

QUANTITATIVE APPROACHES FOR IMPROVED UNDERSTANDING AND MANAGEMENT OF AQUATIC RESOURCES

Mark Scheuerell

*USGS WACFWRU
UW SAFS*

✉ scheuerl@uw.edu

🐦 [@mark_scheuerell](https://twitter.com/mark_scheuerell)

I was trained as a field ecologist



My early research was largely empirical

Nutrient limitation of lake productivity

Vertical migration in juvenile sockeye salmon

Trophic interactions among stream fishes

How do natural & human forces affect
the structure of aquatic ecosystems &
the services we derive from them?

The forces may be

biological (food web interactions, harvest)

physical (climate, habitat modification)

chemical (ocean acidification, contaminants)

The services can be

provisioning (food production)

supporting (nutrient cycling)

regulating (flood control)

cultural (spiritual benefits)

Current research foci

Models for spatio-temporal data

Integrated population models

Ecological portfolios

Lots of focus on *hierarchical models*



Hi·er·ar·chi·cal

adjective

1. Arranged in an order

A hierarchical model is simply
a model within a model

Hierarchical models also masquerade as

Nested data models

Mixed models

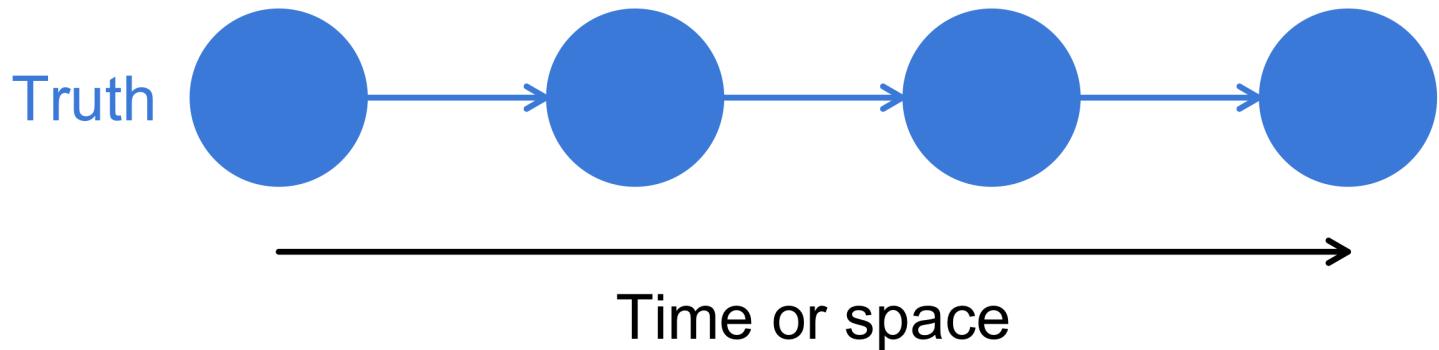
Random-effects models

State-space models

A state-space model has 2 parts

Part 1: State model

Describes the **true state of nature** over time or space



States of nature might be

Animal location

Species density

Age structure

Reproductive status

A photograph of two people wearing ornate Venetian masks, facing each other. The mask on the left is black with gold embroidery and a large orange feathered plume. The mask on the right is gold with red and black patterns and a large green feathered plume. They appear to be in a festive setting.

Revealing the true state requires observations

Observing nature can be easy

A photograph showing a large school of sockeye salmon swimming in a river. The water is clear, revealing a rocky riverbed. The salmon are a vibrant red color, contrasting with the blue and green tones of the water and rocks. They are swimming in various directions, creating a sense of movement.

How many sockeye are there?

Observing nature can also be hard

A close-up photograph of a shallow stream bed. The water is clear, revealing a rocky bottom covered in small, yellowish-green pebbles. Numerous red mayflies are visible, either swimming on the surface or flying just above it. The mayflies appear as small, bright red dots against the darker water.

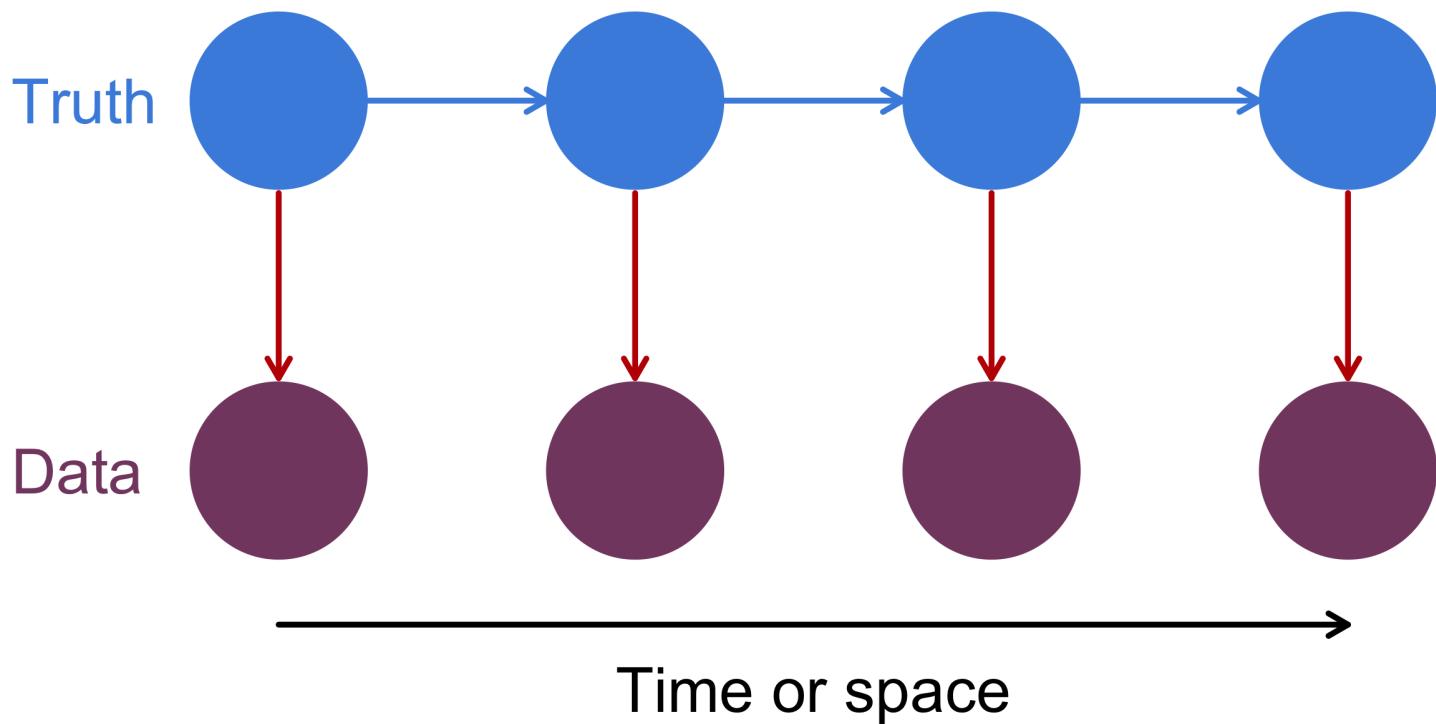
How many mayflies are there?

Part 2: Observation model

Data = Truth \pm Errors

Part 2: Observation model

Data = Truth \pm Errors



OK, but why bother?

Advantages of hierarchical models

1. Can combine many different data types

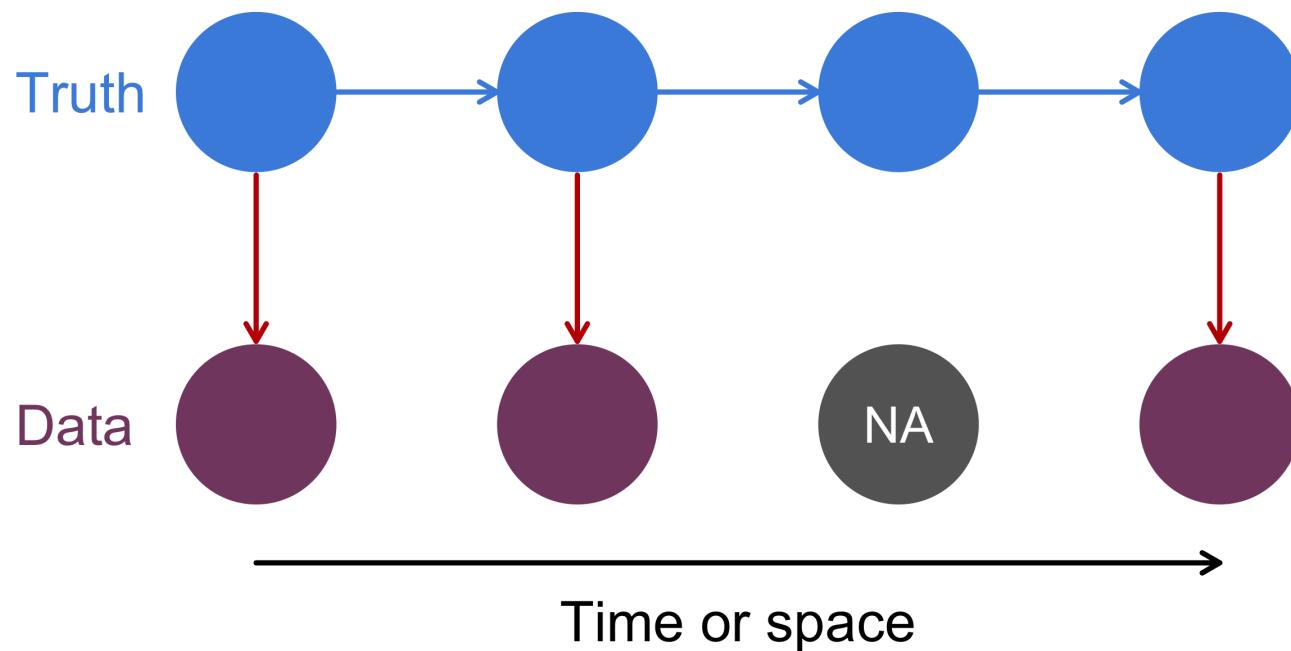
Changes in observers or sensors

Varying survey locations & effort

Direct & remote sampling

Advantages of hierarchical models

2. Missing data are easily accommodated



Advantages of hierarchical models

3. Improved accuracy & precision

Article | [OPEN](#) | Published: 08 February 2016

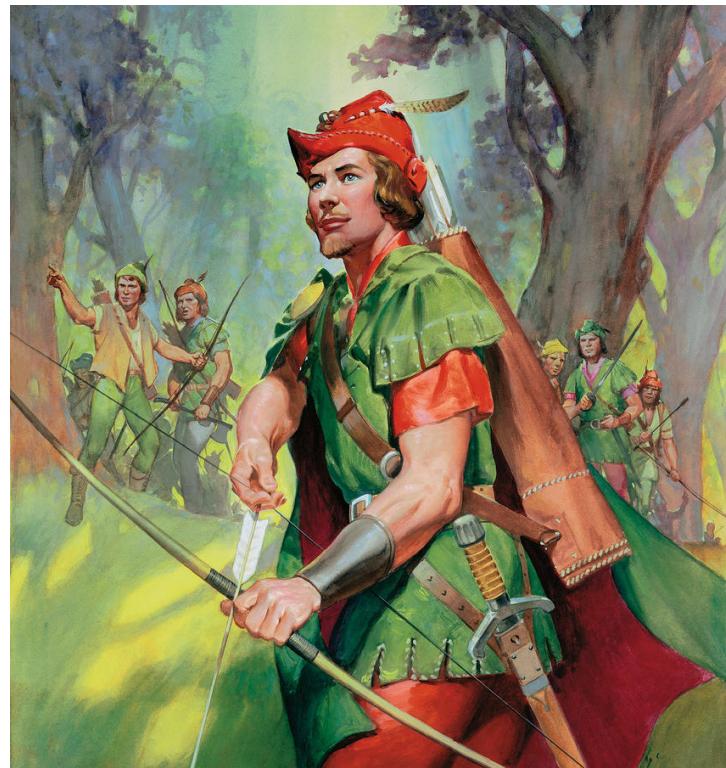
Joint estimation over multiple individuals improves behavioural state inference from animal movement data

Ian Jonsen 

Scientific Reports **6**, Article number: 20625 (2016) | [Download Citation](#) 

Advantages of hierarchical models

4. Data-poor benefit from data-rich



Advantages of hierarchical models

5. Rather flexible

This simple model can be used for 5+ unique applications

$$\mathbf{x}_t = \mathbf{B}\mathbf{x}_{t-1} + \mathbf{w}_t$$

$$\mathbf{y}_t = \mathbf{Z}\mathbf{x}_t + \mathbf{v}_t$$

Conservation of Pacific salmon

Hydropower

Habitat

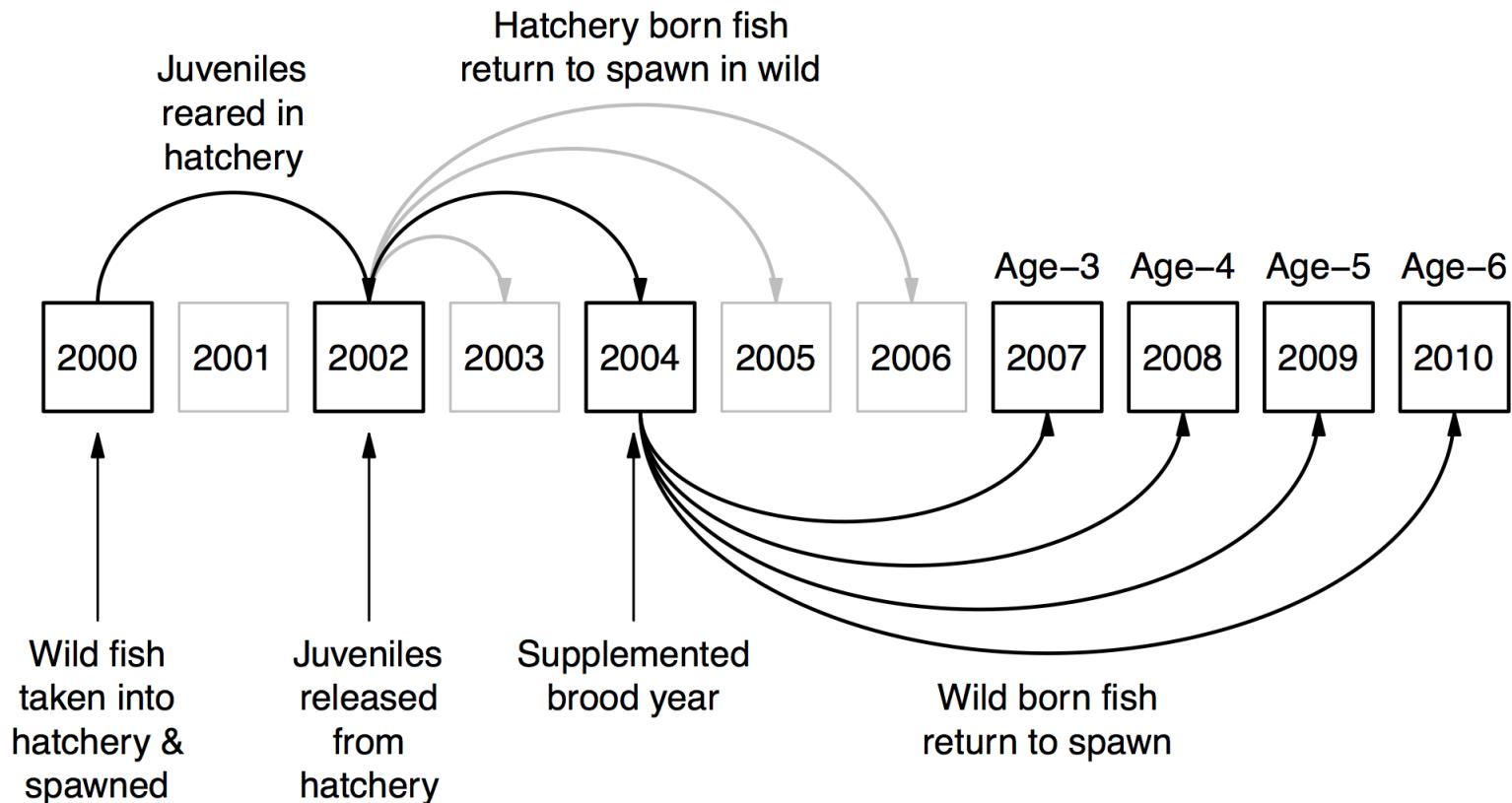
Harvest

Hatcheries

The 4 H's

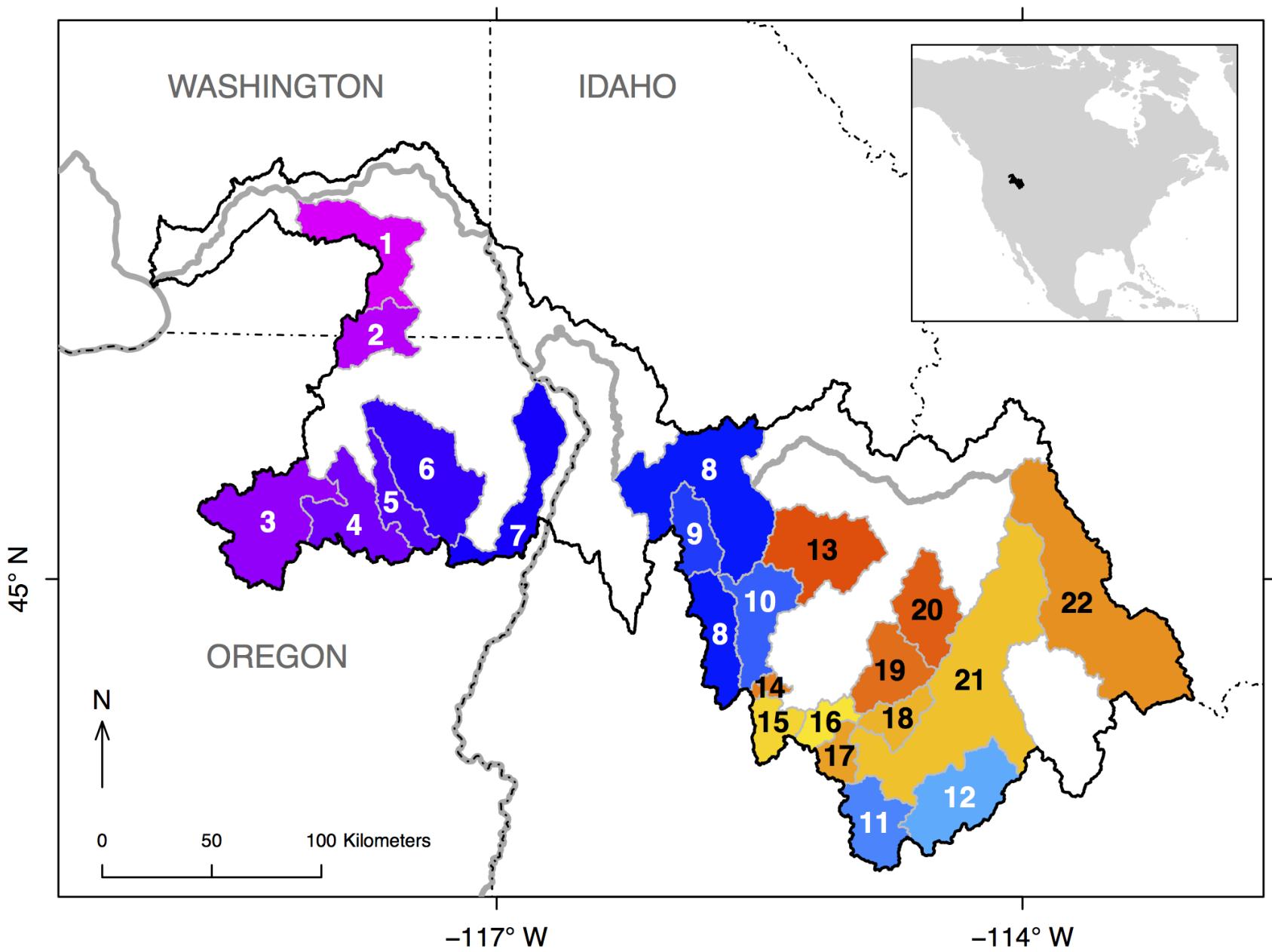
RECOVERY OPTIONS?

One strategy is hatchery supplementation

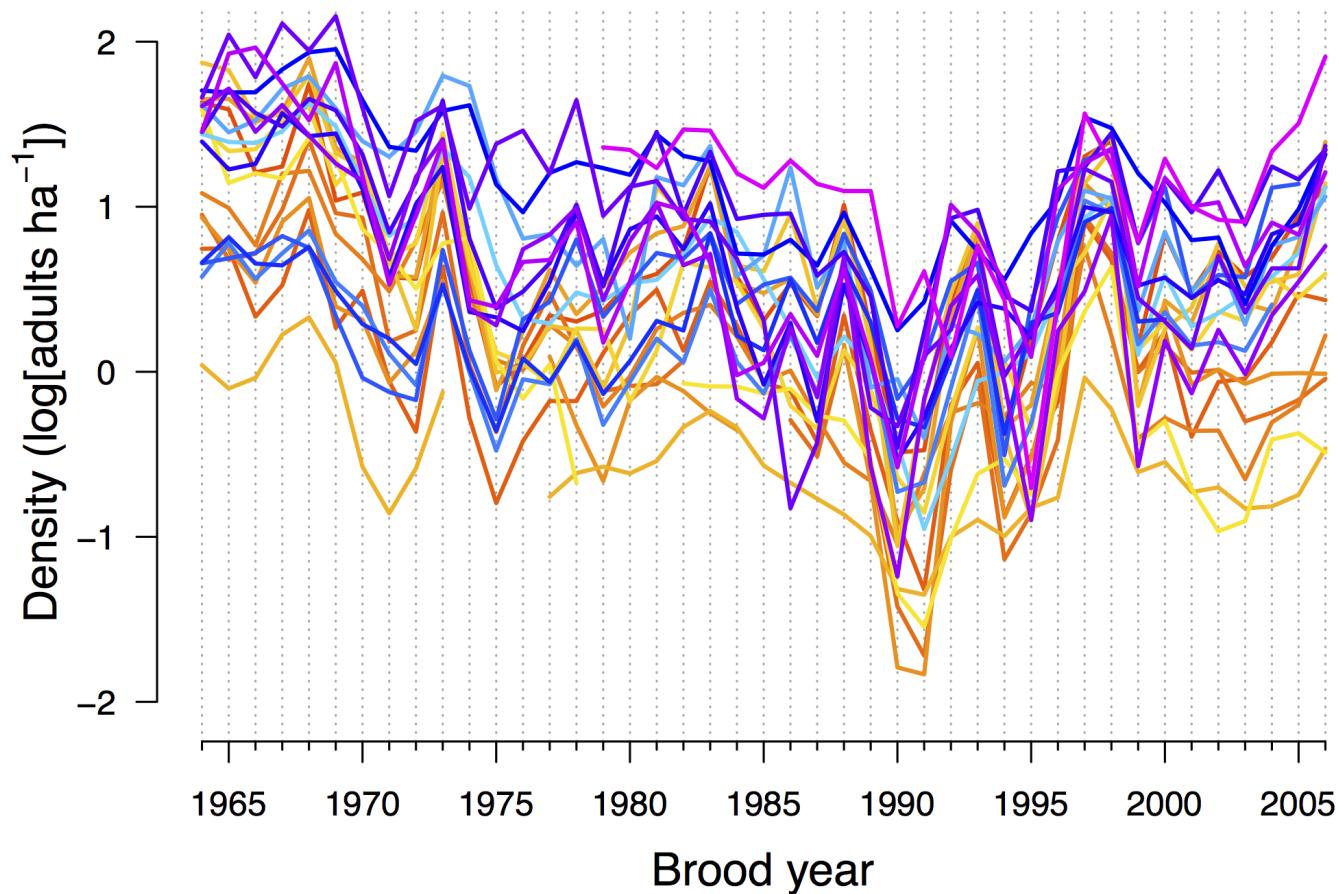


Evaluating conservation interventions

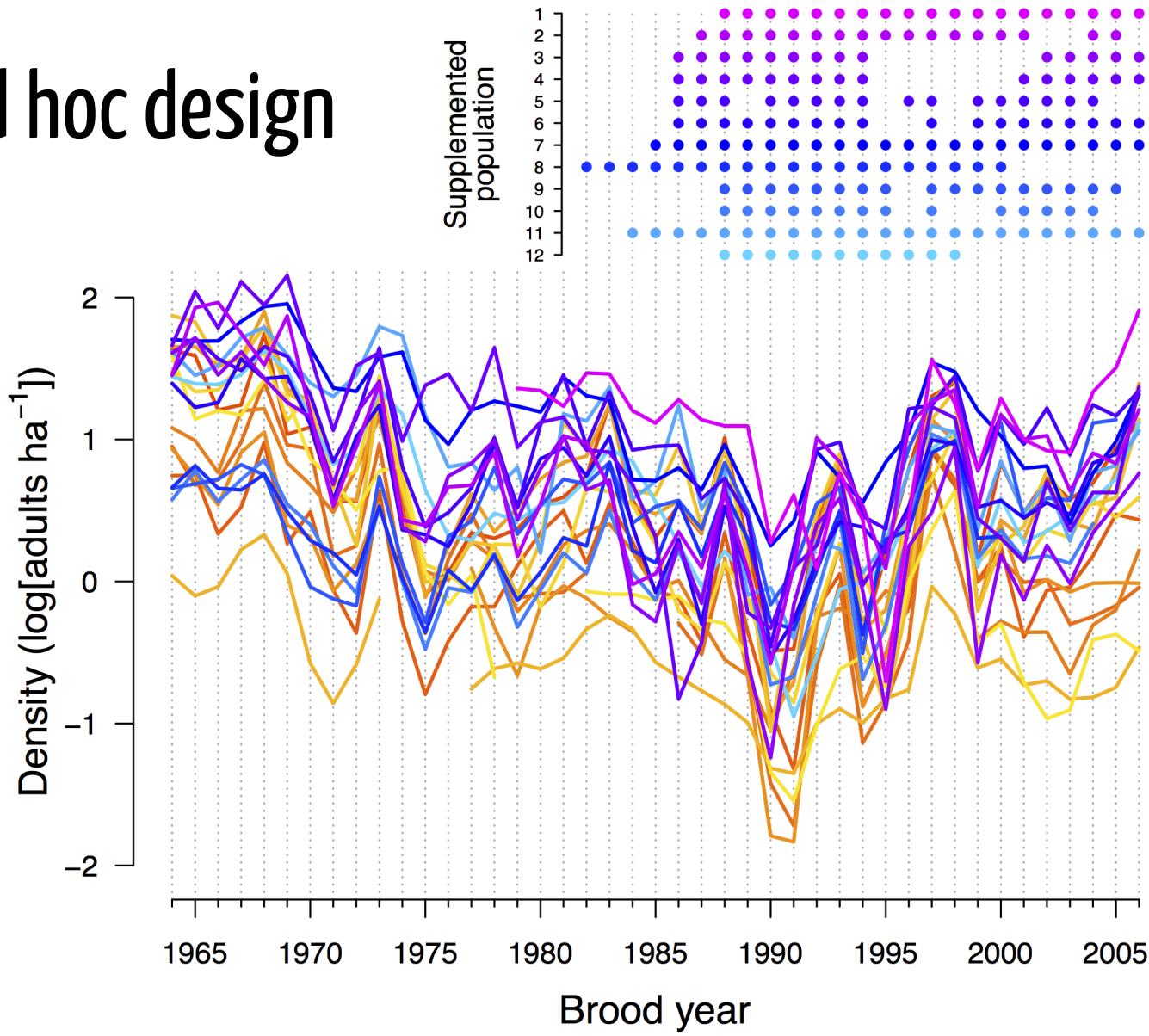
Has 30+ years of hatchery supplementation boosted
the production of wild Chinook in the Snake R?



Density of spawners over time



Ad hoc design



Complications for analysis

No randomized design

Different start/stop & duration

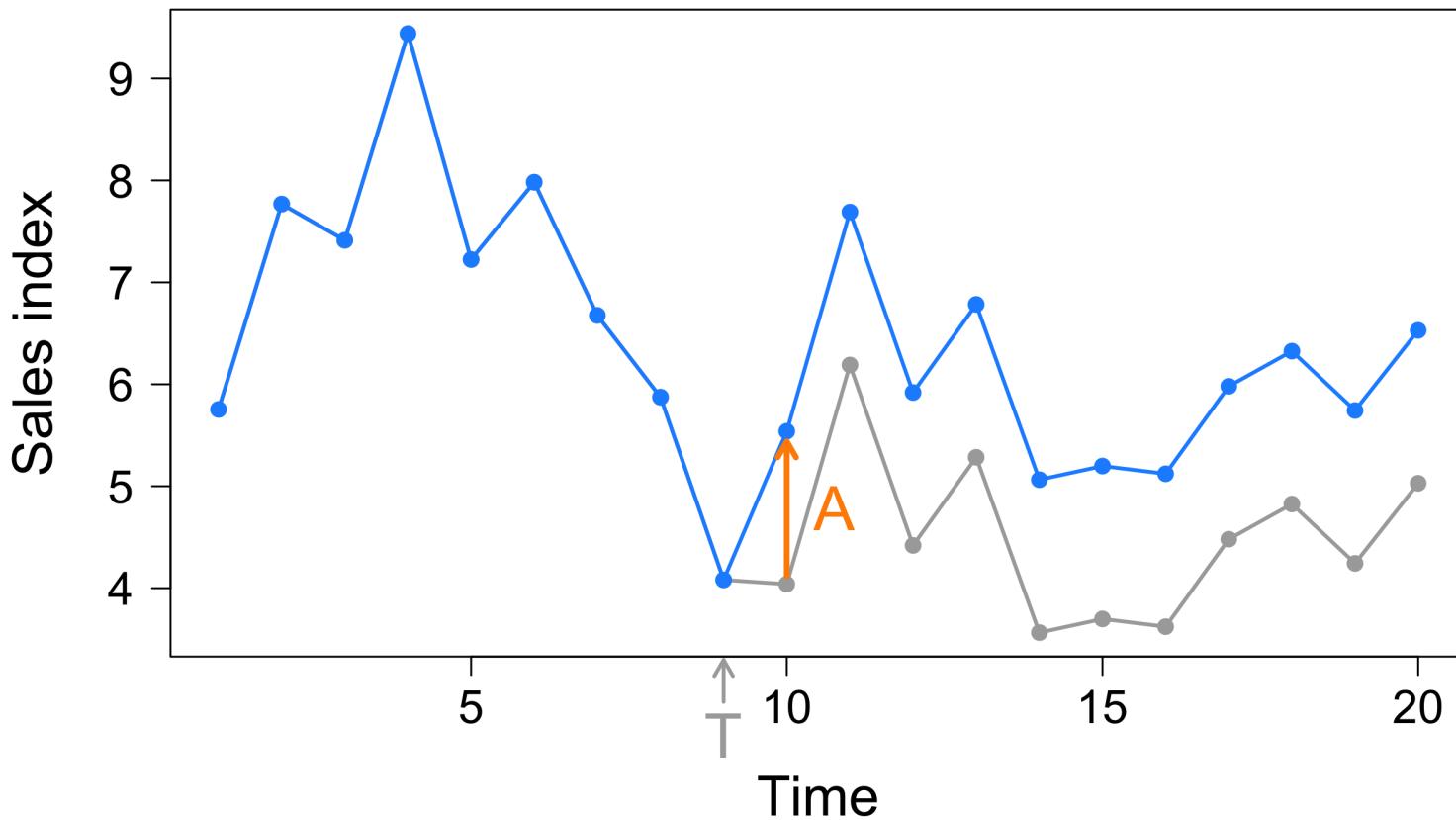
Changing variance & correlated errors

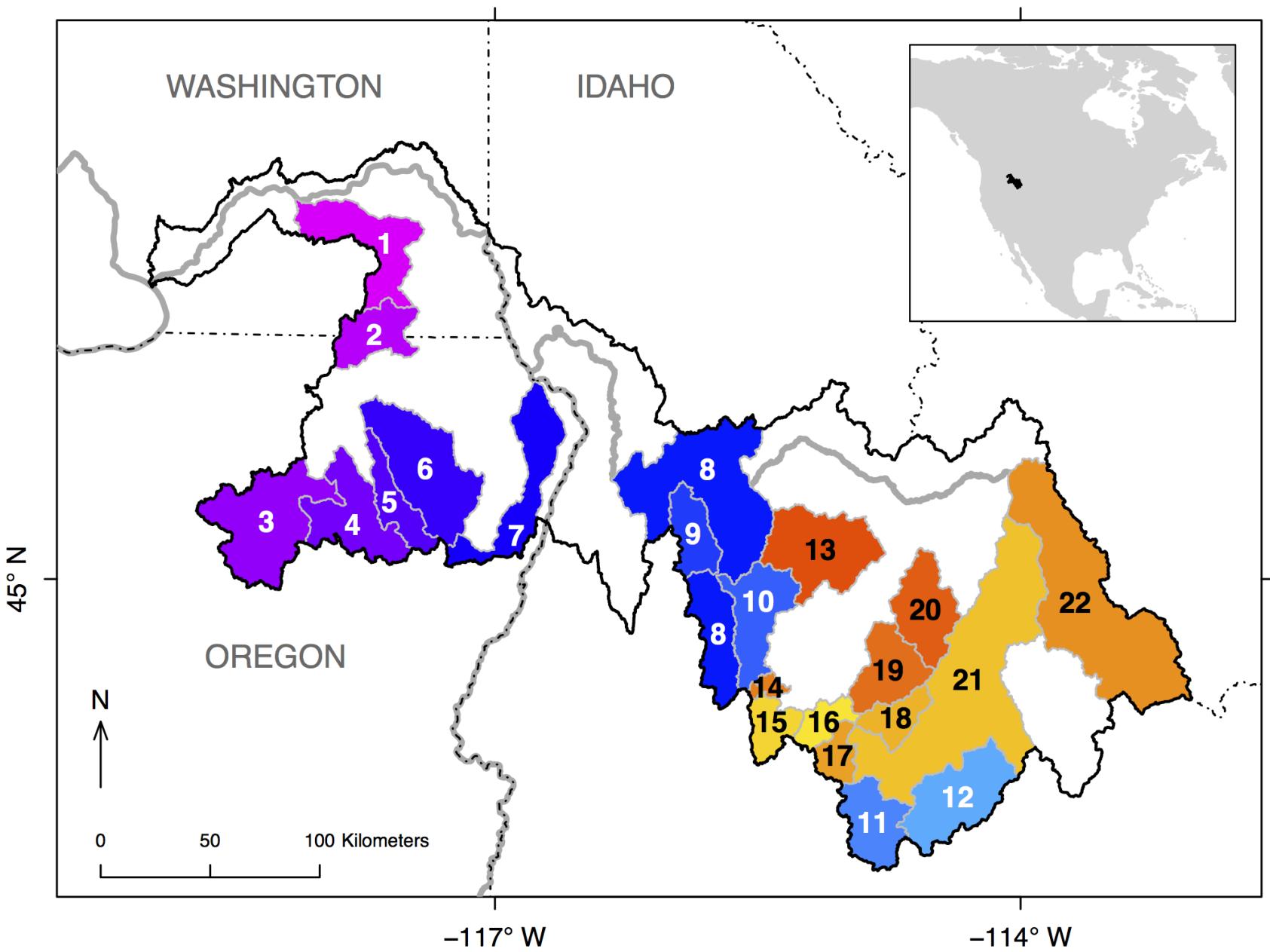
Multiple agencies & tribes

How should we analyze these data?



How much did advertising increase sales?





Two modifications to the model

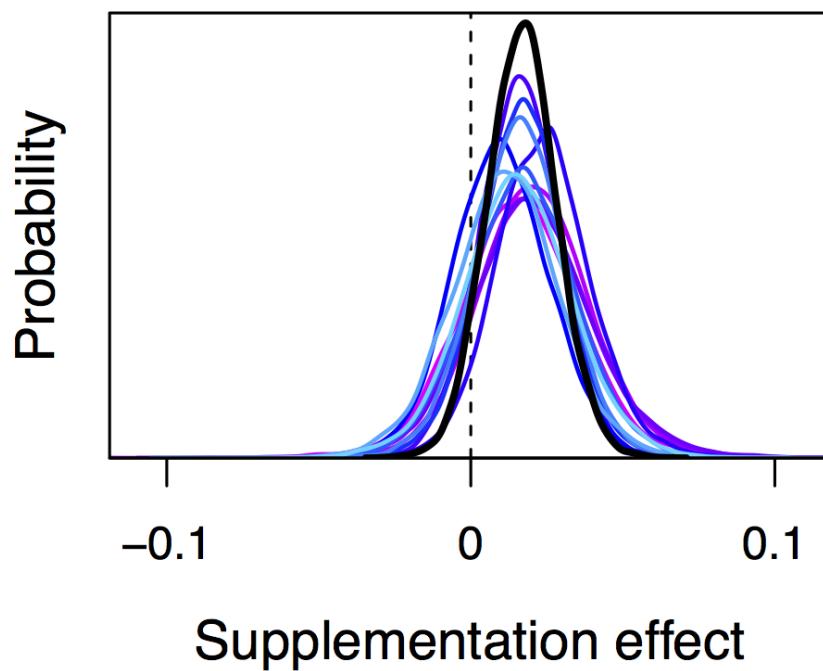
1) Supplementation effect is **hierarchical across popns**

Two modifications to the model

- 1) Supplementation effect is **hierarchical across popns**
- 2) Errors include a **common year effect**

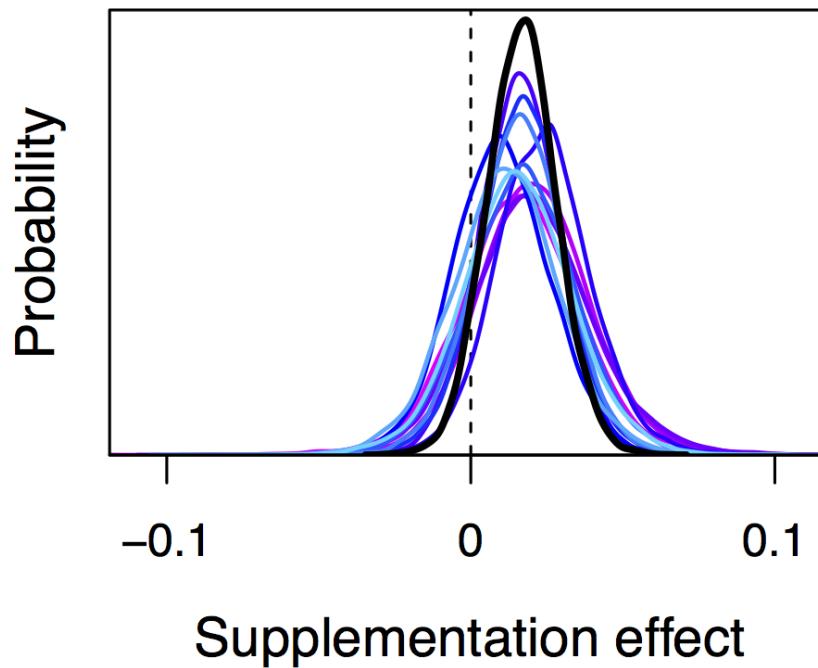
Supplementation effect is rather subtle

Mean increase of only 3.3% over ~25 years

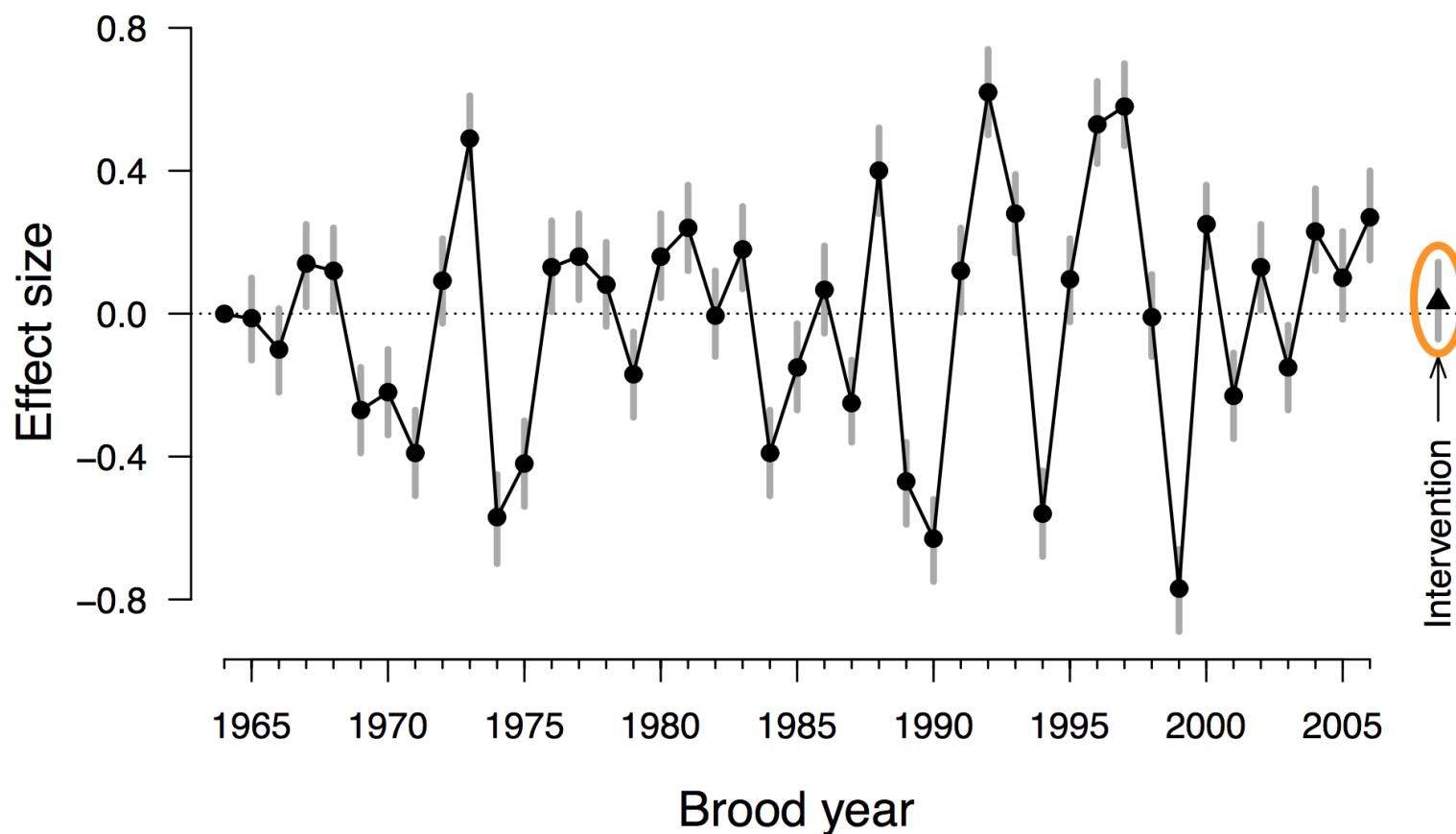


Supplementation effect is rather subtle

Probability of positive effect is ~70%



Common year effects overshadow intervention



What about unplanned experiments?

Deepwater Horizon oil spill

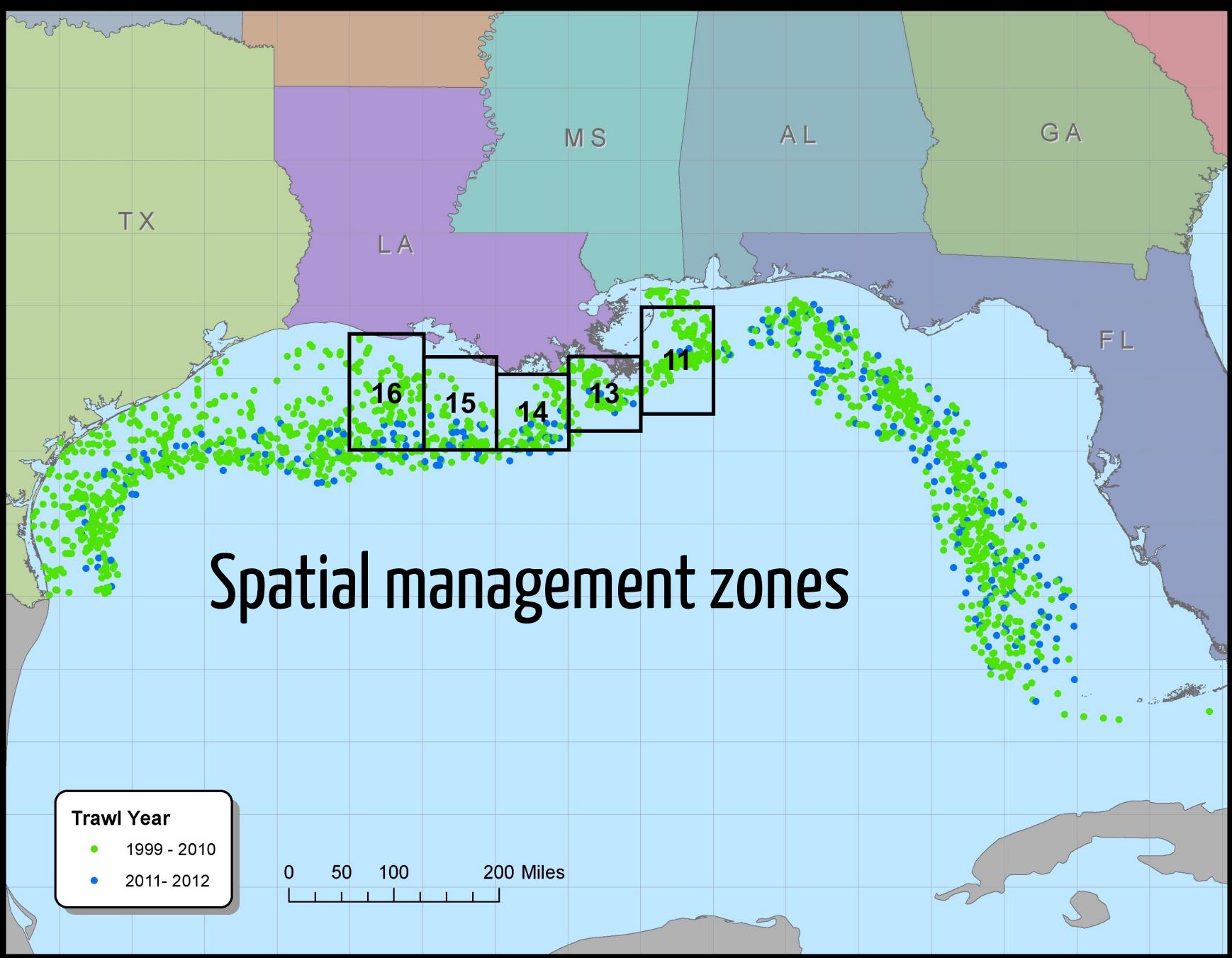


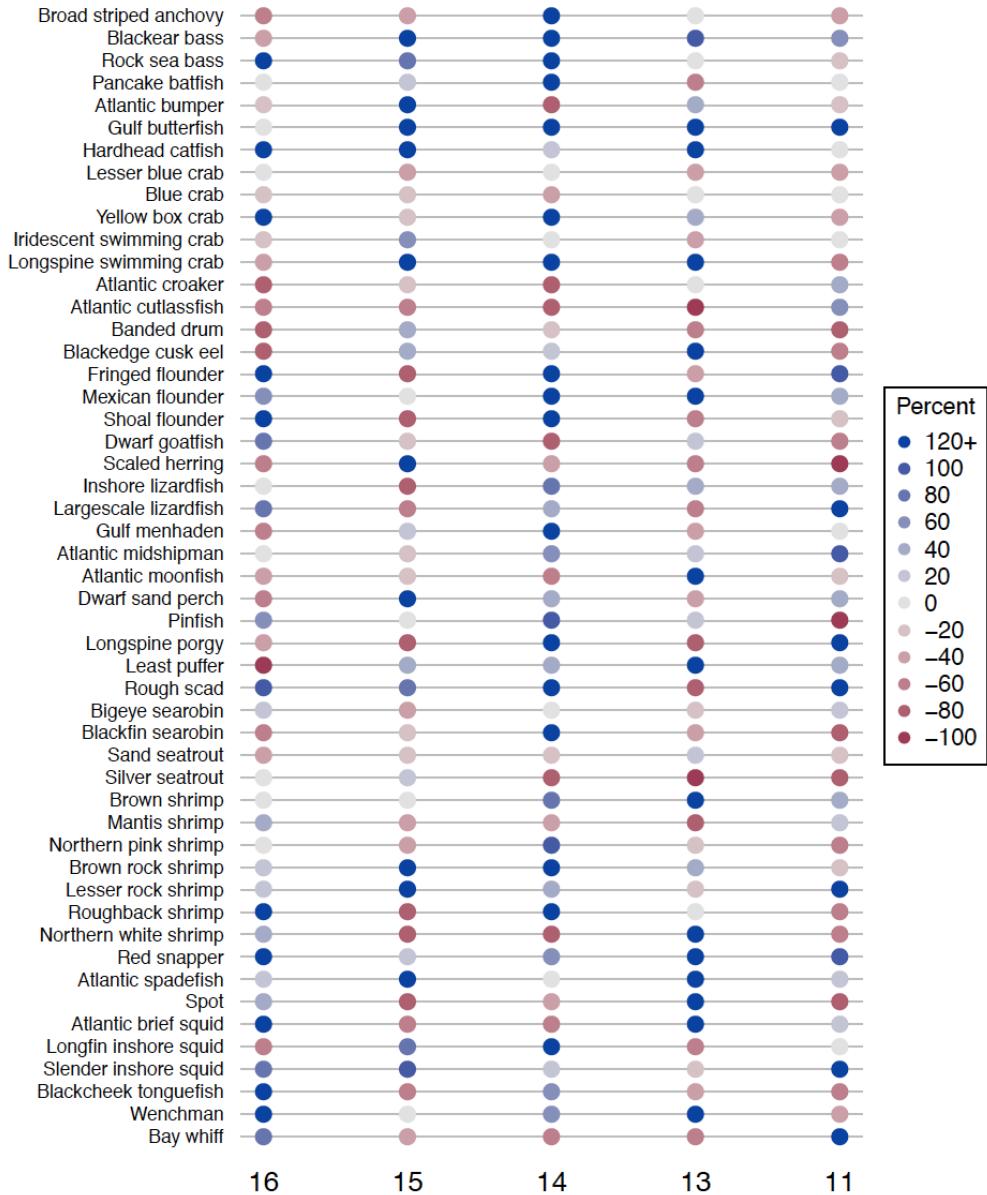
20 April 2010

How did abundance change post-spill?

Quarterly survey data from 1982-present

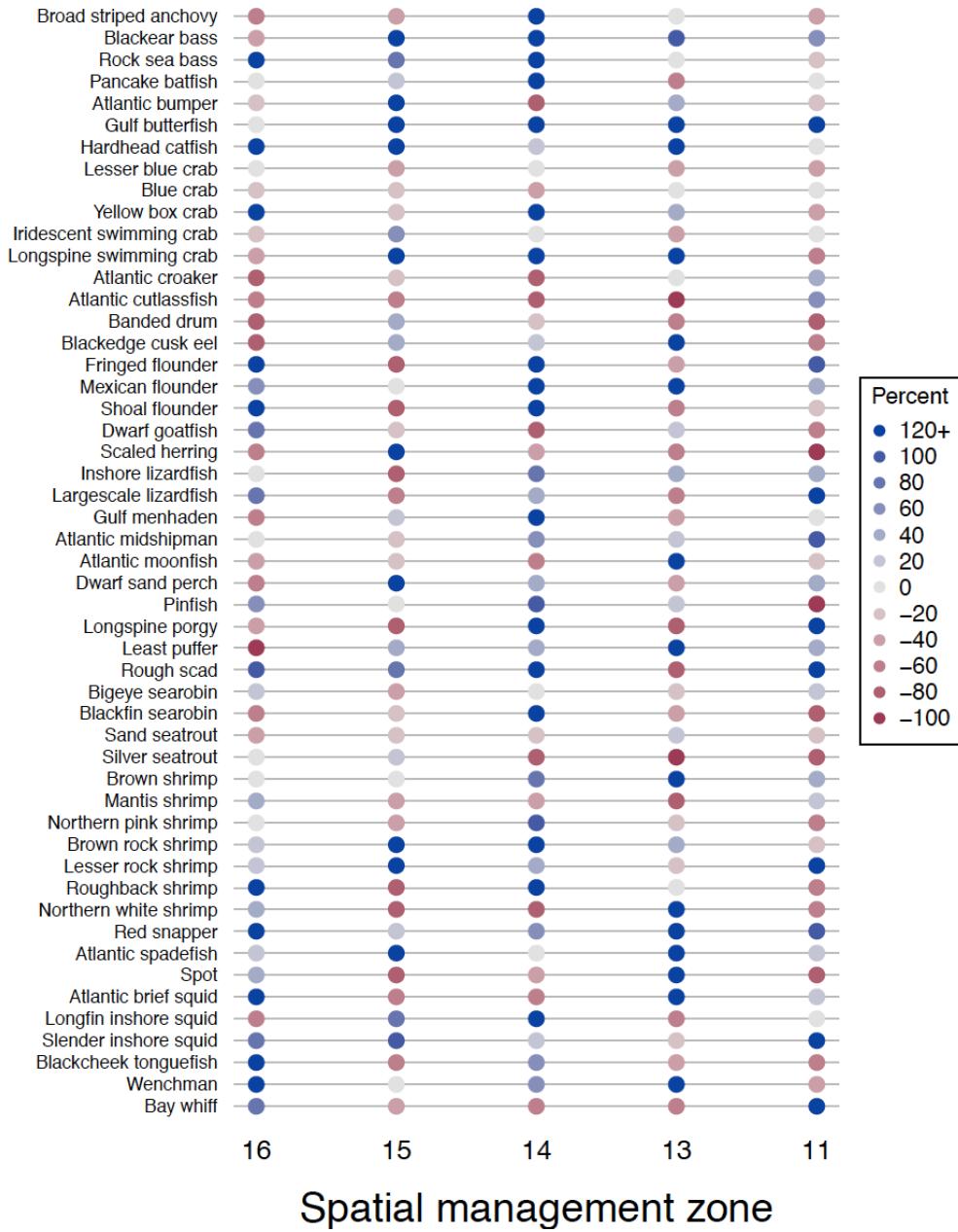
50+ species of fish & inverts



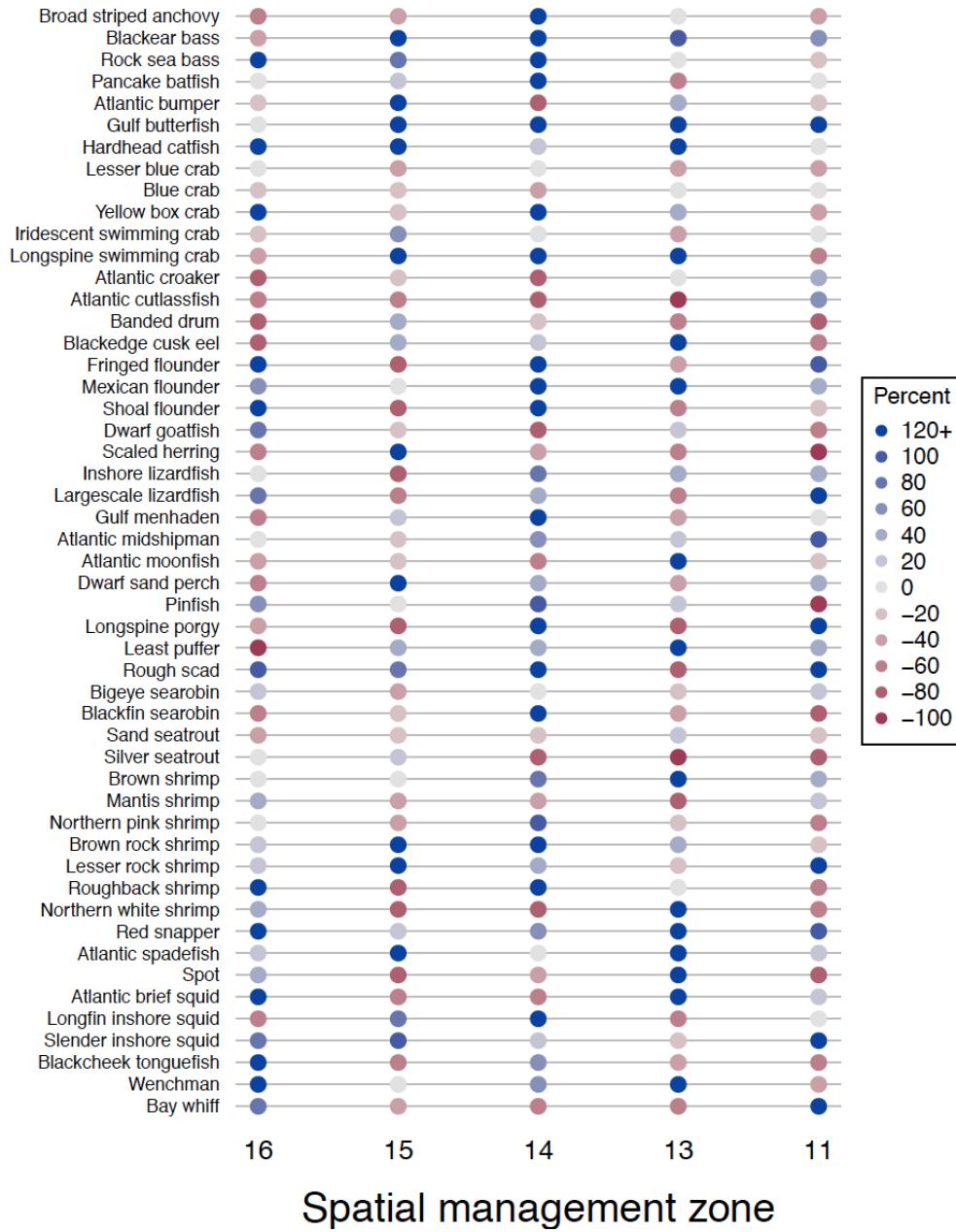


Oil spill (-)

No Fishing (+)



Only 3 yrs later



Future directions

Marine & freshwater food-webs

How do species interactions change over time?

Ecological portfolios

Maximize info from monitoring while minimizing cost

Open science

I'm dedicated to open, reproducible research

As public servants our work should be accessible

Development

<https://github.com/mdscheuerell/>

Slide deck

https://faculty.washington.edu/scheuerl/Scheuerell_WDE_2019.pdf

Image sources

M Caulkin: *20th Century Fox*

Carnival: *Frank Kovalchek (2010)*

Robin Hood: *John Escott*

Budweiser: *Anheiser-Busch*

DWH: *US Coast Guard*

