Acceleration and demographic rates of bird abundance decline in North America

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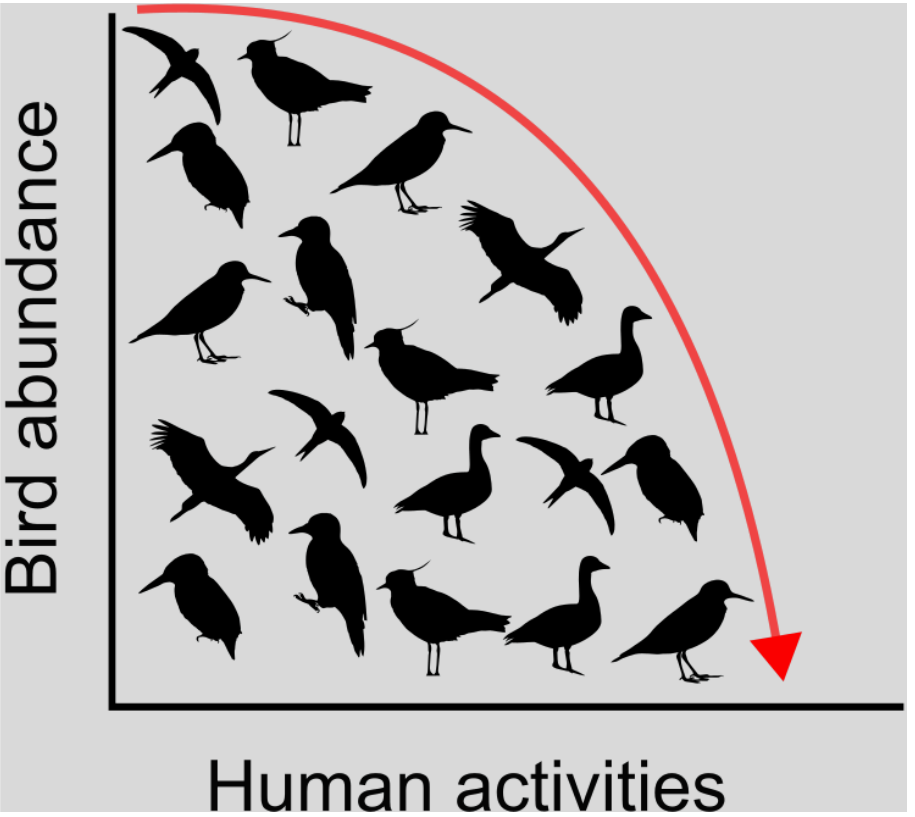

Acknowledgements

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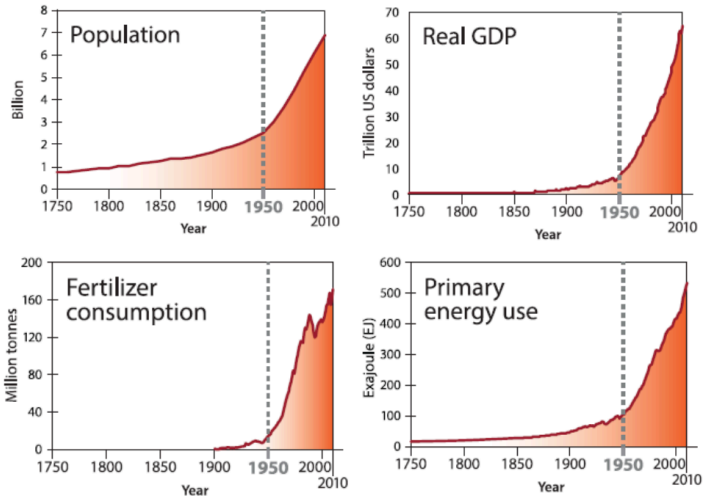
The Great Acceleration

- Since the 50's human population and activities have not only linearly increased, but exponentially increased (i.e. acceleration)
- Exponential growth of GDP is **coupled** with an exponential impact on ecosystems through intensive agriculture, deforestation, transportation, urbanization...
- Exponential growth of GDP is the aim of every national economy



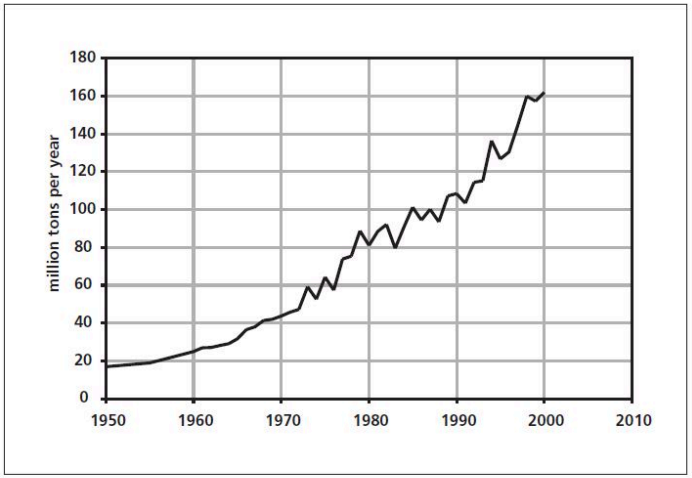
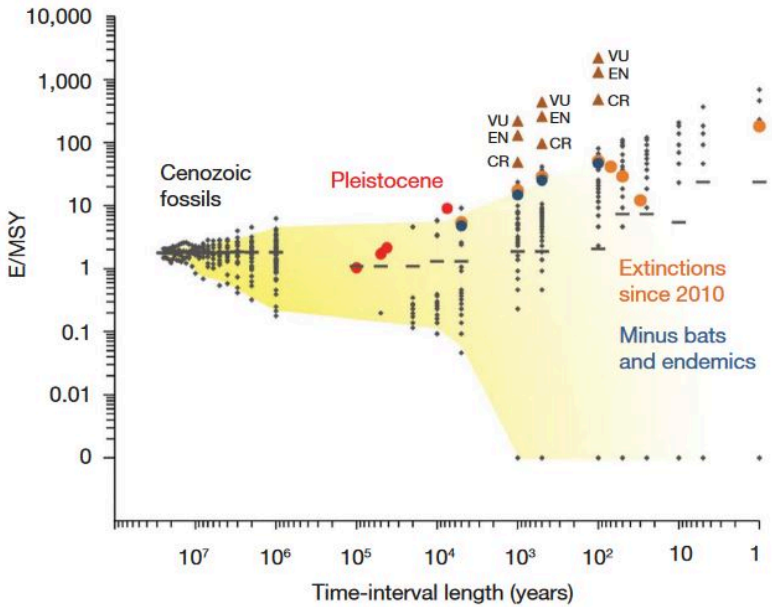


FIGURE 2-1 World Soybean Production

Steffen *et al.*, 2015; Meadows *et al.*, 2004

Impact on biodiversity

- **Acceleration of species extinction**: the current rate of extinction is estimated between 10s to 100s times higher than the background rate
- Road to the sixth mass extinction



Barnosky *et al.*, 2011

Impact on biodiversity

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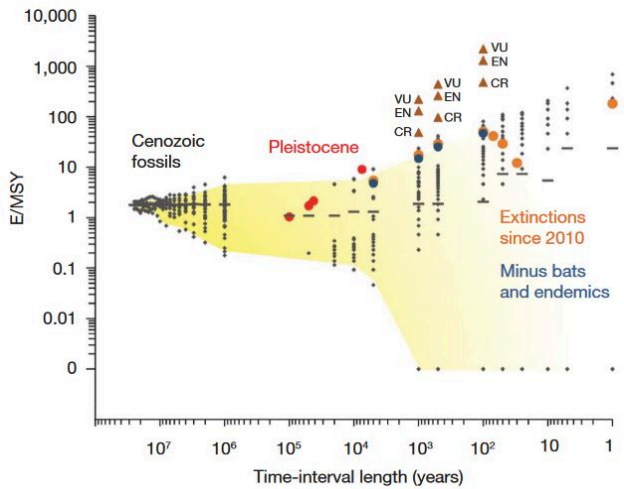


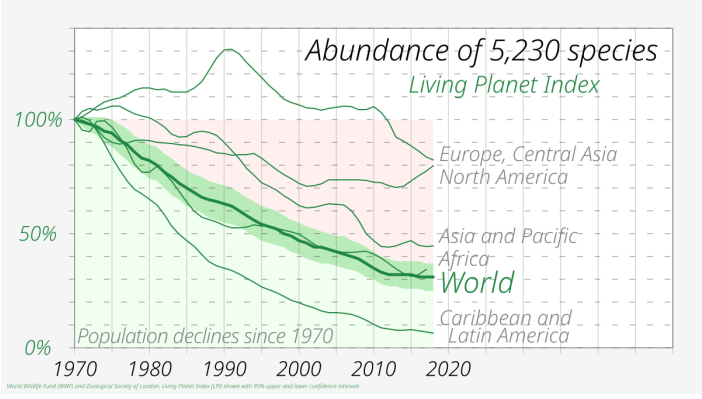
- But species extinctions start with a decline in abundance, so:

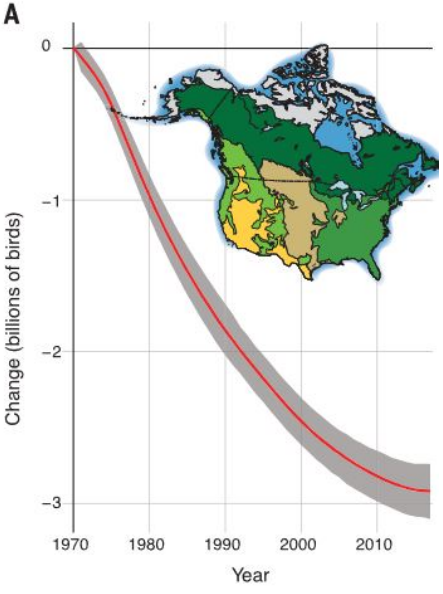
Is the decline of abundance accelerating?

Barnosky *et al.*, 2011

What we know about abundance decline

- The Living Planet Index (though controversial), estimated an average decline per species of 69%
- The IPBES estimated a 20% decline
- Overall bird abundance decline in North America is around 29%





Living Planet Index; Rosenberg *et al.*, 2019

What we know about abundance decline

- The Living Planet Index (though controversial), estimated an average decline per species of 69%
- The IPBES estimated a 20% decline
- Overall bird abundance decline in North America is around 29%

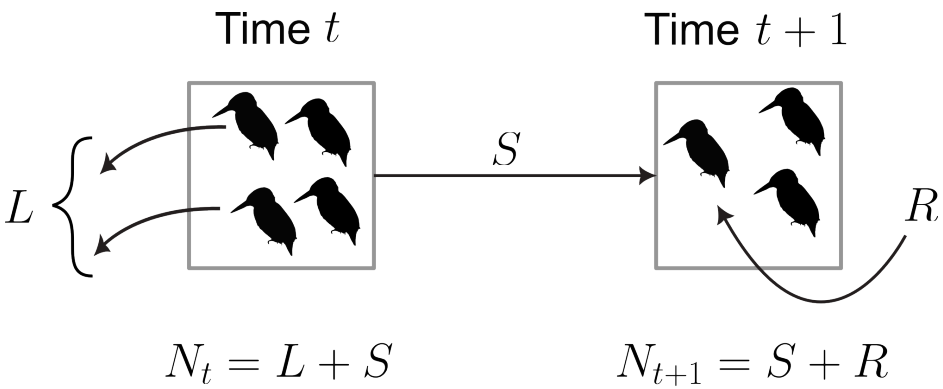
In average this decline seems linear

Why don't we observe an acceleration of abundance decline?

Living Planet Index; Rosenberg *et al.*, 2019

Acceleration and its decomposition

- Change in abundance ΔN = increase or decrease
- Change in yearly growth rate Δg = acceleration or deceleration
- Δg is the difference between change in recruitment rate Δr and loss rate Δl



$$\Delta N = N_{t+1} - N_t = R - L$$

$$g = \frac{\Delta N}{N_t} = \frac{R}{N_t} - \frac{L}{N_t} = r - l$$

$$\Delta g = \Delta r - \Delta l = \Delta(\frac{\Delta N}{N_t})$$

Acceleration and its decomposition

- Change in abundance ΔN = increase or decrease
- Change in yearly growth rate Δg = acceleration or deceleration
- Δg is the difference between change in recruitment rate Δr and loss rate Δl

Problem

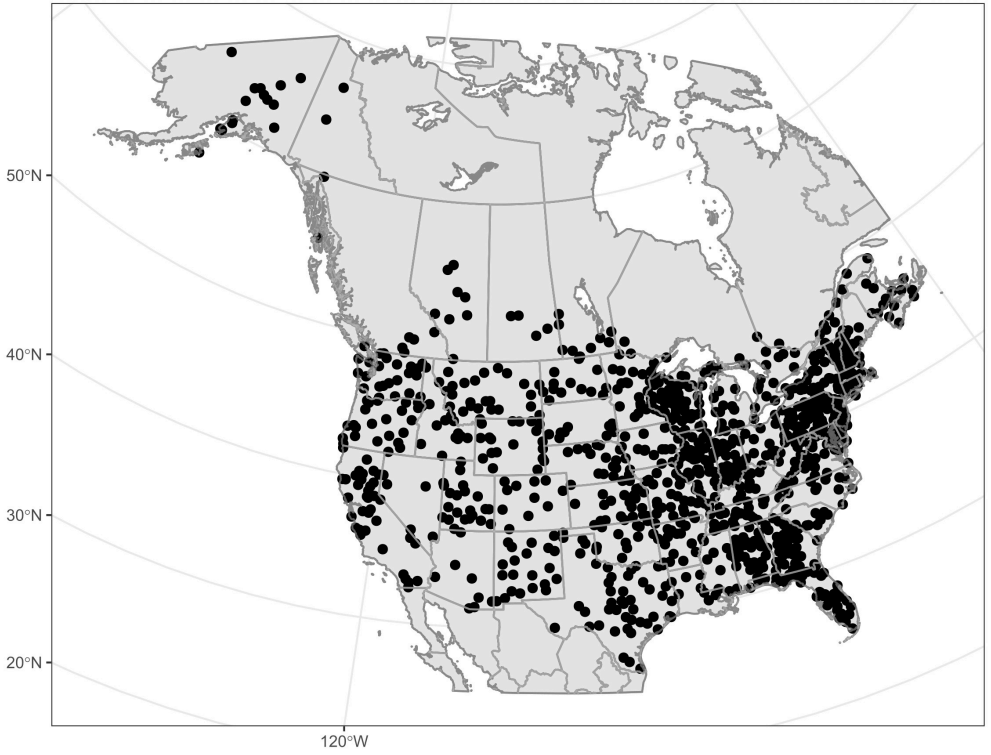
A value of Δg can be the results of infinite combinations of Δr and Δl

From a conservation perspective, it is important to know which process, between Δr and Δl, is the driving force of the temporal dynamic

Methods

Data - Breeding Bird Survey (BBS)

- Structured data on North American avifauna
- From 1987 to 2021
- More than 1000 routes
- 564 species



Dynamic N-mixture model

- Occupancy model: assess survival and recruitment from count data

$$N_{t+1} = Survival_{t+1} + Recruitment_{t+1}$$

with

$$Survival_{t+1} \sim Bin(N_t, \omega)$$

$$Recruitment_{t+1} \sim Poisson(\gamma)$$

$$Loss_t = N_t - S_{t+1}$$

- Accounting for detection probabilities, depending on weather:

$$N^*{}_t \sim Bin(N_t, p)$$

$\Rightarrow$ Sky condition, wind condition, temperature & time of the day

- One model per species. Then stacked to get the overall abundance

Dynamic N-mixture model

- 3 MCMC chains per species $\times$ 564 species $=$ **1692 MCMC chains**

$\Rightarrow$ **5 years** to fit the model using 1 core

Marta Jarzyna

THE OHIO STATE UNIVERSITY

$\Rightarrow$ Ohio Supercomputer Center to **parallelize** the learning on **1692 cores**

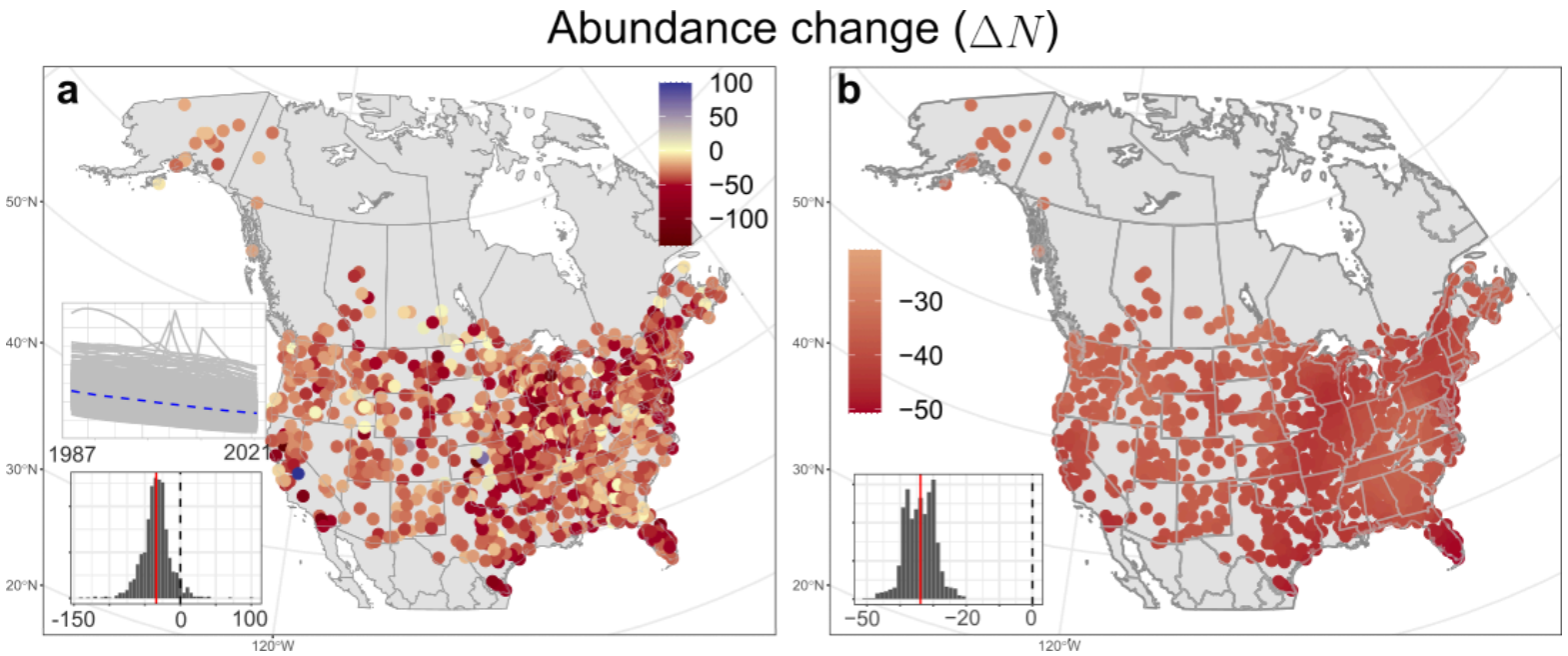
Ohio Supercomputer Center

An OH·TECH Consortium Member

Results

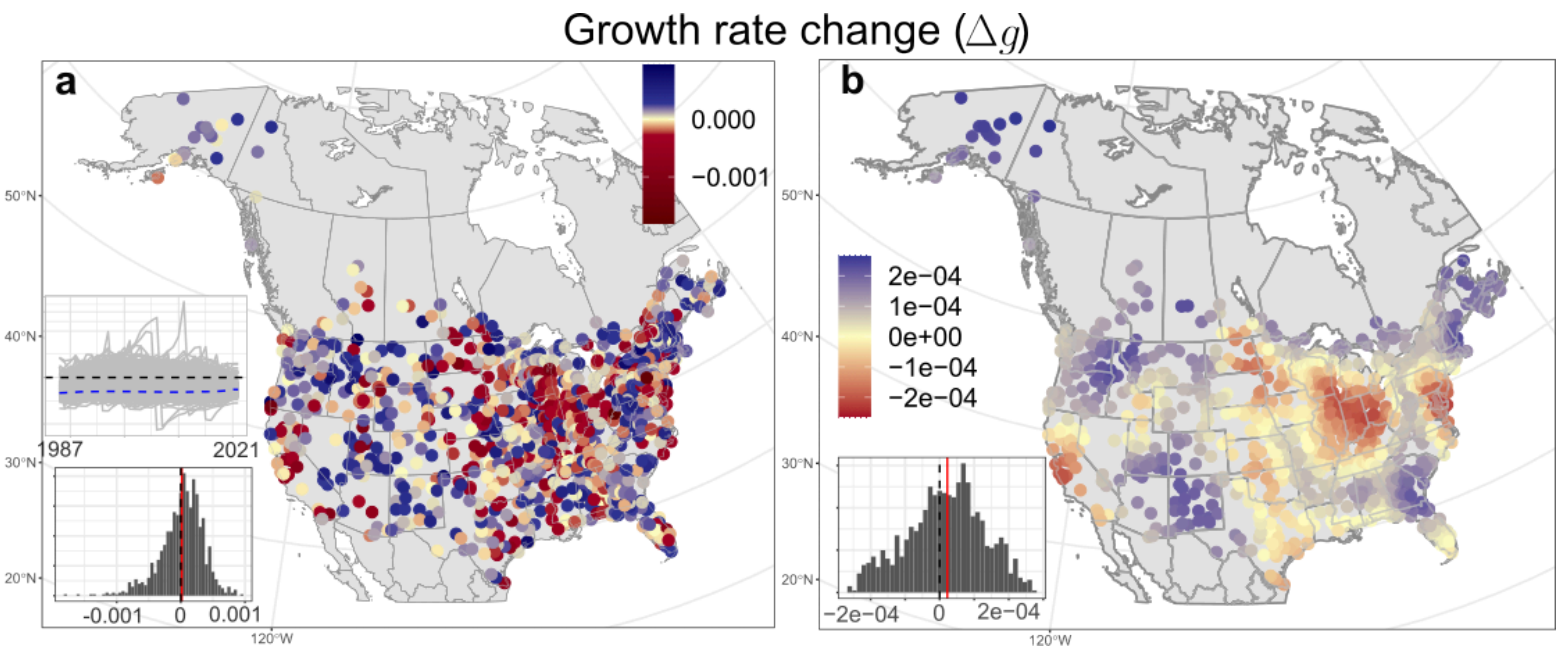
Trend in abundance

- Continental decline: 96% of the route with negative ΔN
- Hot-spots in Texas, Florida, Delaware and New Jersey
- Average decline per route of 22%



Acceleration of the decline

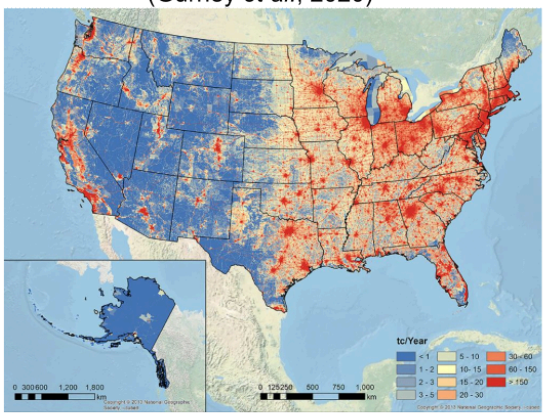
- As ΔN is mostly negative, mapping Δg shows acceleration or deceleration of the decline
- At the continental scale, no trend toward acceleration (42%) or deceleration (58%)
- Hot-spots of acceleration in Midwest, California and Mid Atlantic regions



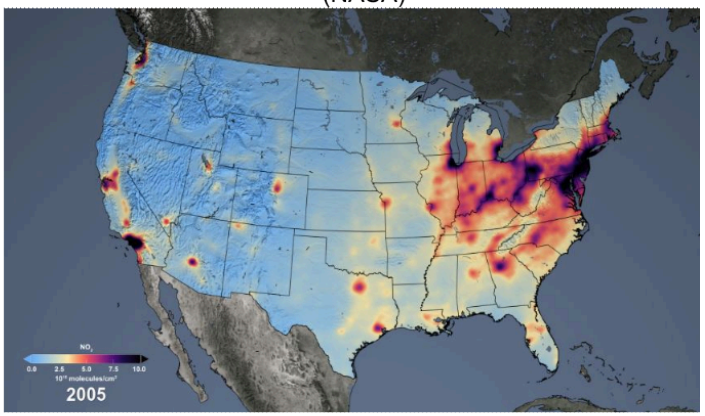
Acceleration matches human activities

- Patterns of ΔN don't match human activities, but Δg patterns do

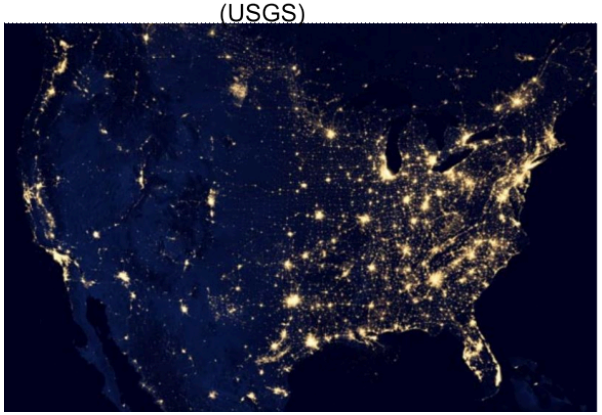
CO2 emissions
(Gurney *et al.*, 2020)

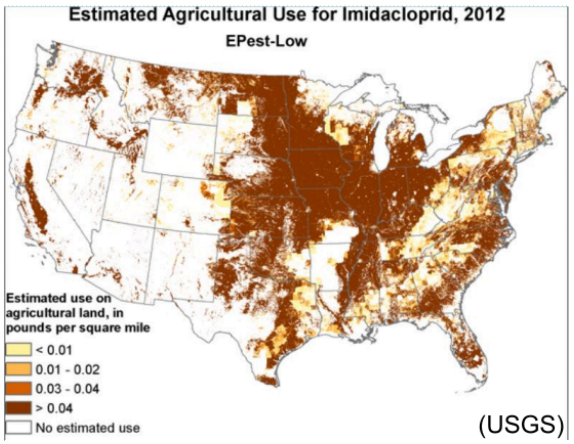


NO2 emissions
(NASA)



Night Lights
(USGS)

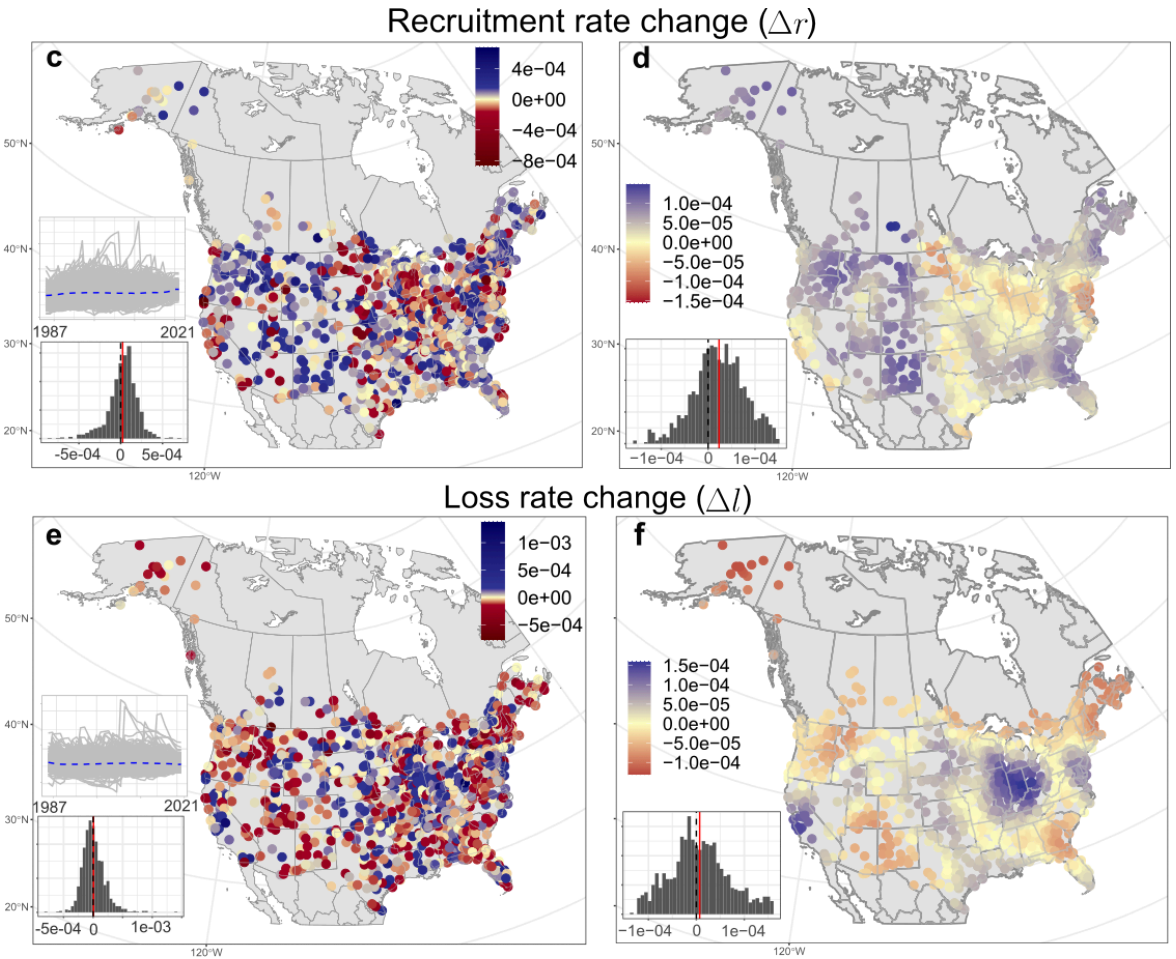




(USGS)

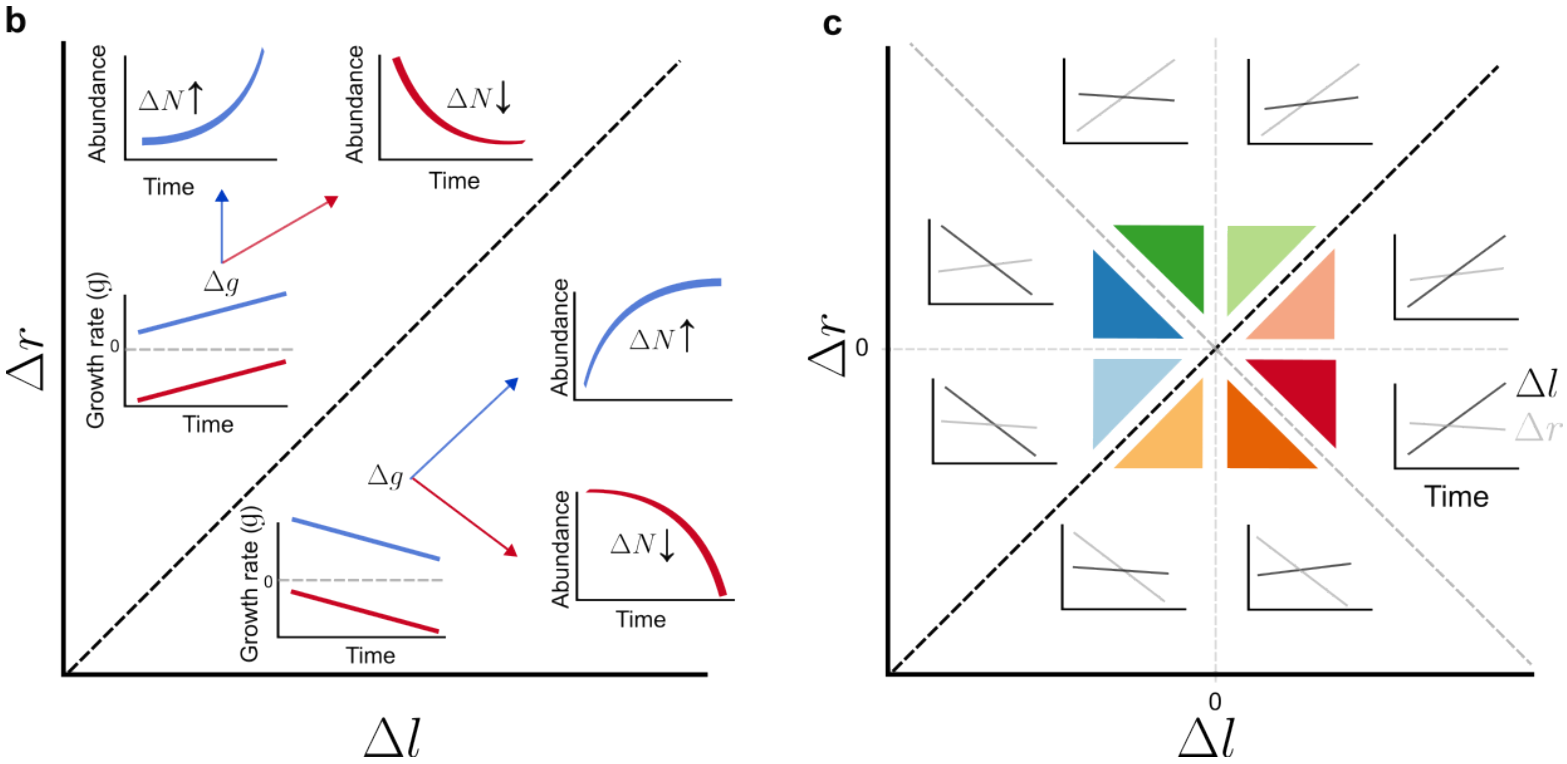
Decomposition of acceleration

$$\Delta g = \Delta r - \Delta l$$



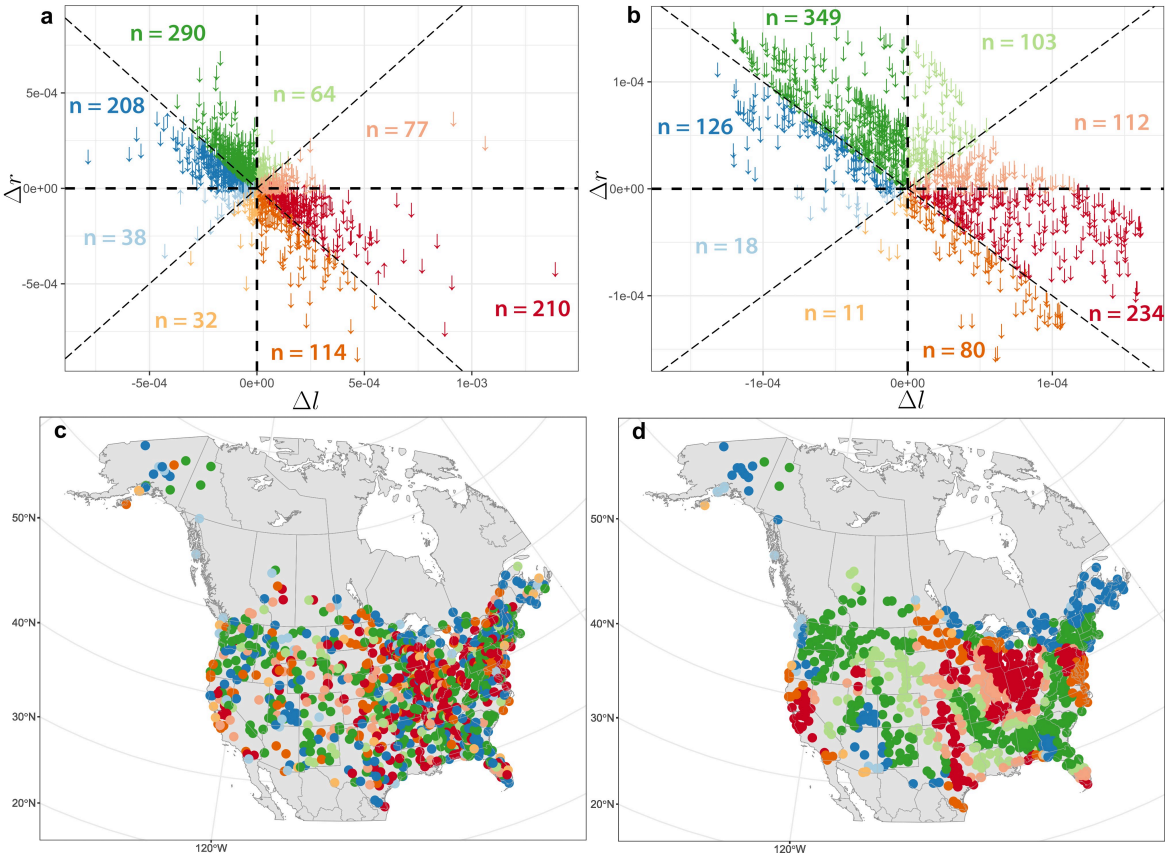
Decomposition of acceleration

Map Δr and Δl in a $2D$ space

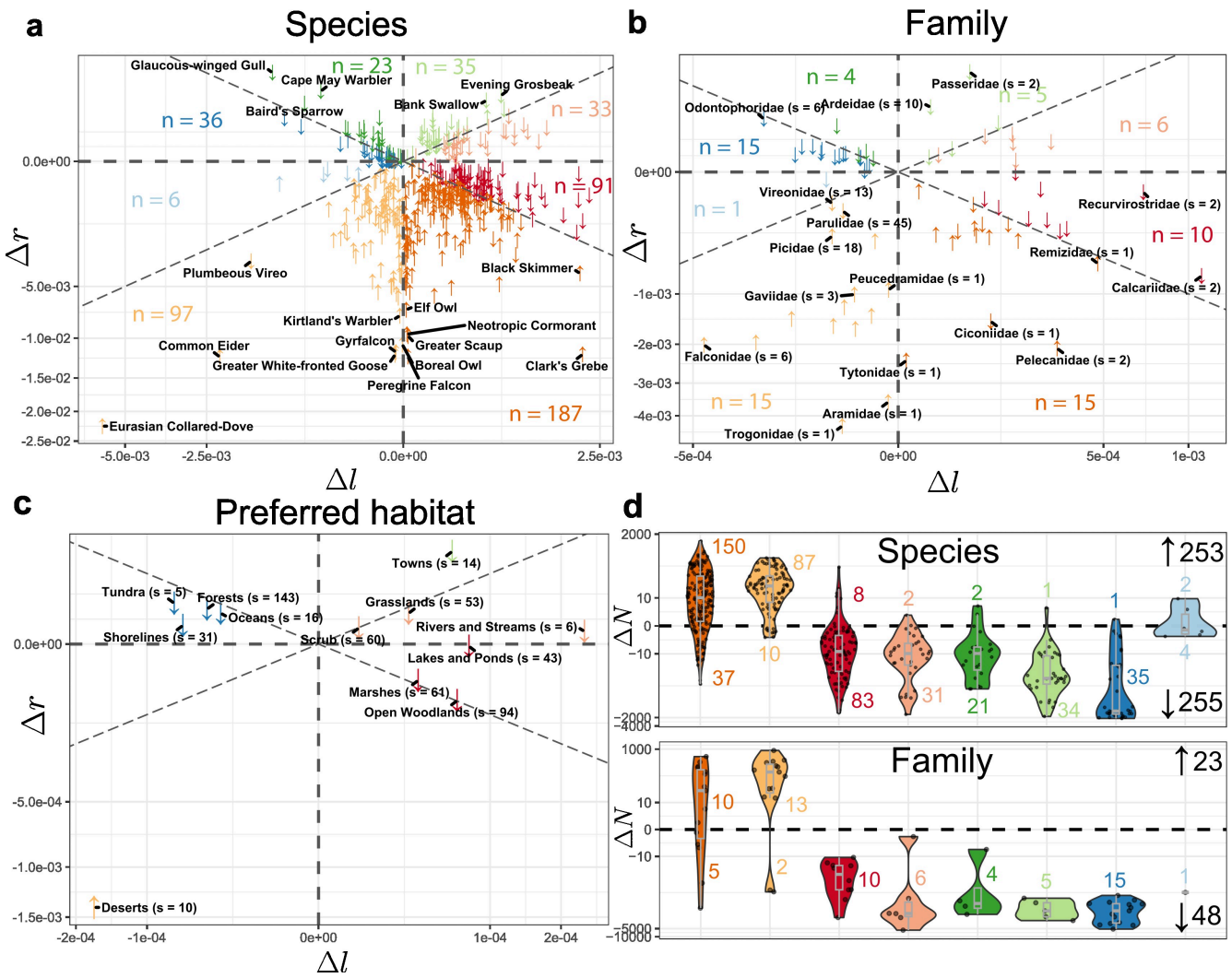


Decomposition of acceleration

- Increase in Δl dominates in Midwest and California
- Decrease in Δr dominates in Mid Atlantic



Decomposition of acceleration



Take home messages

- The decline of bird is continental, with an average of 22% (in line with Rosenberg. *et al.*, 2019)
- The decline is accelerating where human activities take place (Midwest, California and Mid Atlantic)
- Decrease in recruitment rate is the main process in Mid Atlantic, and increase in loss rate in Midwest and California
- 96% of species and 100% of families with increasing abundance are undergoing a decline in recruitment rate
- Enhancing recruitment rate should be considered in conservation policies

Caveats

- **Propagation of uncertainty, from per species model, to overall abundance:**

I stacked the abundance of each per species model using the mean of the posterior distributions. The uncertainty of the parameters are not propagated into the trends.

Are there any experts in Bayesian statistics or occupancy models in this room?

Please, let's have a chat!

🙏🙏🙏

- **Density dependence not considered:** the fact that Δr is negative for most of the increasing species could be an artefact of the occupancy models? Accounting for density dependence may change this result?

Thank you for your attention

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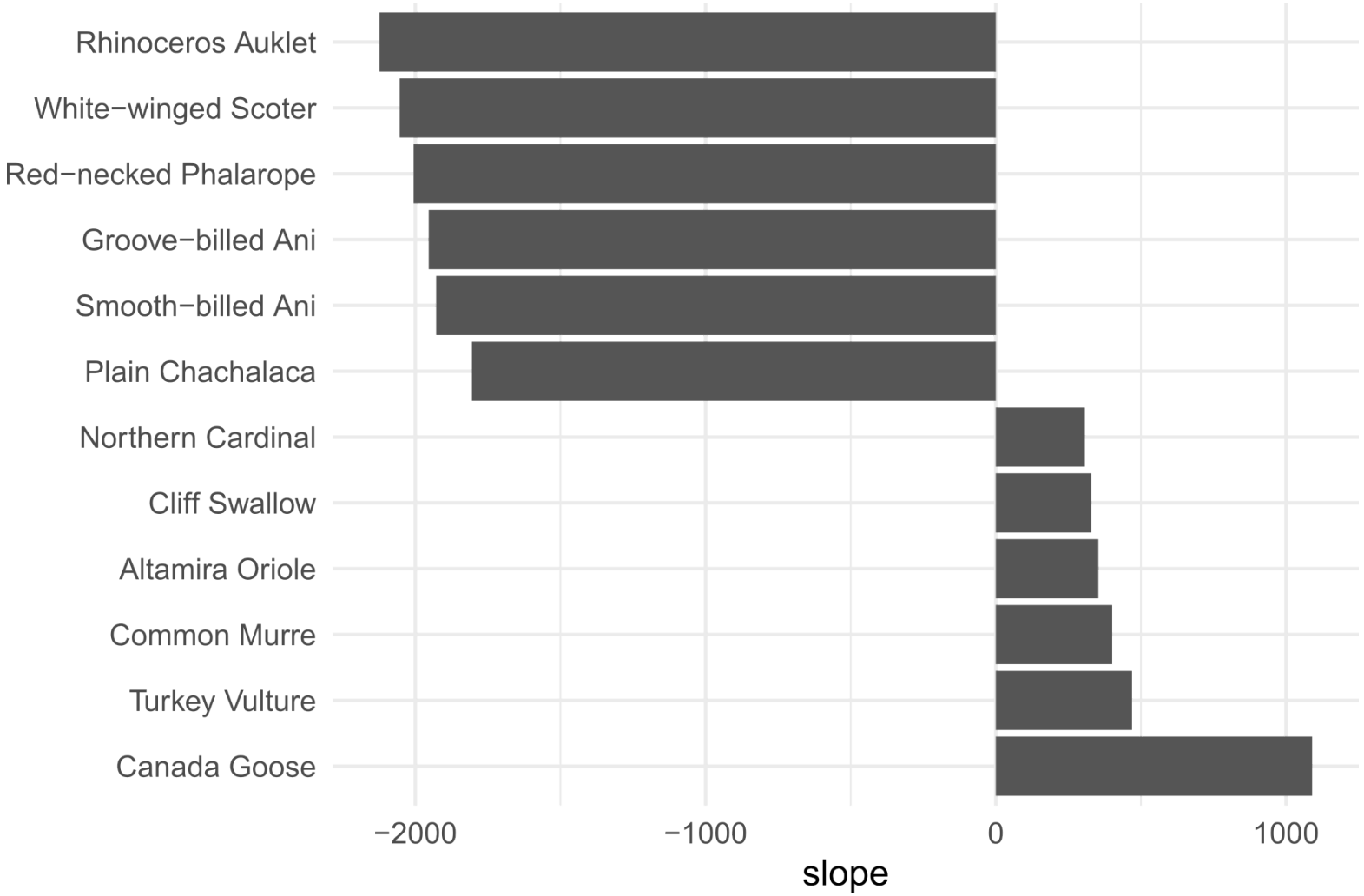
@FrsLry

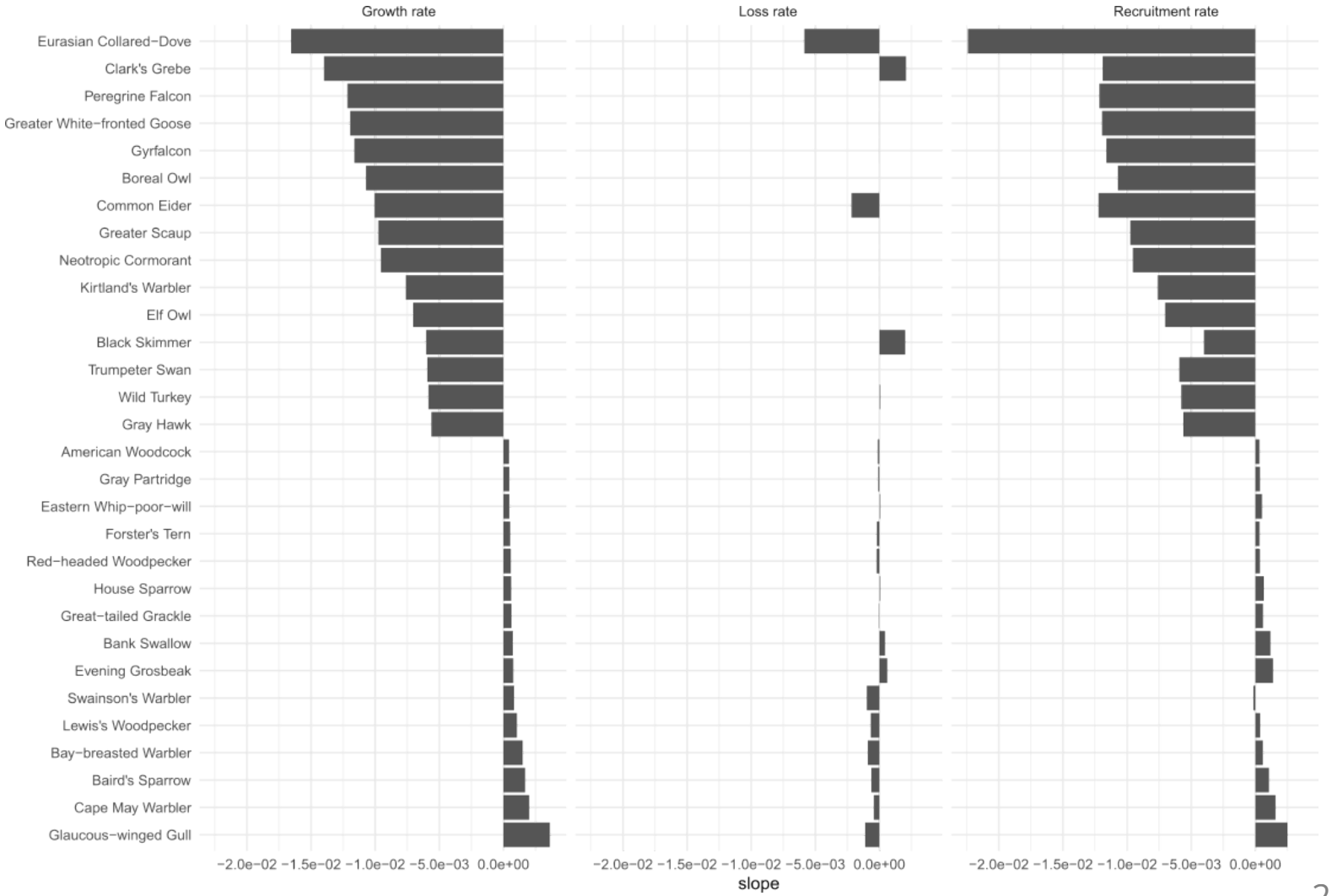
FrsLry

Supplementary

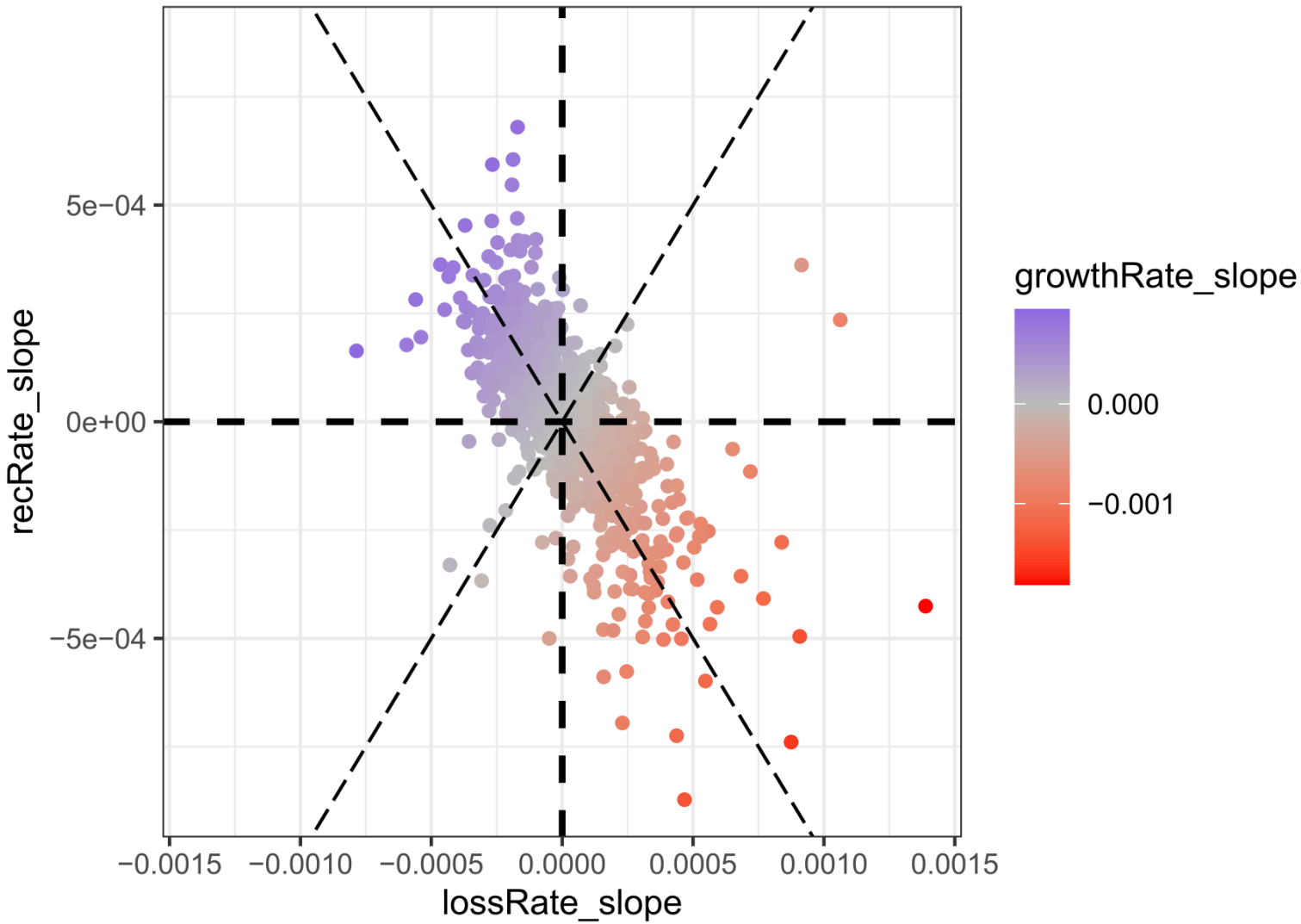
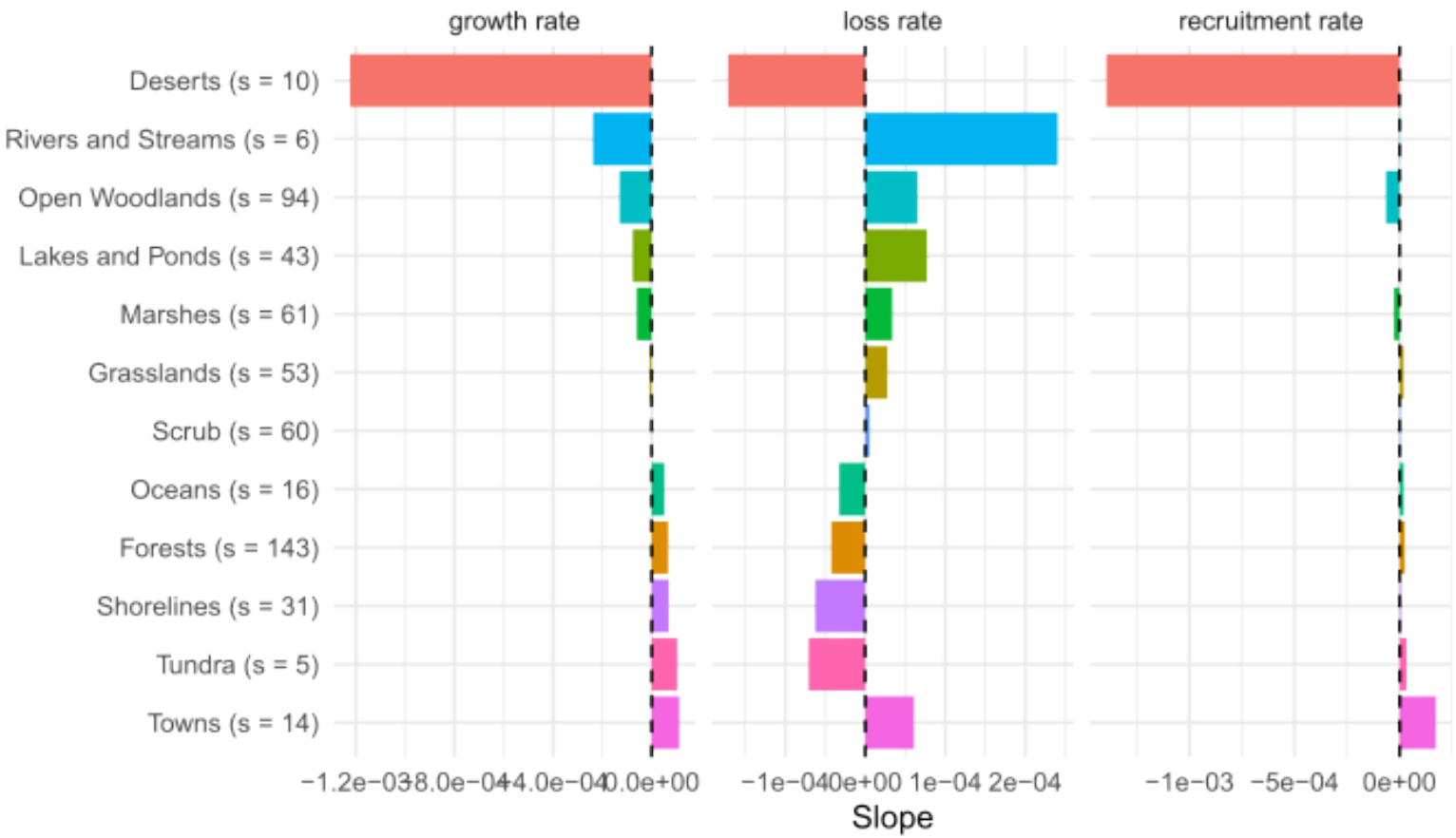
Per species change - Abundance



Rate change


Growth rate
Loss rate
Recruitment rate
Eurasian Collared−Dove
Clark's Grebe
Peregrine Falcon
Greater White−fronted Goose
Gyrfalcon
Boreal Owl
Common Eider
Greater Scaup
Neotropic Cormorant
Kirtland's Warbler
Elf Owl
Black Skimmer
Trumpeter Swan
Wild Turkey
Gray Hawk
American Woodcock
Gray Partridge
Eastern Whip−poor−will
Forster's Tern
Red−headed Woodpecker
House Sparrow
Great−tailed Grackle
Bank Swallow
Evening Grosbeak
Swainson's Warbler
Lewis's Woodpecker
Bay−breasted Warbler
Baird's Sparrow
Cape May Warbler
Glaucous−winged Gull
−2.0e−02 −1.5e−02 −1.0e−02 −5.0e−03 0.0e+00
slope

Rec. rate vs. Loss rate colored by growth rate



Species' preferred habitat - Rates