

# Anthropogenic air pollution and American bird abundance

Yuanning Liang – Cornell University

Ivan Rudik – Cornell University

Eric Zou – University of Oregon

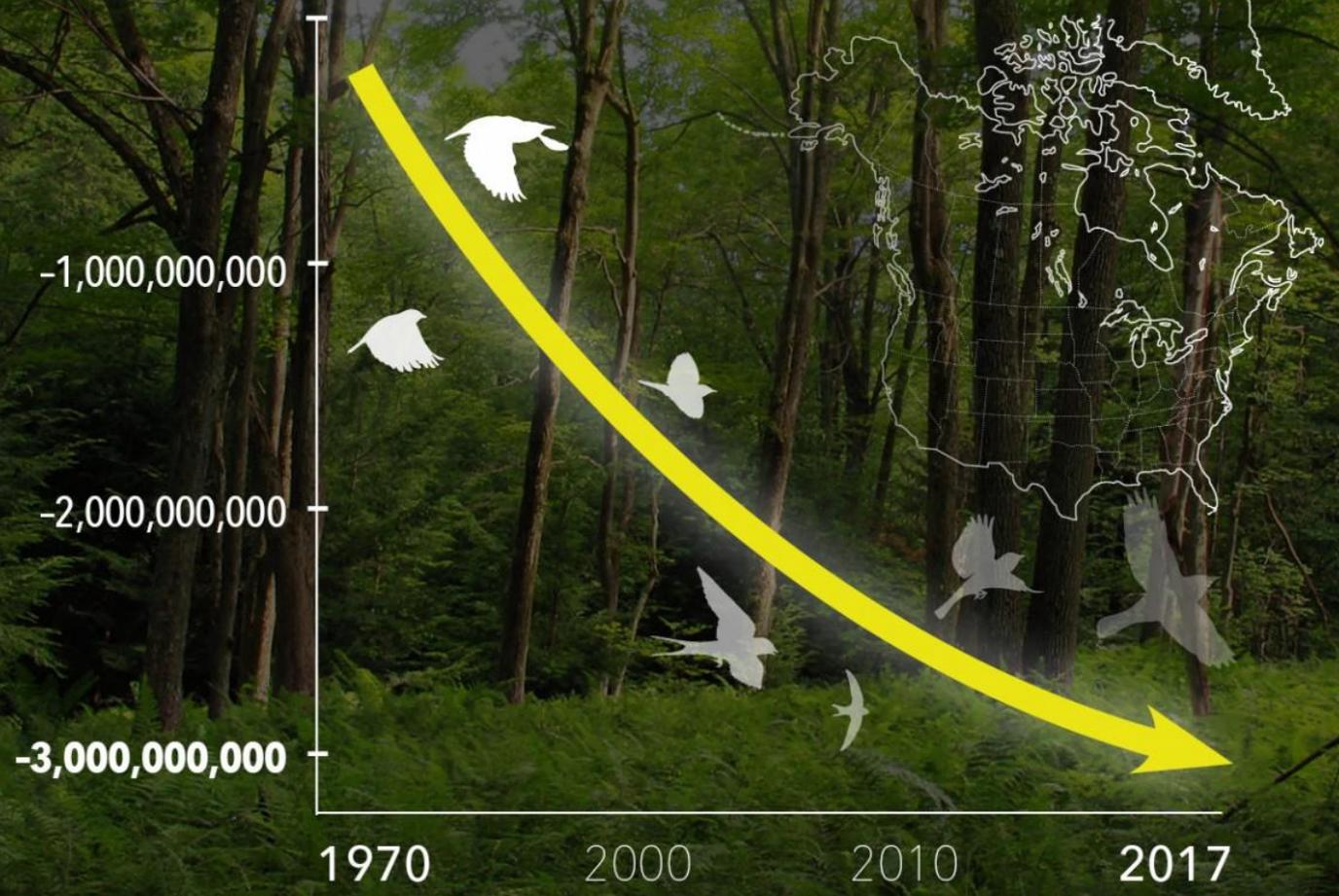
Alison Johnston – Cornell University

Amanda D. Rodewald – Cornell University

Cathy Kling – Cornell University

February, 2020

# 2.9 billion birds gone since 1970



Courtesy of the Cornell Lab of Ornithology. Source: Science, 2019

Forest by Nicholas Tonelli/Creative Commons, Map from Birds of North America birdsna.org

# Potential causes?

## Habitat loss



# Potential causes?

## Climate change



# Potential causes?

## Pesticides



# Potential causes?

## **Air pollution**



Is there evidence that air pollution is associated with bird populations?

Why are economists doing this?

Don't you study unemployment rates?

Why are economists doing this?

Don't you study unemployment rates?

**What do environmental economists do?**

Why are economists doing this?

Don't you study unemployment rates?

**What do environmental economists do?**

**Among many other things:** estimate impacts and value of changes in environmental quality

Why are economists doing this?

Don't you study unemployment rates?

**What do environmental economists do?**

**Among many other things:** estimate impacts and value of changes in environmental quality

Economists have been largely human-focused in their efforts (e.g. human health, labor markets, cognition, production)

# Why air pollution?

There is little large-scale evidence for the effects of air pollution (Sanderfoot and Holloway 2017)

# Why air pollution?

There is little large-scale evidence for the effects of air pollution (Sanderfoot and Holloway 2017)

Valuing air pollution directly informs environmental policy (e.g. ~~Clean Power Plan~~, Clean Air Act, Regional Haze Rule)

# Why air pollution?

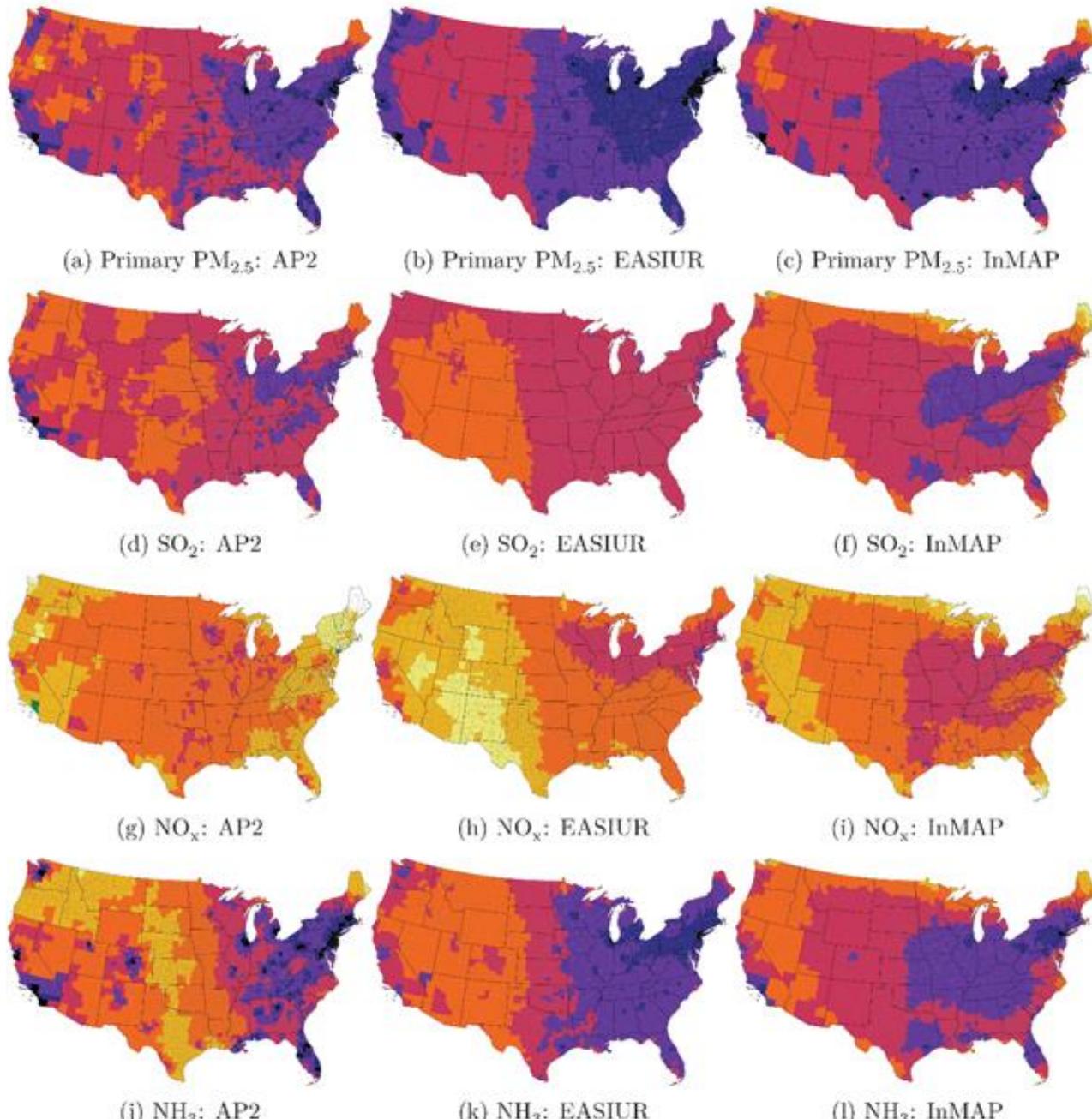
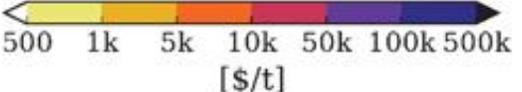
There is little large-scale evidence for the effects of air pollution (Sanderfoot and Holloway 2017)

Valuing air pollution directly informs environmental policy (e.g. ~~Clean Power Plan~~, Clean Air Act, Regional Haze Rule)

**Air pollution is really, really bad for living things; may be worse for avian species (Sanderfoot and Holloway 2017)**

Integrated assessment models suggest damages from some pollutants can be

**\$10,000-\$1,000,000/ton**

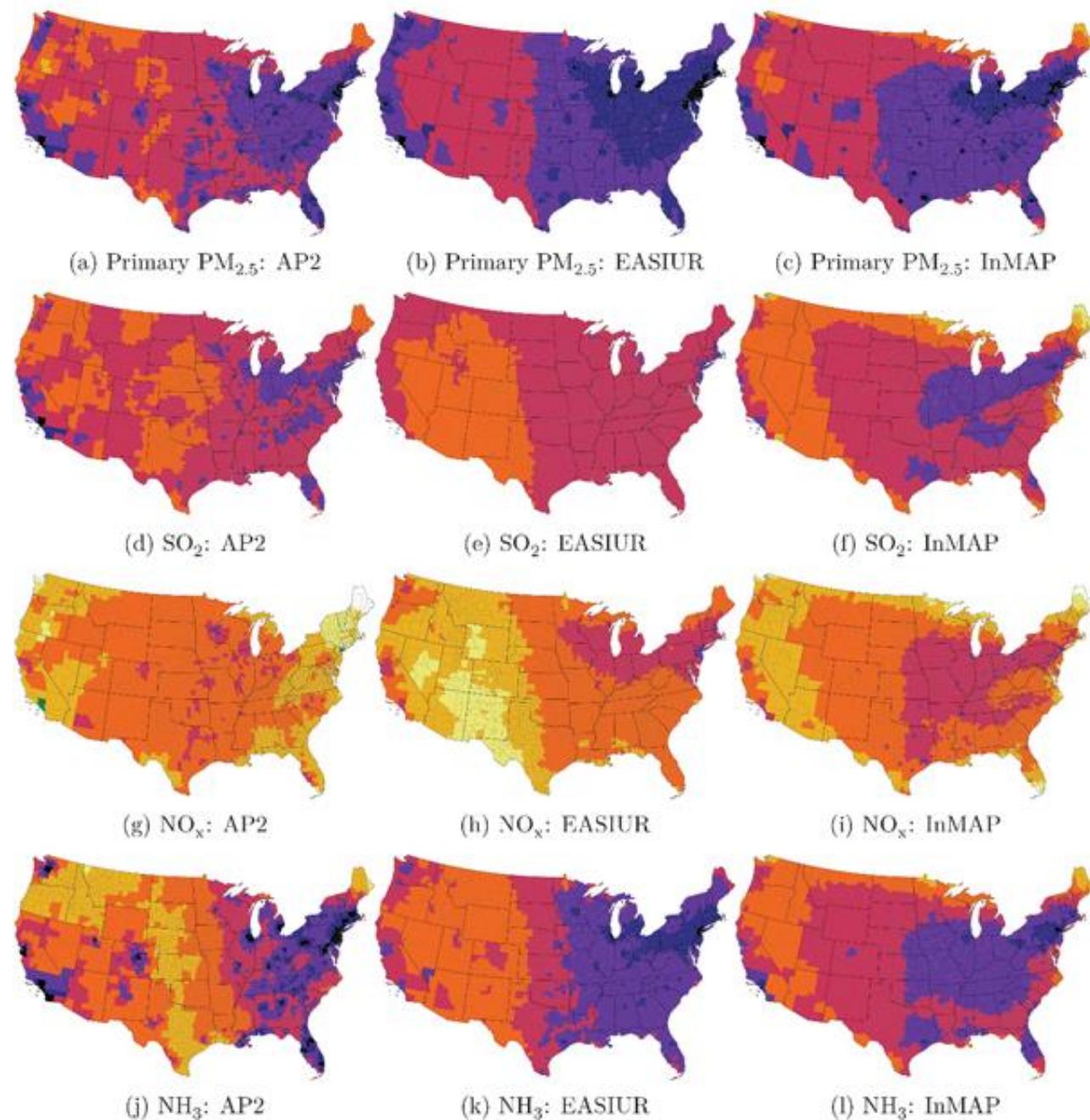


Gilmore et al. (2019)

Integrated assessment models suggest damages from some pollutants can be **\$10,000-\$1,000,000/ton**

Damages are generally human-focused: human health, crops, timber, building damage, etc

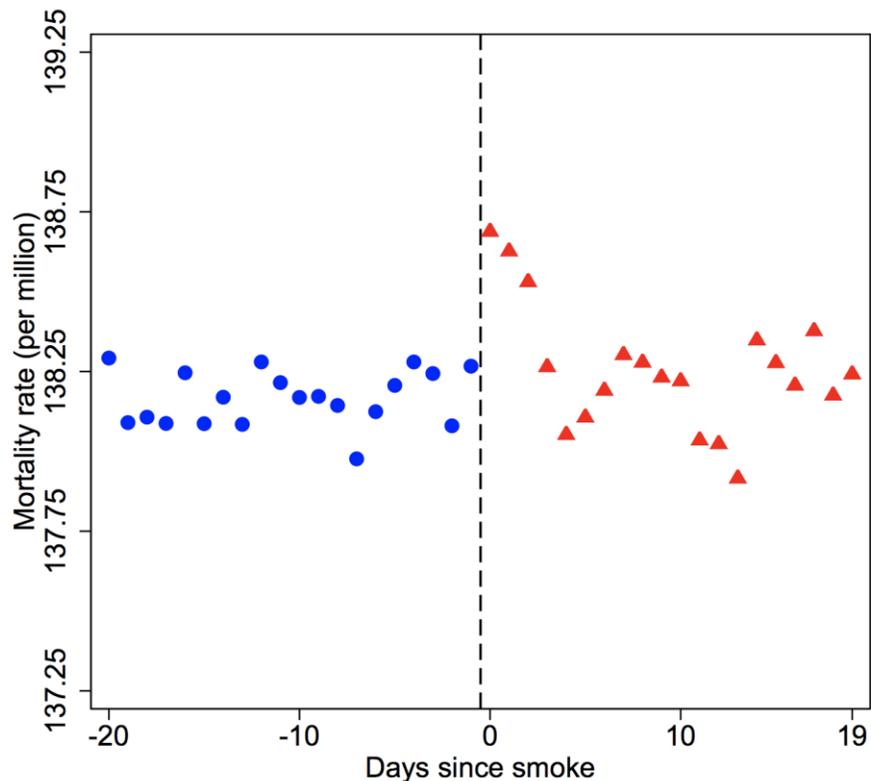
500 1k 5k 10k 50k 100k 500k  
[\$/t]



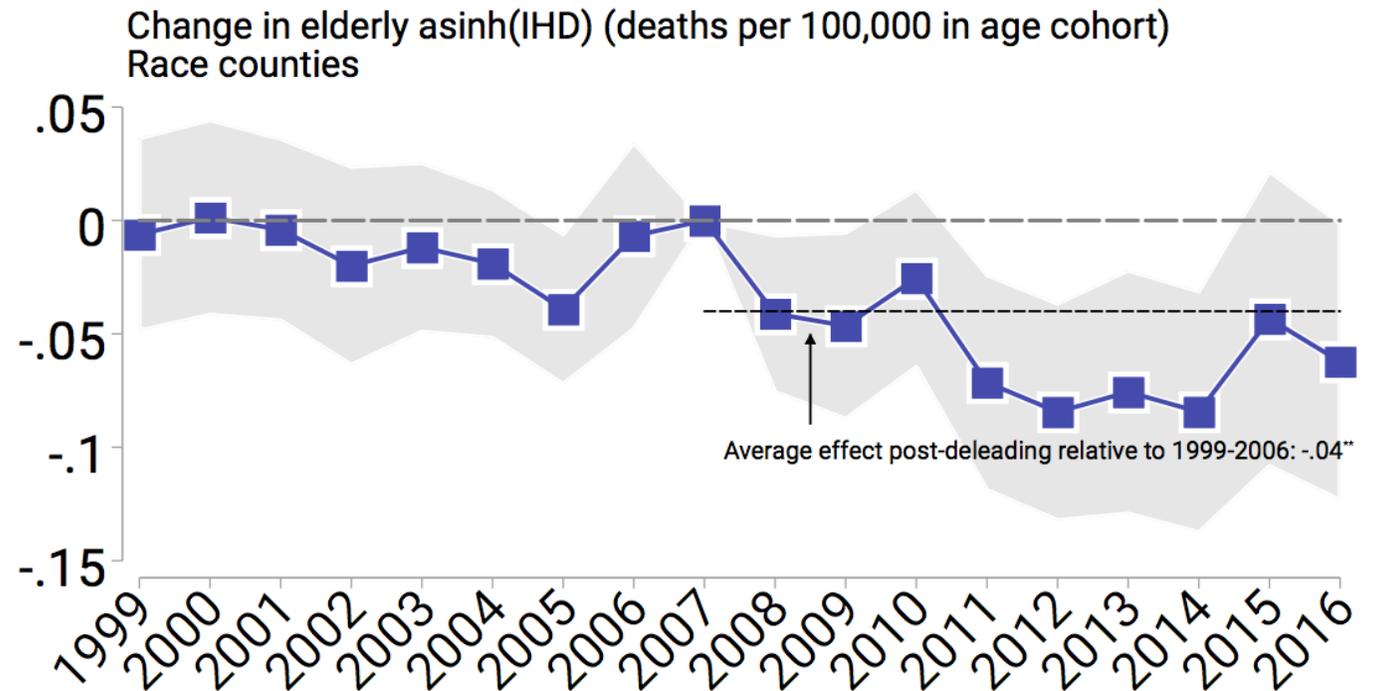
Gilmore et al. (2019)

# Why air pollution?

Extensive recent evidence shows air pollution is a major determinant of **human** mortality and

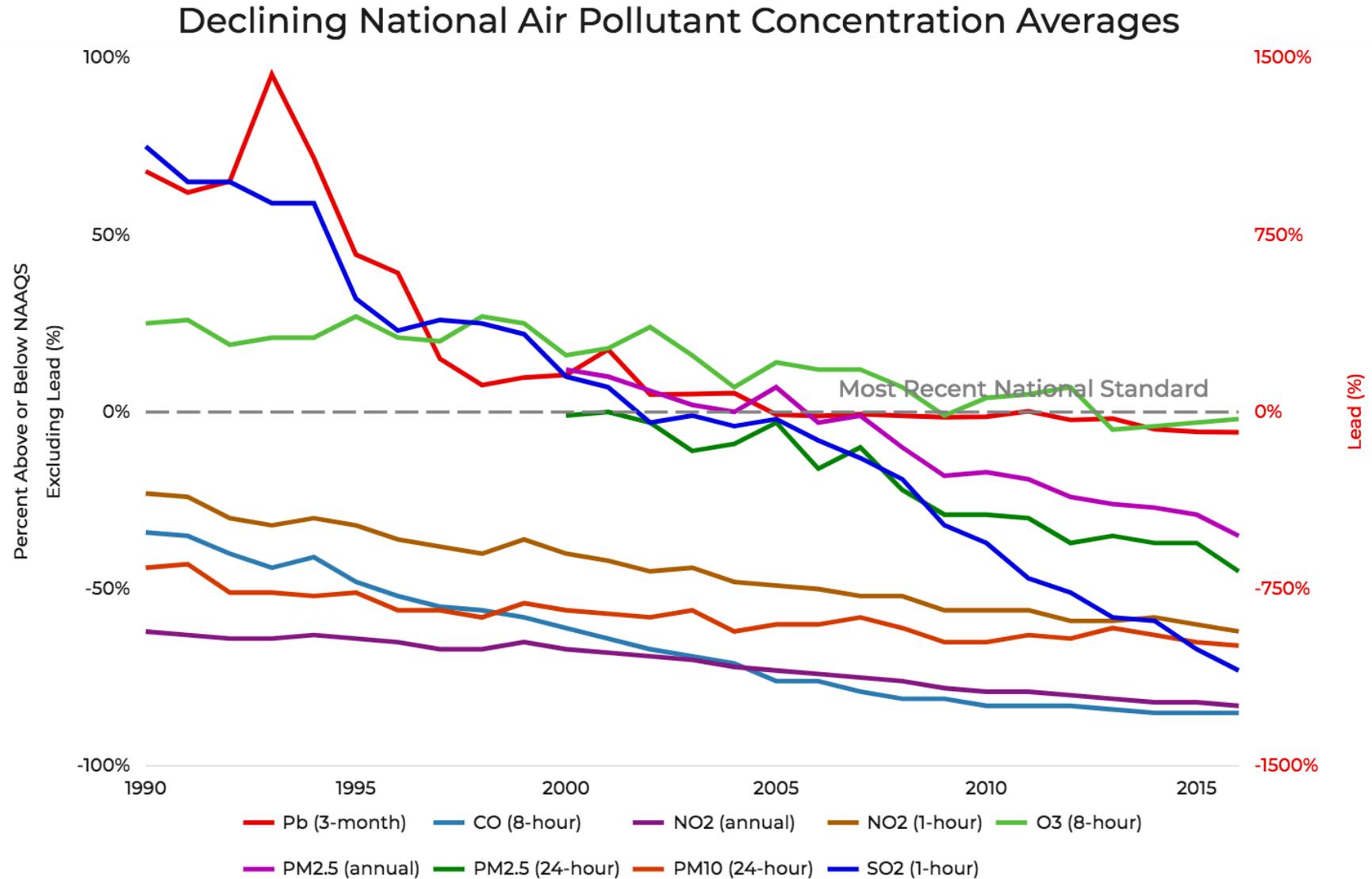


Miller, Molitor, Zou (2019)

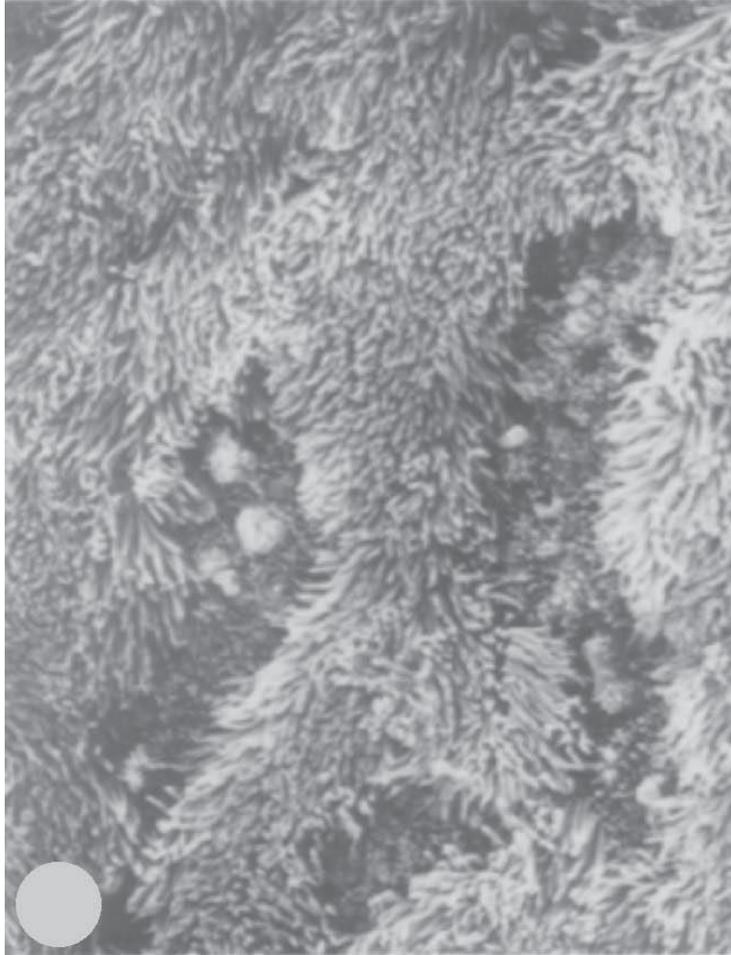


Hollingsworth and Rudik (2019)

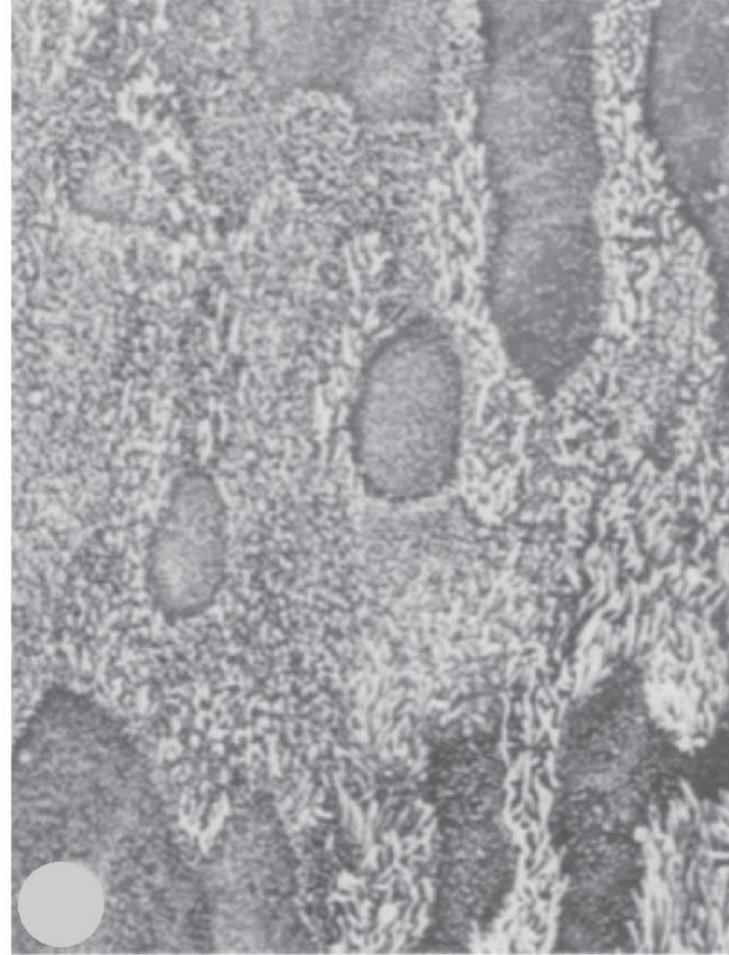
# Criteria pollution has dramatically improved over the last 30-50 years; uptick since 2017



# How does pollution harm living things?



Healthy quail lung  
tissue and cilia



Damaged quail cilia  
from ozone

Source:  
Rombout et al. (1991)

# How does pollution destroy habitat?

Source: USDA



Ozone oxidizes and kills plant tissue



Causes more damage than all other air pollutants combined

# How does pollution harm living things?

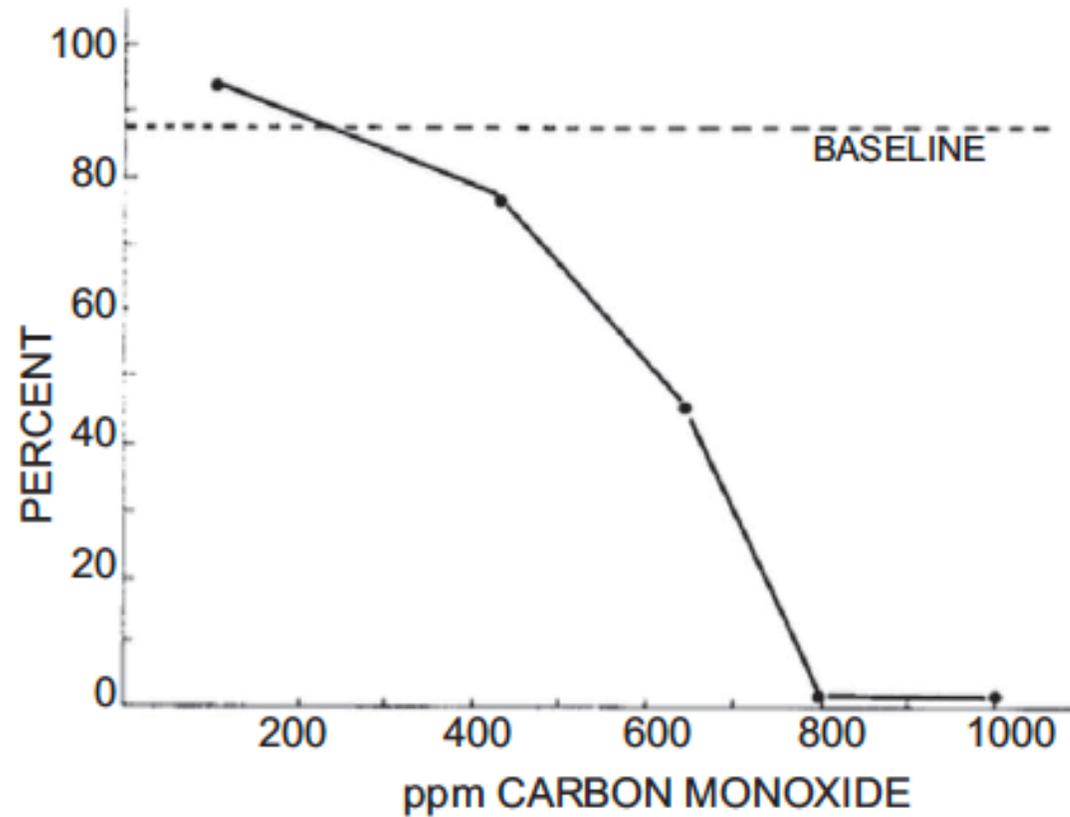


Figure 4. Plot from Baker and Tumasonis 1972, showing percent hatchability as a function of carbon monoxide concentration. As carbon monoxide concentrations increase, hatchability declines. Permission to reuse this figure obtained from Taylor & Francis Ltd ([www.tandfonline.com](http://www.tandfonline.com)).

We take a two stage approach to estimating the association between pollution and bird counts

**First stage:** we effort-adjust bird counts from eBird at our observational level (county-year-month)

We take a two stage approach to estimating the association between pollution and bird counts

**First stage:** we effort-adjust bird counts from eBird at our observational level (county-year-month)

**Second stage:** we estimate effect of pollution on effort-adjusted bird counts using several different empirical strategies

# First stage: effort-adjust bird counts

## Log-linearized Poisson regression

$$\log(\text{counts}_{iy\text{mdhc}}) = \mathbf{f}(\mathbf{effort\ variables}_{iy\text{mdhc}}; \boldsymbol{\beta}) + \Gamma_{\text{cym}} + \varepsilon_{iy\text{mdhc}}$$

# First stage: effort-adjust bird counts

## Log-linearized Poisson regression

$$\log(\text{counts}_{iy\text{mdhc}}) = \mathbf{f}(\text{effort variables}_{iy\text{mdhc}}; \boldsymbol{\beta}) + \boldsymbol{\Gamma}_{\text{cym}} + \varepsilon_{iy\text{mdhc}}$$

$\mathbf{f}(\text{effort variables}_{iy\text{mdhc}}; \boldsymbol{\beta})$  is either:

# First stage: effort-adjust bird counts

## Log-linearized Poisson regression

$$\log(\text{counts}_{iy\text{mdhc}}) = \mathbf{f}(\text{effort variables}_{iy\text{mdhc}}; \boldsymbol{\beta}) + \boldsymbol{\Gamma}_{\text{cym}} + \varepsilon_{iy\text{mdhc}}$$

$\mathbf{f}(\text{effort variables}_{iy\text{mdhc}}; \boldsymbol{\beta})$  is either:

- Linear in all effort variables

# First stage: effort-adjust bird counts

## Log-linearized Poisson regression

$$\log(\text{counts}_{iy\text{mdhc}}) = \mathbf{f}(\text{effort variables}_{iy\text{mdhc}}; \boldsymbol{\beta}) + \boldsymbol{\Gamma}_{\text{cym}} + \varepsilon_{iy\text{mdhc}}$$

$\mathbf{f}(\text{effort variables}_{iy\text{mdhc}}; \boldsymbol{\beta})$  is either:

- Linear in all effort variables
- Selected using LASSO from fully interacted cubics and dummies/quantiles for effort variables

# First stage: effort-adjust bird counts

## Log-linearized Poisson regression

$$\log(\text{counts}_{iy\text{mdhc}}) = \mathbf{f}(\mathbf{effort\ variables}_{iy\text{mdhc}}; \boldsymbol{\beta}) + \boldsymbol{\Gamma}_{\text{cym}} + \varepsilon_{iy\text{mdhc}}$$

$\boldsymbol{\Gamma}_{\text{cym}}$  is a fixed effect we want to recover

# First stage: effort-adjust bird counts

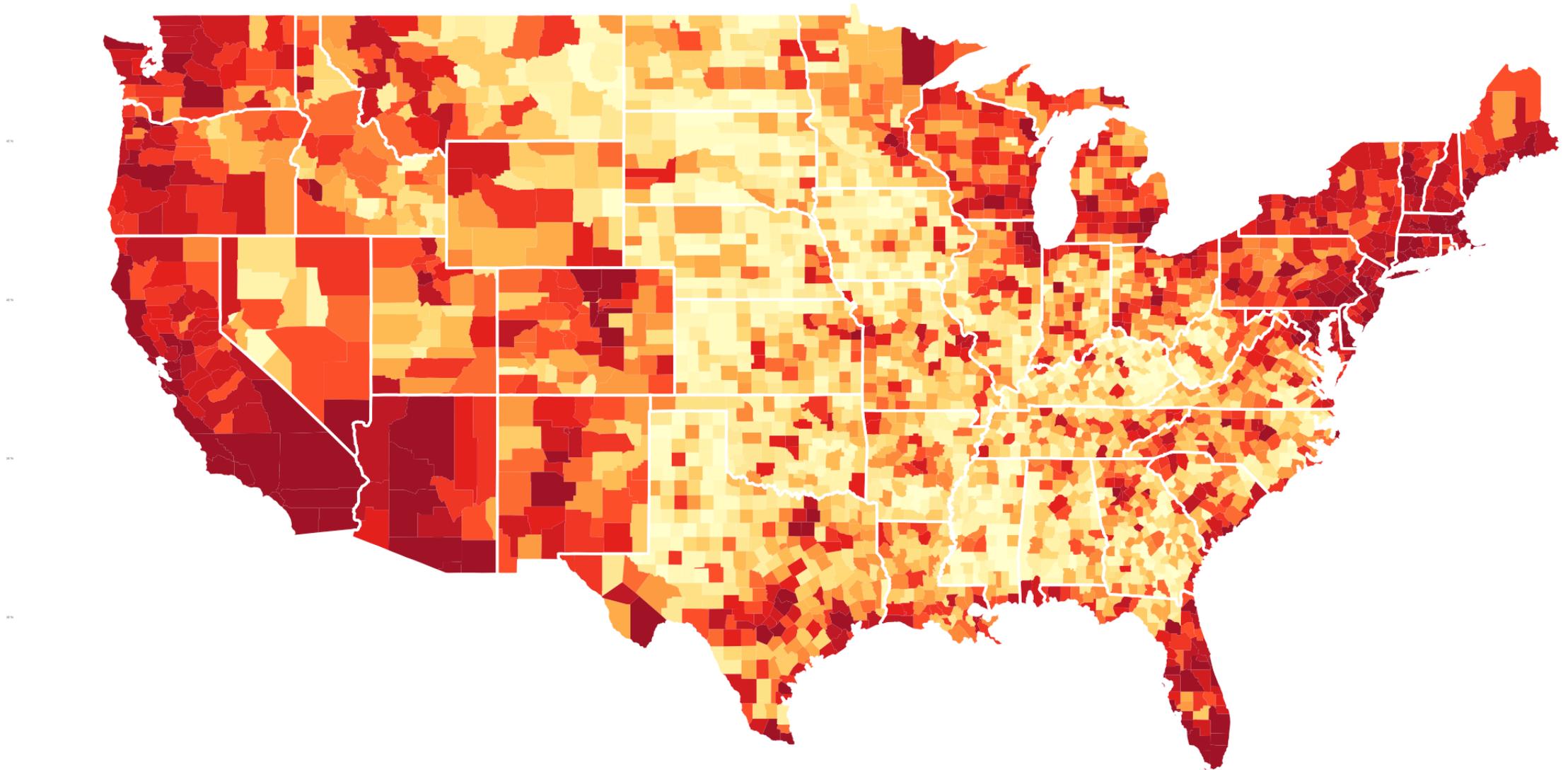
## Log-linearized Poisson regression

$$\log(\text{counts}_{iymdhc}) = \mathbf{f}(\text{effort variables}_{iymdhc}; \boldsymbol{\beta}) + \Gamma_{cym} + \varepsilon_{iymdhc}$$

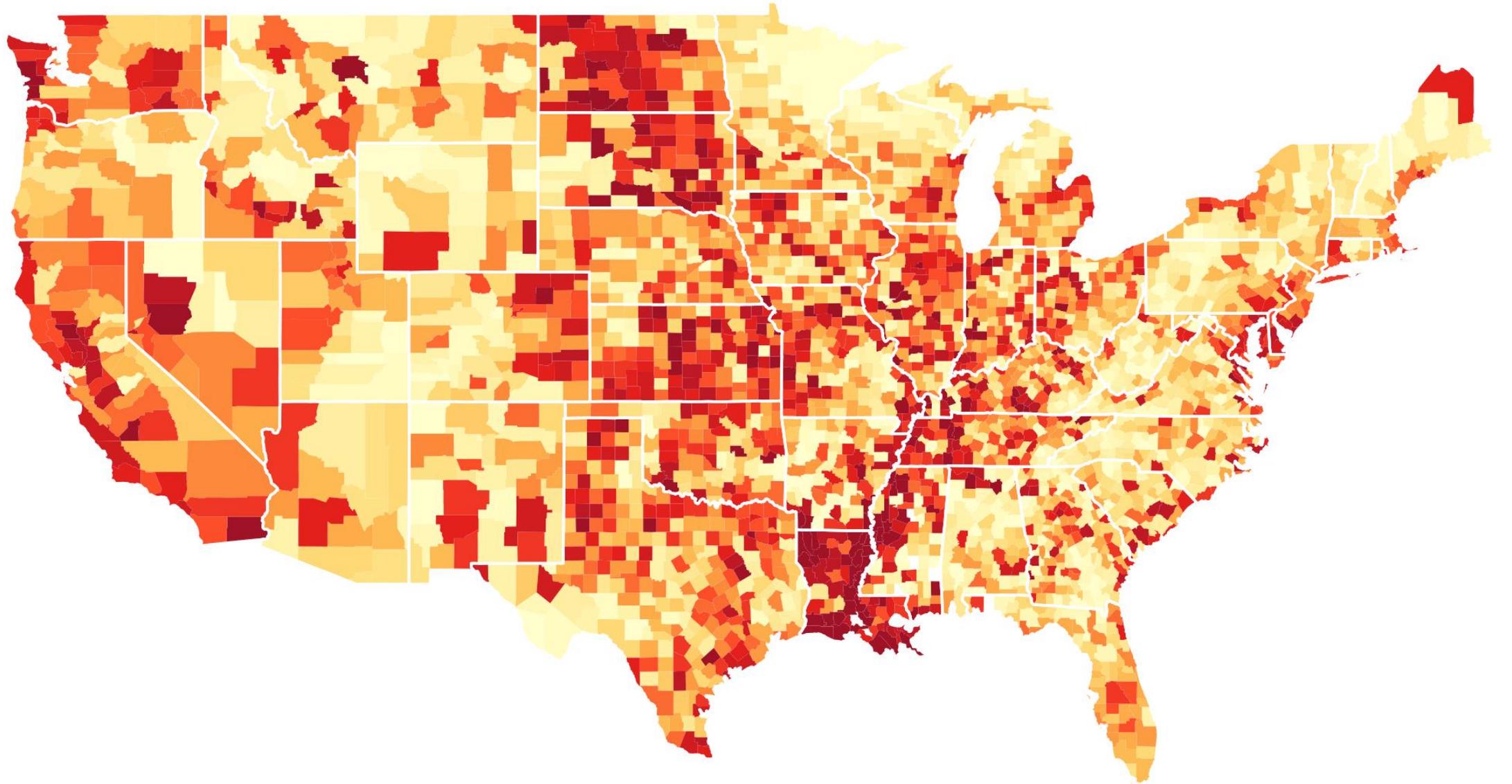
$\Gamma_{cym}$  is a fixed effect we want to recover

- It captures variation in counts at the county-year-month level conditional on a level of birder effort
- Let  $\Gamma_{cym} \equiv \log(\widehat{\text{counts}}_{cmy})$

Why effort-adjusting may matter:  
hours birding is heterogenous across space



# The average effort-adjusted bird cross-section: 2002-2018



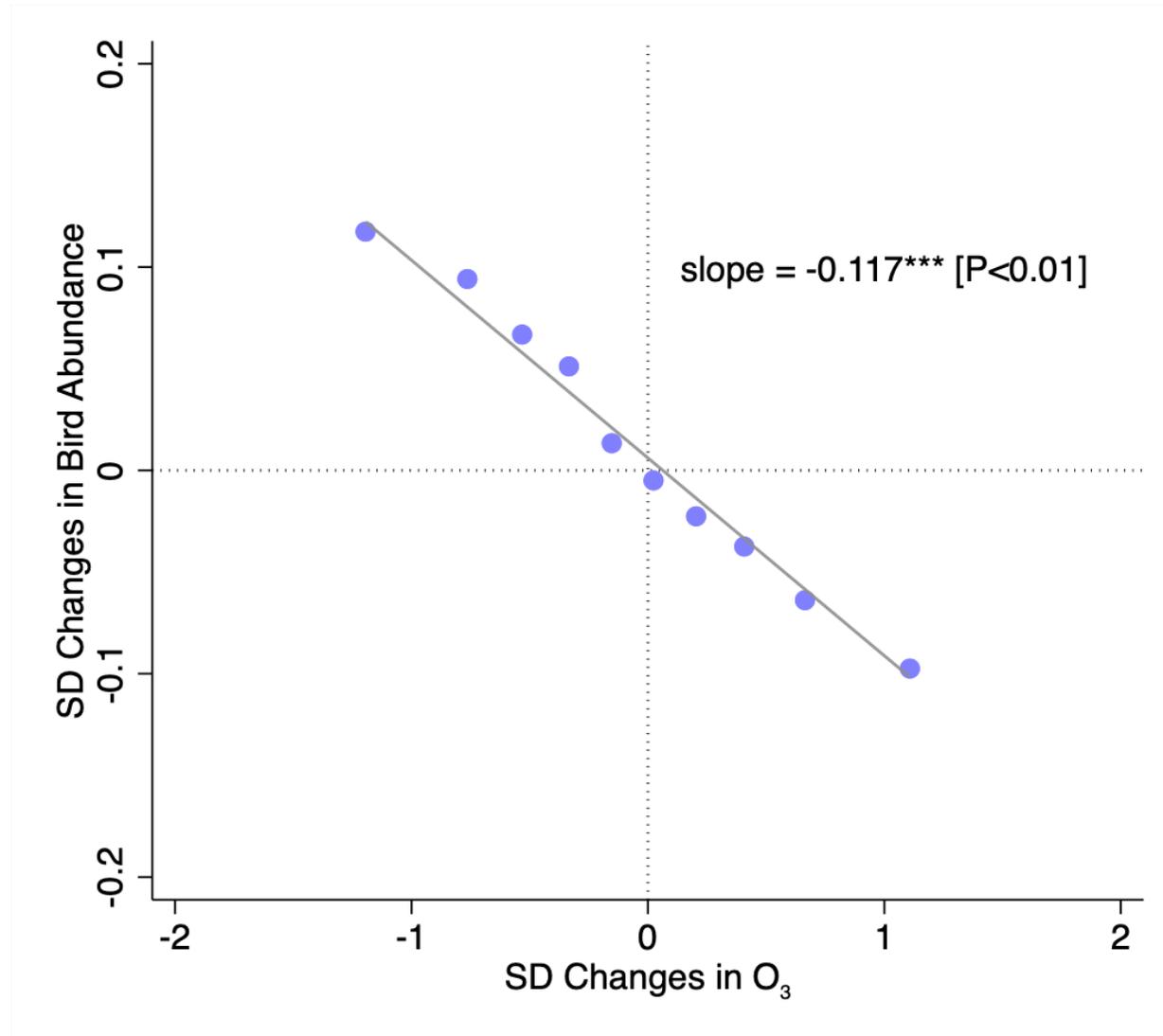
# Second stage: effect of pollution on effort-adjusted bird counts

## Fixed effects

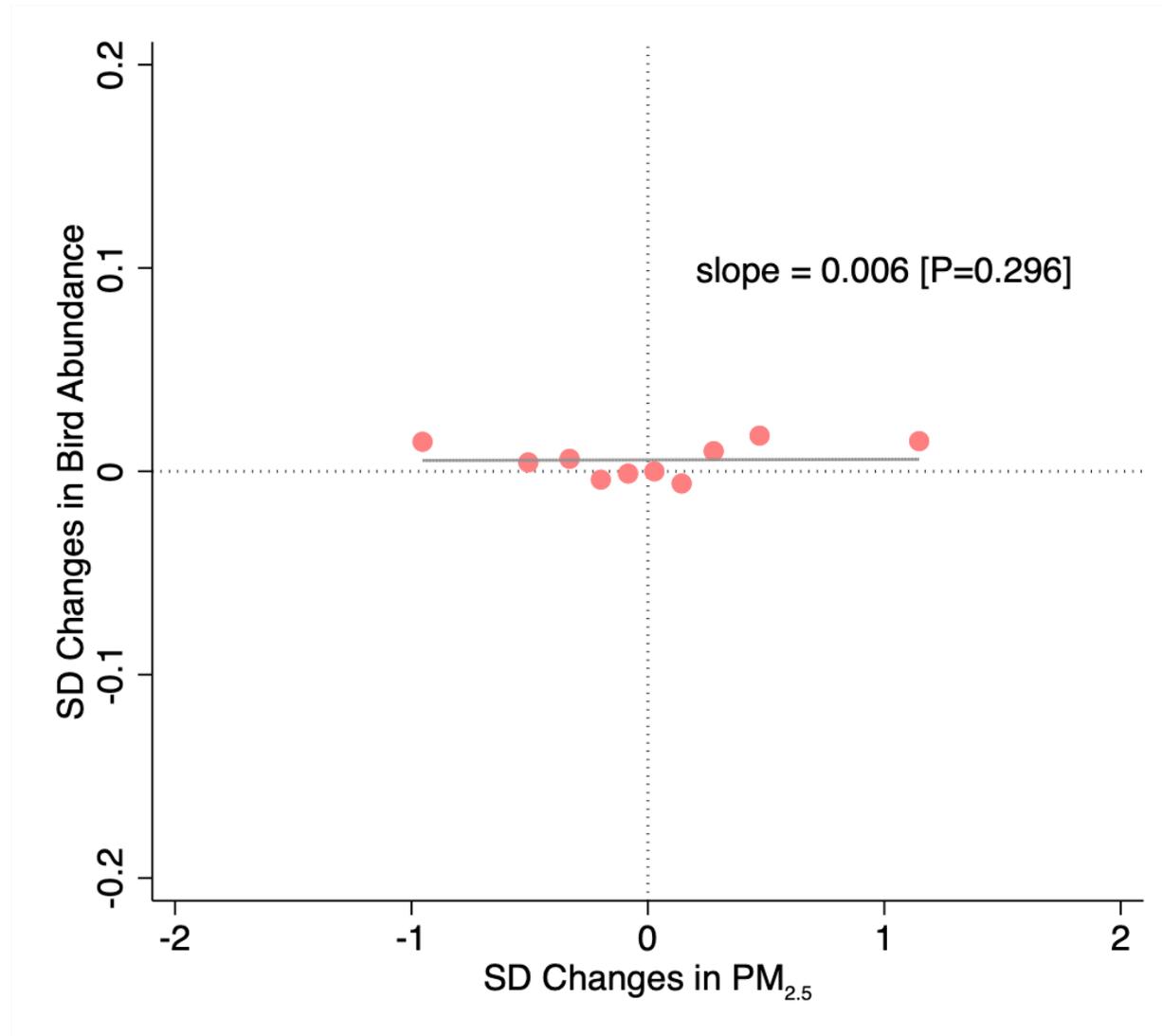
$$\begin{aligned} \log(\widehat{\text{counts}}_{\text{cmy}}) \\ = \mathbf{f}(\mathbf{pollution}_{\text{cmy}}; \boldsymbol{\beta}) + \mathbf{g}(\mathbf{weather}_{\text{cmy}}; \boldsymbol{\gamma}) + \mathbf{FEs} + \varepsilon_{\text{cmy}} \end{aligned}$$

We are interested in  $\boldsymbol{\beta}$  the marginal effect of pollution on effort-adjusted counts

# The conditional relationship between ozone and effort-adjusted bird counts



# The conditional relationship between PM<sub>2.5</sub> and effort-adjusted bird counts



Next step: are interventions associated with improvements in bird counts?

Focus on the **NO<sub>x</sub> Budget Trading Program (NBP)**

Cap and trade program for **summertime** nitrogen oxide (NO<sub>x</sub>) emissions

Implemented in 2004

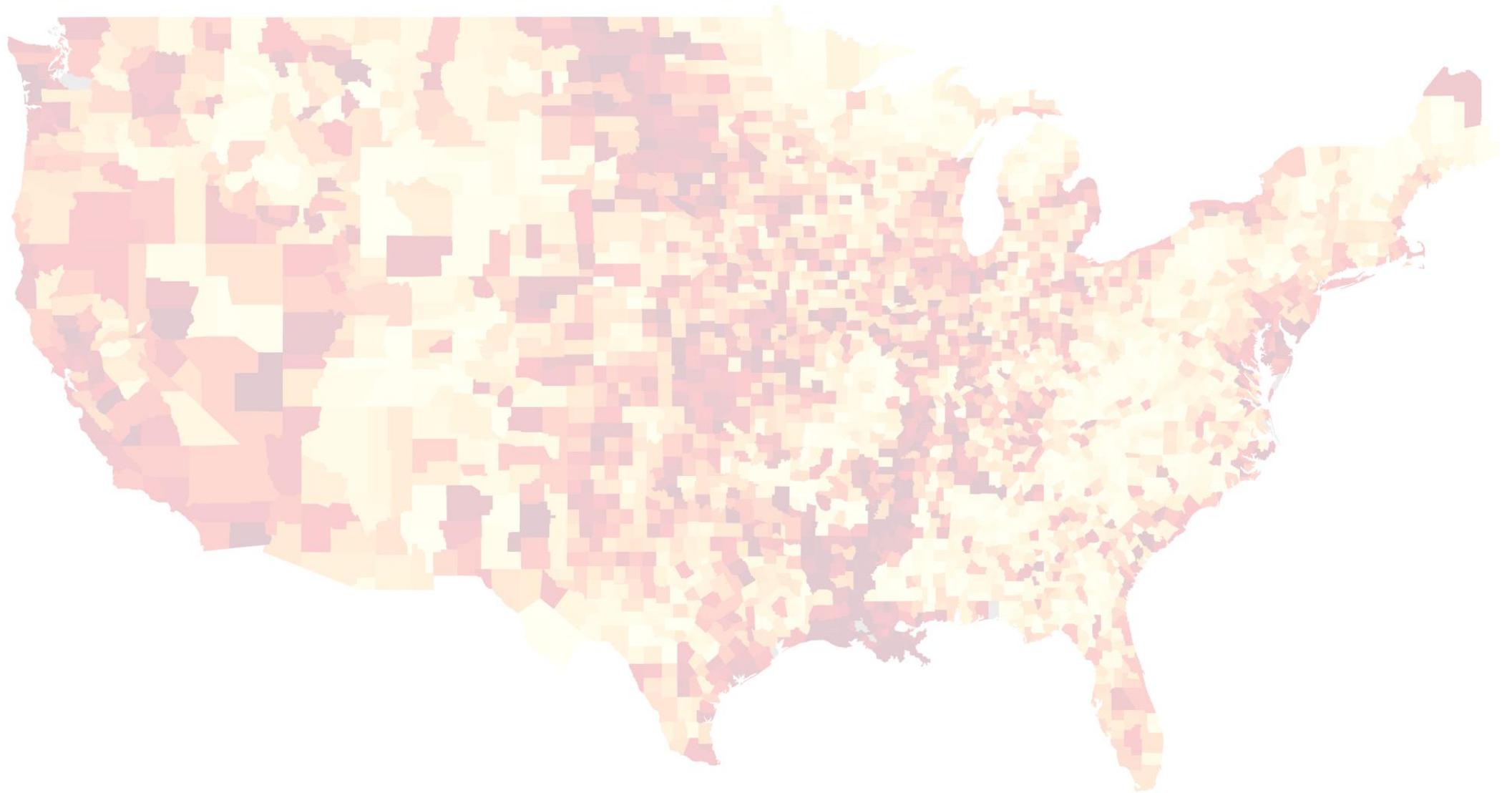
# The human effects of the NBP

Deschenes, Greenstone, Shapiro (2017)

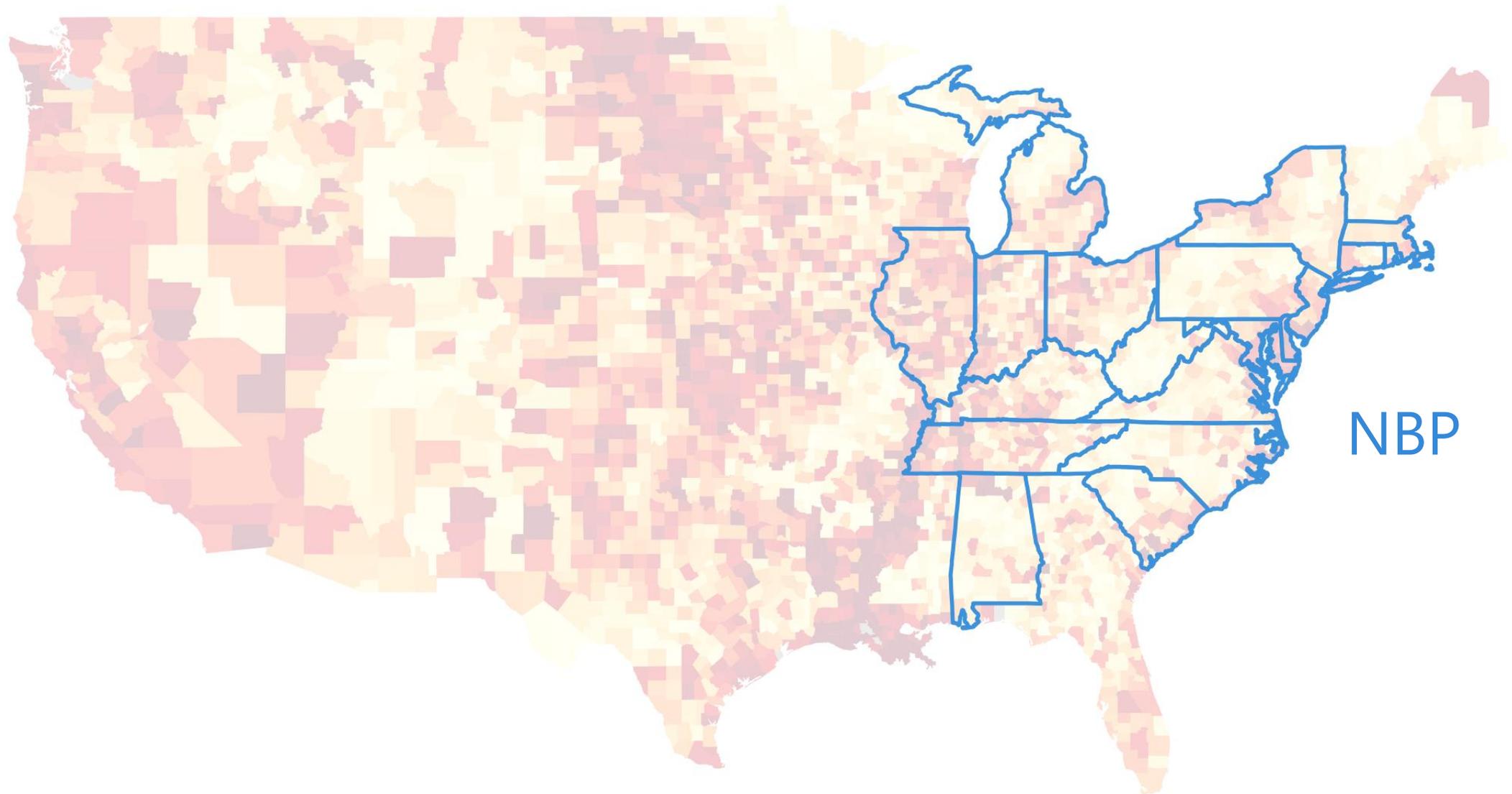
Prior evidence indicates that the NBP:

- Decreased O<sub>3</sub> levels
- Decreased mortality rates
- Decreased cardiovascular/respiratory mortality
- Decreased medical expenditures
- (Birds can't do this)

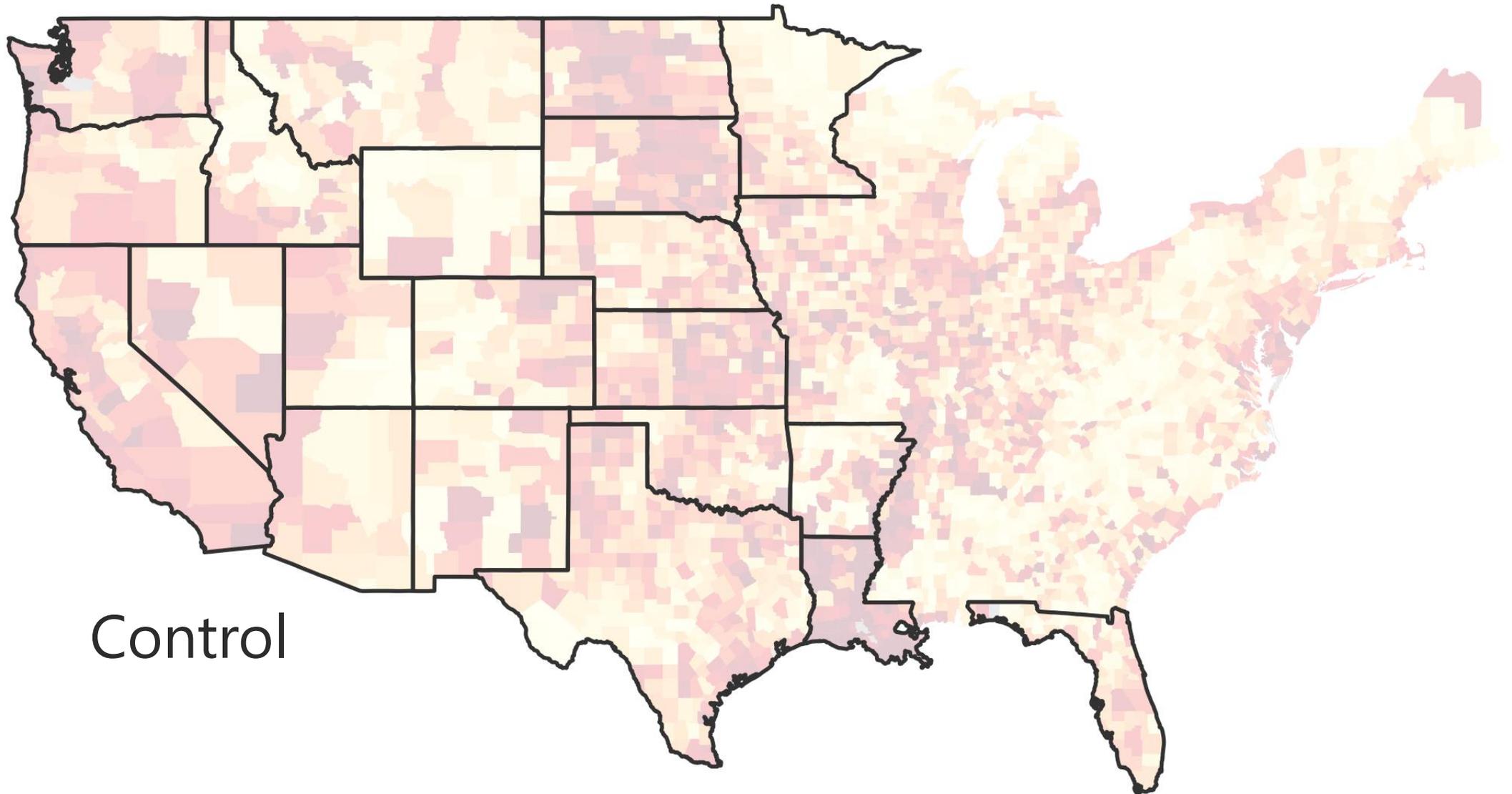
We split the US into three categories



# The NBP affects the eastern US

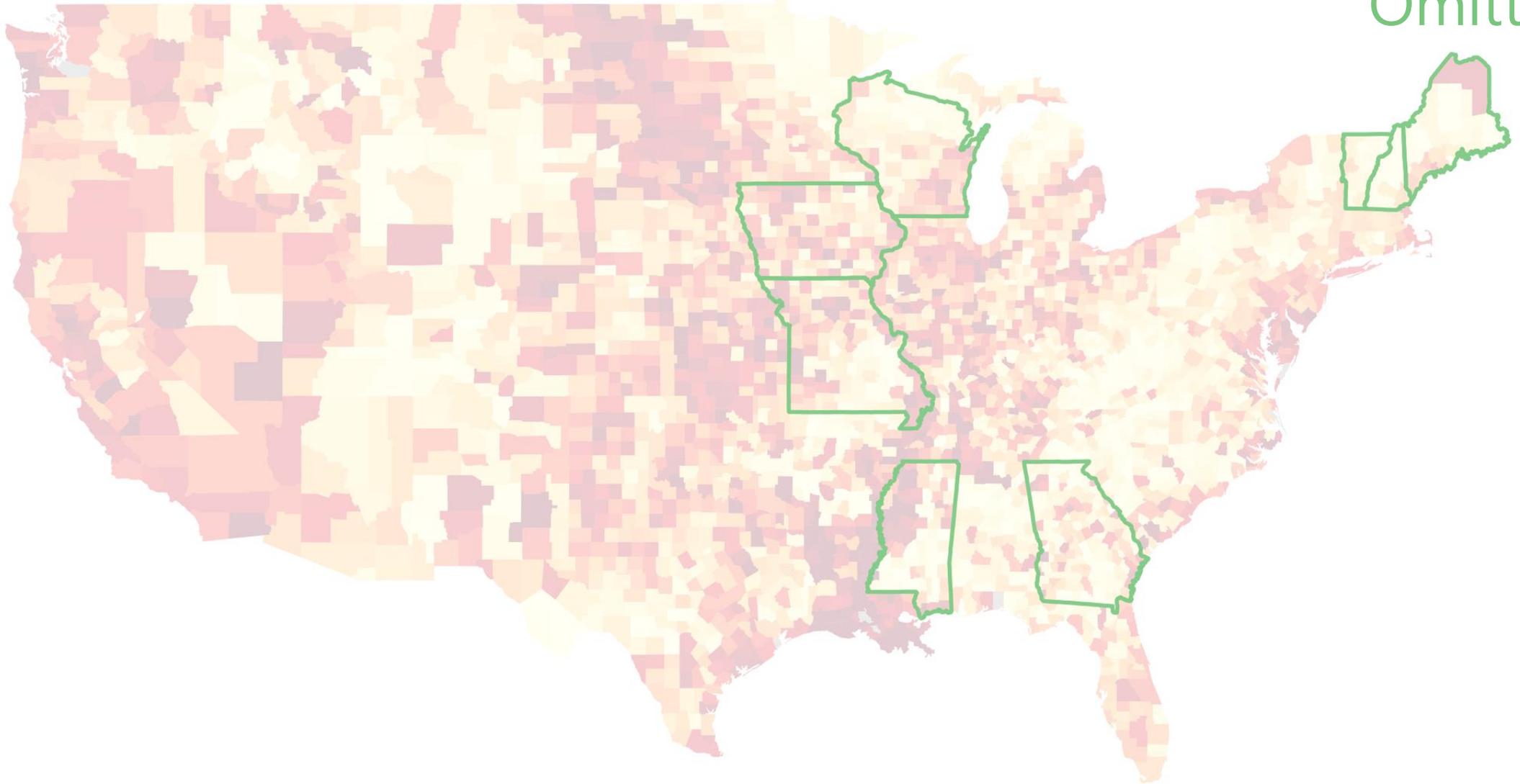


# Western states are not subject to NBP

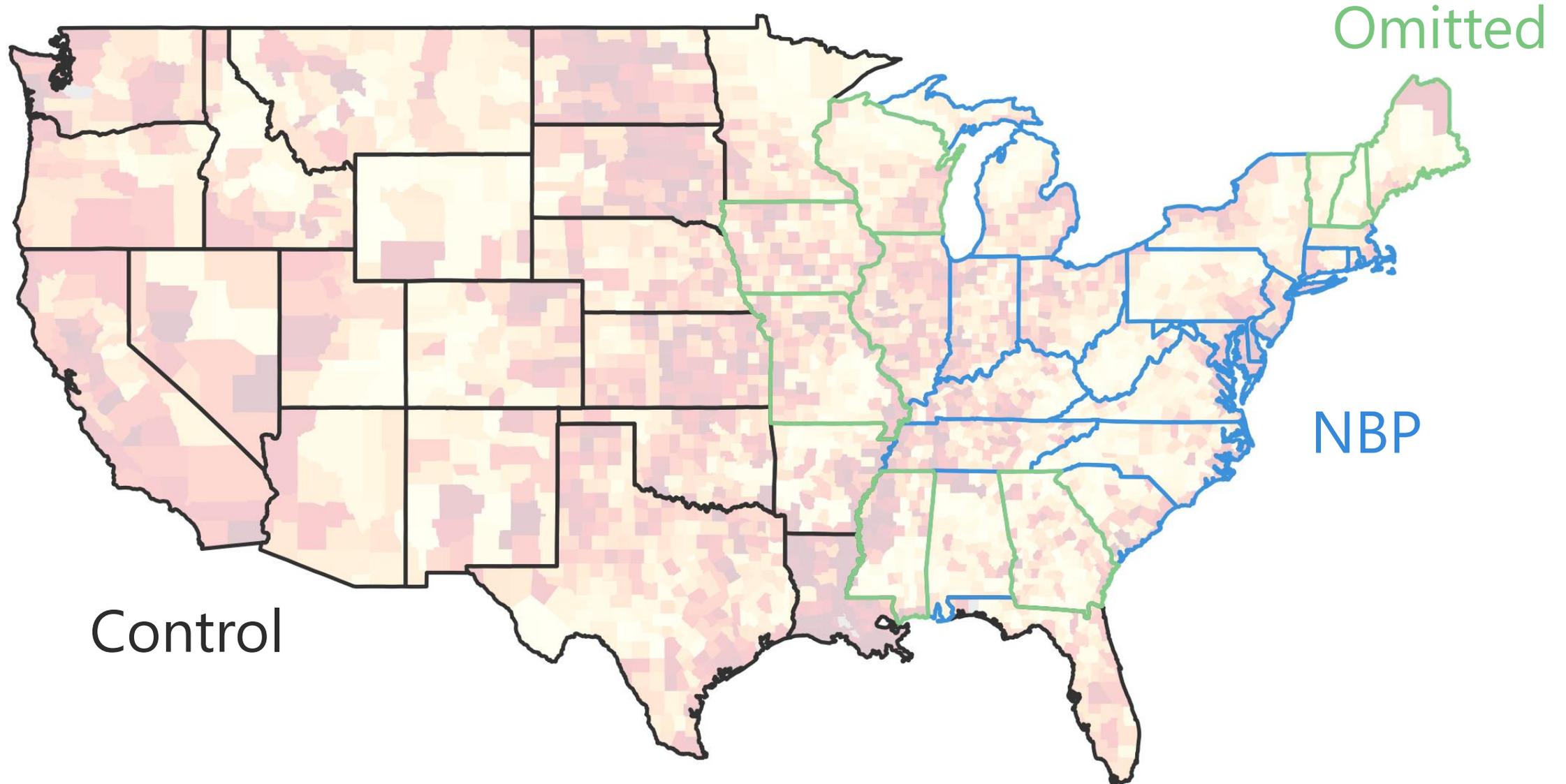


We omit border states because of pollution spillovers / atmospheric transport

Omitted



# Do bird counts in NBP states increase relative to control states after 2004?



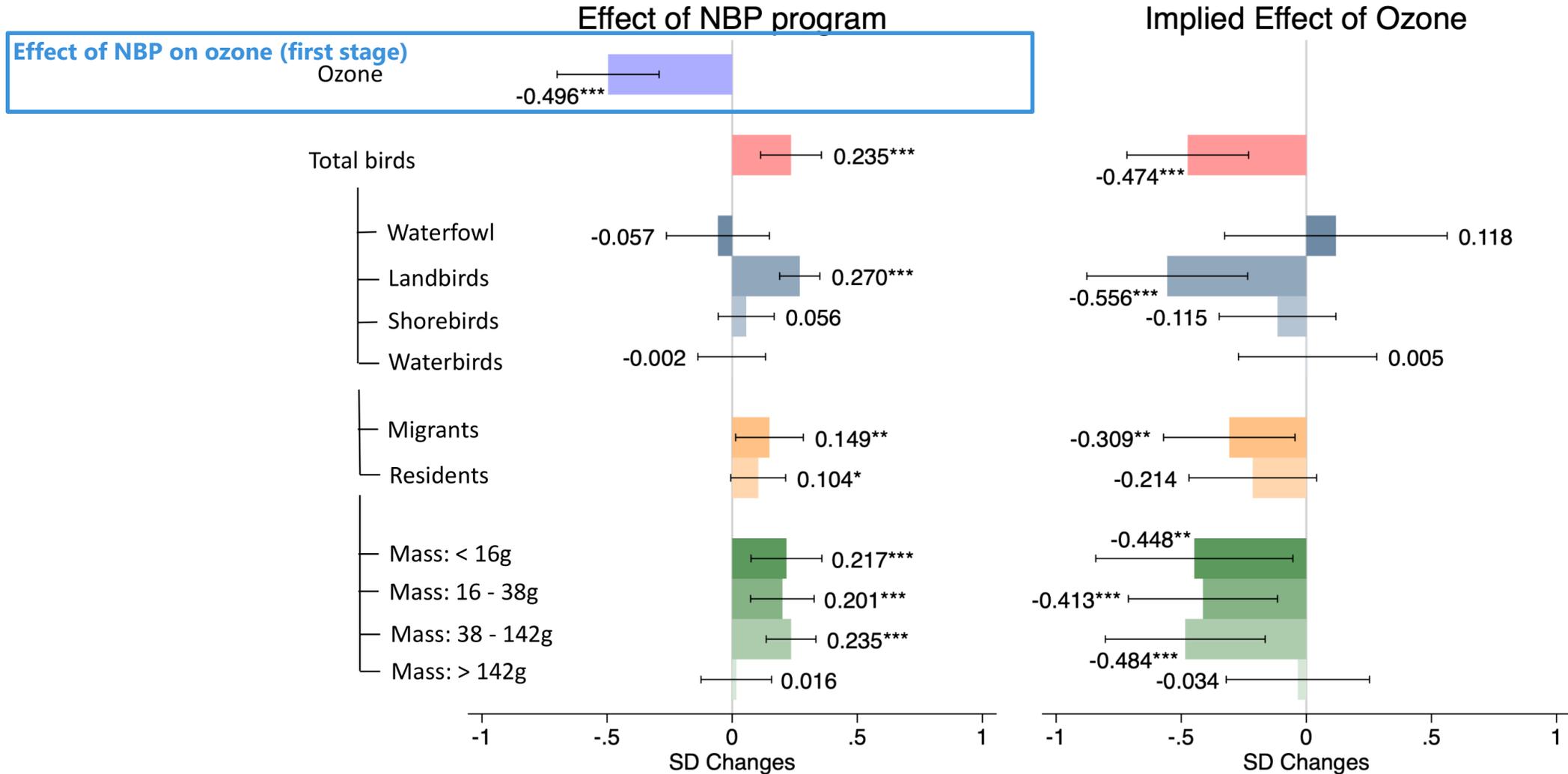
# Are interventions associated with improvements in bird counts?

## **2SLS strategy with longitudinal data**

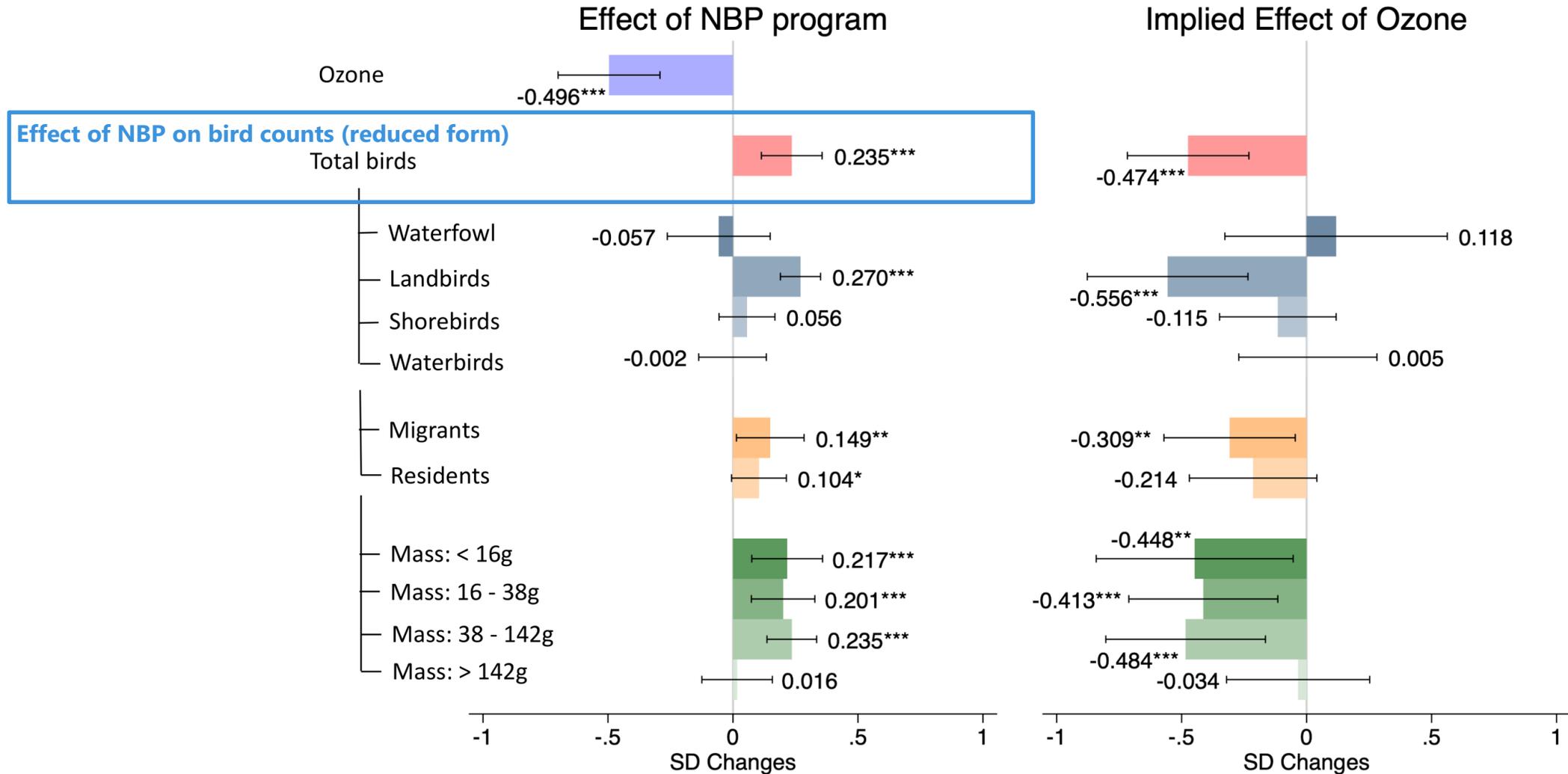
1. Estimate effect of NBP on ozone, get predicted ozone
2. Estimate effect of predicted ozone on bird counts using a **triple difference strategy**

Comparing the level of birds in NBP vs control, before and after 2004, in and out of the summer season

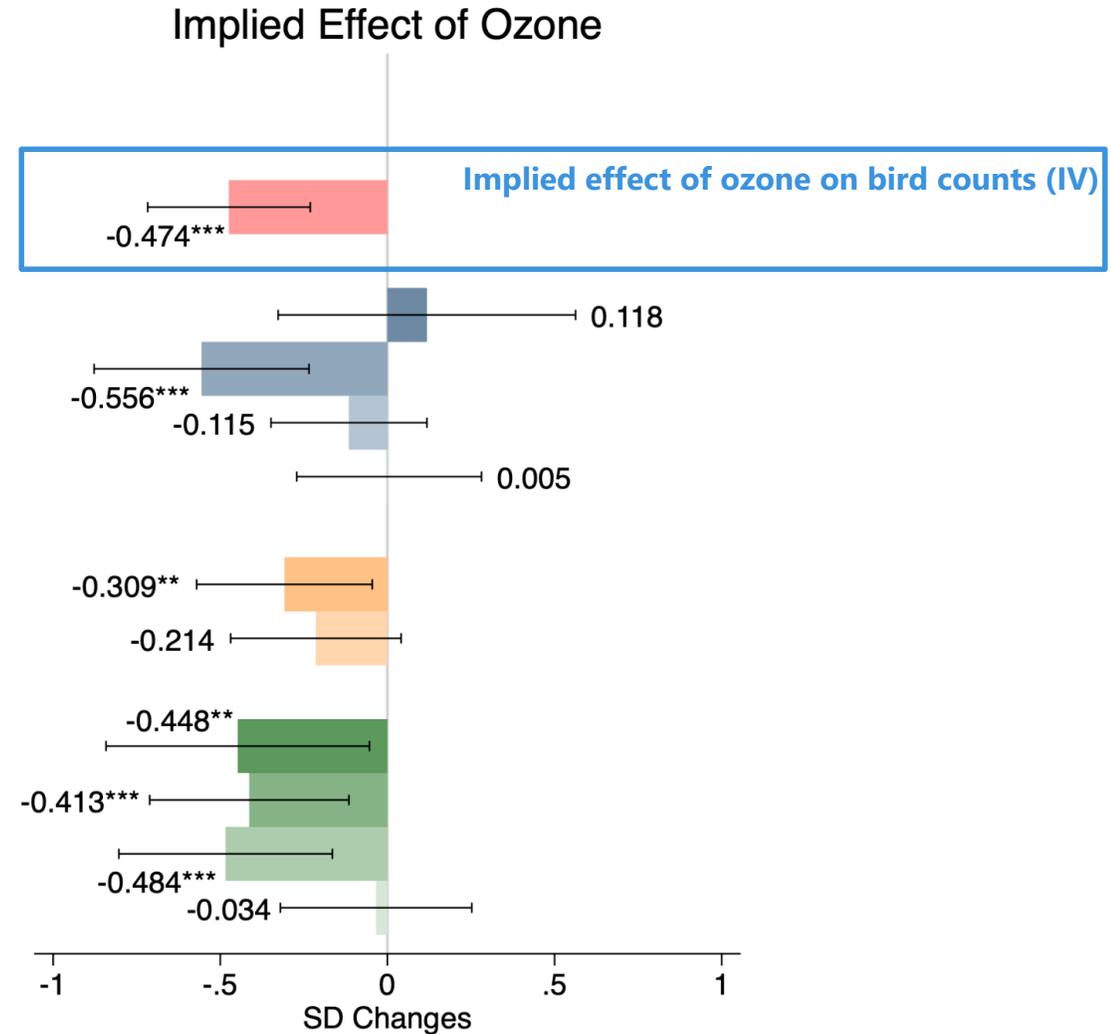
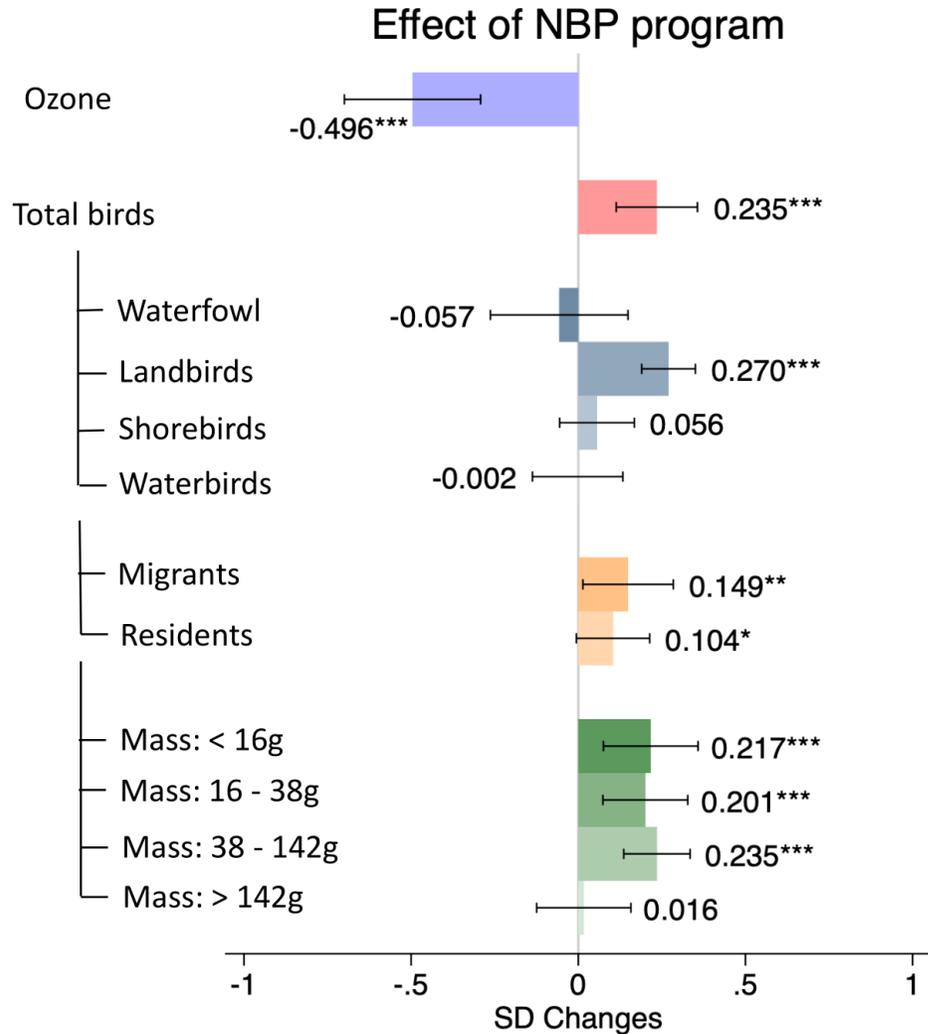
# The effect of the NBP and ozone on bird counts



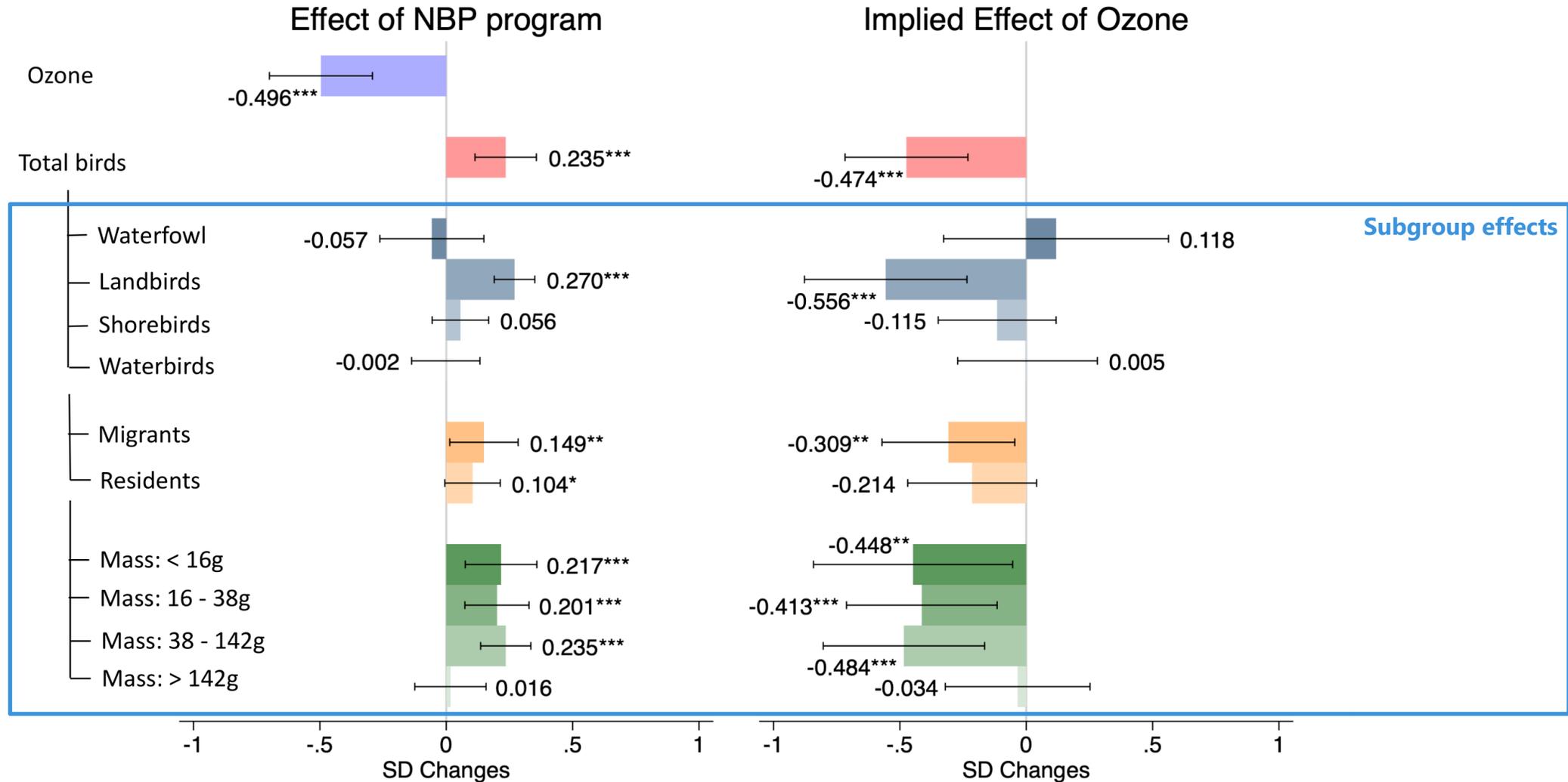
# The effect of the NBP and ozone on bird counts



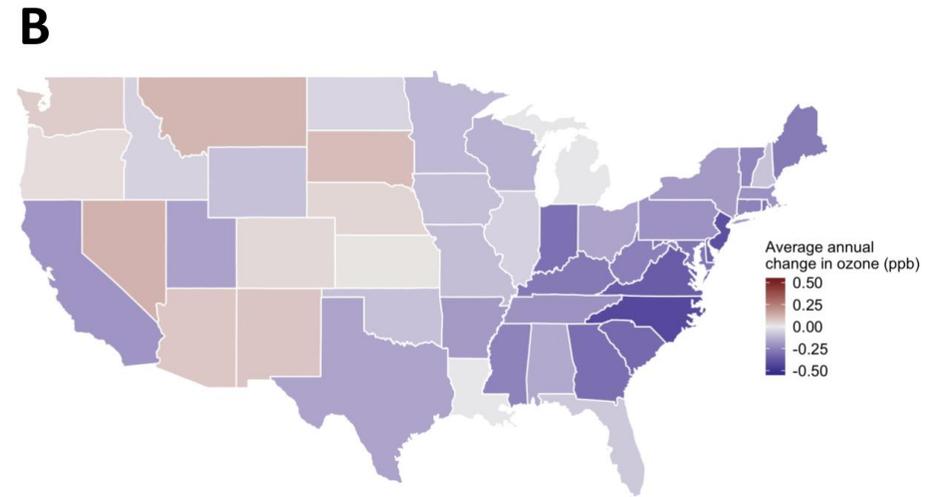
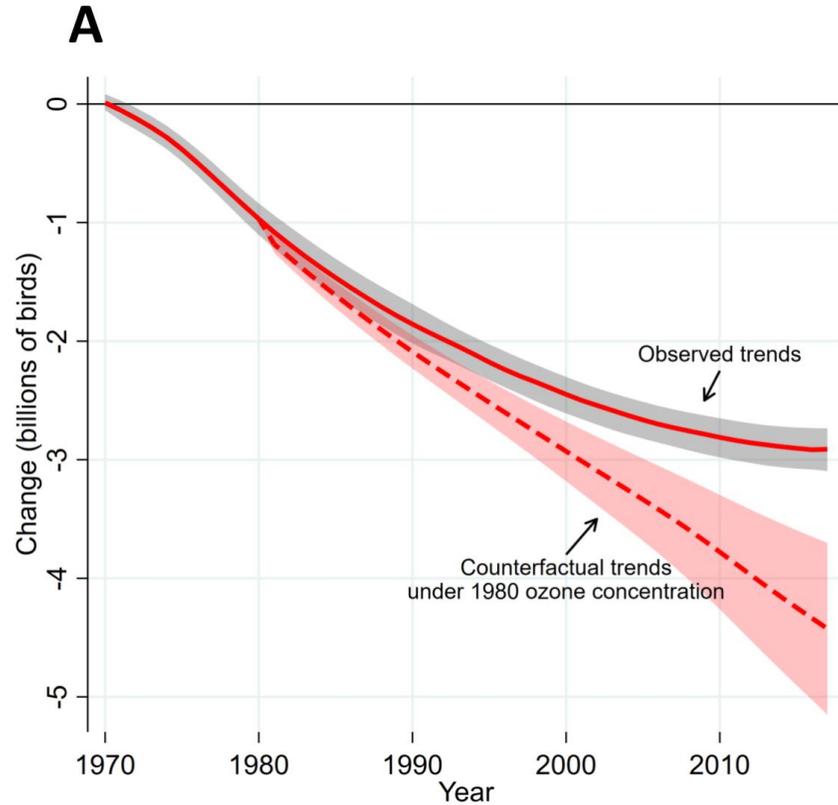
# The effect of the NBP and ozone on bird counts



# The effect of the NBP and ozone on bird counts



# Implied effect of ozone air quality improvement over the past decades



Ozone pollution is negatively associated with bird counts

Air pollution interventions nominally designed for human health protection may have provided co-benefits on bird population conservation