

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



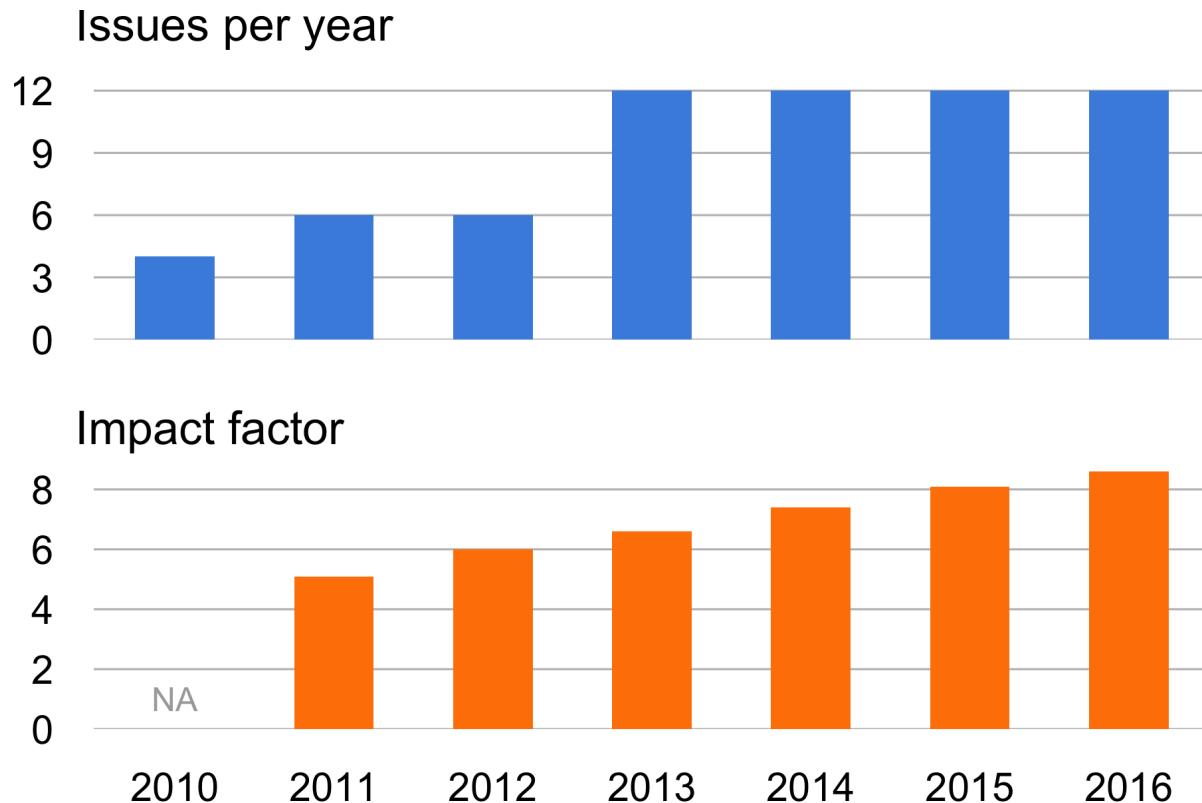
Many advances in methods for naturalists

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

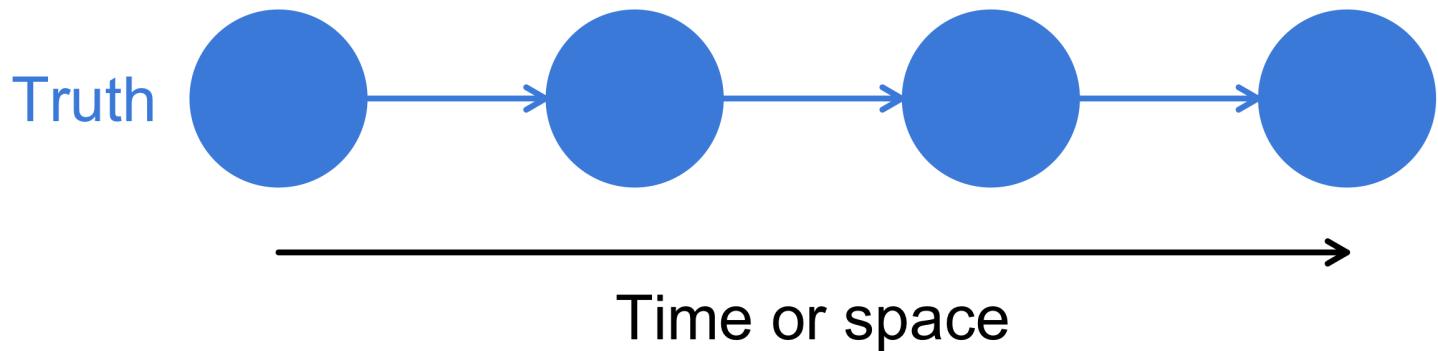
Random-effects models

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



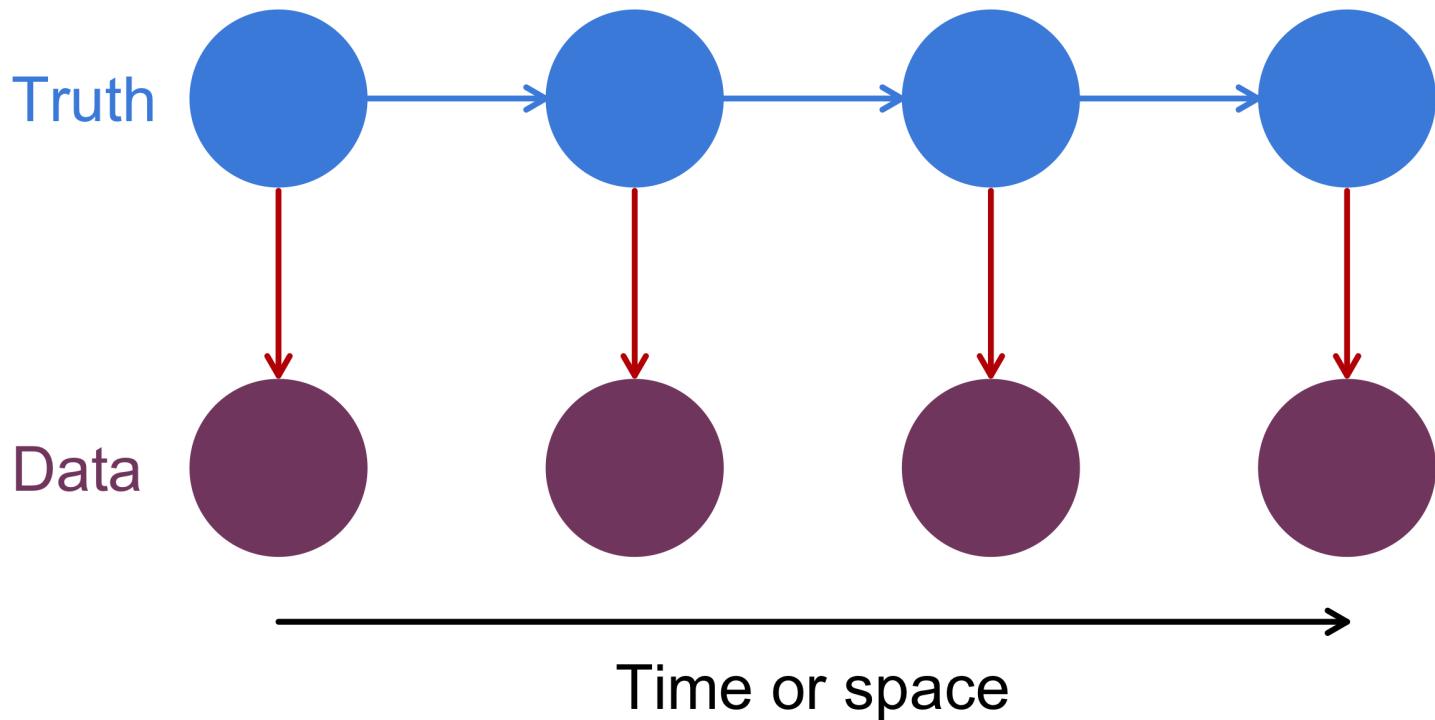
How many mayflies are there?

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

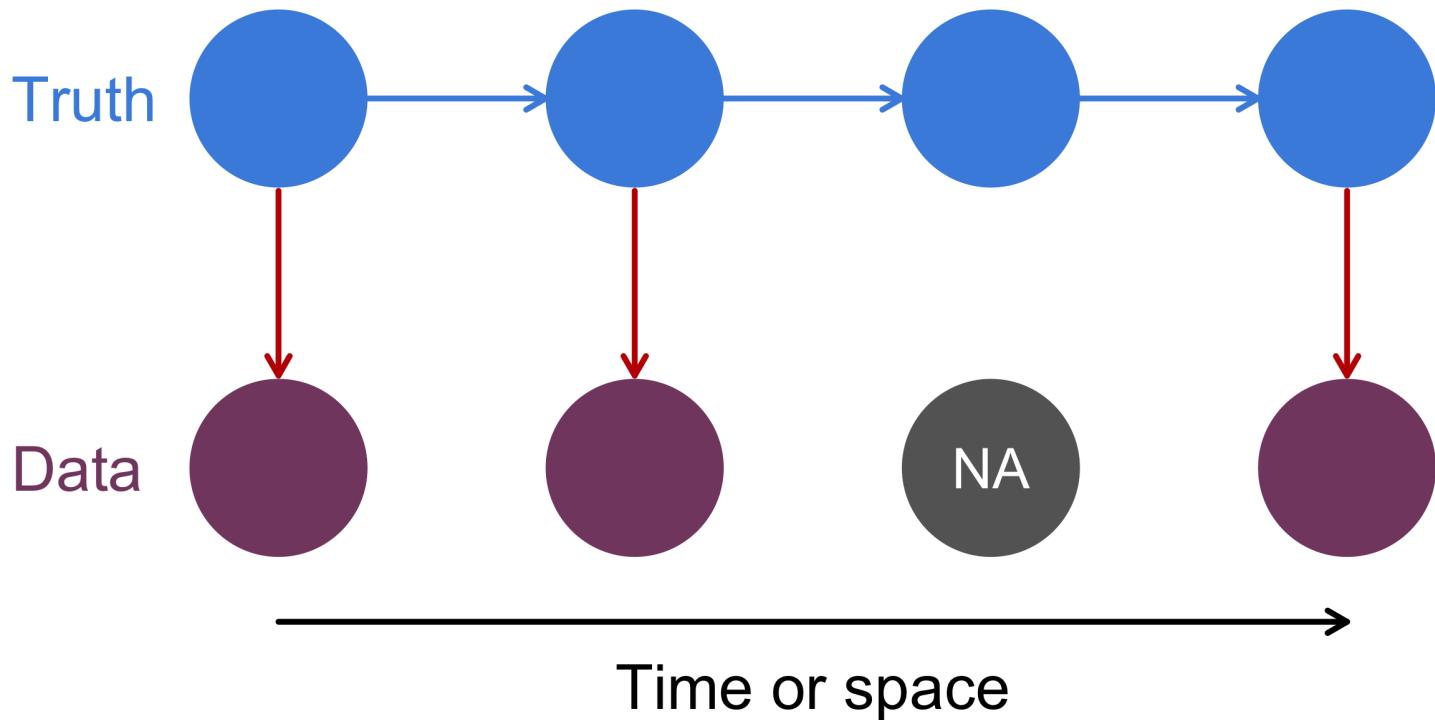
Changes in observers or sensors

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

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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

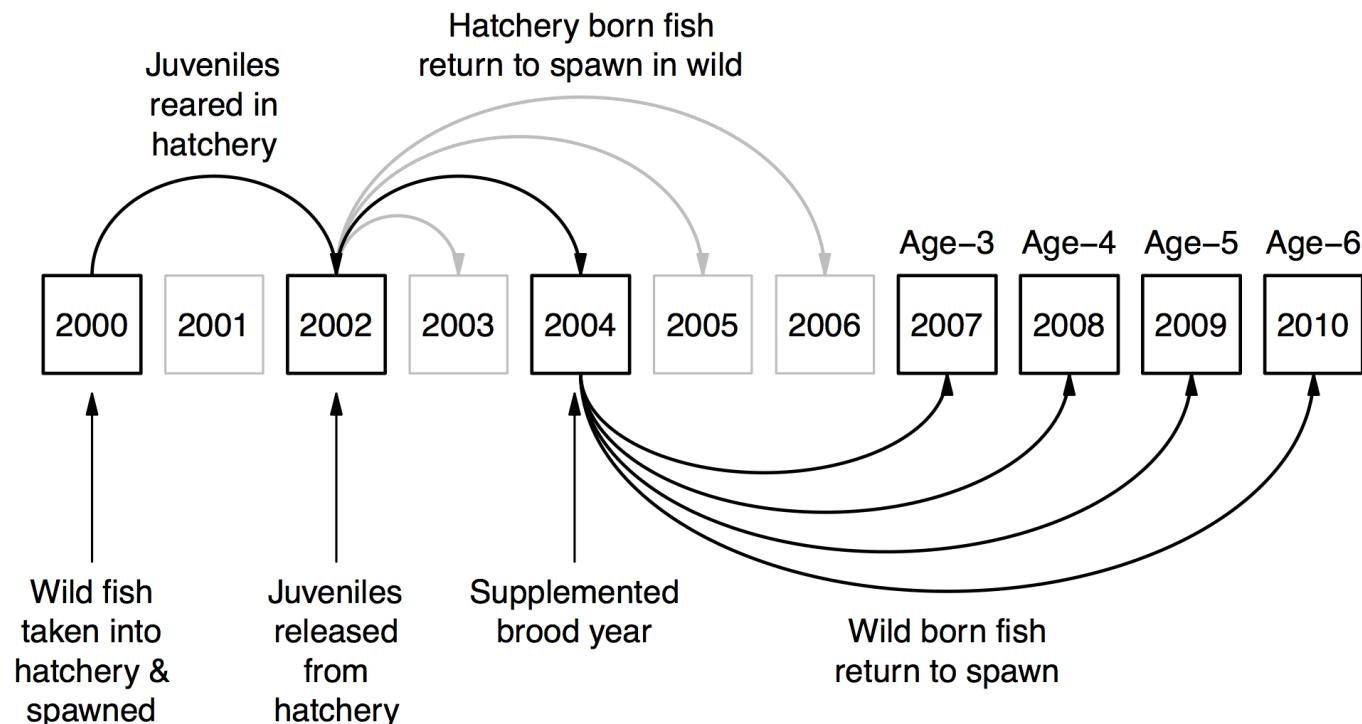
AN EXAMPLE

Conservation of Pacific salmon

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

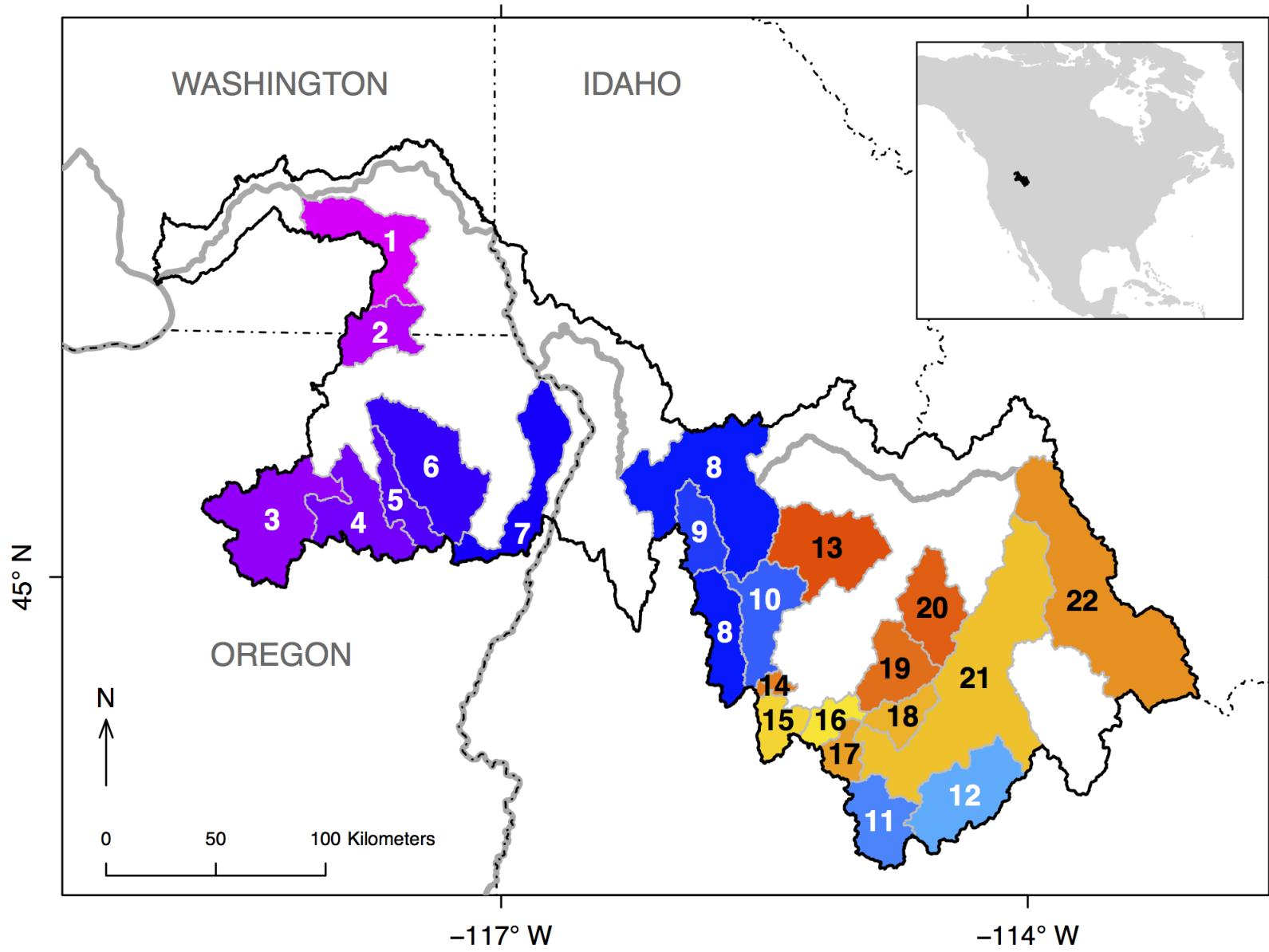
Recovery options for Pacific salmon

One strategy is hatchery supplementation

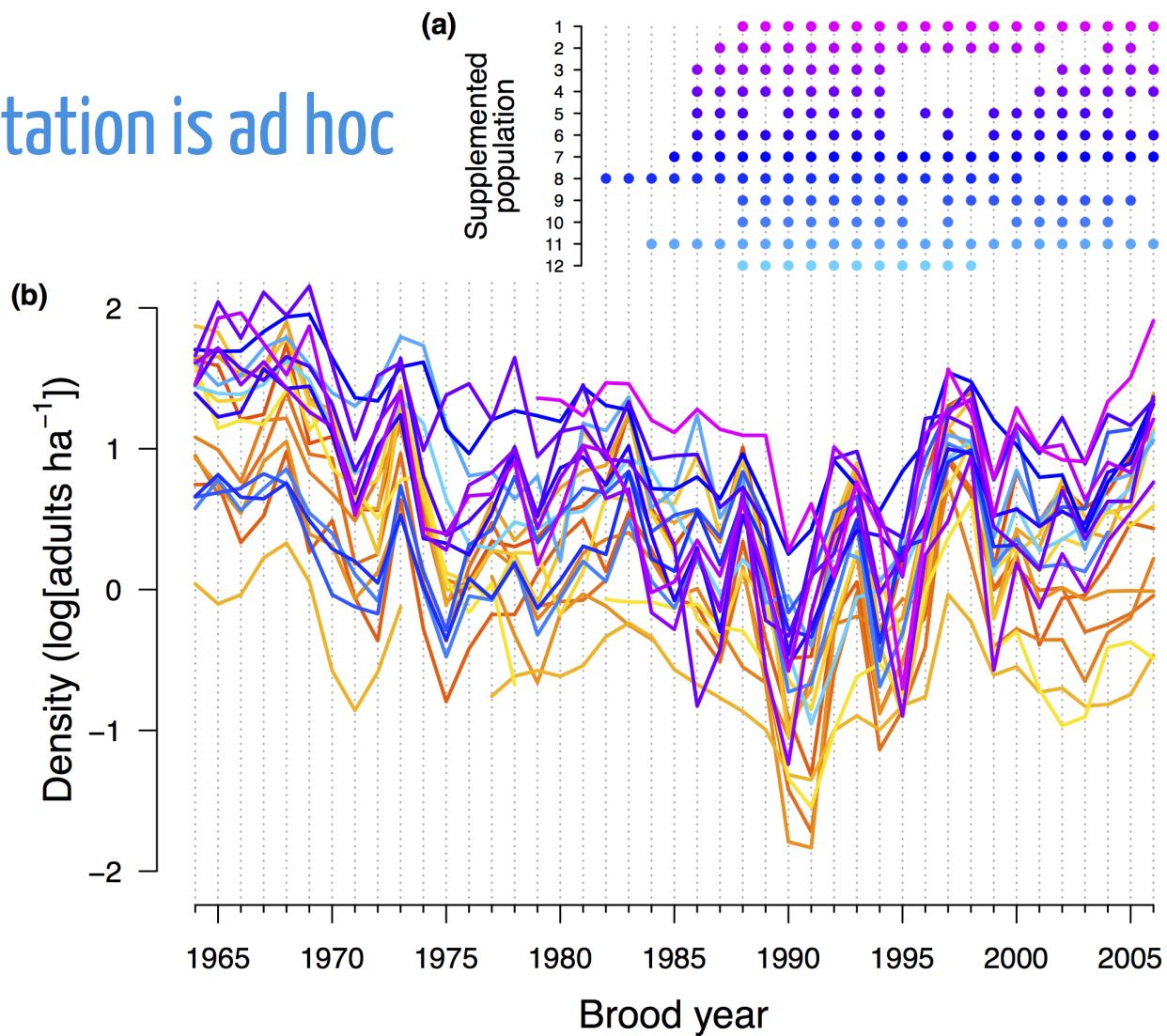


Evaluating conservation interventions

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

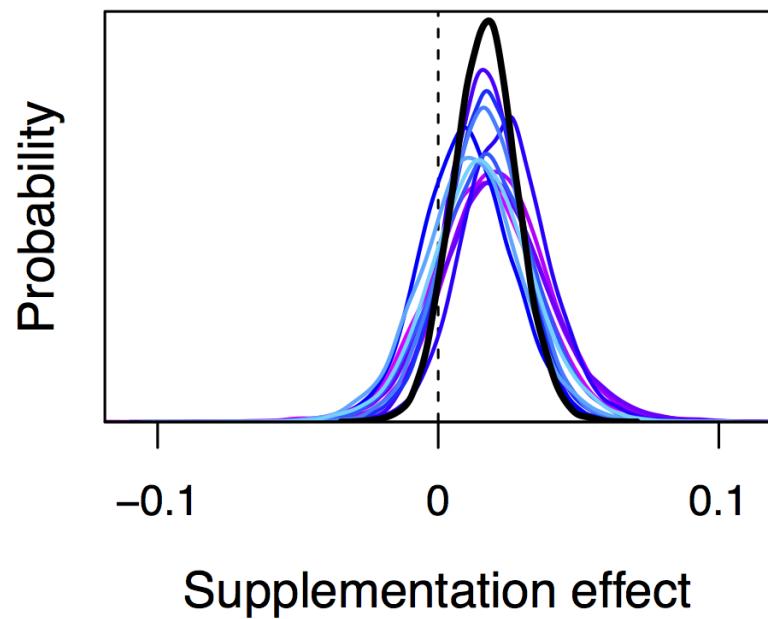


Supplementation is ad hoc



Effect size is rather subtle

Probability of positive effect = 0.73



ANOTHER EXAMPLE

Emergence of high-dimension data

Remote sensing

Citizen science

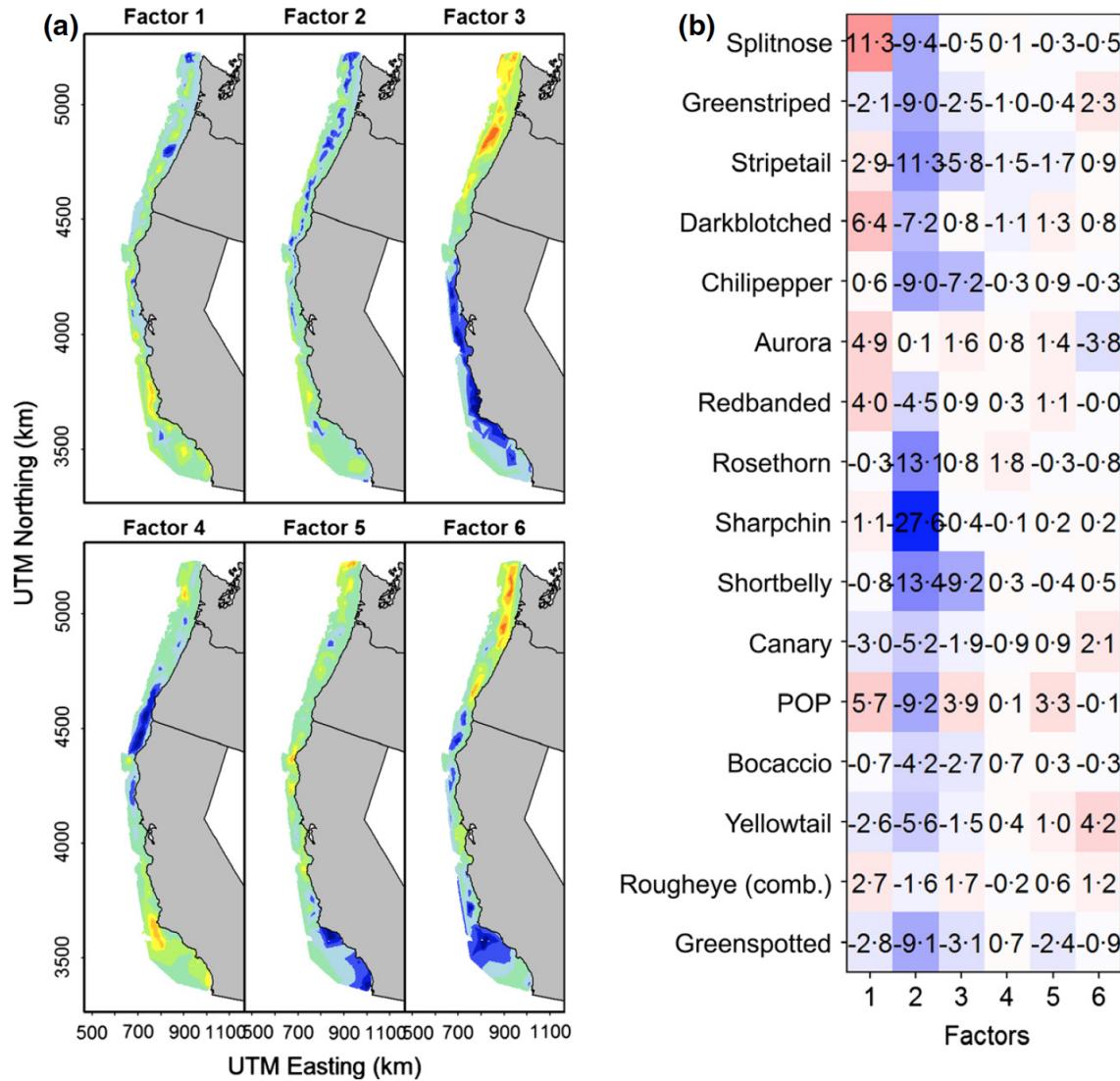
Large-scale surveys

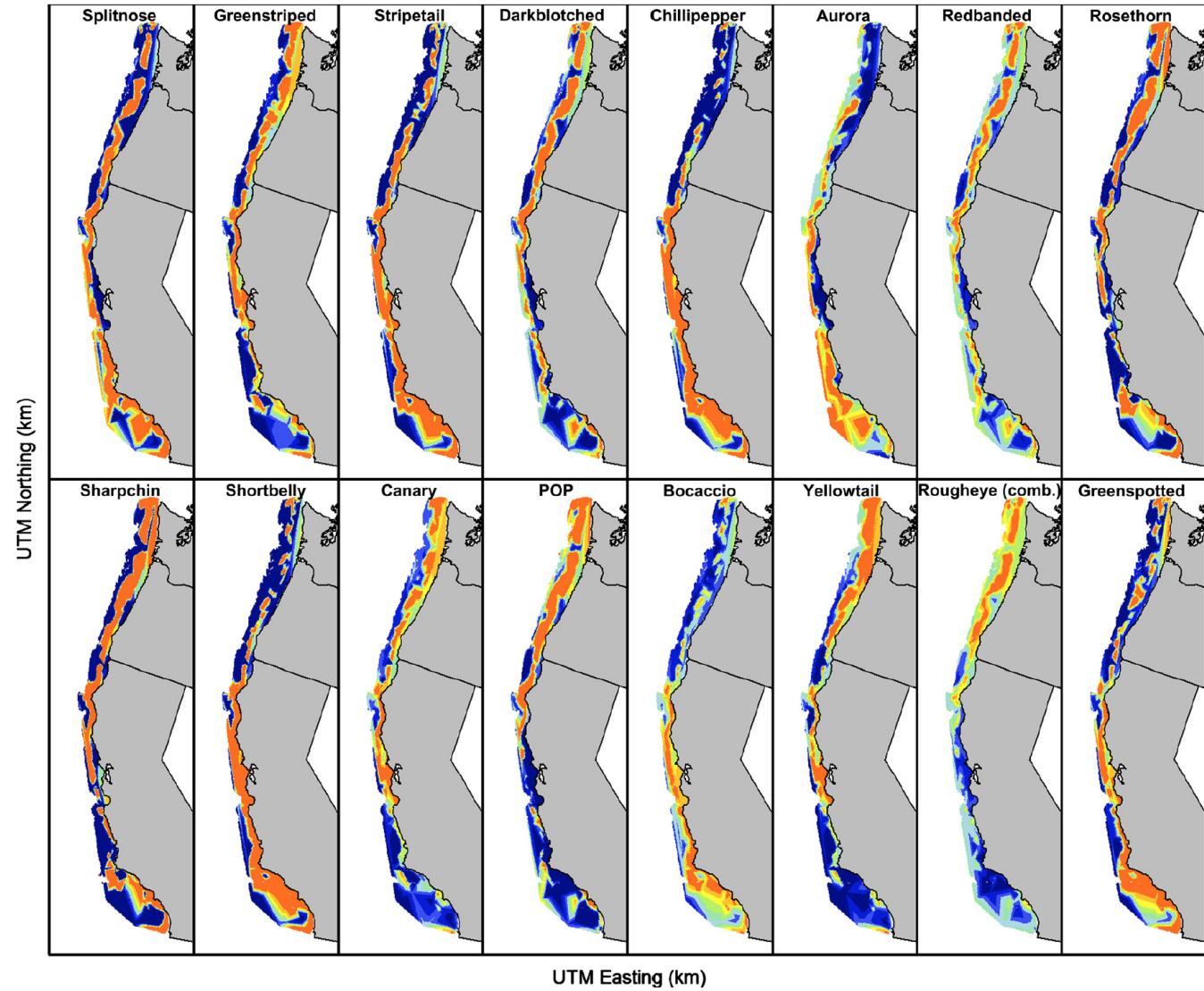
Groundfish surveys along the West Coast

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*