

# THE DEVELOPMENT AND APPLICATION OF NEW TOOLS IN QUANTITATIVE ECOLOGY

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I hope you're thirsty!



# A brief outline

## 1. Background

- Early mathematical flute music
- Emergence of cool stuff
- The future of cool stuff
- Can we get through all of this?

## 2. Methods

- Old school stats
- New school stats
- Software improvements
- Hardware is not soft

## 3. Results

- Some plots
- Unrelated tangent
- More plots
- Really hard-to-read table
- Horrendogram

## 4. Discussion

- Where is this headed?
- So much inference
- Did we get through all of this?
- When is he done?

## 5. Supplement

- There's more?!
- Who does this in a talk?

# I was trained as a field ecologist



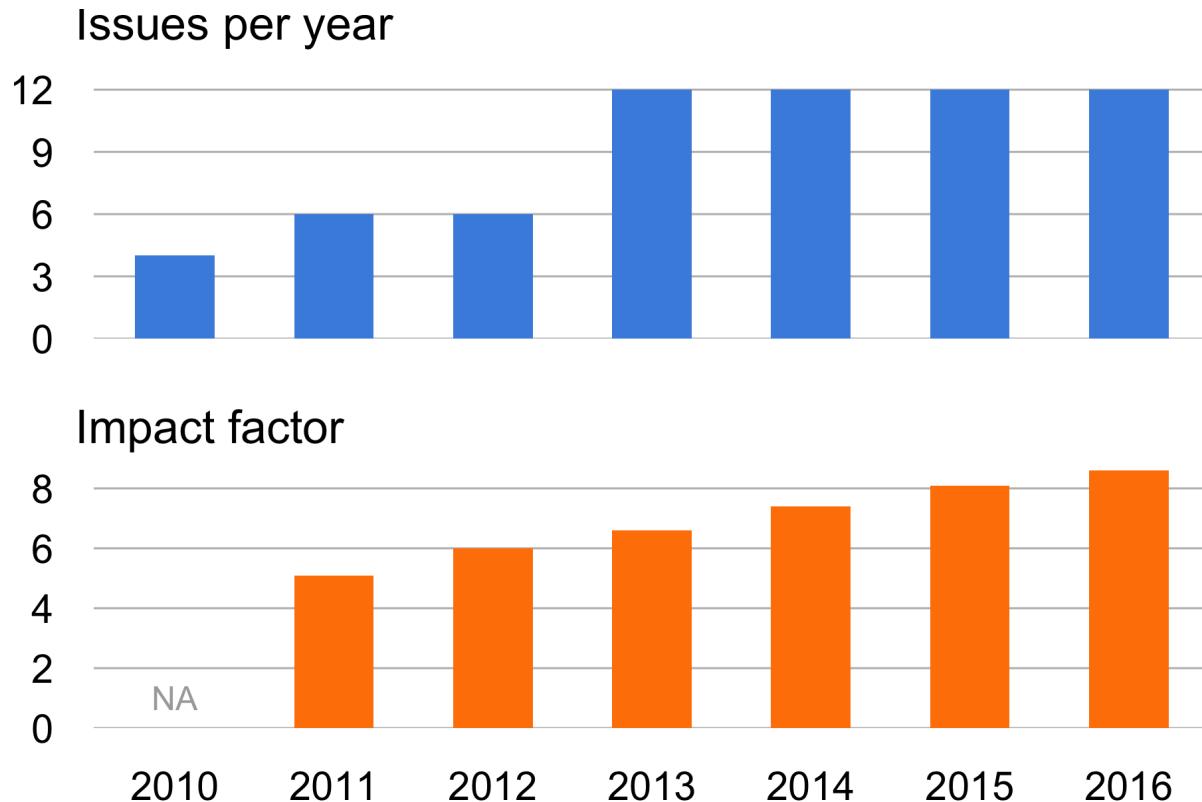
# Many advances in methods for naturalists

Genetics

Remote sensing

Statistics

# *Methods in Ecology and Evolution* (Est. 2010)



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

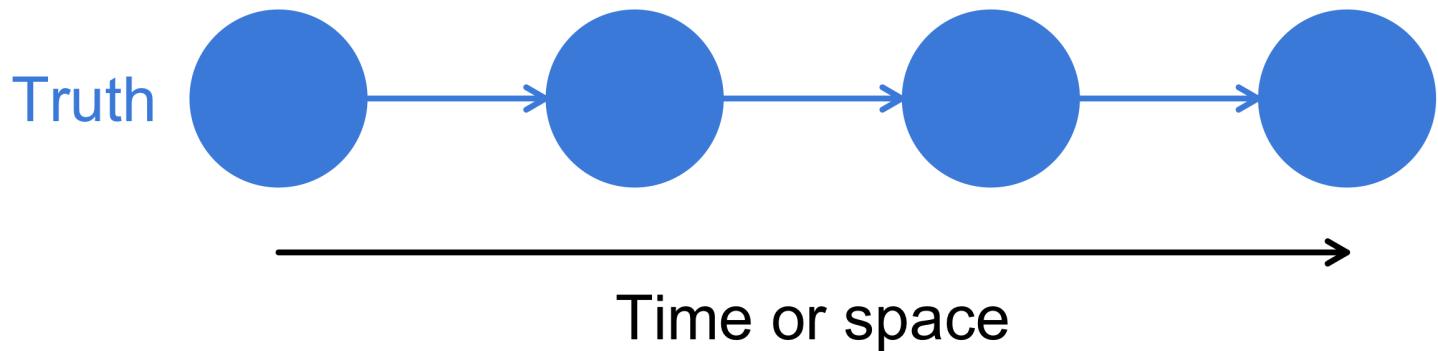
Random-effects models

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

Revealing the state of nature  
requires some observations

Observing nature can be easy

A photograph showing a large school of salmon swimming in a clear, shallow stream. The water is filled with numerous salmon, their bodies glowing with a vibrant red color against the blue and green hues of the surrounding environment. The salmon are moving in various directions, creating a sense of dynamic movement. The stream bed is visible through the clear water, showing rocks and pebbles.

How many salmon are there?

Observing nature can also be hard



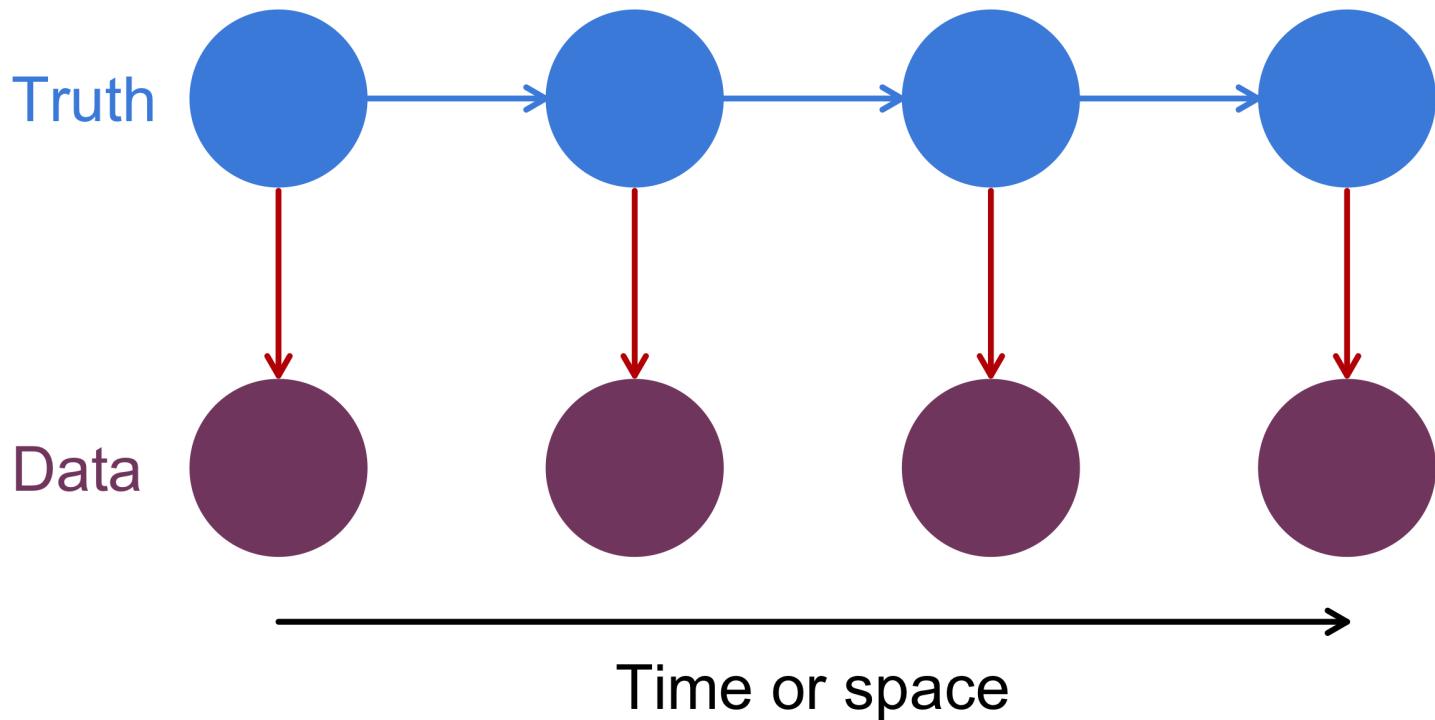
How many mayflies are there?

# 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

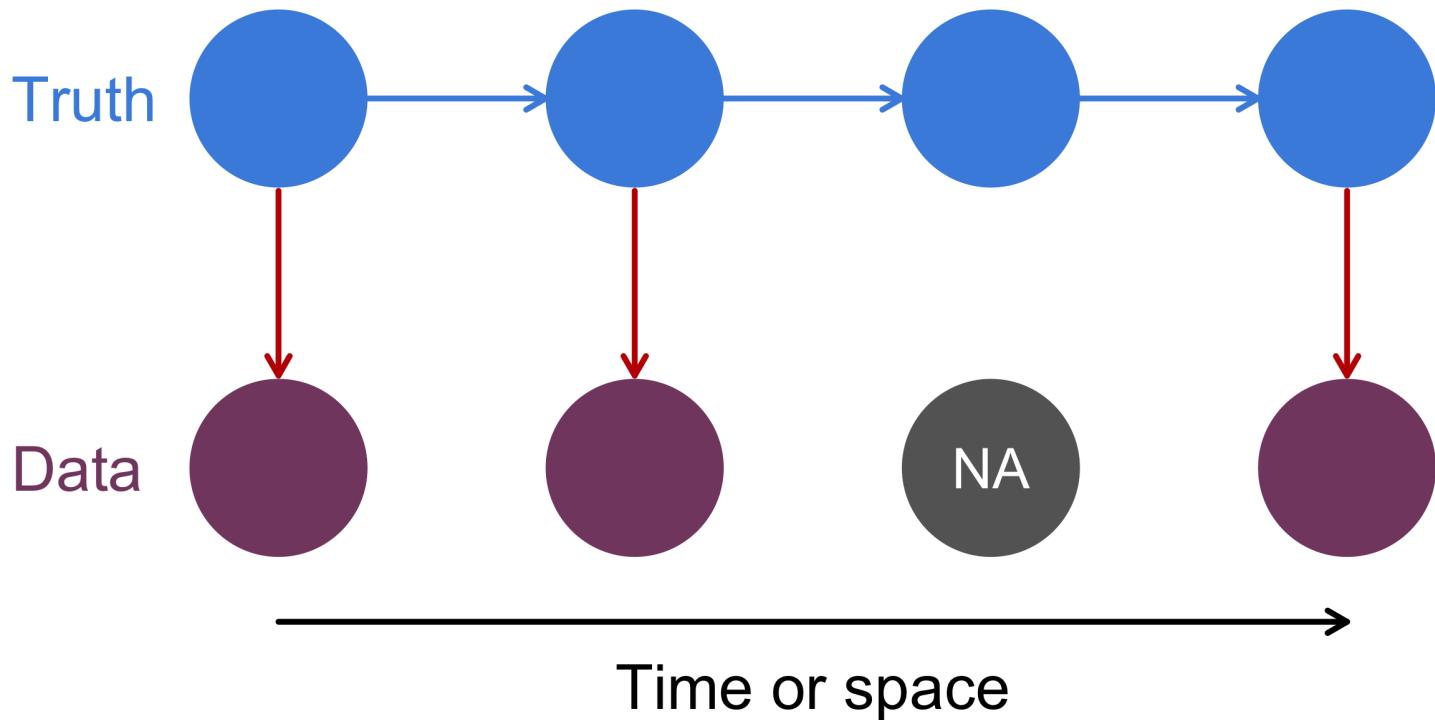
Changes in observers or sensors

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](#)

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

Ian Jonsen 

*Scientific Reports* **6**, Article number: 20625

(2016)

[doi:10.1038/srep20625](https://doi.org/10.1038/srep20625)

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# Advantages of hierarchical models

## 4. Rather flexible

This simple model can be used for 5+ unique applications!

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

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

How do I actually do this?

# Many software options

Canned R packages (MARSS\*, dlm, vars)

Code-your-own (JAGS, Stan, greta)

\*See Holmes, Ward & Scheuerell (2014) for *lots* of worked examples



SNAKE  
OIL

For Nervousness  
For Weak Stomach  
For Telling Dose

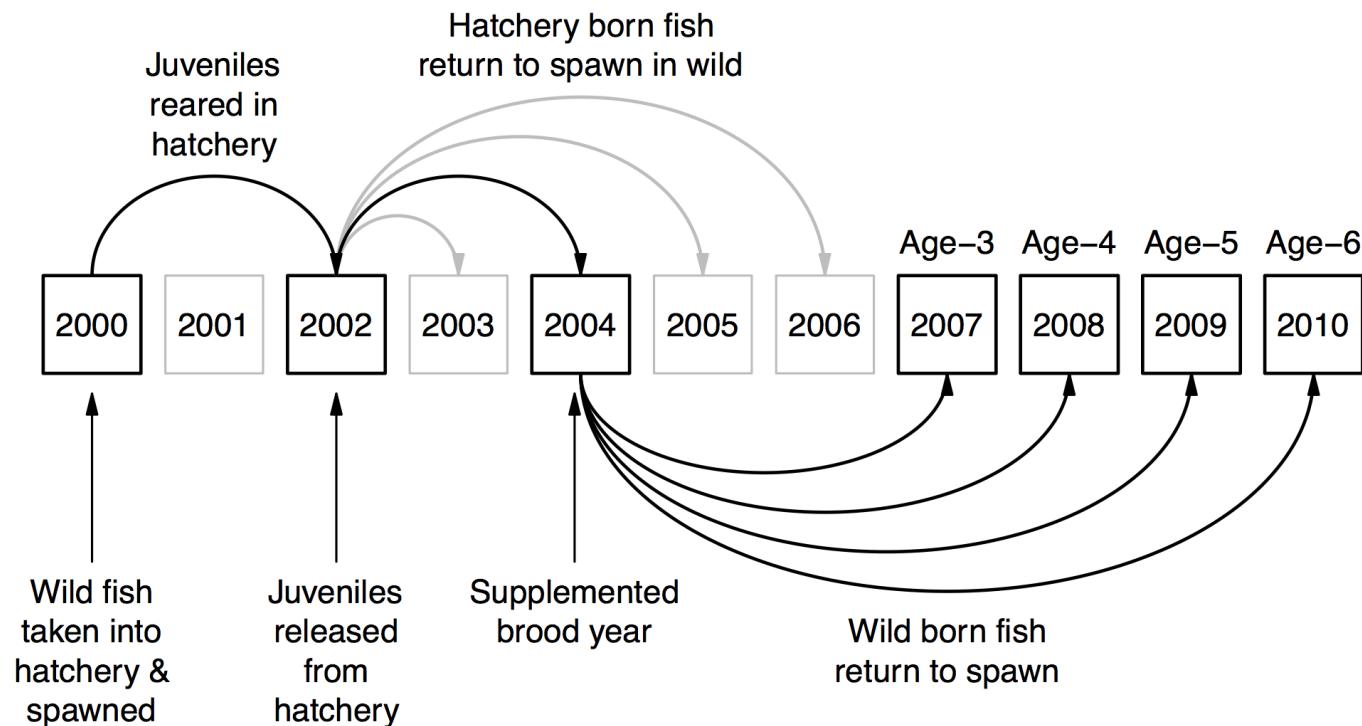
# AN EXAMPLE

# Conservation of Pacific salmon

50% of salmon populations along the US West Coast  
are listed under the Endangered Species Act

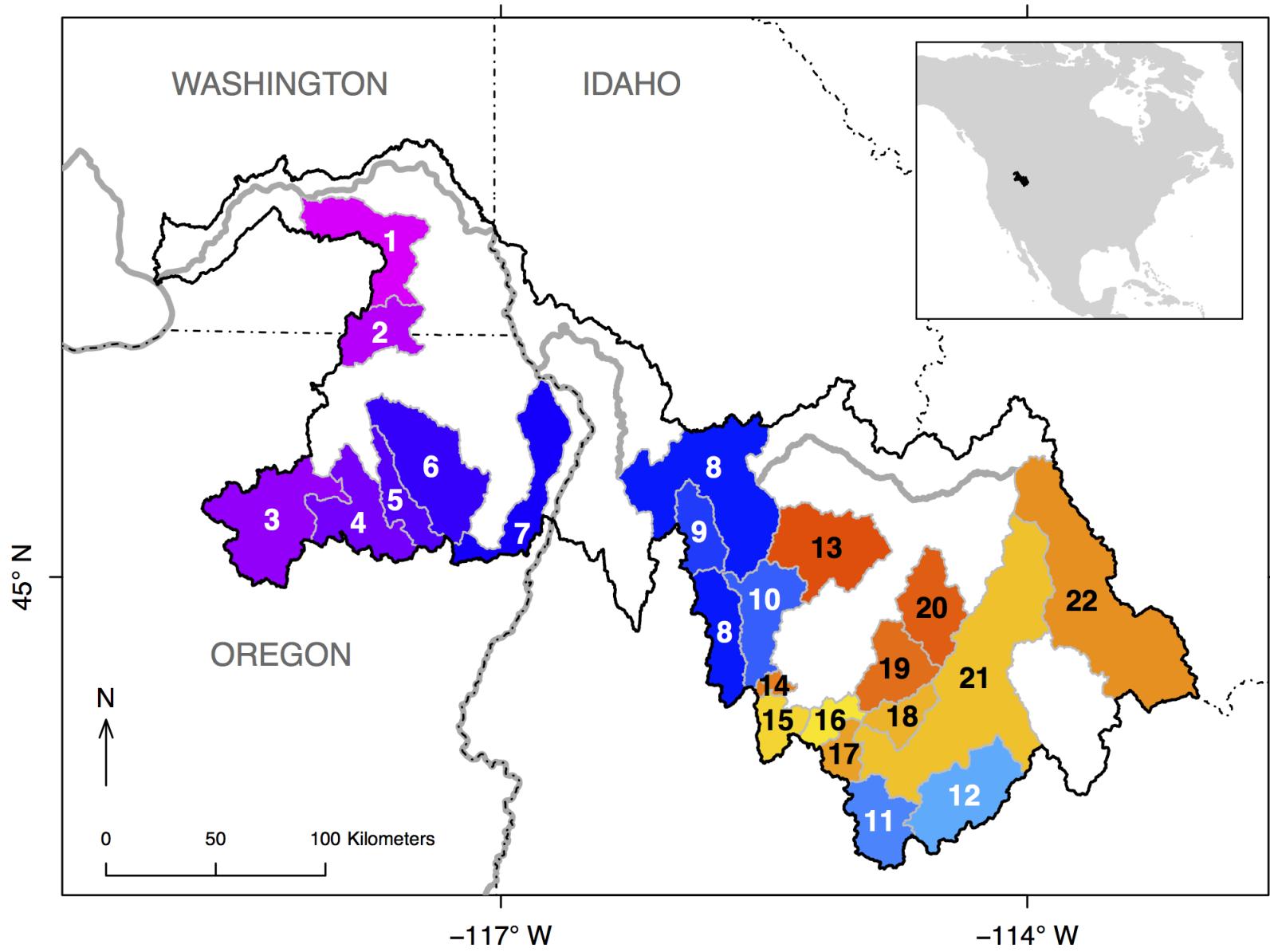
# Recovery options for Pacific salmon

One strategy is hatchery supplementation

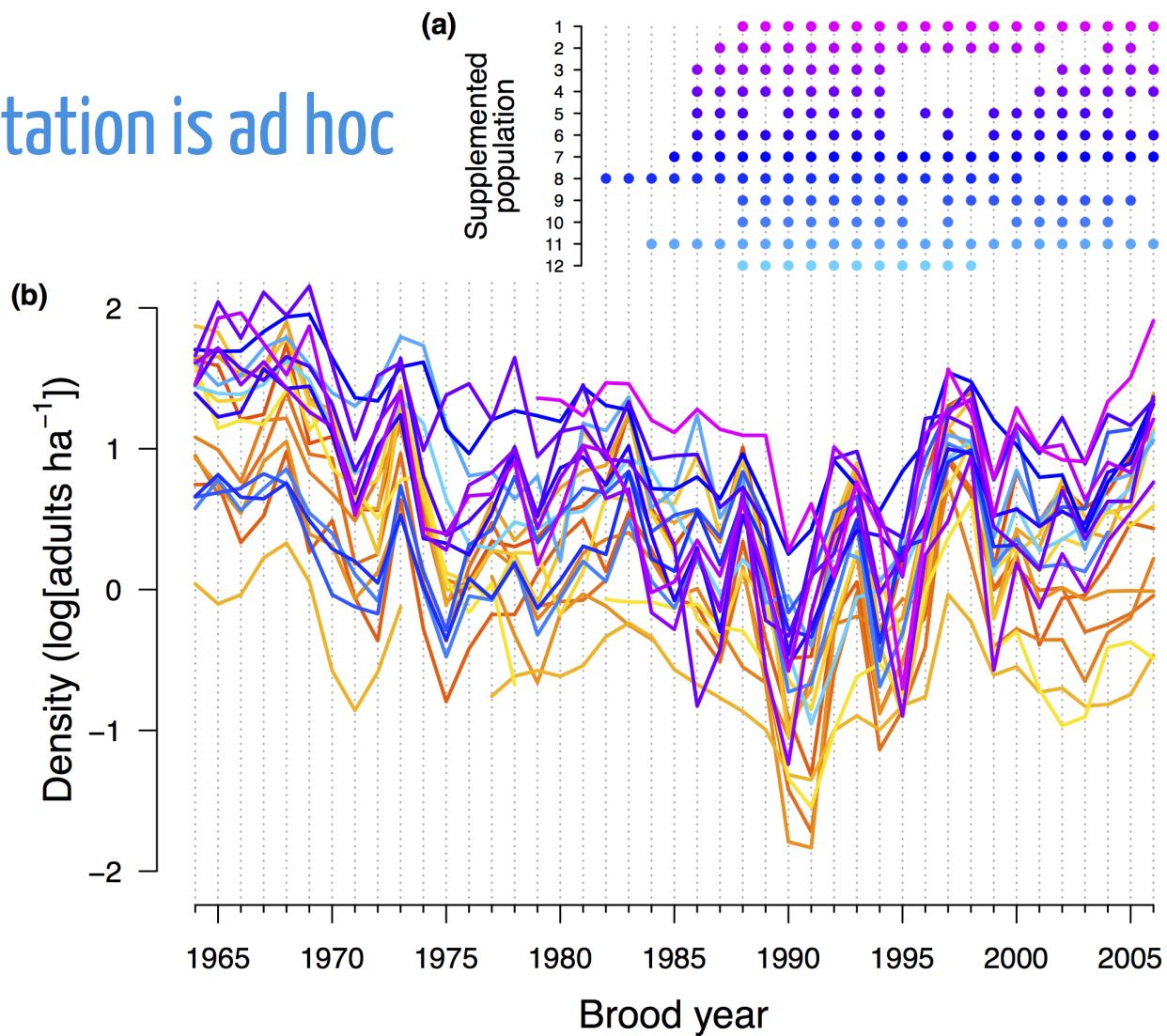


# Evaluating conservation interventions

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

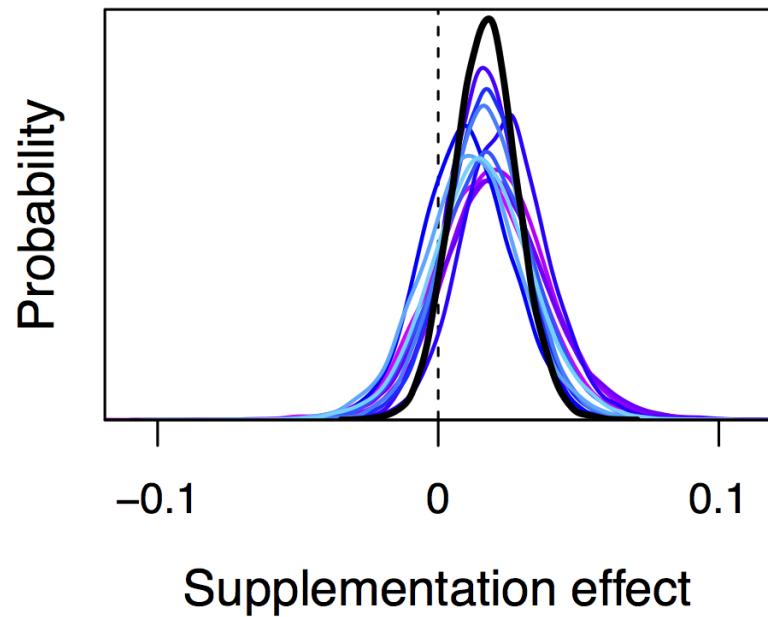


# Supplementation is ad hoc



# Effect size is rather subtle

Probability of positive effect = 0.73



# ANOTHER EXAMPLE

# Emergence of high-dimension data

Remote sensing

Citizen science

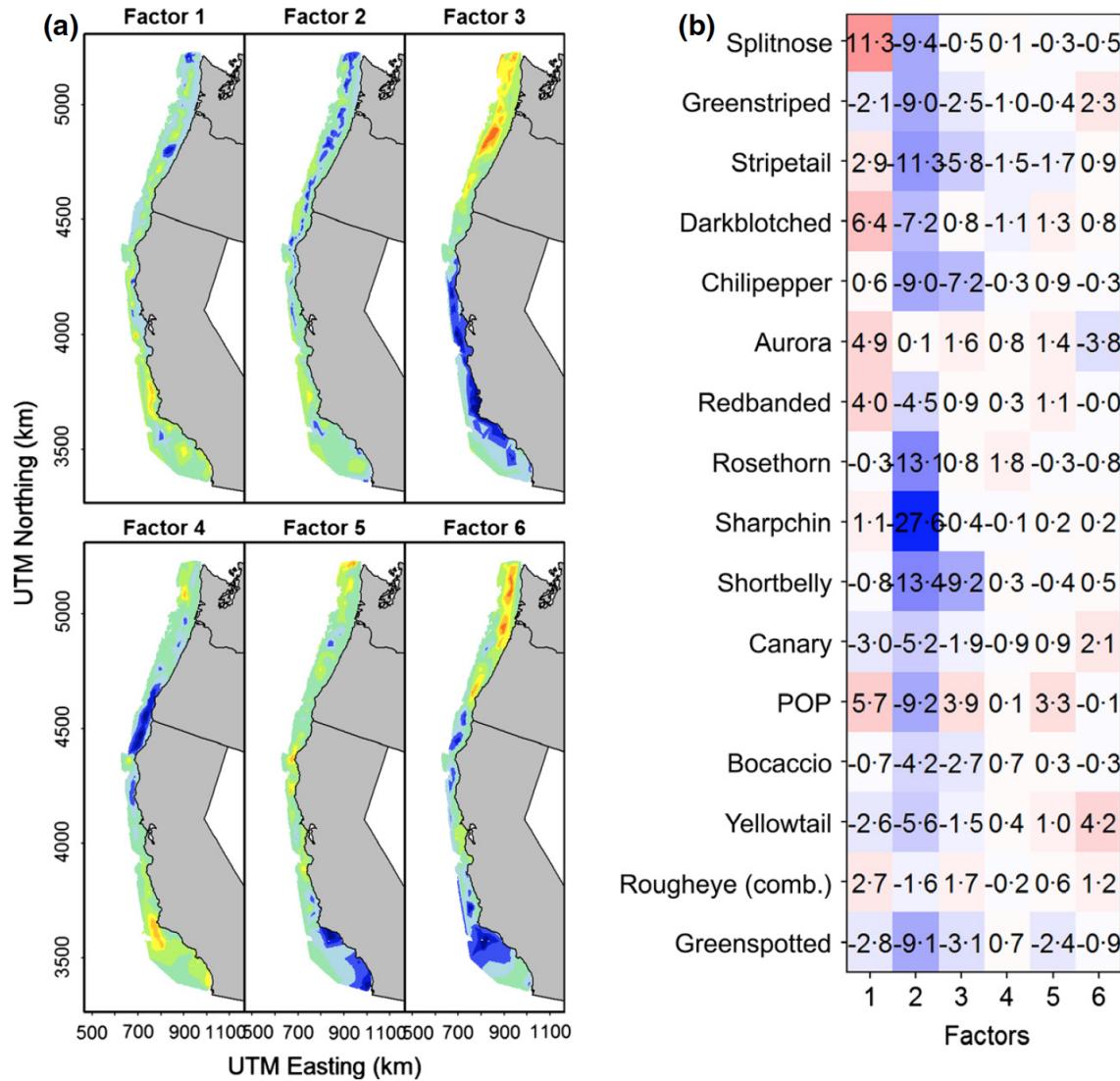
Large-scale surveys

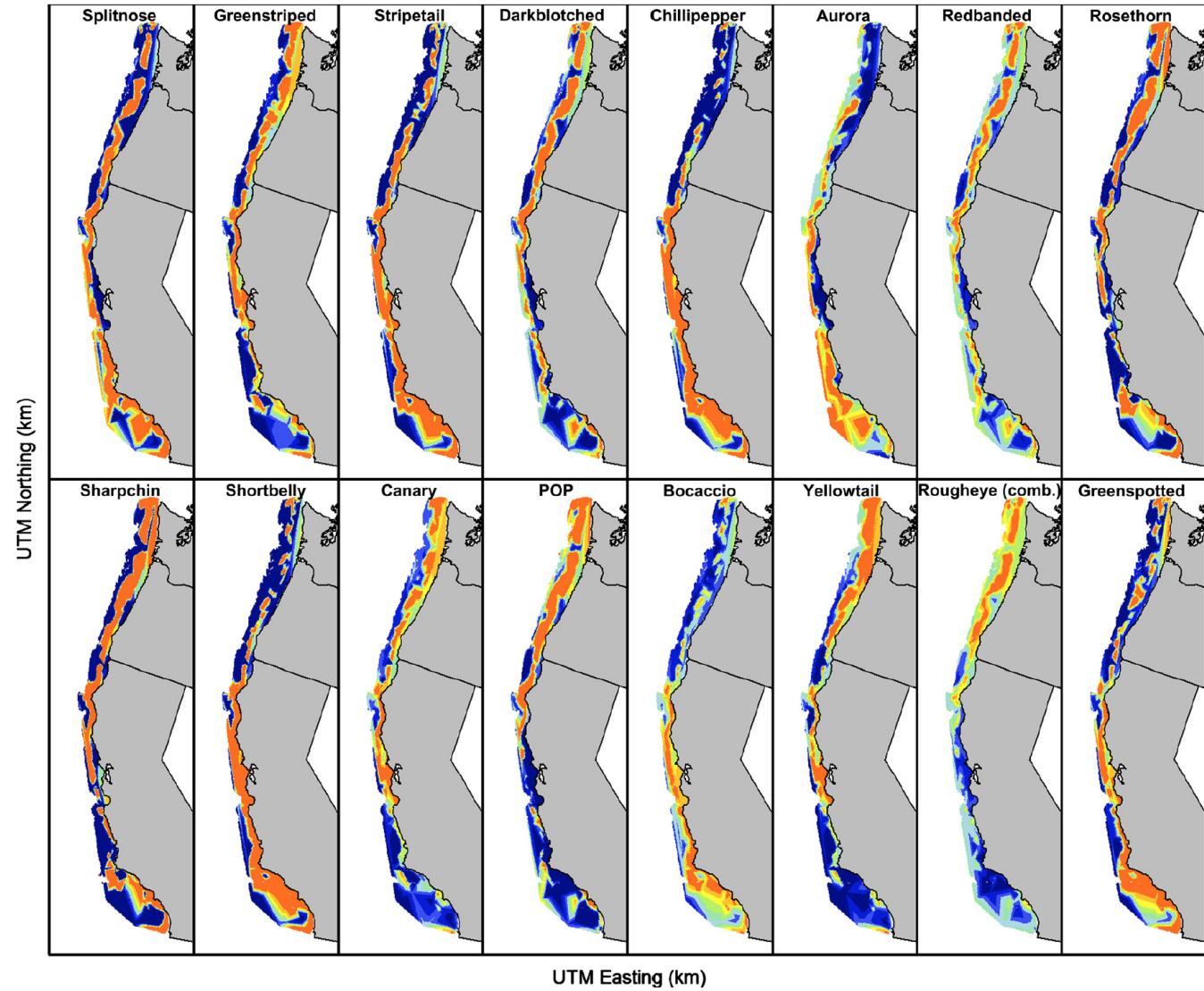
# Groundfish surveys along the West Coast

Massive effort to assess stock status & set catch limits for 100+ species

# Data reduction techniques

Can we detect a few common patterns in the data?





# Other applications of hierarchical models

## Identifying metapopulation structure

Ward et al (2010) *J Appl Ecol* 47:47–56

# Other applications of hierarchical models

Reducing bias in estimates of density dependence

Knape & de Valpine (2012) *Ecol Lett* 15:17–23

# Other applications of hierarchical models

Improving precision in species extinction forecasts

See & Holmes (2015) *Ecol Appl* 25:1157–1165

# In summary

There is plethora of new methods for naturalists

Among them, hierarchical models show real promise

Software & hardware improvements open new doors

# Slide deck

<https://github.com/mdscheuerell/WSN2017>

## Image sources

Drinking fountain: *Massachusetts Inst Tech*

Janet Leigh: *Paramount Studios*

Snake oil: *The Register*