

# THE DEVELOPMENT AND APPLICATION OF NEW TOOLS IN QUANTITATIVE ECOLOGY

Mark Scheuerell

*Northwest Fisheries Science Center  
National Oceanic and Atmospheric Administration  
Seattle, WA*

# Acknowledgments - WSN

Jenn Caselle

Brian Gaylord

# Acknowledgments - colleagues

Elizabeth Holmes, Jim Thorson, Eric Ward (NOAA)

Eric Buhle, Kevin See (Quantitative Consultants, Inc)

Stephanie Hampton, Steve Katz (WSU)

Brice Semmens (Scripps)

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



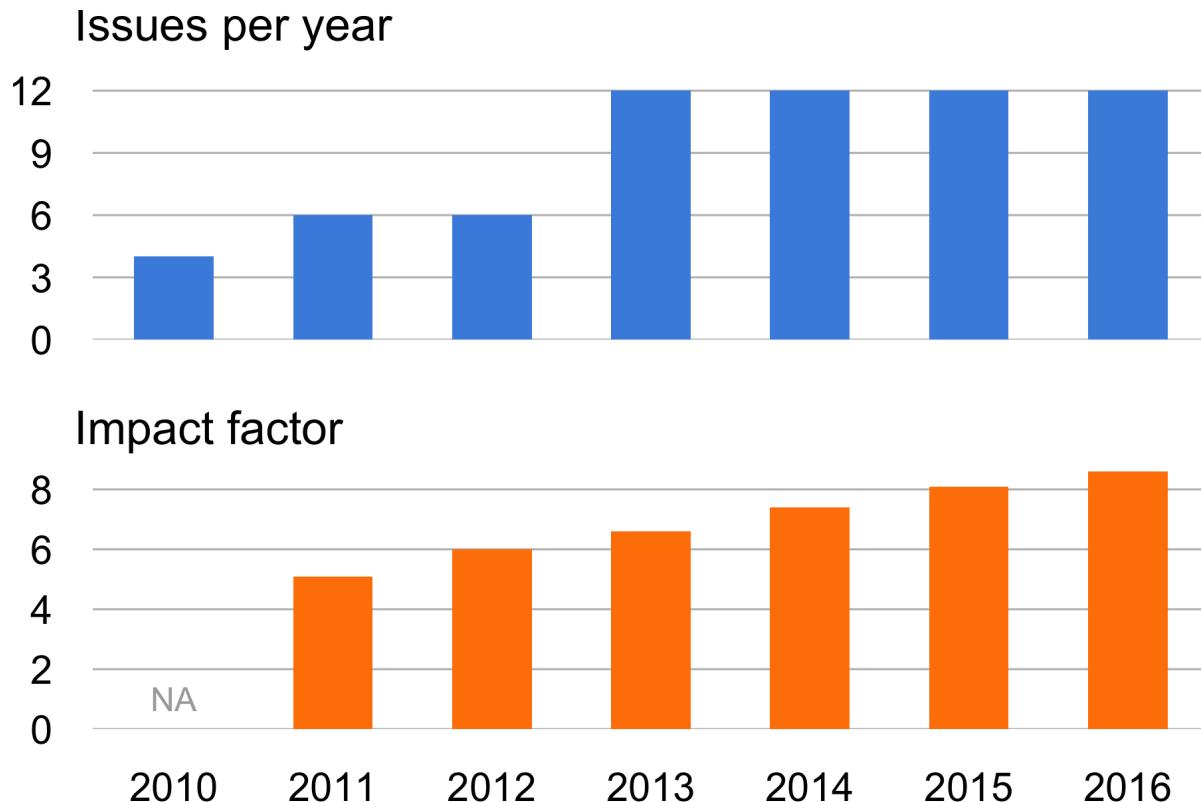
# Many advances in methods for naturalists

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

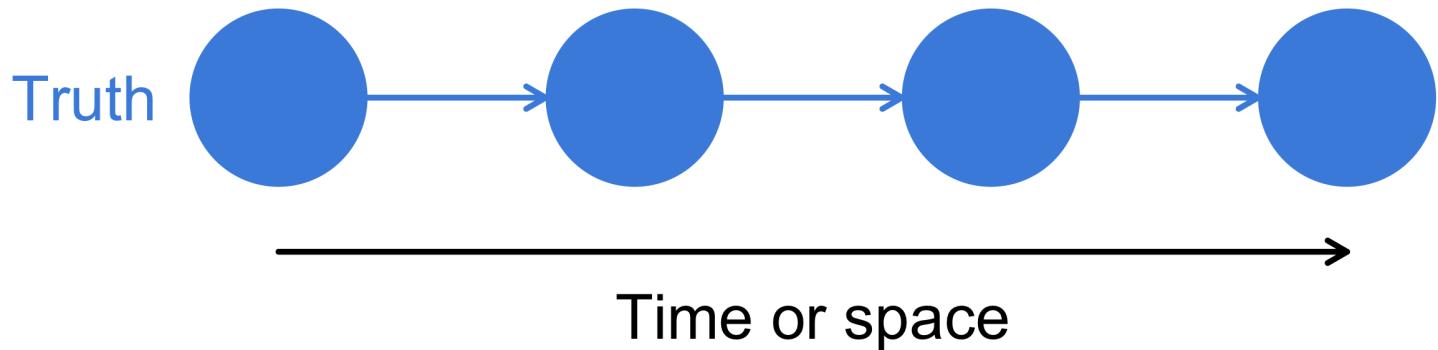
Random-effects models

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 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 salmon are there?

Observing nature can also be hard



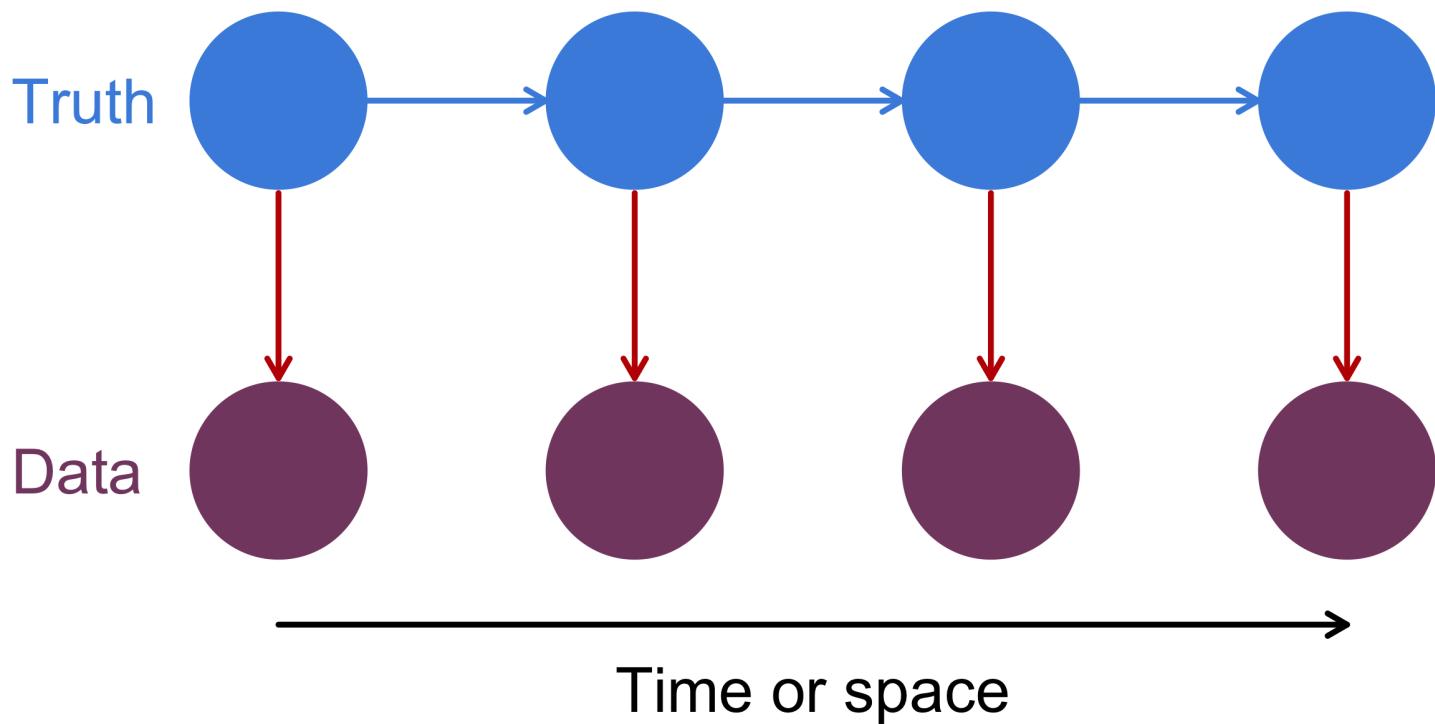
How many mayflies are there?

# 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

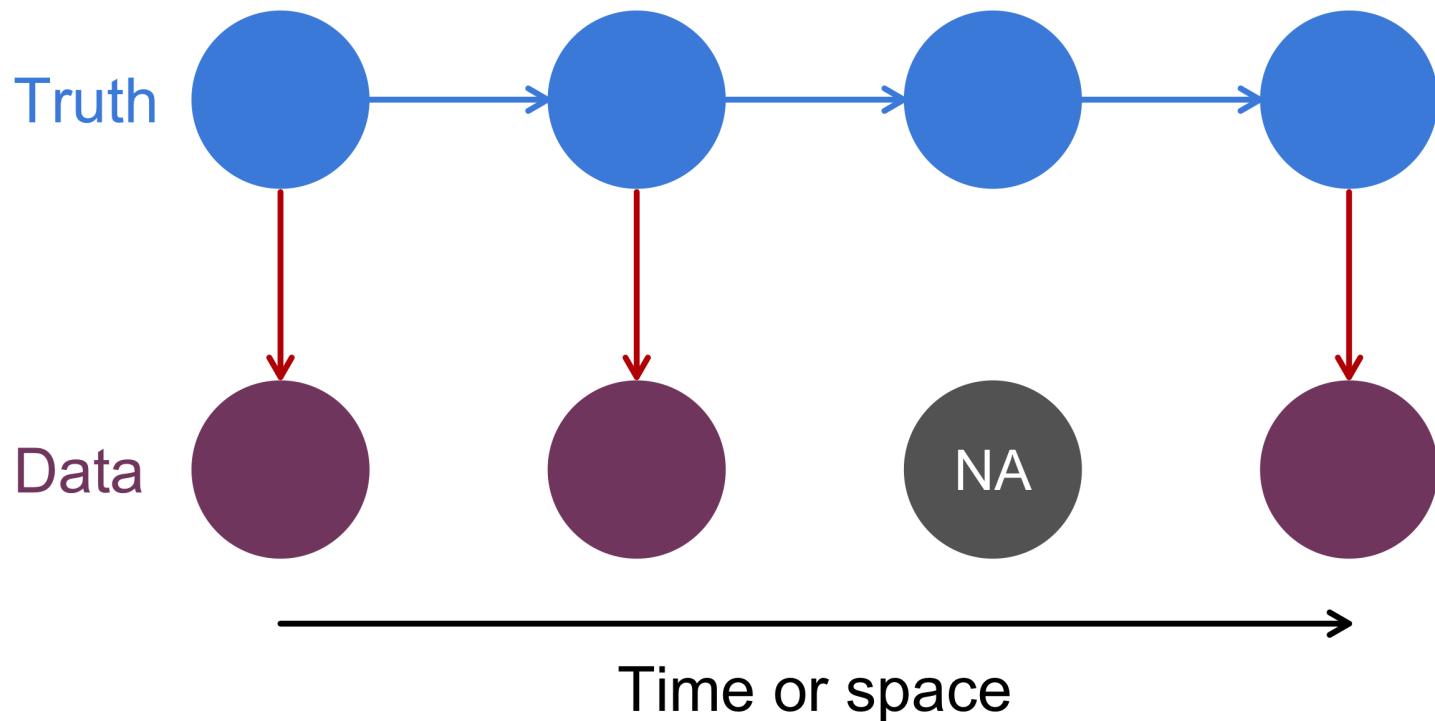
Changes in observers or sensors

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

Received: 07 October 2015

Accepted: 08 January 2016

Published online: 08 February 2016

# 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 Tiring Eyes

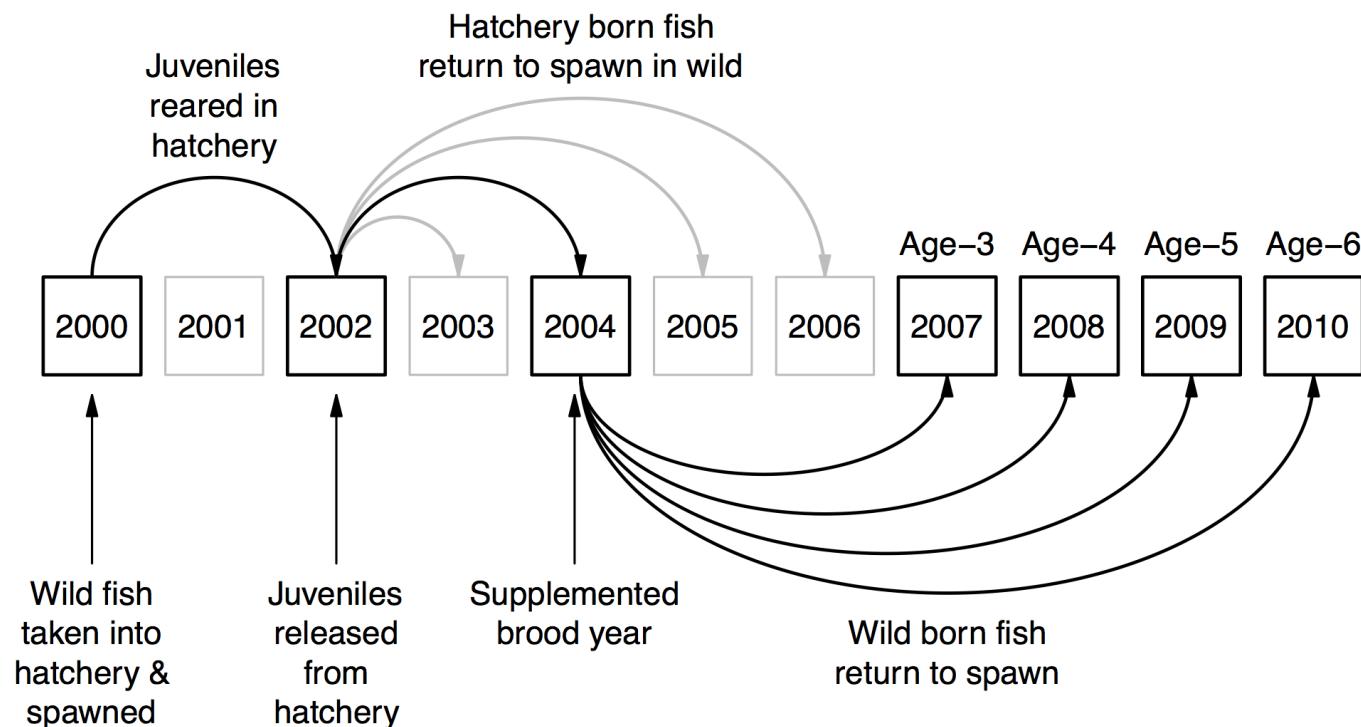
AN EXAMPLE

# Conservation of Pacific salmon

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

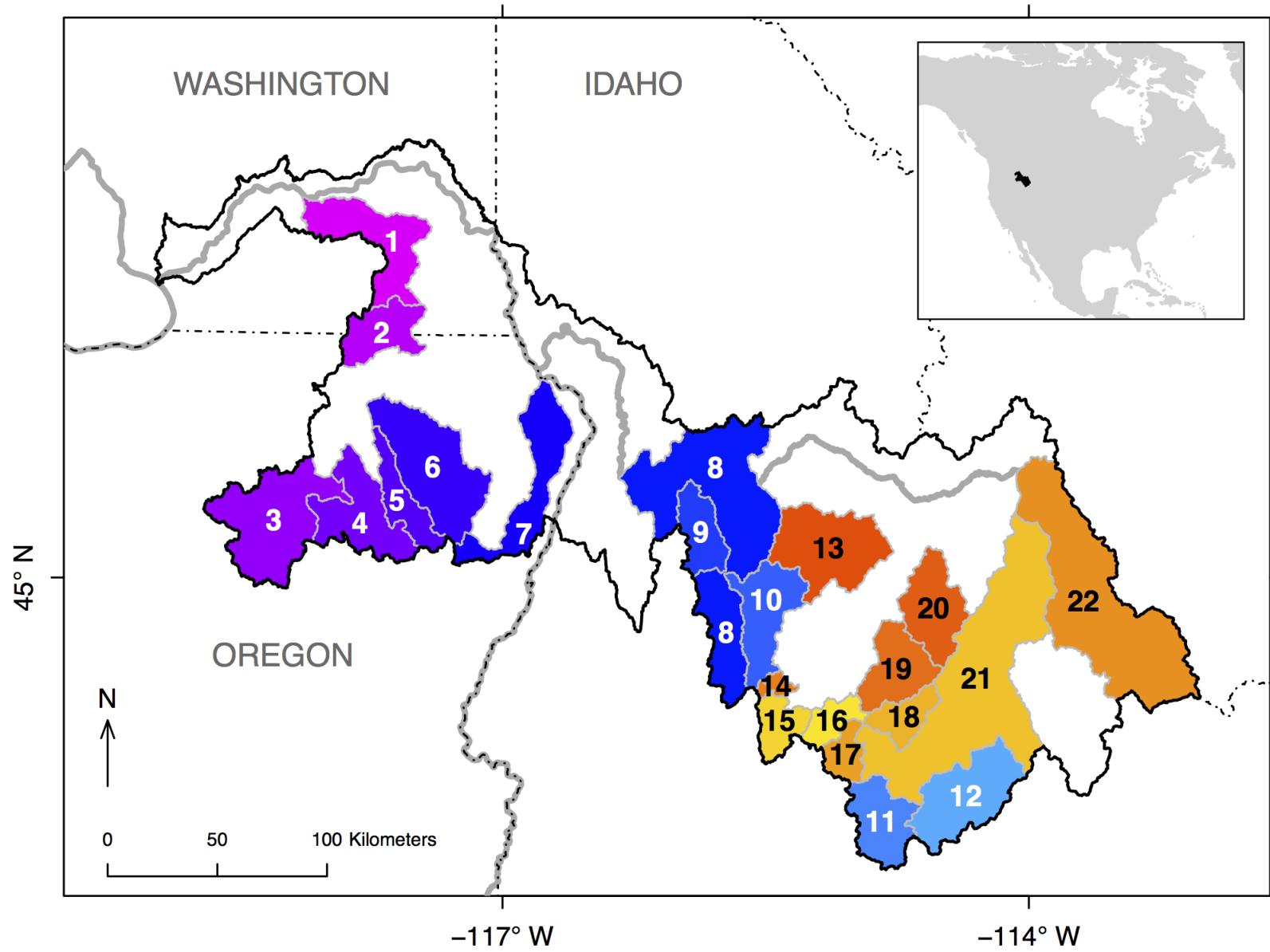
# Recovery options for Pacific salmon

One strategy is hatchery supplementation

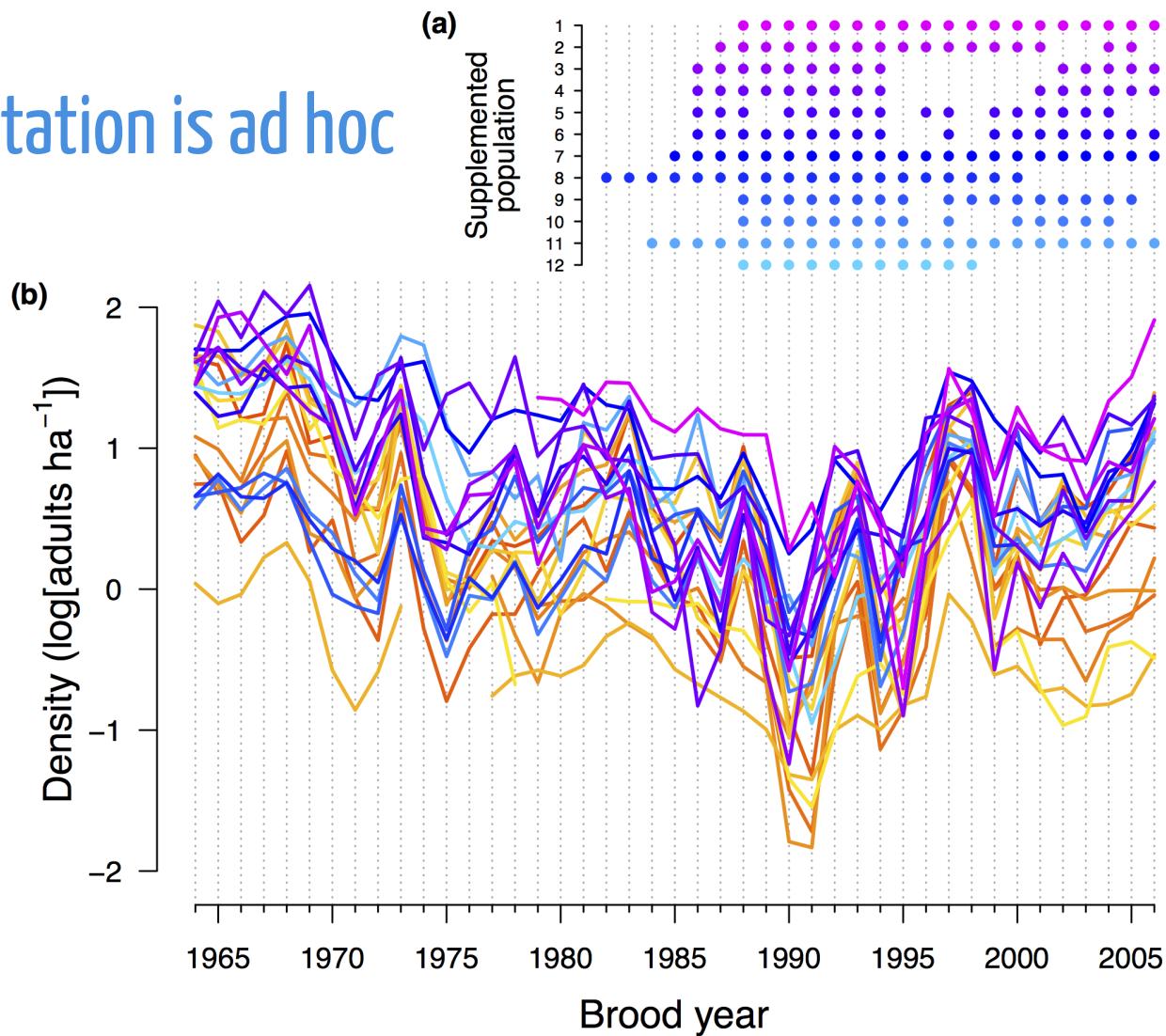


# Evaluating conservation interventions

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

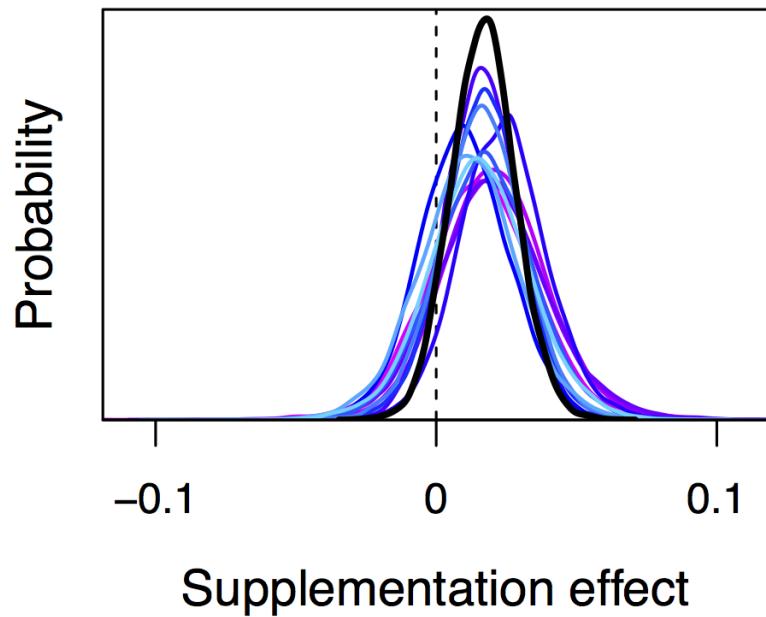


# Supplementation is ad hoc



# Effect size is rather subtle

Probability of positive effect = 0.73



# ANOTHER EXAMPLE

# Emergence of high-dimension data

Remote sensing

Citizen science

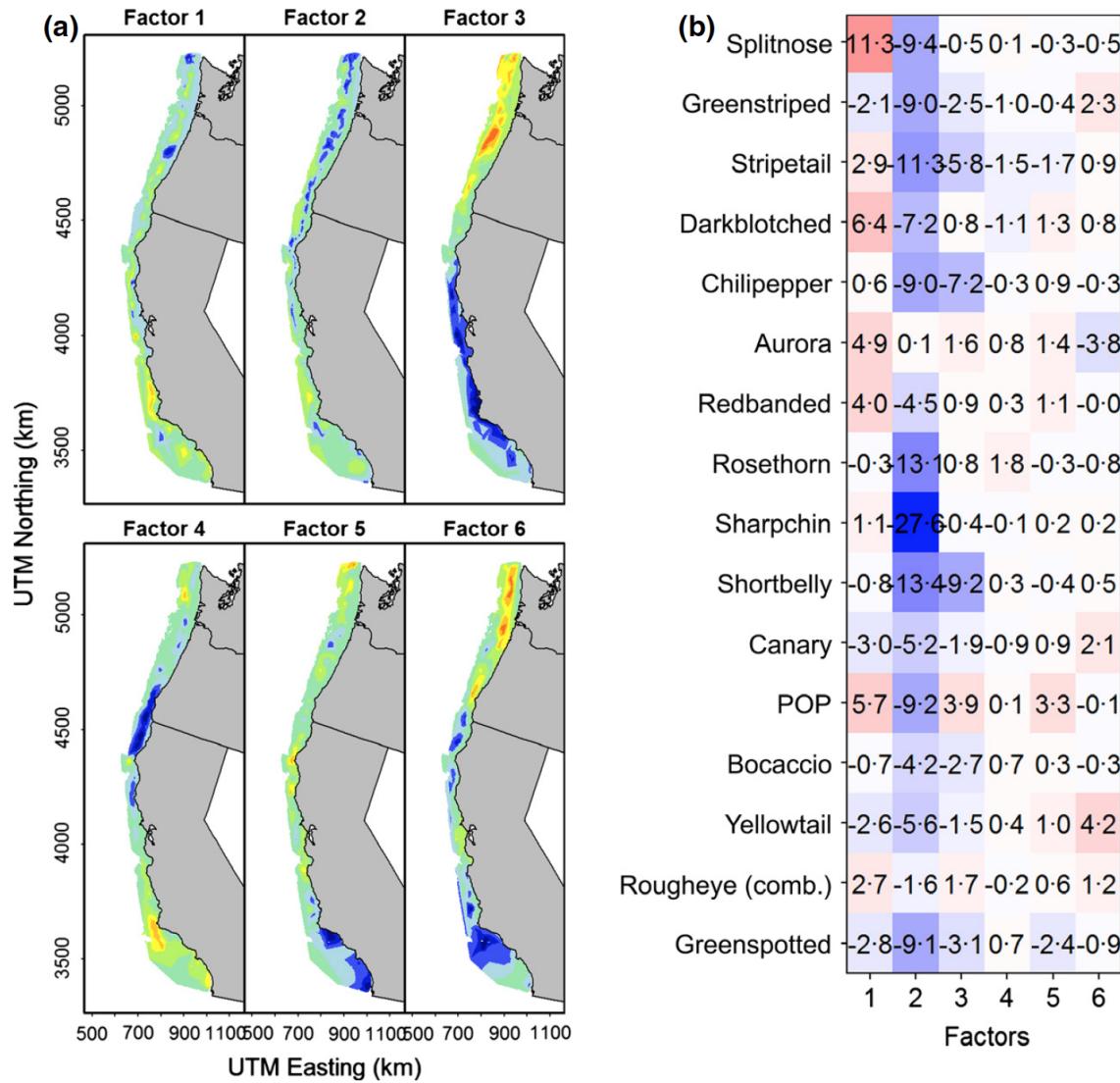
Large-scale surveys

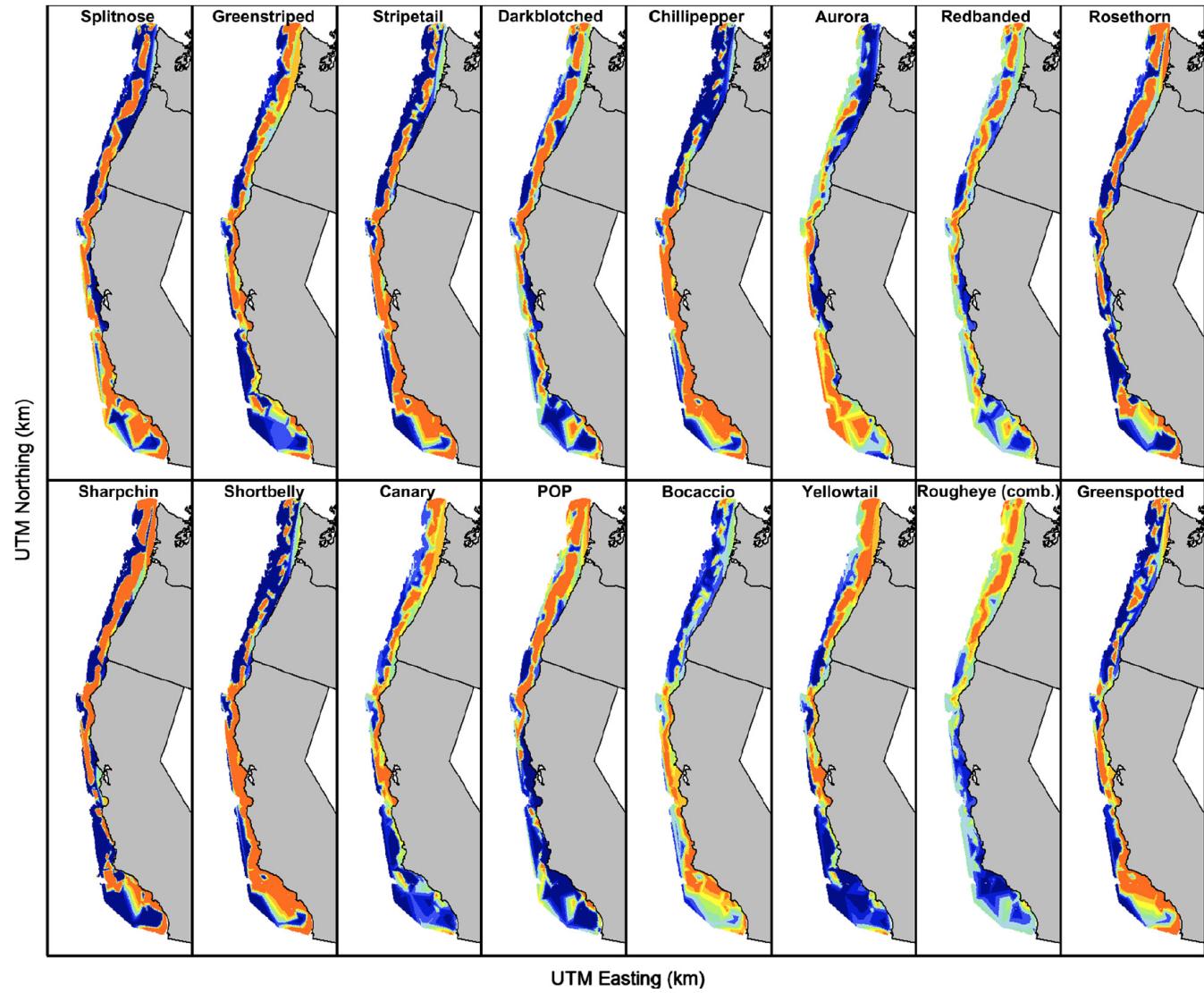
# Groundfish surveys along the West Coast

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*