M. Strimas-Mackey, M. Iliff, and S. Kelling. eBird Status and Trends. Version: November 2018. <https://ebird.org/science/status-and-trends>. Cornell Lab of Ornithology, Ithaca, New York.

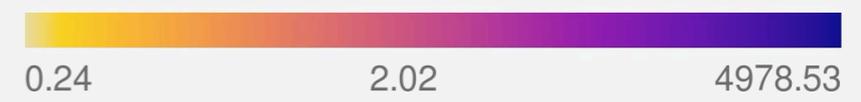


## Purple Martin *Progne subis*

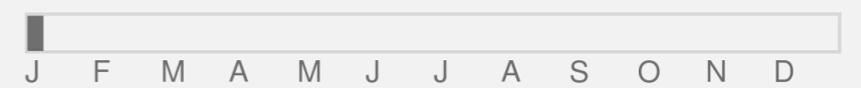
### Abundance

This map animates weekly estimated relative abundance, defined as the expected count on a one-hour, one kilometer eBird Traveling Count conducted at the ideal time of day for detection of that species in a region.

**RELATIVE ABUNDANCE** birds per km/hr



**WEEK OF THE YEAR** January 4



-  Modeled area (0 abundance)
-  No prediction

eBird data from 2004-2016. Estimated for 2016.

Fink, D., T. Auer, A. Johnston, M. Strimas-Mackey, M. Iliff, and S. Kelling. eBird Status and Trends. Version: November 2018. <https://ebird.org/science/status-and-trends>. Cornell Lab of Ornithology, Ithaca, New York.

## Bird Banding

- 1.2 million / yr in N.A. and recover 85,000
- >63 million birds have been banded since the early 1900s, with 3.5 million reported
- 226,156 white-crowned sparrows banded over 40 years, 198 recovered

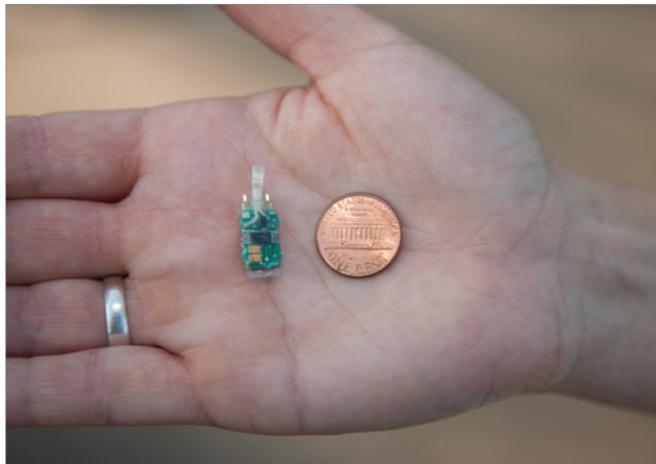


Emma White '16 got the band number from this  
Western Gull in Redondo Beach w/ binos

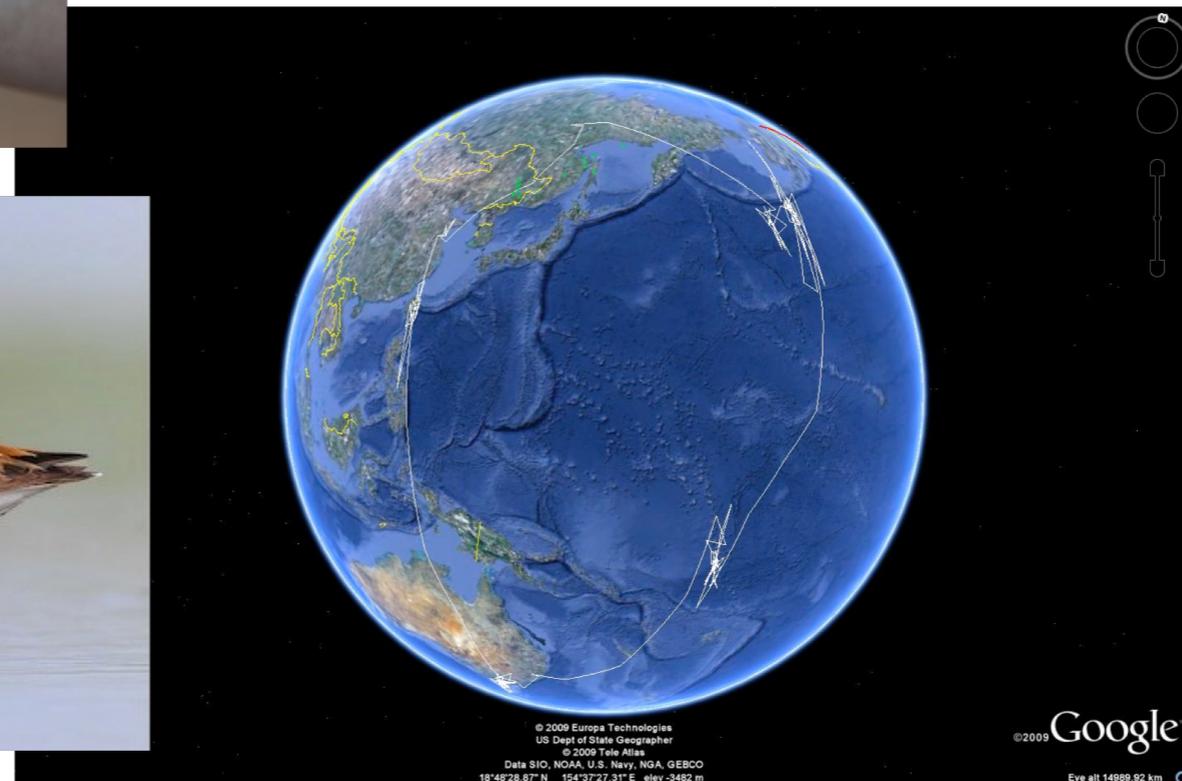


And found out from the Bird Banding Lab (USGS)  
that it was banded in 2010 in Cabrillo Beach

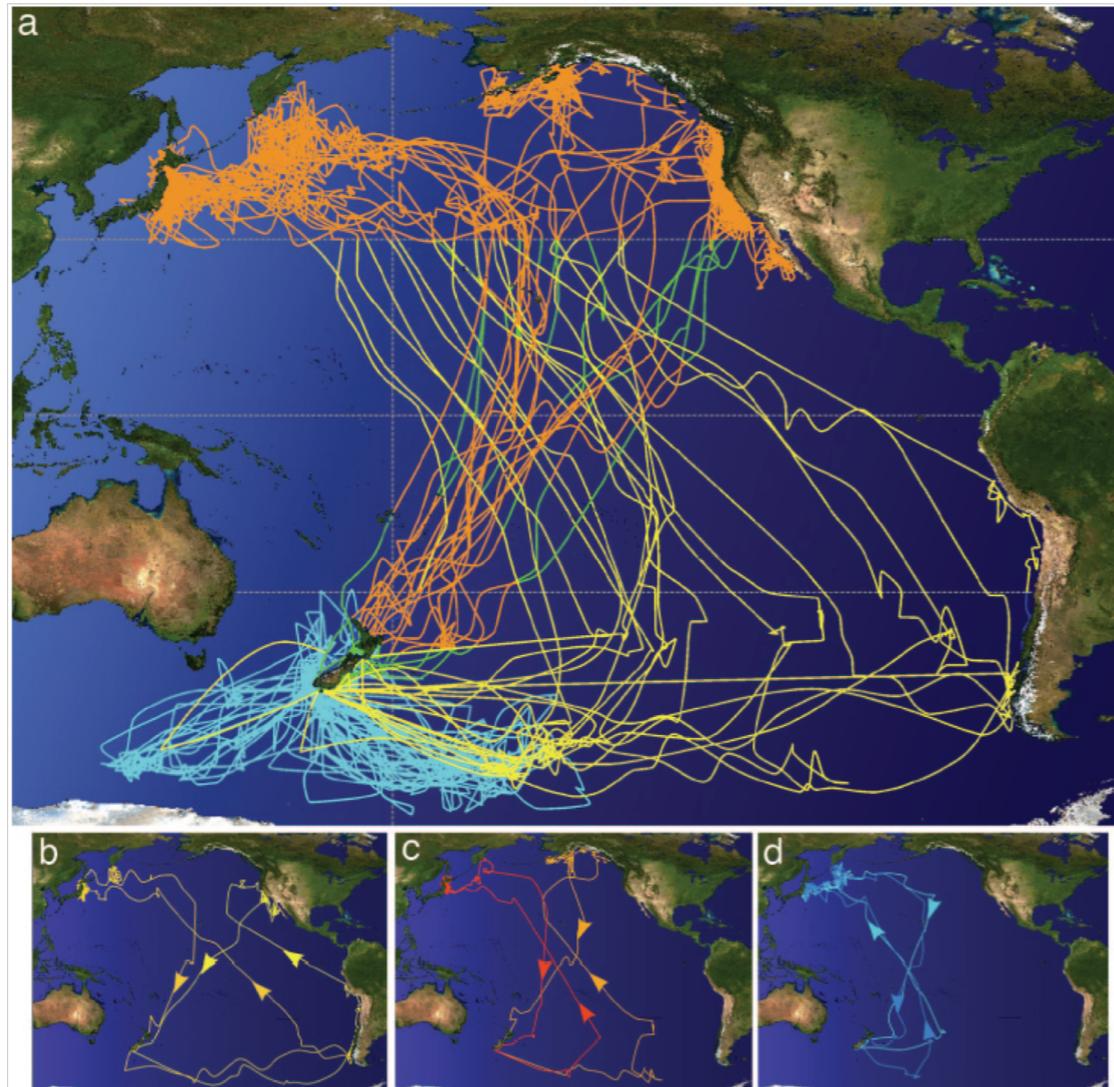
Geolocators: track daylight – tiny, but you have to find the bird again to get the data!



Ruddy Turnstone  
27,000 km in one year



# GPS tracking



Geolocation

19 Sooty Shearwaters

Breeding (light blue)

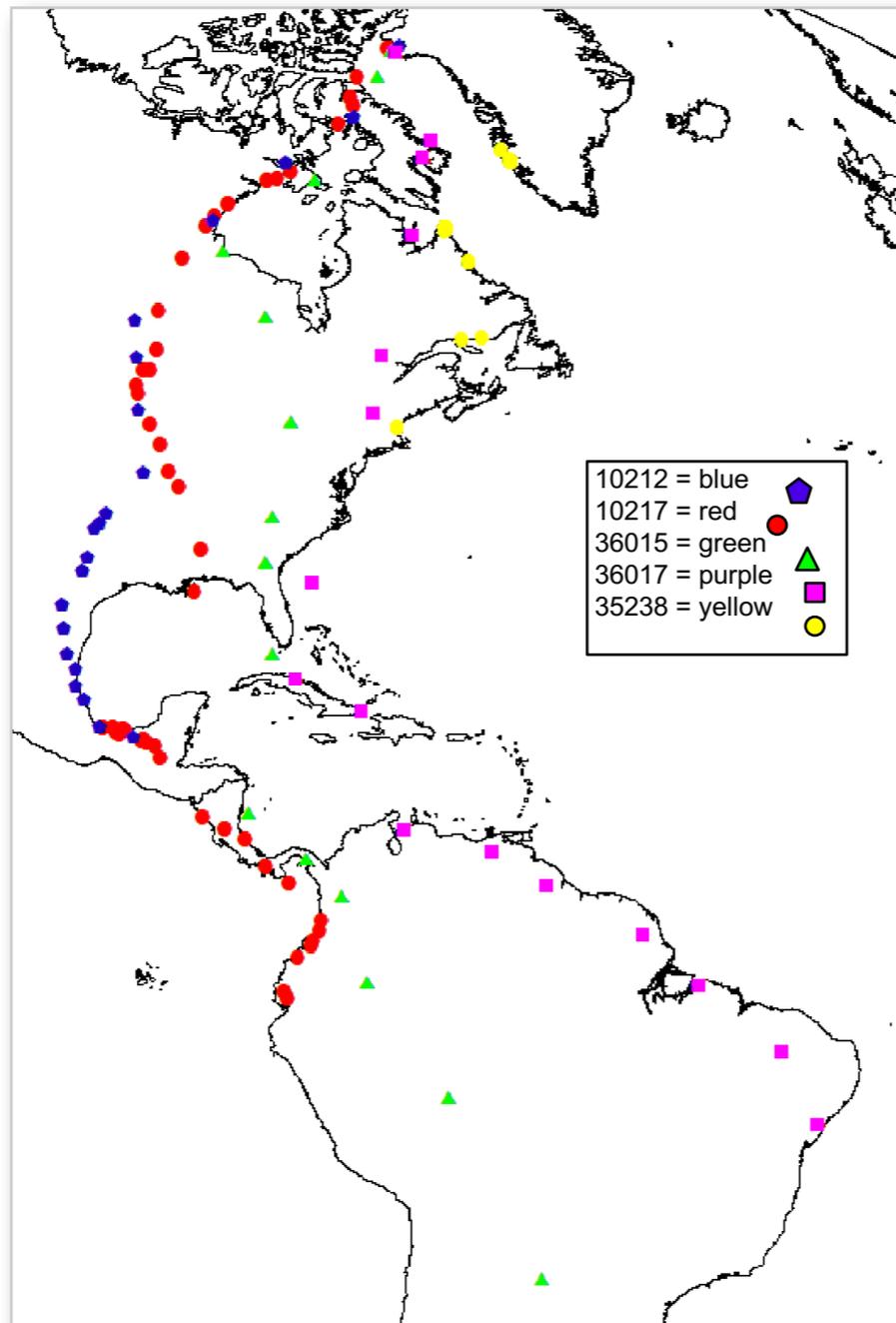
Migration (yellow,  
orange)



Lower graphs are individual breeding pairs

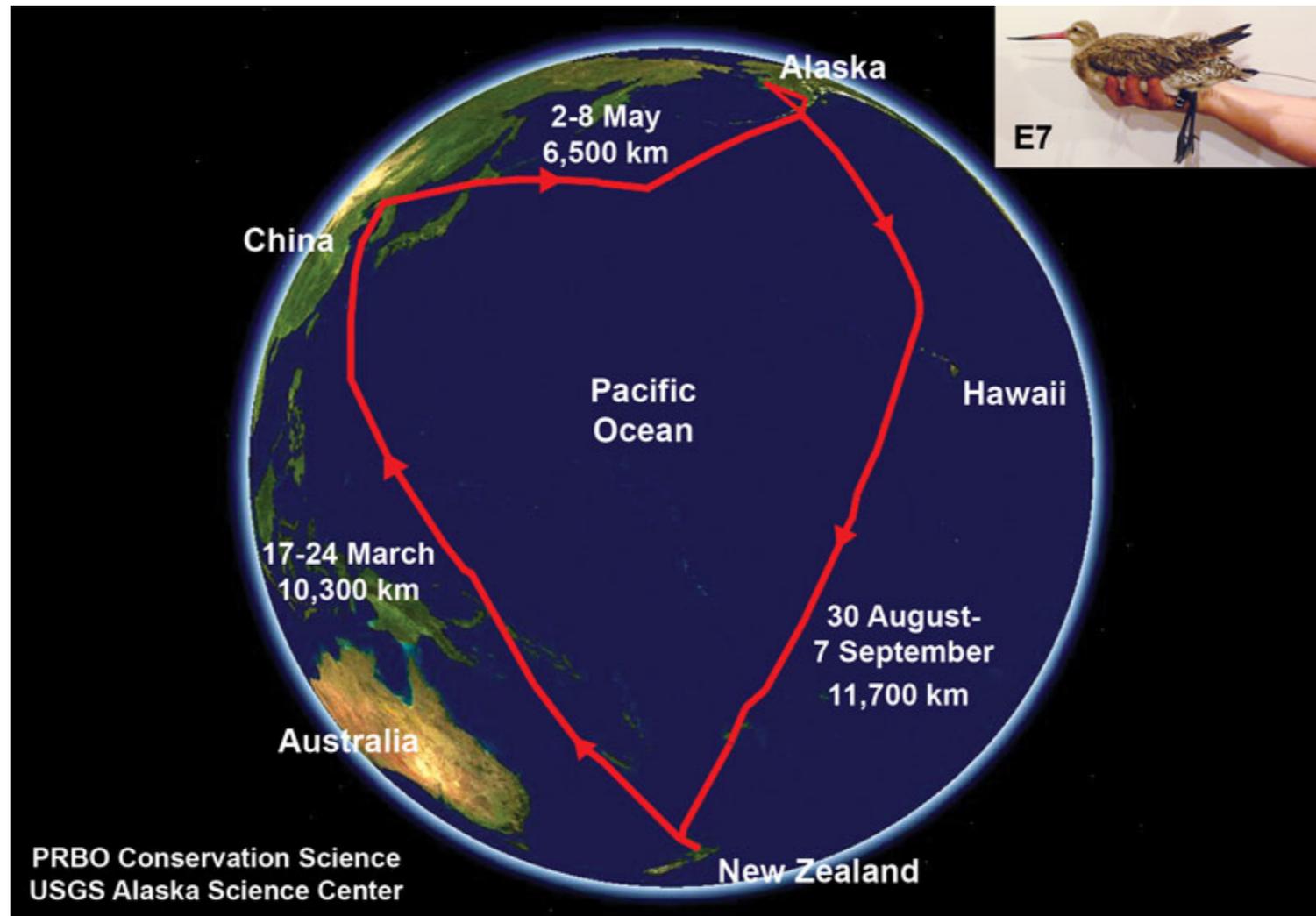
Shaffer et al. (2006) PNAS 103:12799-12802

## Satellite tracking! Peregrine Falcon autumn migration



18,000-mile-long series of flights tracked by satellite, including the longest non-stop flight (7,200 miles) recorded for a land bird

-- Female Bar-tailed Godwit, named "E7"



<http://www.usgs.gov/newsroom/article.asp?ID=1774>

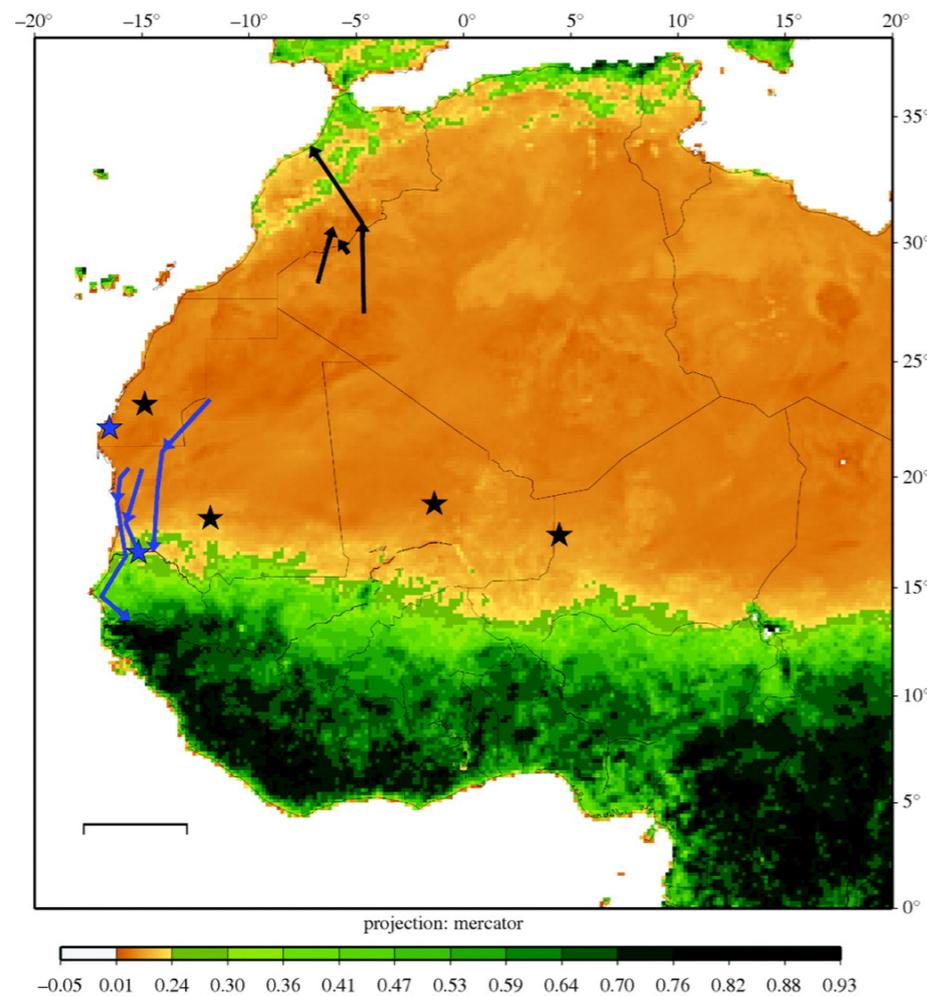
## Costs of migration:

- extremely energetic
- high mortality (~50% return rate)
- predation, storms, oceanic or desert crossings, obstacles (radio towers, oil rigs, hunters)

## Tactics for reducing costs:

- head winds and tail winds
- migrants go in 'waves' = good weather
- sensitive to barometric pressure influenced by rain, wind, temp
- migratory birds have higher aspect ratio wings

## Migration is hazardous



Lines are retreating raptors who started a migration across

Stars are raptor deaths

Migration ain't easy

Strandberg et al. 2009. How hazardous is the Sahara Desert crossing for migratory birds? Indications from satellite tracking of raptors. *Biology Letters*.

# Facultative vs. obligate migratory birds

- Facultative migration is opportunistic to avoid weather and other disturbances
- Obligate is generally required yearly migration
- Can the latter do the former?

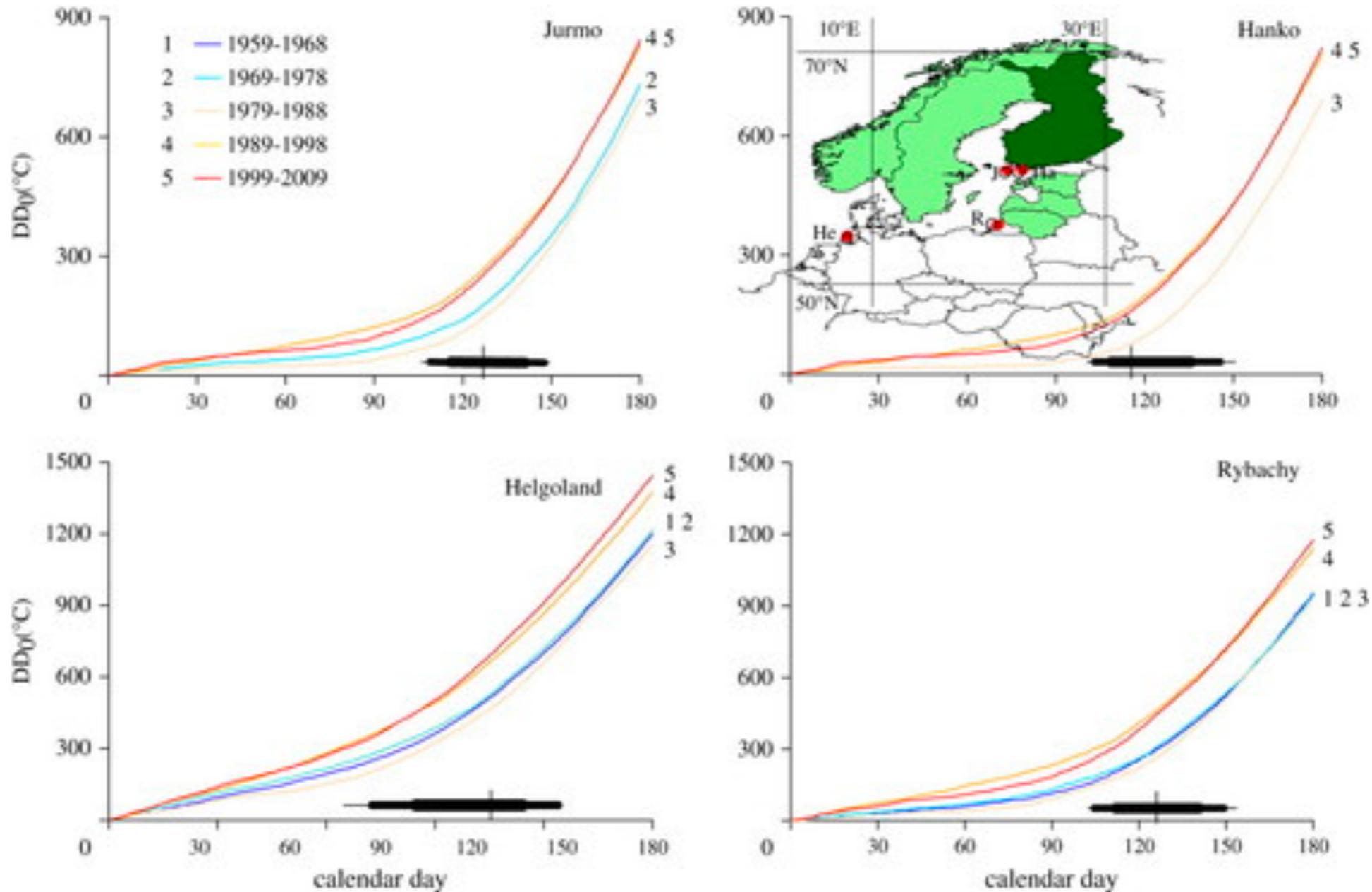


Golden-cheeked Warbler

# Phenological mismatches

## Climate warming, ecological mismatch at arrival and population decline in migratory birds

Saino et al. 2010



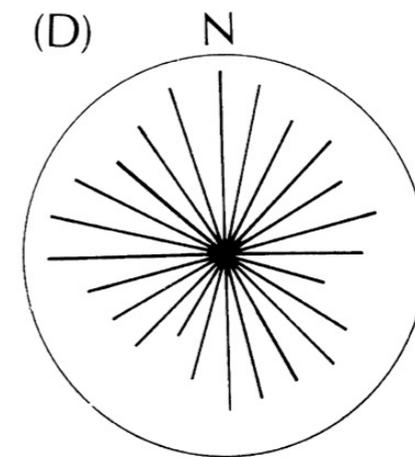
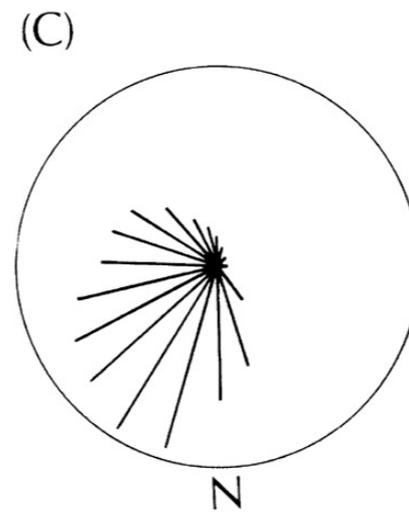
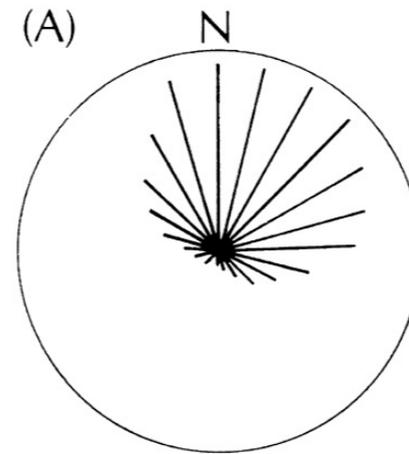
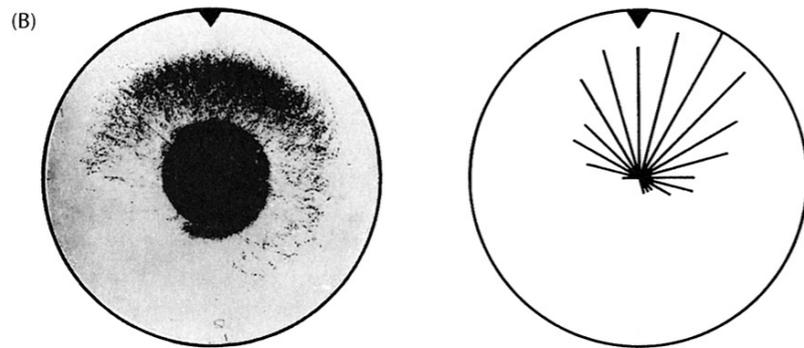
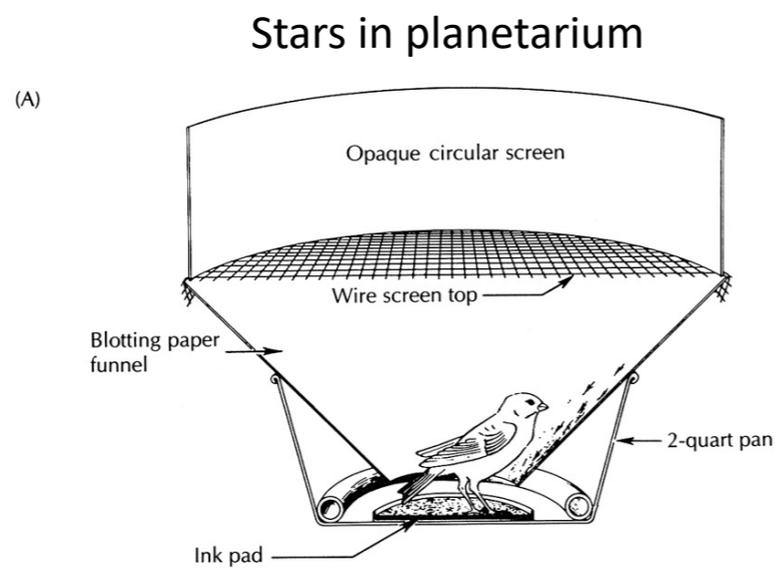
**Species that aren't changing their migratory timing are seeing population declines**



## Navigation

- Visual Landmarks
  - Not always “as the crow flies”
  - Sometimes follow rivers or even highways!
- Sun compass
  - Experiments in the 1950s showed that birds orient based on the sun and orient more poorly on overcast days or when tricked by light bulbs
- Star compass
- Geomagnetism

# Star Compass

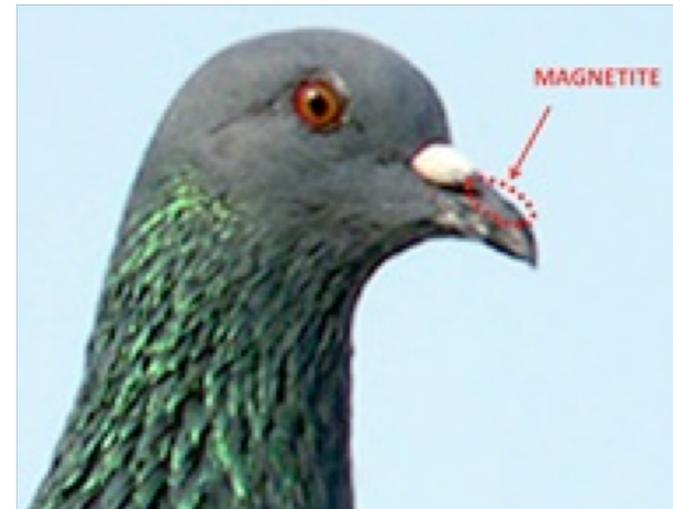


## Geomagnetism

- Disputed for a long time
- Finally accepted when:
  - It was shown that birds in cages with no external cues could orient properly
  - Reversed magnetic fields resulted in reversed bird orientation
- What is the mechanism?
  - A structure to detect the field
  - A brain structure to process information
  - A brain structure to store the “map”

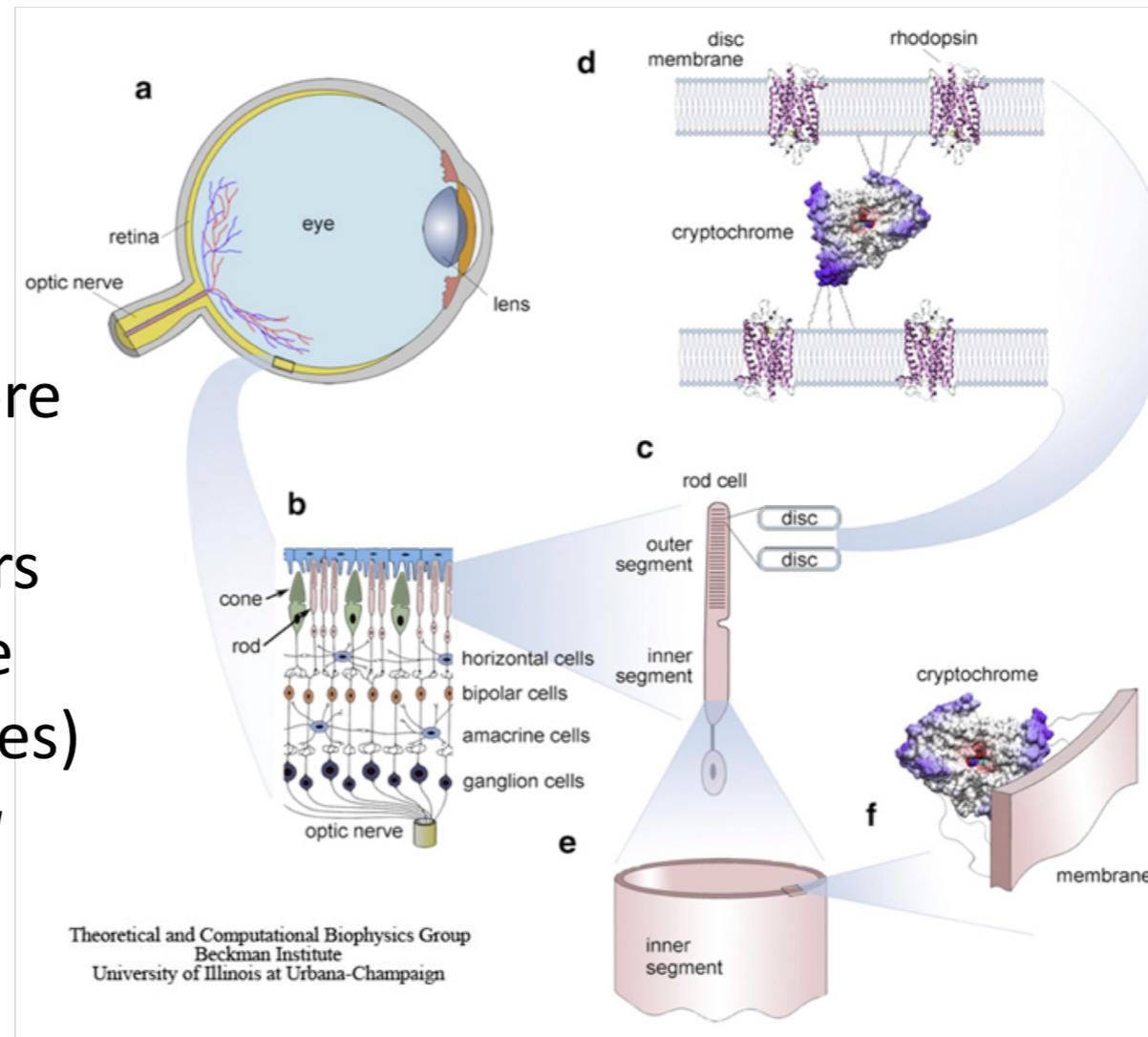
## Geomagnetism

- A structure to detect the field
  - Previously it was thought that iron-containing cells (magnetite) in the bird beak were magnetoreceptors (Mora et al. 2004 *Nature*)
  - But this was discredited; they were iron-containing macrophages (Treiber et al. 2012 *Nature*)



# Geomagnetism

- A structure to detect the field
  - It now seems more likely that the magnetoreceptors are located in the eye (cryptochromes) like in *Drosophila*



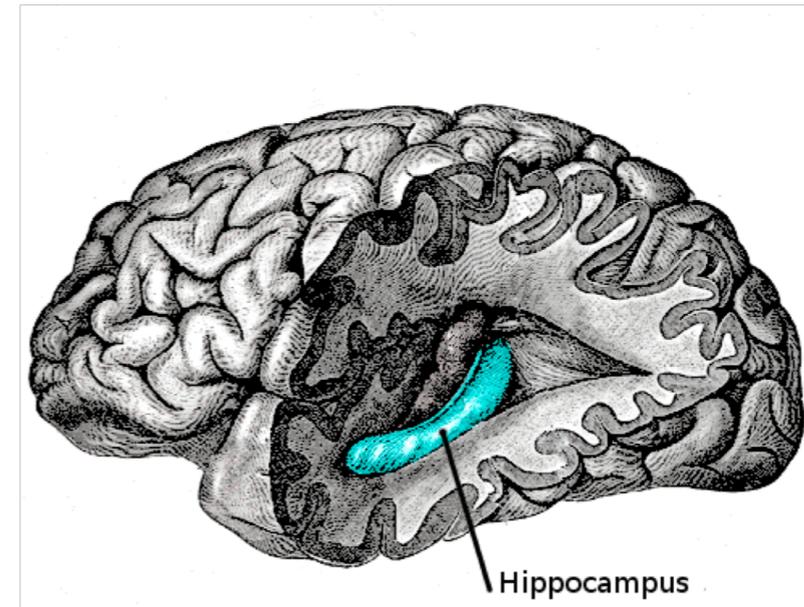
**But ears are a candidate too!**

## Geomagnetism

- A brain structure to process information
  - Wu & Dickman 2012 - neural center for receiving impulses from the sensory system
  - Cells in the brain stem (vestibular nuclei) encode magnetic direction, polarity, & intensity
  - Impulses came from inner ear structure (lagena) – not sure how

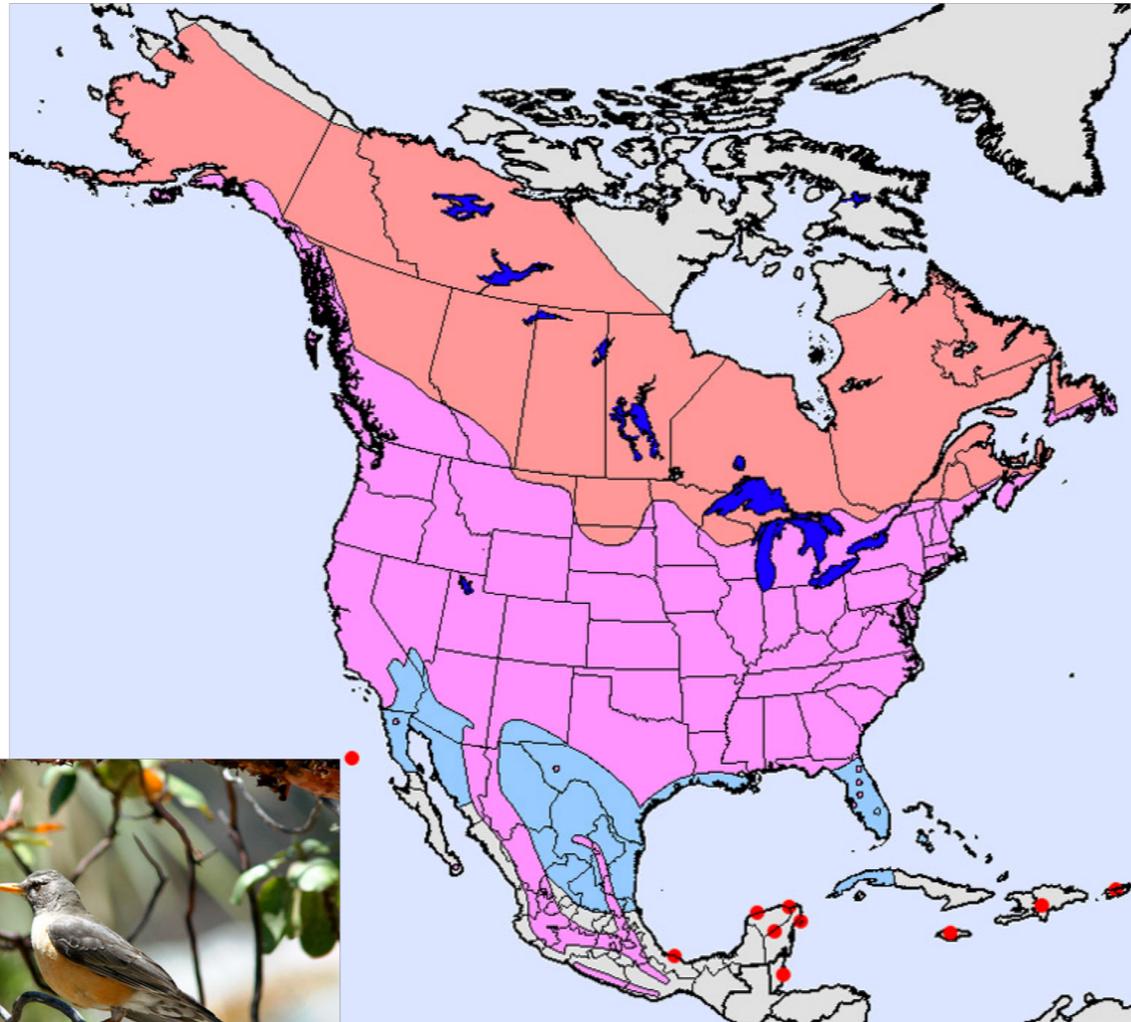
## Geomagnetism

- Where is the comparison “map” stored?
  - Not sure yet, but likely in the hippocampus



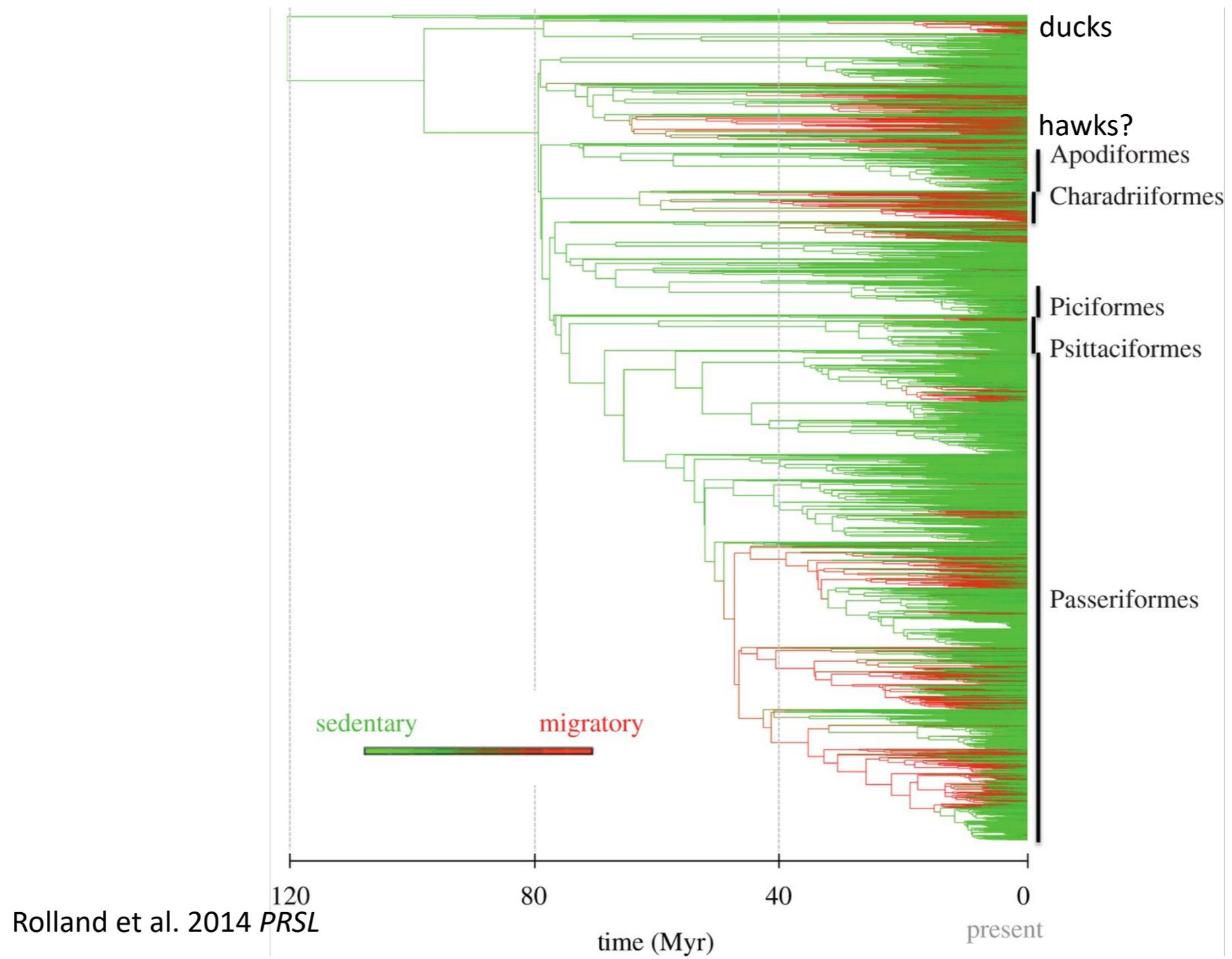
## Evolution of Migration

- How easy is it to turn migration off and on evolutionarily?
- Not that hard --- many bird species have both sedentary AND migratory populations

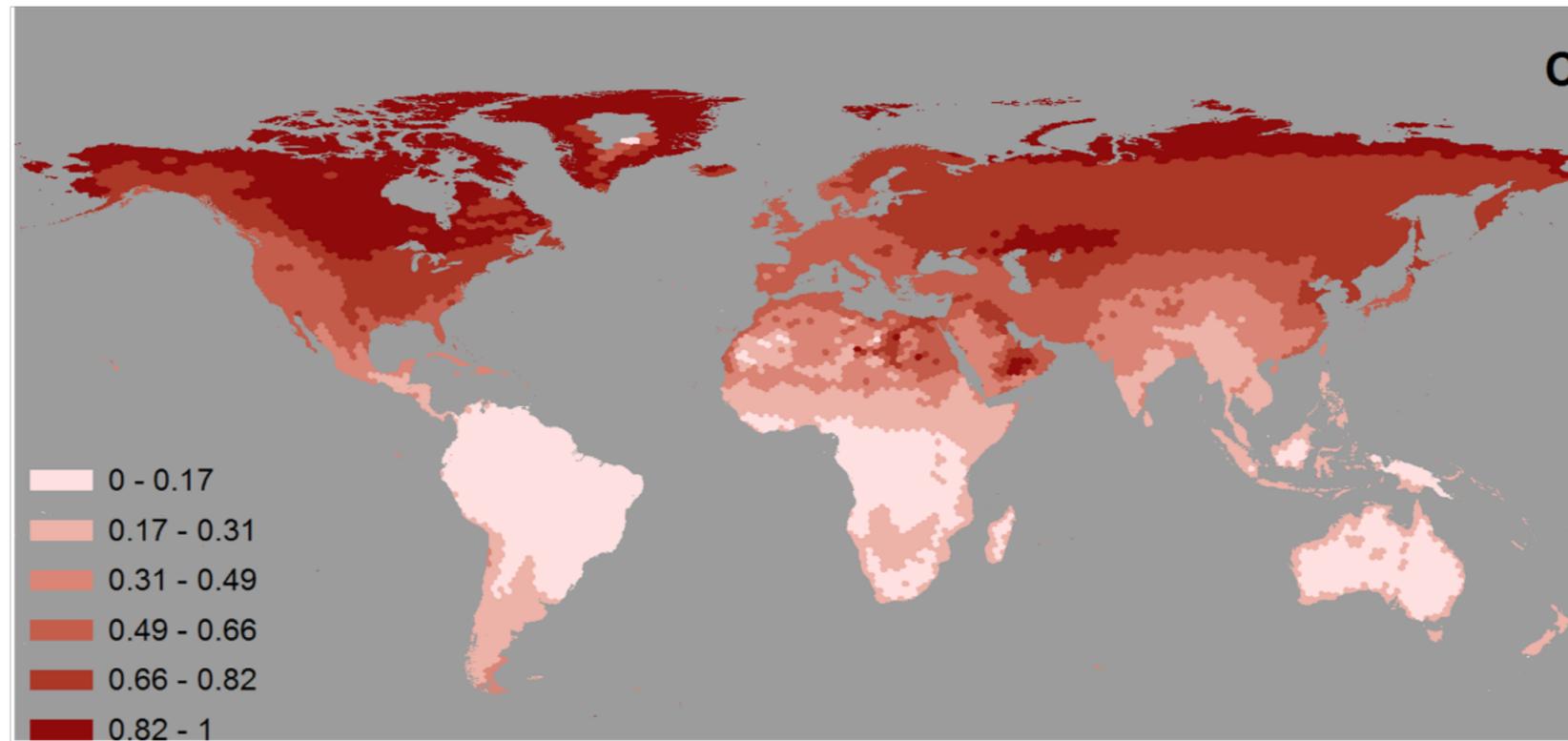


- Permanent Resident
- Breeding Resident
- Nonbreeding Resident
- Passage Migrant
- Introduced
- Uncertain Status
- Vagrant

Map created by Terry Sohl,  
Data from NatureServe



# Migration is mostly a Northern Hemisphere thing

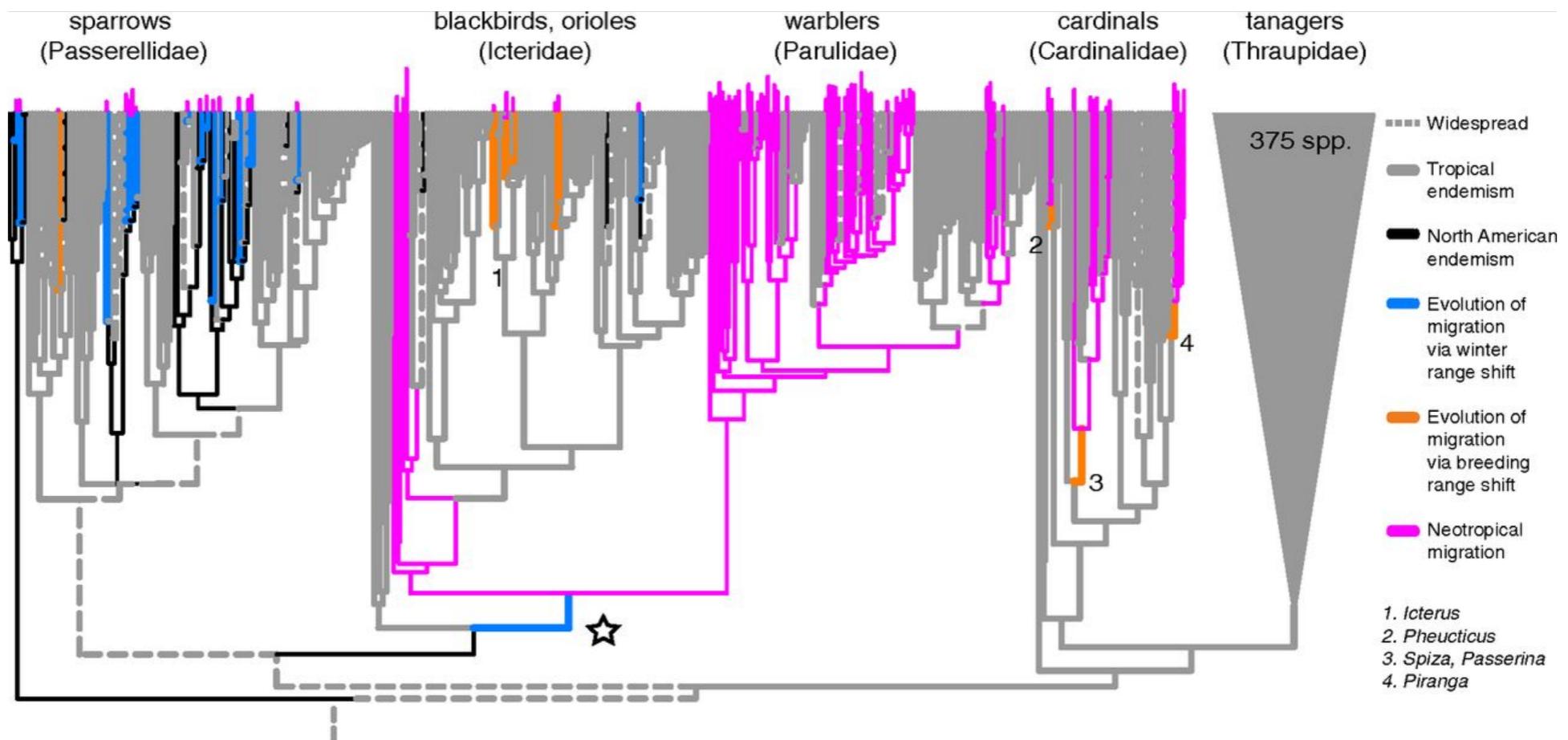


More land in north, plus more seasonality due to less oceanic buffering?

Somveille et al. 2013 *PLoS One*

# How did migration evolve?

- Southern home hypothesis
  - Selective pressure was on finding open breeding grounds to the north
- Northern home hypothesis
  - Selective pressure was on more suitable climates to spend winter



Winger et al. 2014 *PNAS*