# Analyses of intervention effects

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*FISH 507 – Applied Time Series Analysis*

7 March 2017

# Big question in the finance world

What is the effect of advertising on sales?



Anheuser-Busch
spends $35 million/yr
on Super Bowl ads

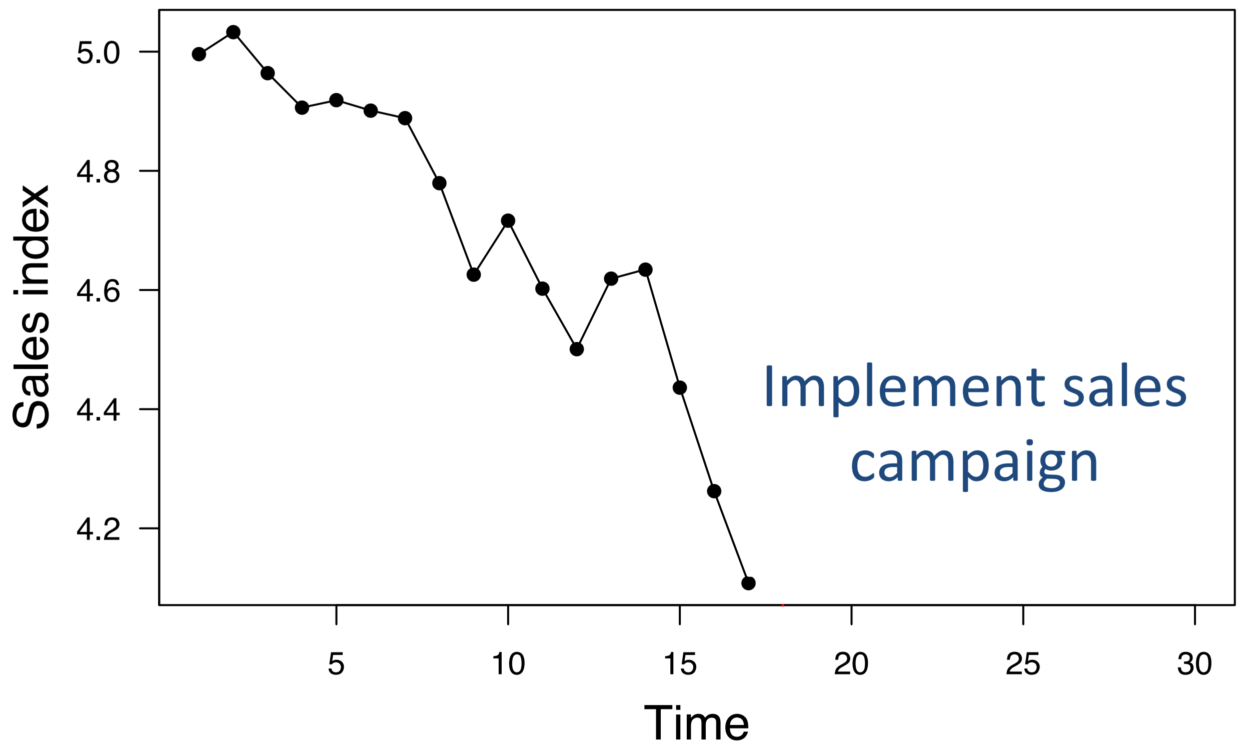
↓

$95 million/yr in revenue
(170% return!)

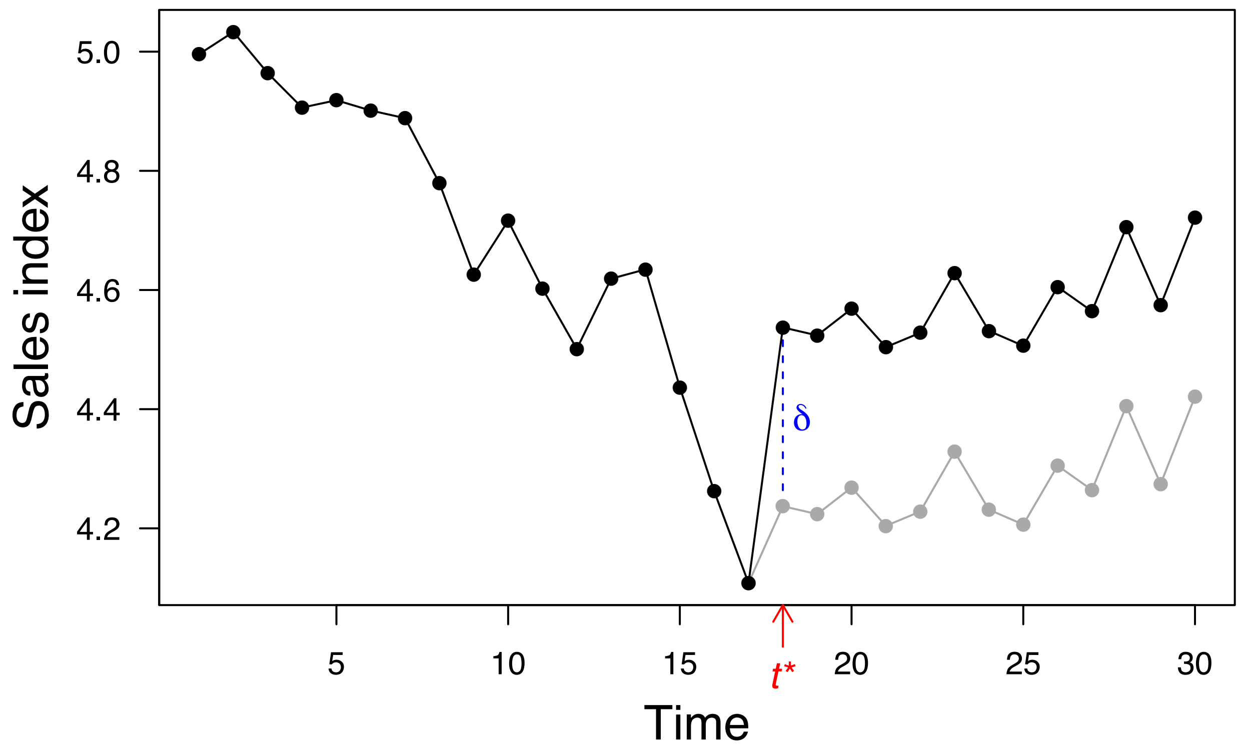
How do they know this?

Hartman *et al* (2015)

# An example of sales data



# How much did sales change?



# Model from finance world

*Sales*

State equation

$$x_t = x_{t-1} + \delta I_{t-h} + w_t \qquad w_t \sim \mathrm{N}(0,q)$$

*Advertising effect*

*Indicator function*

$$I_{t-h} = \begin{cases} 0 & \text{if } t-h \neq \text{event} \\ 1 & \text{if } t-h = \text{event} \end{cases}$$

Hamilton (1989), West & Harrison (1997)

# Model from finance world

State equation

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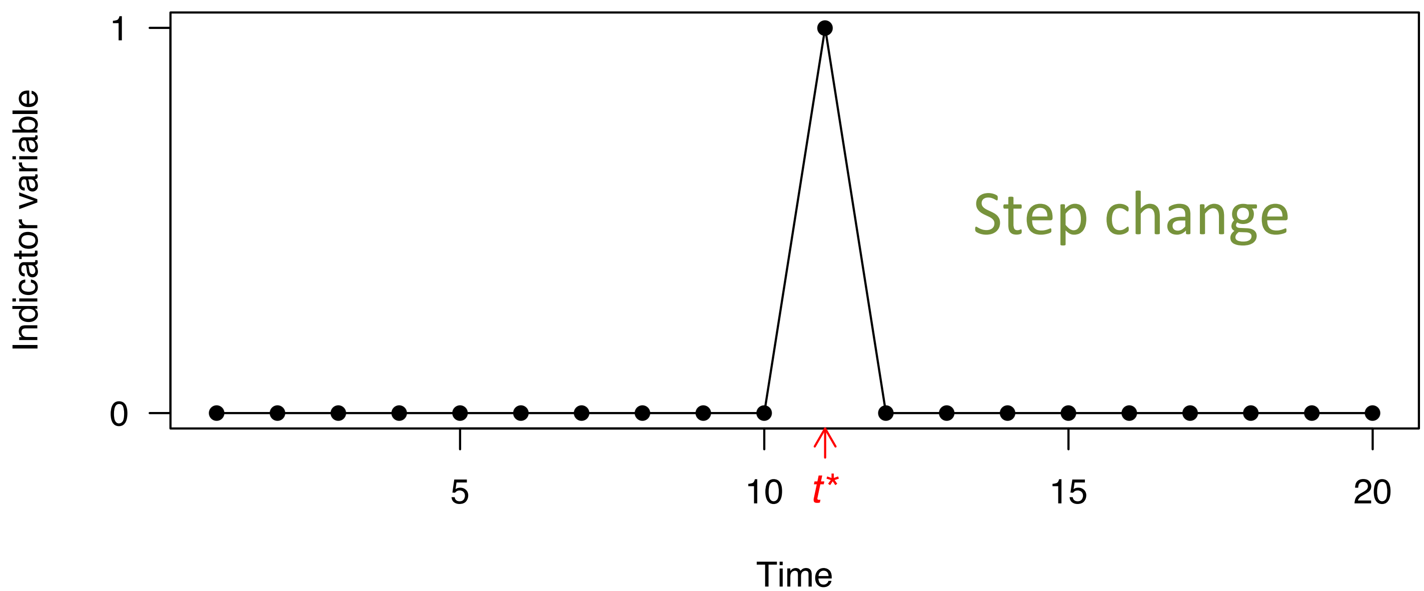

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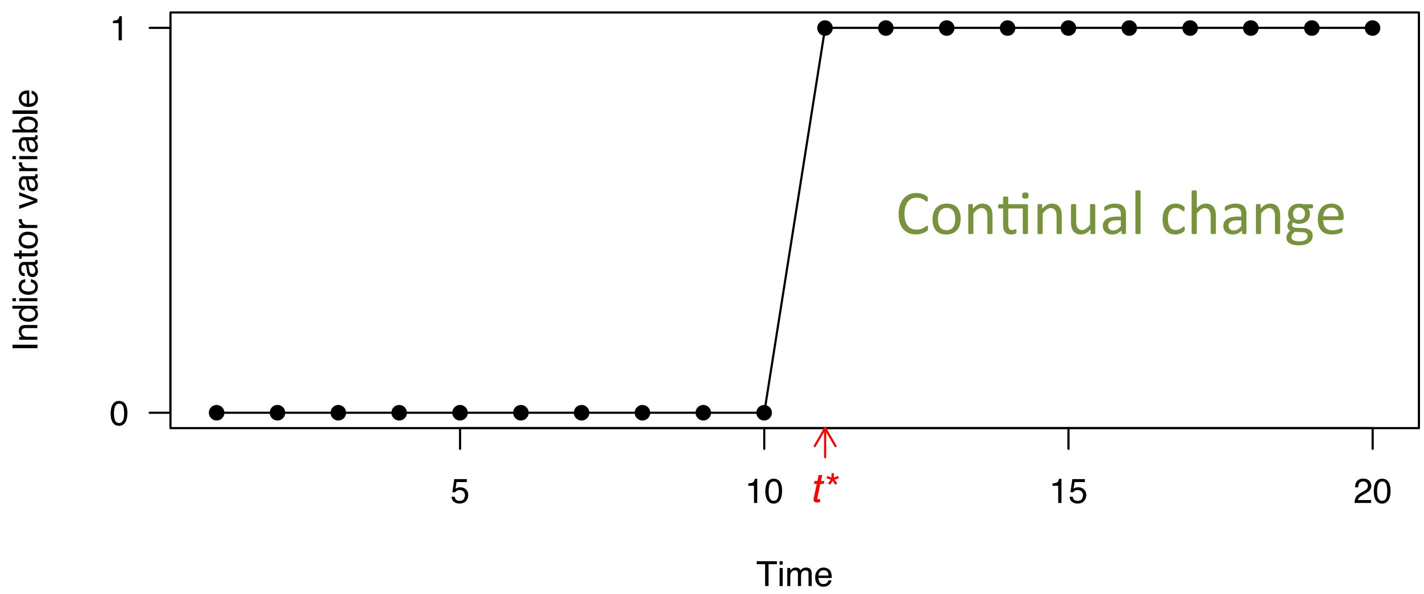

# Model from finance world

*Sales*

State equation

$$x_t = x_{t-1} + \delta E_{t-h} + w_t \qquad w_t \sim \mathrm{N}(0, q)$$

*Advertising effect*

*Advertising expense*

$$E_{t-h} = \begin{cases} 0 & \text{if } t-h \neq \text{event} \\ E_{t-h} & \text{if } t-h = \text{event} \end{cases}$$

Hamilton (1989), West & Harrison (1997)

# Model from finance world

State equation

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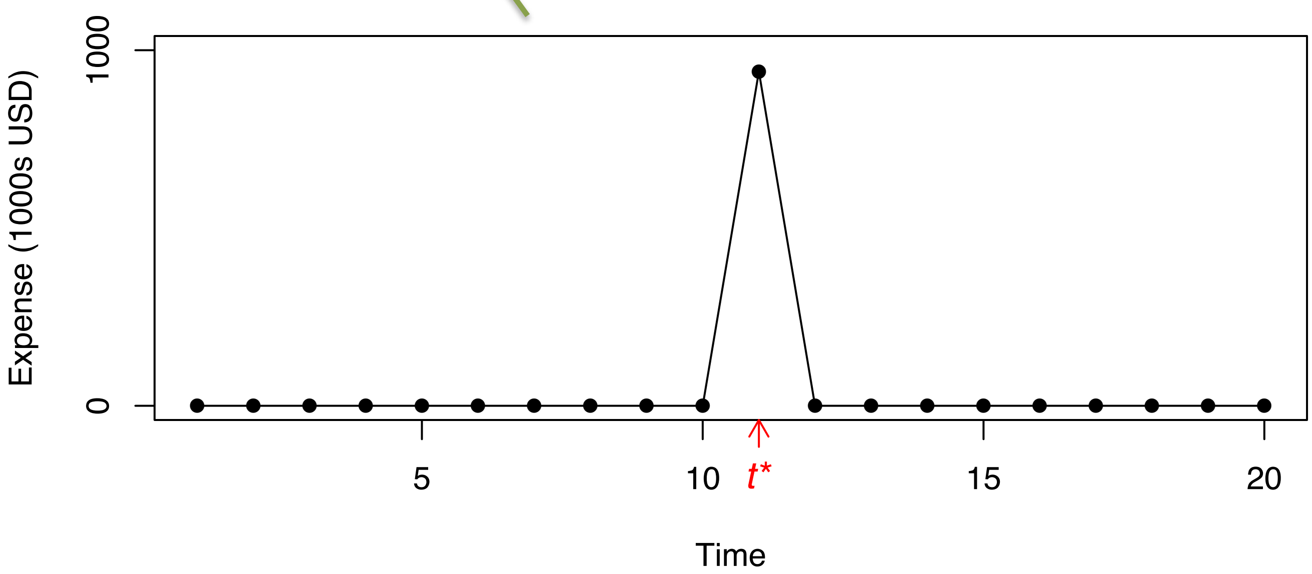
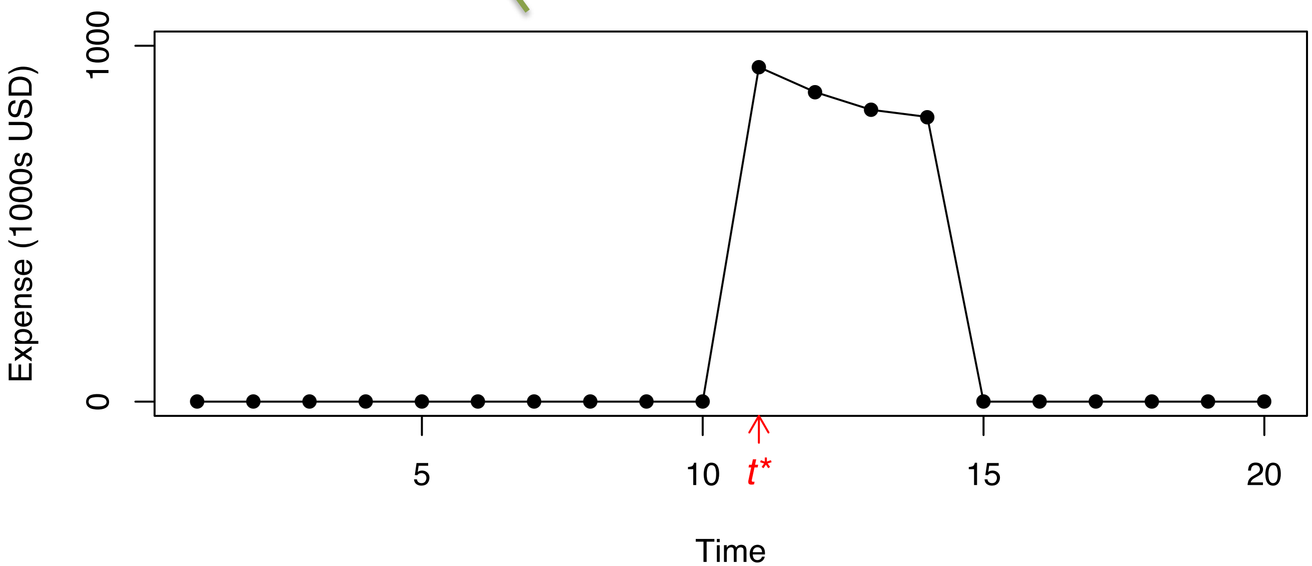


# Model from finance world

## State equation

$$x_t = x_{t-1} + \delta E_{t-h} + w_t \qquad w_t \sim \mathrm{N}(0, q)$$



# Model from finance world

What if the sales data were incomplete
(e.g., they came from a subset of stores)?

# Model from finance world

*True sales*

State equation

$$x_t = x_{t-1} + \delta I_{t-h} + w_t \qquad w_t \sim \mathrm{N}(0,q)$$

*Advertising effect*

*Indicator function*

$$I_{t-h} = \begin{cases} 0 & \text{if } t-h \neq \text{event} \\ 1 & \text{if } t-h = \text{event} \end{cases}$$

Observation equation

$$y_t = x_t + v_t \qquad v_t \sim \mathrm{N}(0,r)$$

*Observed sales*

Hamilton (1989), West & Harrison (1997)

# What about interventions in obs?

- It is entirely possible for their to be a change (intervention) in the observations
- Field ecology (fisheries, ornithology)
- Laboratory (microscopy, genetics, chemistry)

# Model for change in observation

State equation

$$x_t = x_{t-1} + w_t \qquad w_{i,t} \sim \mathrm{N}(0, q_i)$$

Observation equation

$$y_t = x_t + \delta I_{t-h} + v_t \qquad v_t \sim \mathrm{N}(0, r)$$

*Intervention effect*

*Indicator function*

# Model for change in observation

Observation equation

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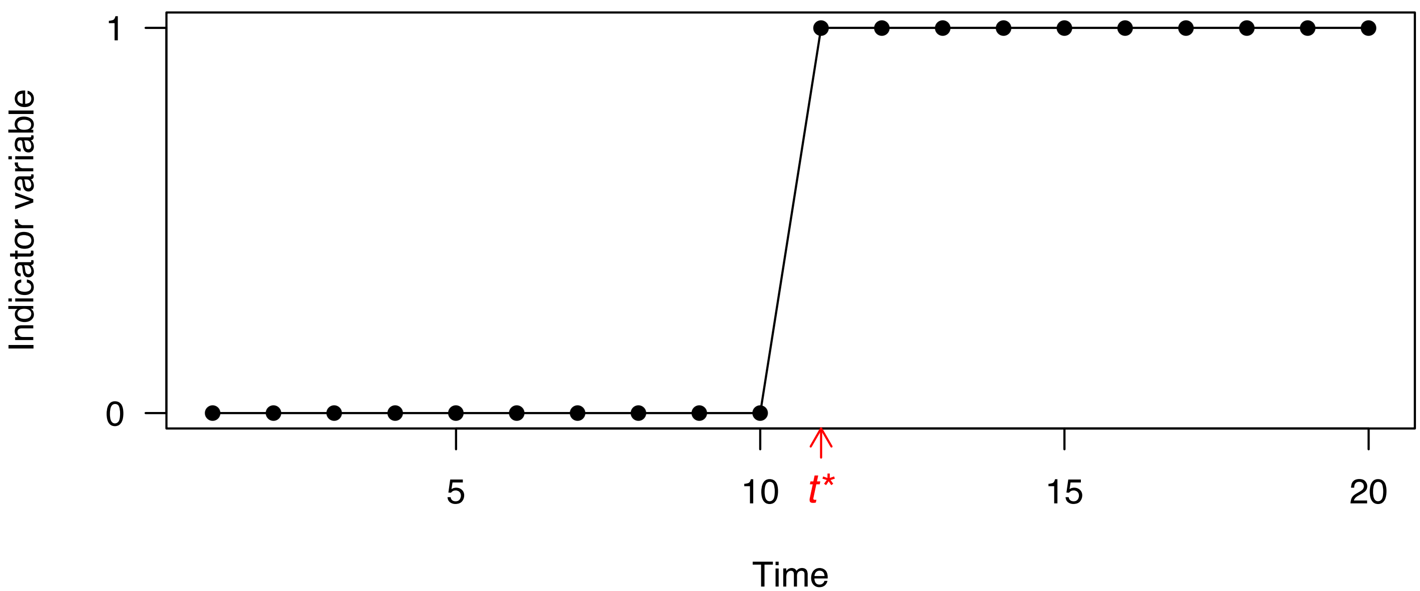

# Model for change in observation

State equation

$$x_t = x_{t-1} + w_t \qquad w_{i,t} \sim \mathrm{N}(0, q_i)$$

Observation equation

$$y_t = x_t + Dd_{t-h} + v_t \qquad v_t \sim \mathrm{N}(0, r)$$

*Effect on observation*

*Covariate (obsID, daylight)*

Ecology and Evolution

Open Access

# Analyzing large-scale conservation interventions with Bayesian hierarchical models: a case study of supplementing threatened Pacific salmon

Mark D. Scheuerell[1], Eric R. Buhle[1], Brice X. Semmens[2], Michael J. Ford[3], Tom Cooney[3] & Richard W. Carmichael[4]

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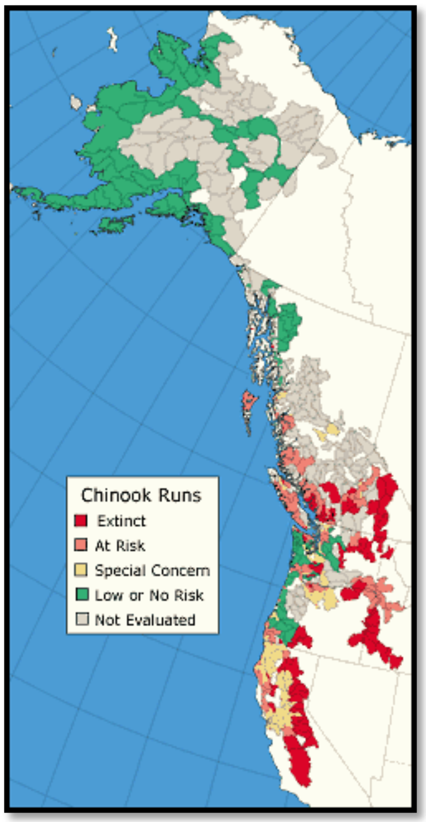
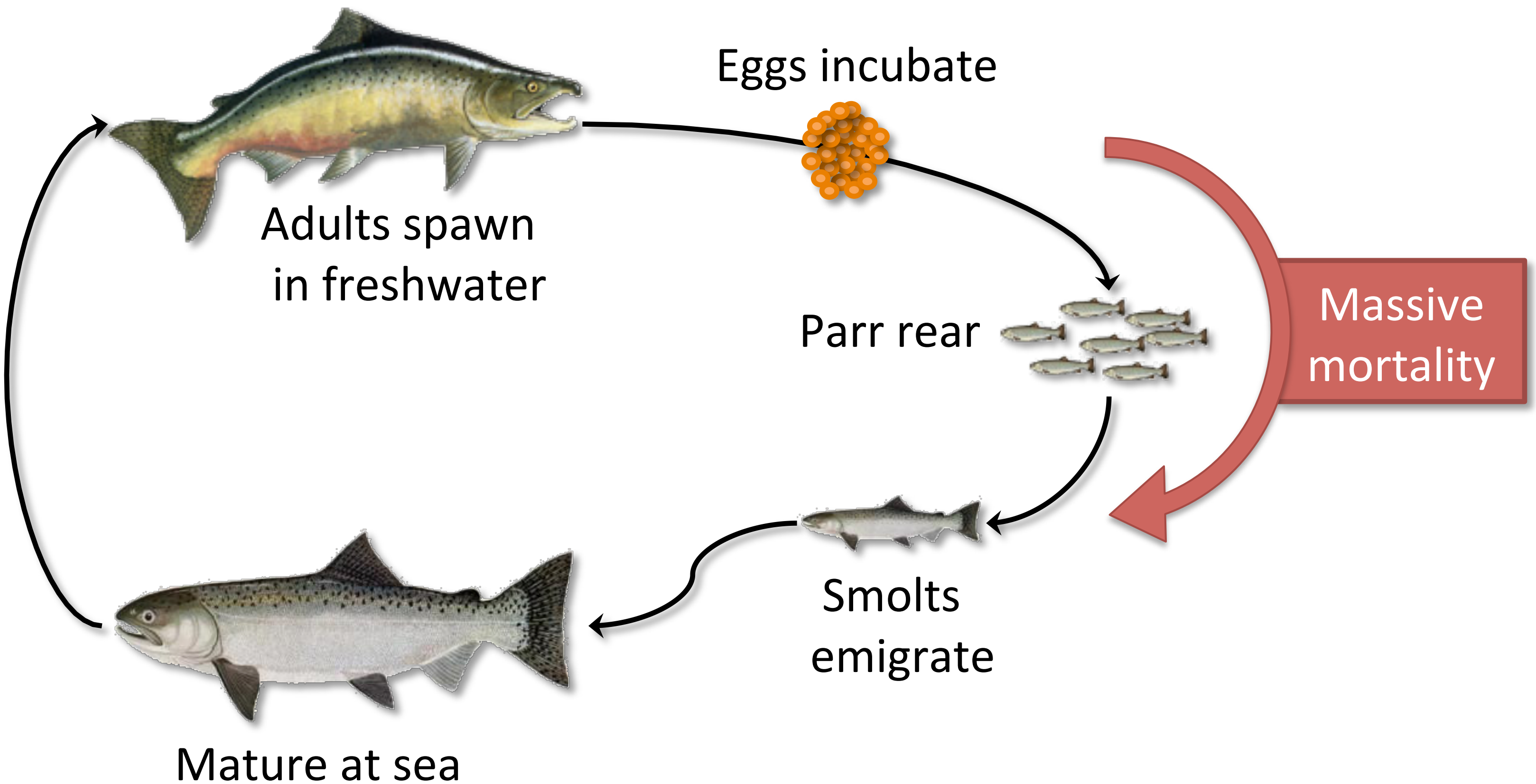
# The salmon story



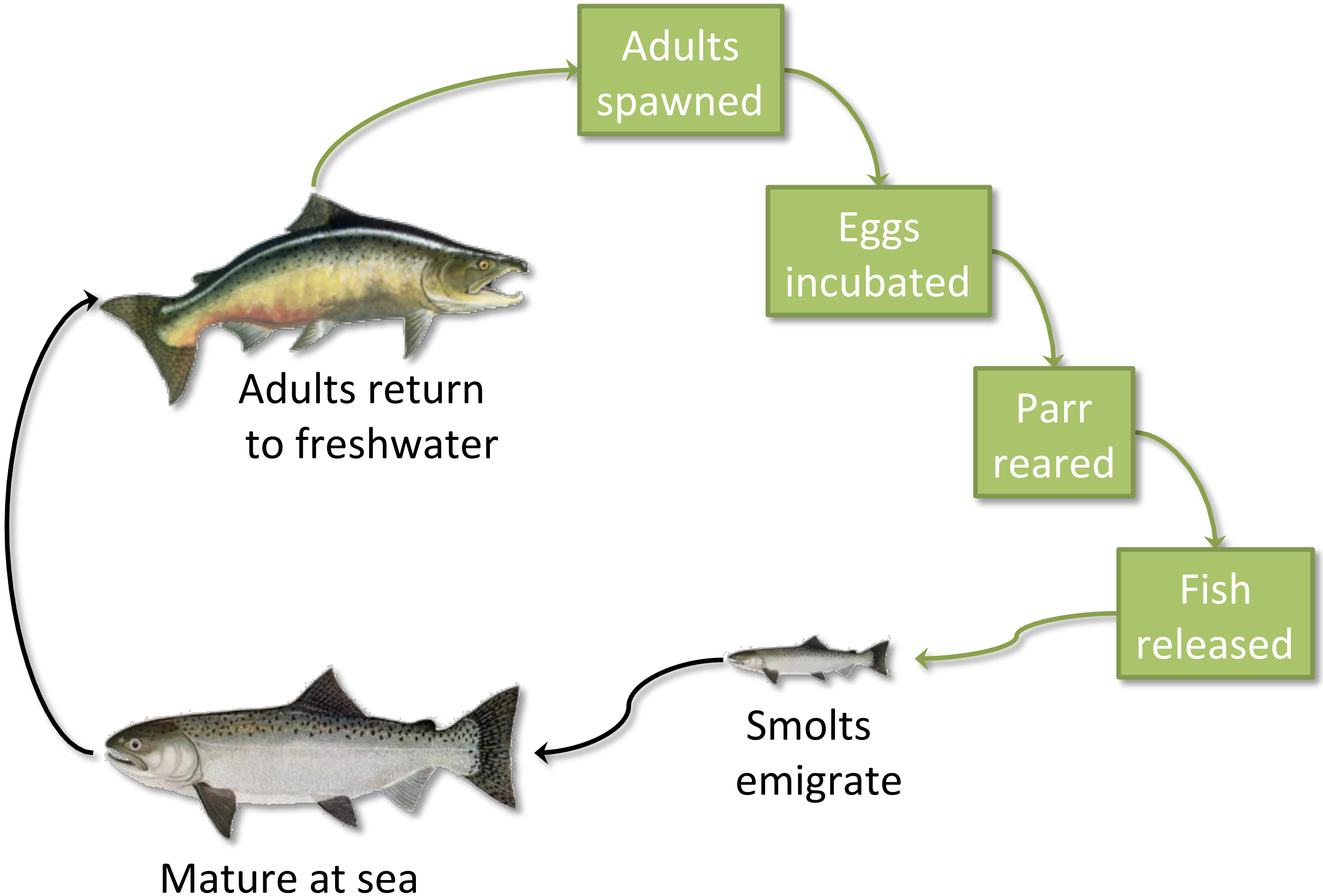

*Source*: State of the Salmon

- Major declines in populations across the continental U.S. & southern Canada
- Evolutionary Significant Units (ESUs) form basis for conservation & management
- 28/52 ESUs listed as *threatened* or *endangered* under U.S. Endangered Species Act
- Human (eg, dams, harvest) & natural (climate) causes have contributed to declines
- Big money business ($4 billion per decade)

# Recall the salmon life cycle



# “Conservation” hatcheries



# Adverse effects of hatcheries

Growing evidence that hatchery fish have reduced fitness & adverse demographic effects

(eg, Araki et al. 2007, Buhle et al. 2009, Christie et al. 2014)


# The big picture

Issue

Despite decades of hatchery supplementation, no formal assessment exists at the ESU level.

Question

What is the effect of supplementation on Snake River spring/summer Chinook salmon at

1) population level, and
2) broader ESU scale?

# Definition of “supplemented”

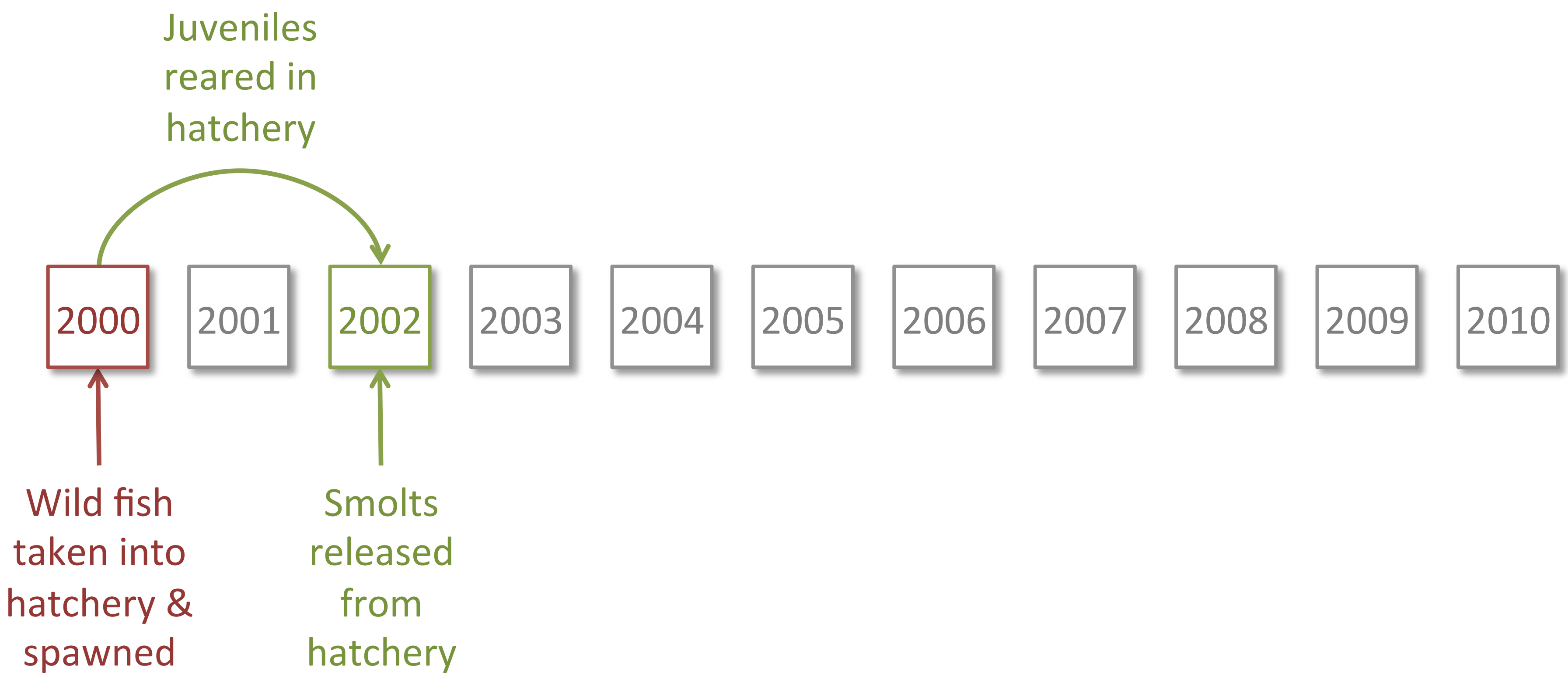
| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |

# Definition of “supplemented”

2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010

Wild fish
taken into
hatchery &
spawned

# Definition of “supplemented”



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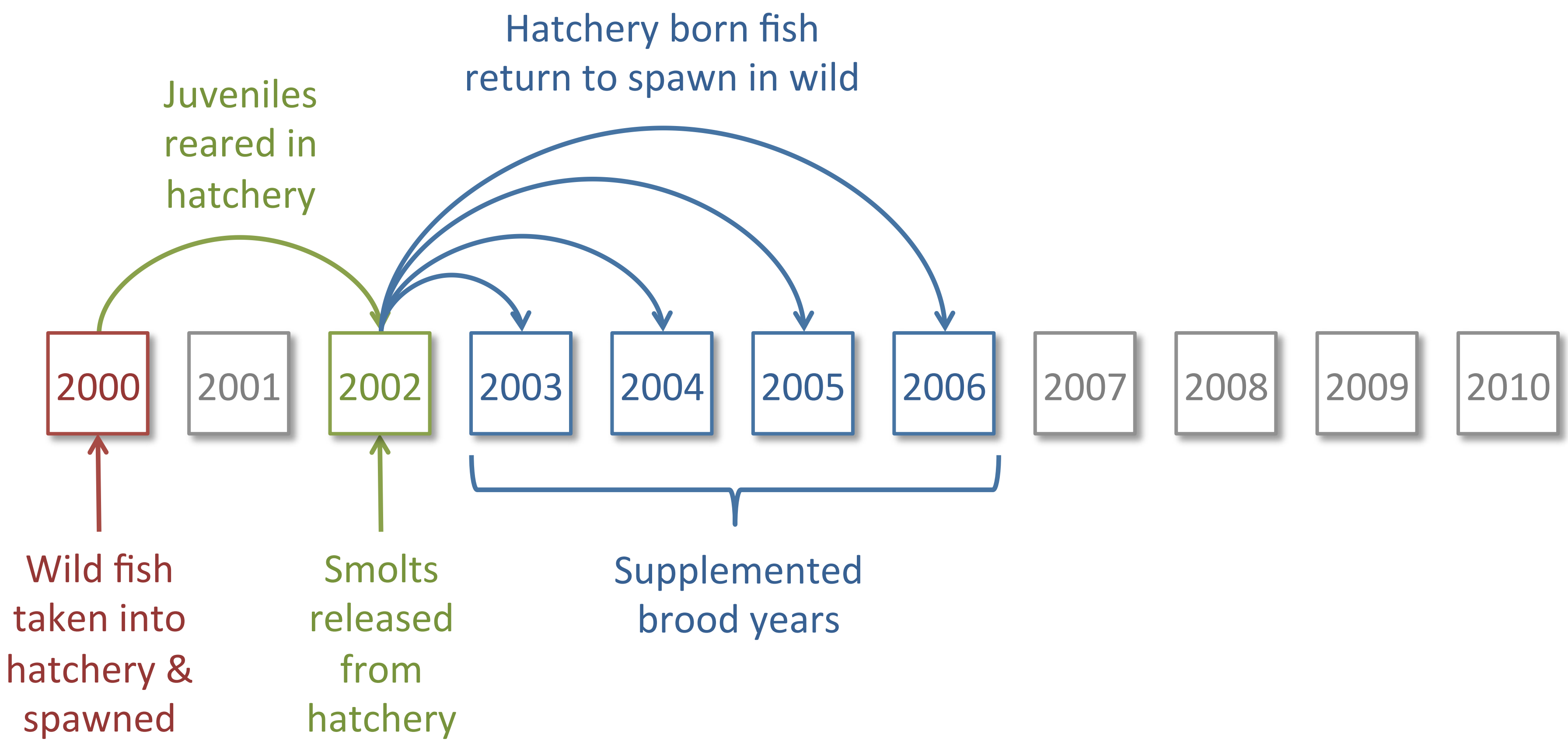

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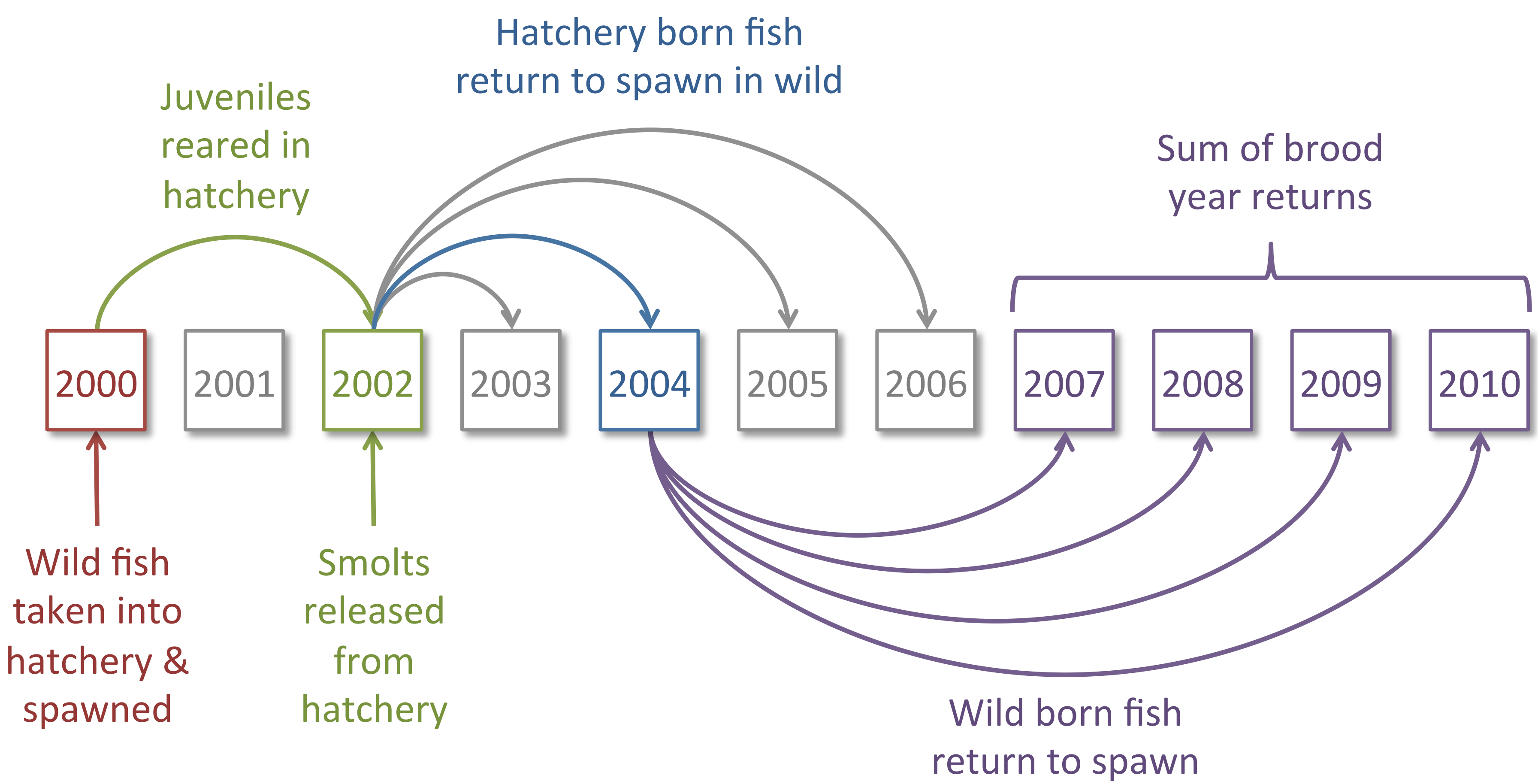
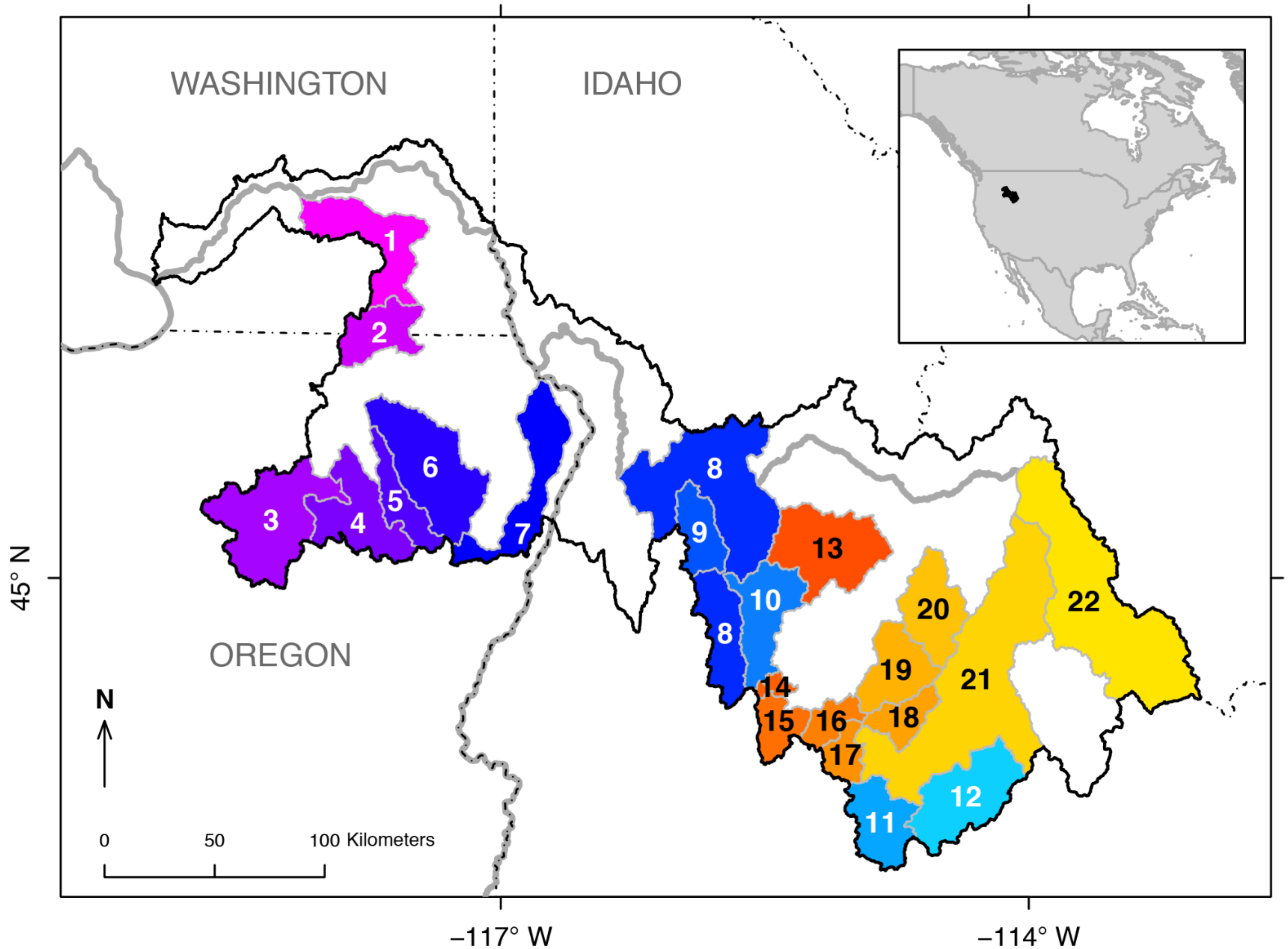
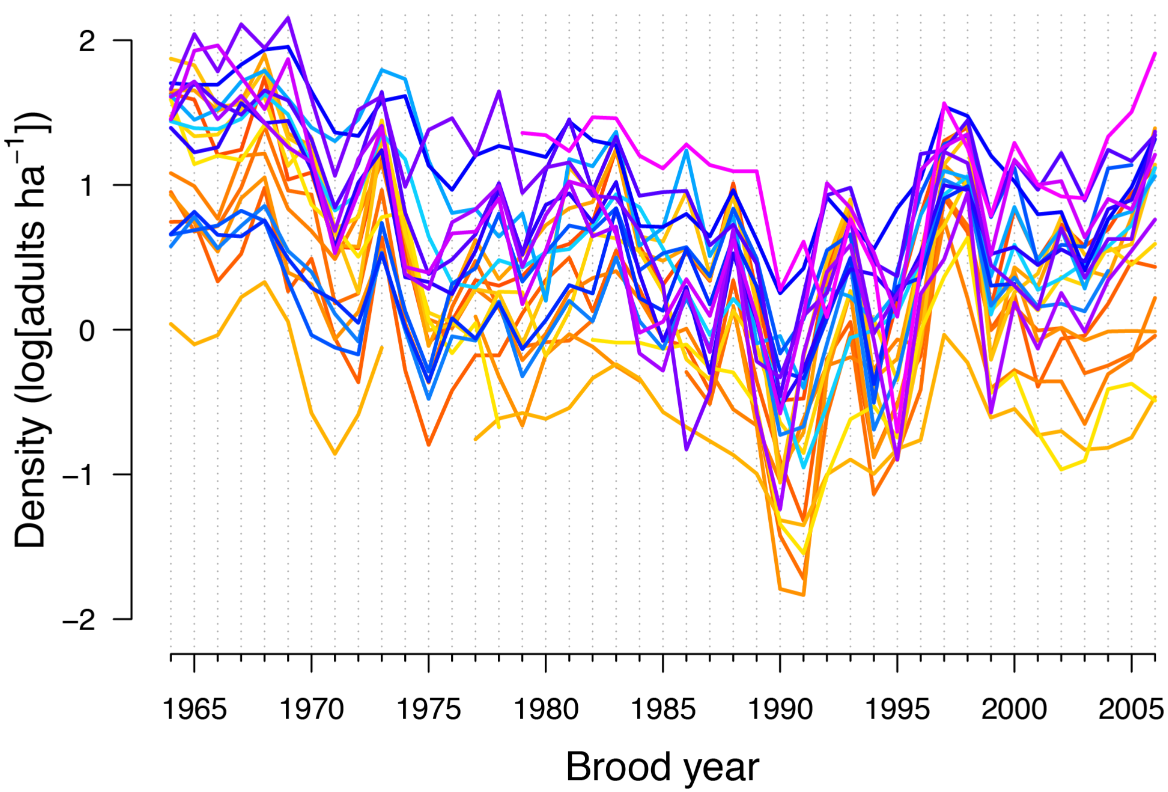
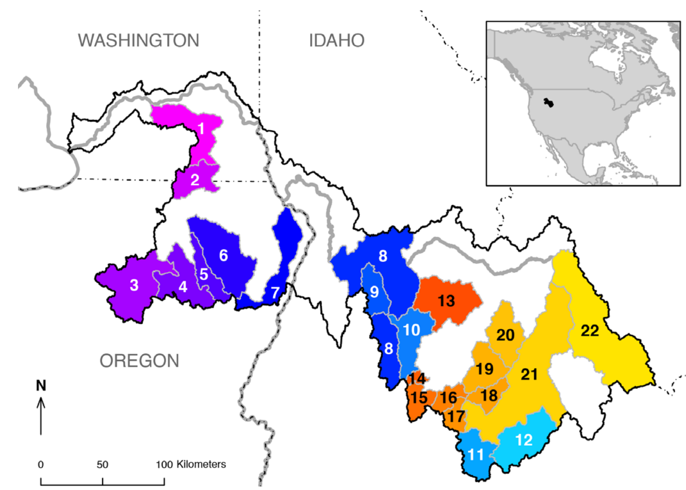


# Map of study region

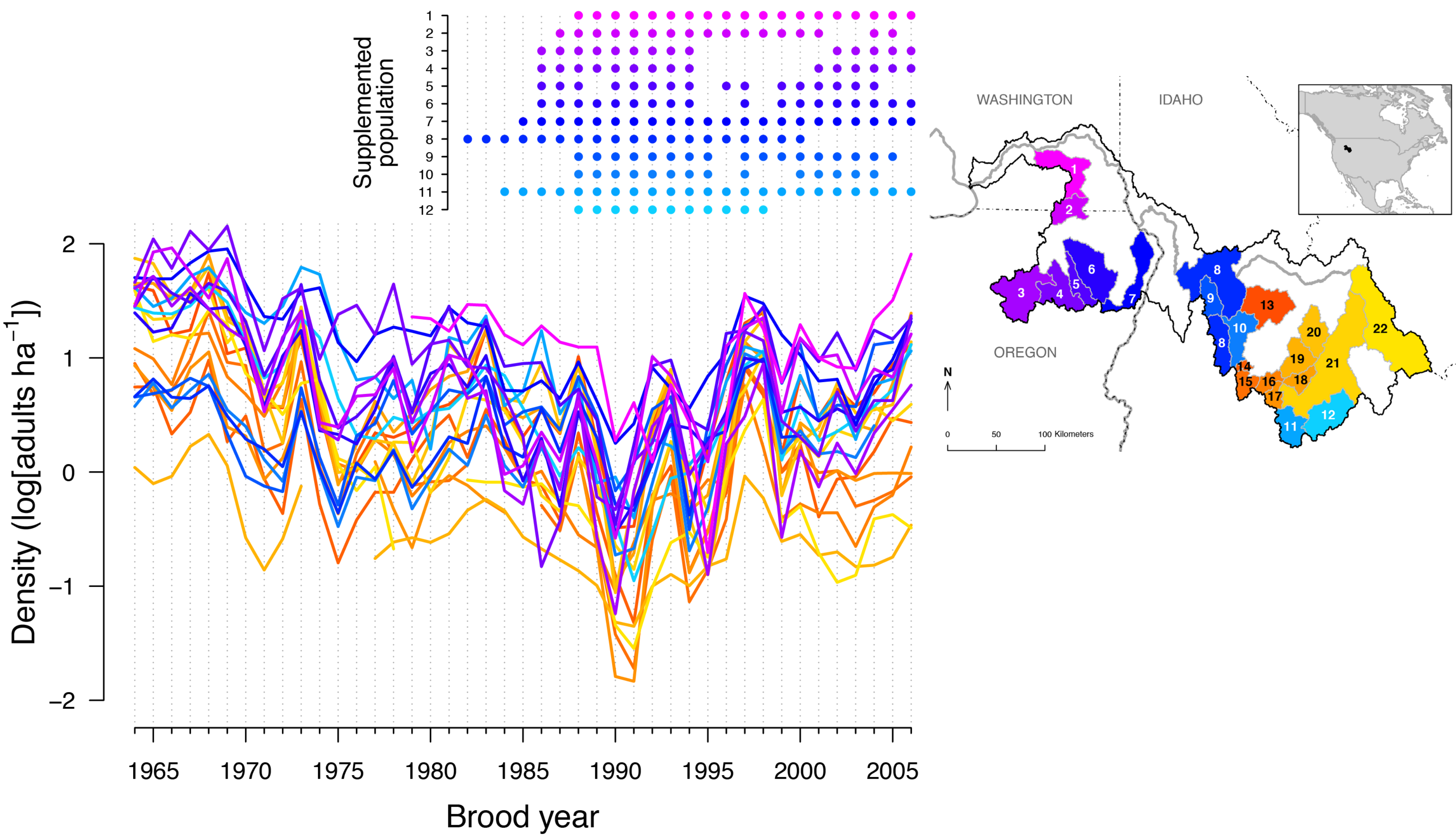


# Time series of spawner density



# Time series of supplementation



# Model for supplementation


Wordcloud from Axess Multimedia

# Model for supplementation

*True density*

State equation

$$x_{i,t} = x_{i,t-1} + \alpha_t + \delta_i I_{i,t-h} + w_{i,t} \qquad w_{i,t} \sim \mathrm{N}(0, q_i)$$

*Common year effect*

# Model for supplementation

*True density*

State equation

$$x_{i,t} = x_{i,t-1} + \alpha_t + \delta_i I_{i,t-h} + w_{i,t} \qquad w_{i,t} \sim \mathrm{N}(0, q_i)$$

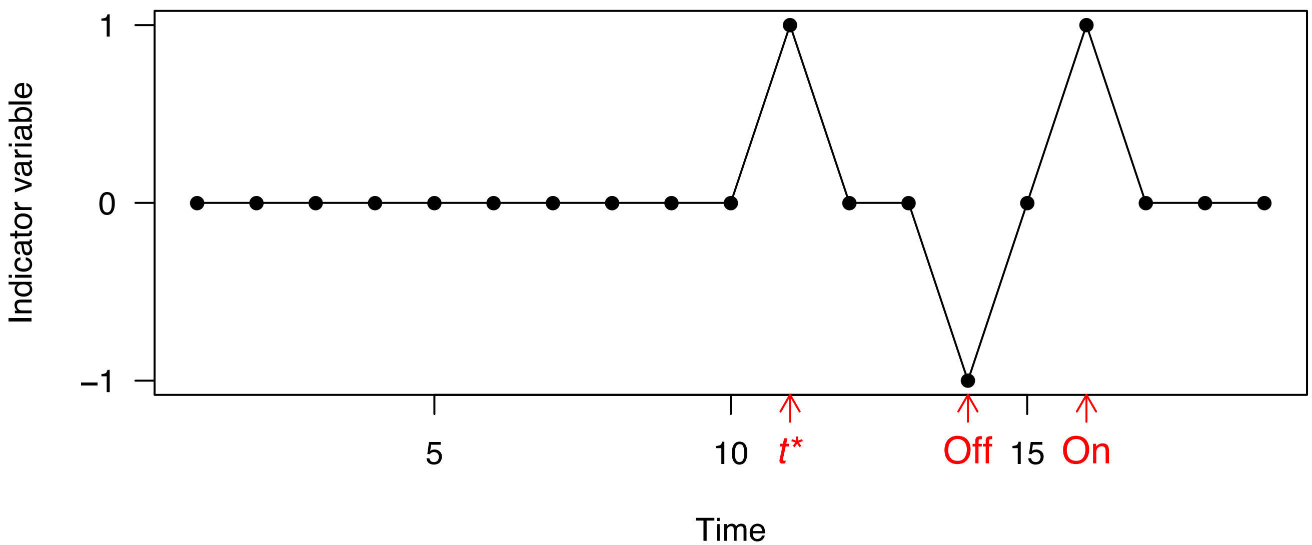
*Supplementation effect*

*Indicator function*

# Model for supplementation

State equation

$$x_{i,t} = x_{i,t-1} + \alpha_t + \delta_i I_{i,t-h} + w_{i,t} \qquad w_{i,t} \sim \mathrm{N}(0, q_i)$$



# Model for supplementation

*True density*

<u>State equation</u>

$$x_{i,t} = x_{i,t-1} + \alpha_t + \delta_i I_{i,t-h} + w_{i,t} \qquad w_{i,t} \sim \mathrm{N}(0, q_i)$$

*Supplementation effect*

*Indicator function*

<u>Observation equation</u>

$$y_t = x_t + v_t \qquad v_t \sim \mathrm{N}(0, r)$$

*Observed density*

# Versions of our models

Year effect

- Markov
- Random

Supplementation effect

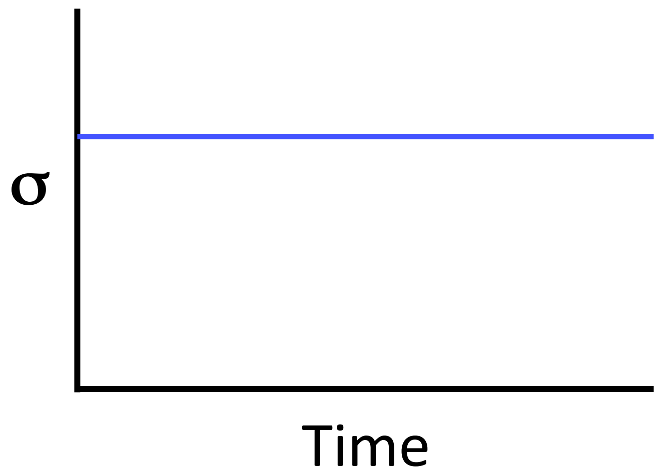
- Fixed
- Random

✓ Also allowed for supplementation effect on process and/or observation variance

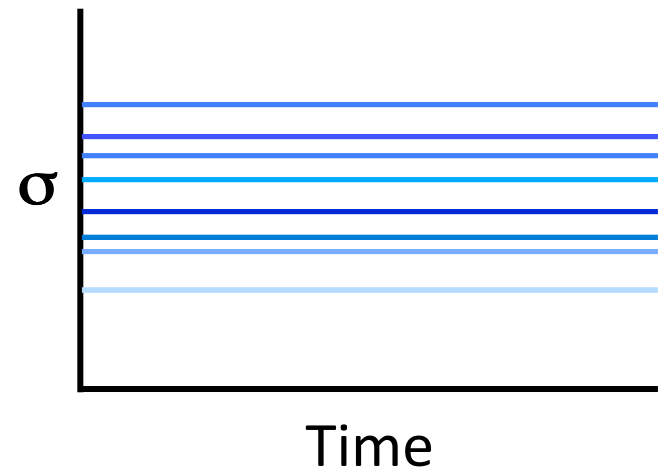
# Variance-covariance structure

*For both process and observation errors*

All popns share variance



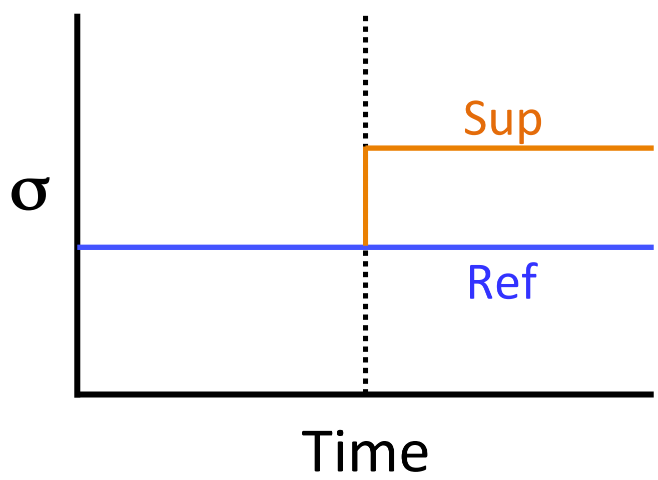

Independent variance



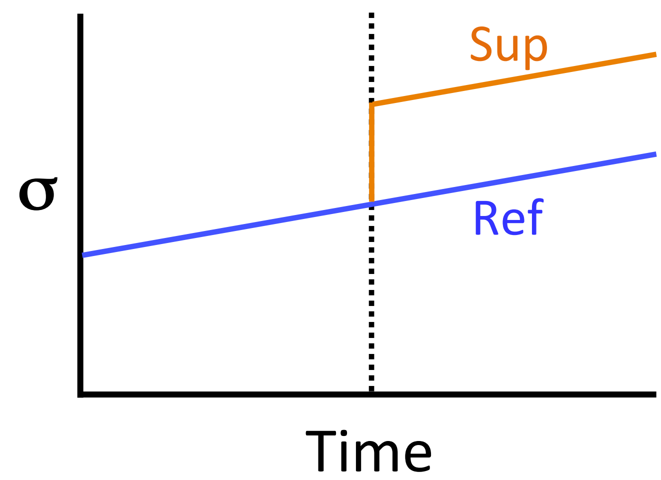
# Variance-covariance structure

*For process errors only*

Intervention only




Trend + intervention



# Our “best” model structure

Year effect

Markov Random

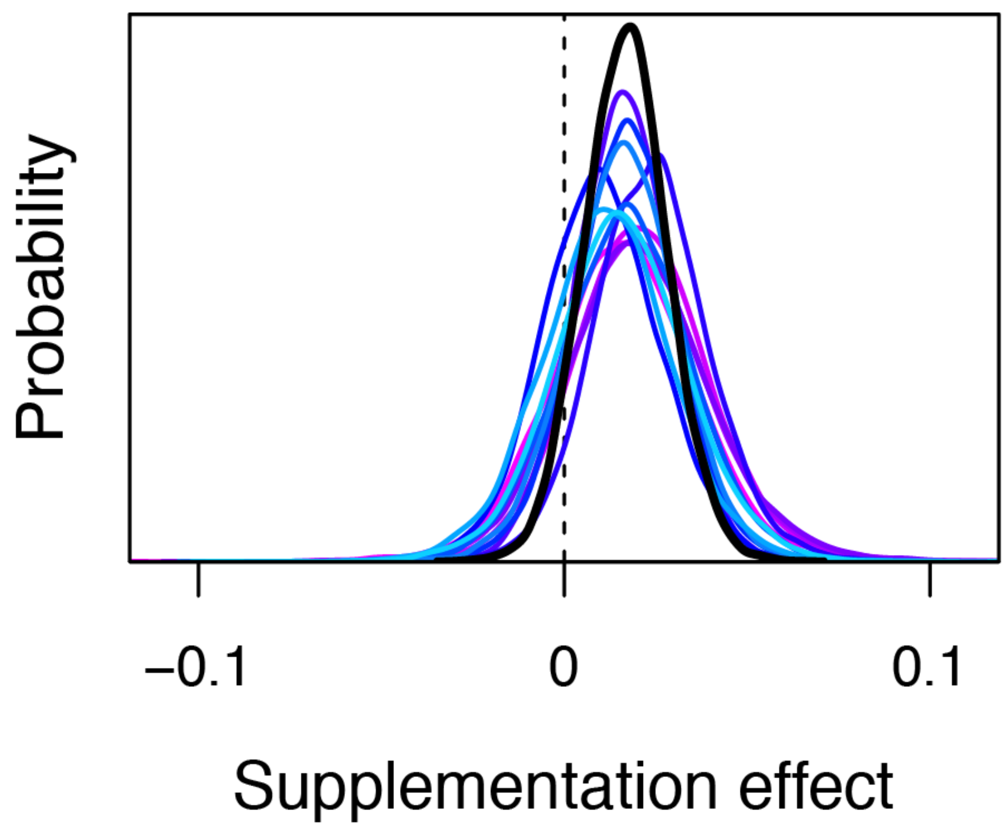
Supplementation effect

Fixed Random

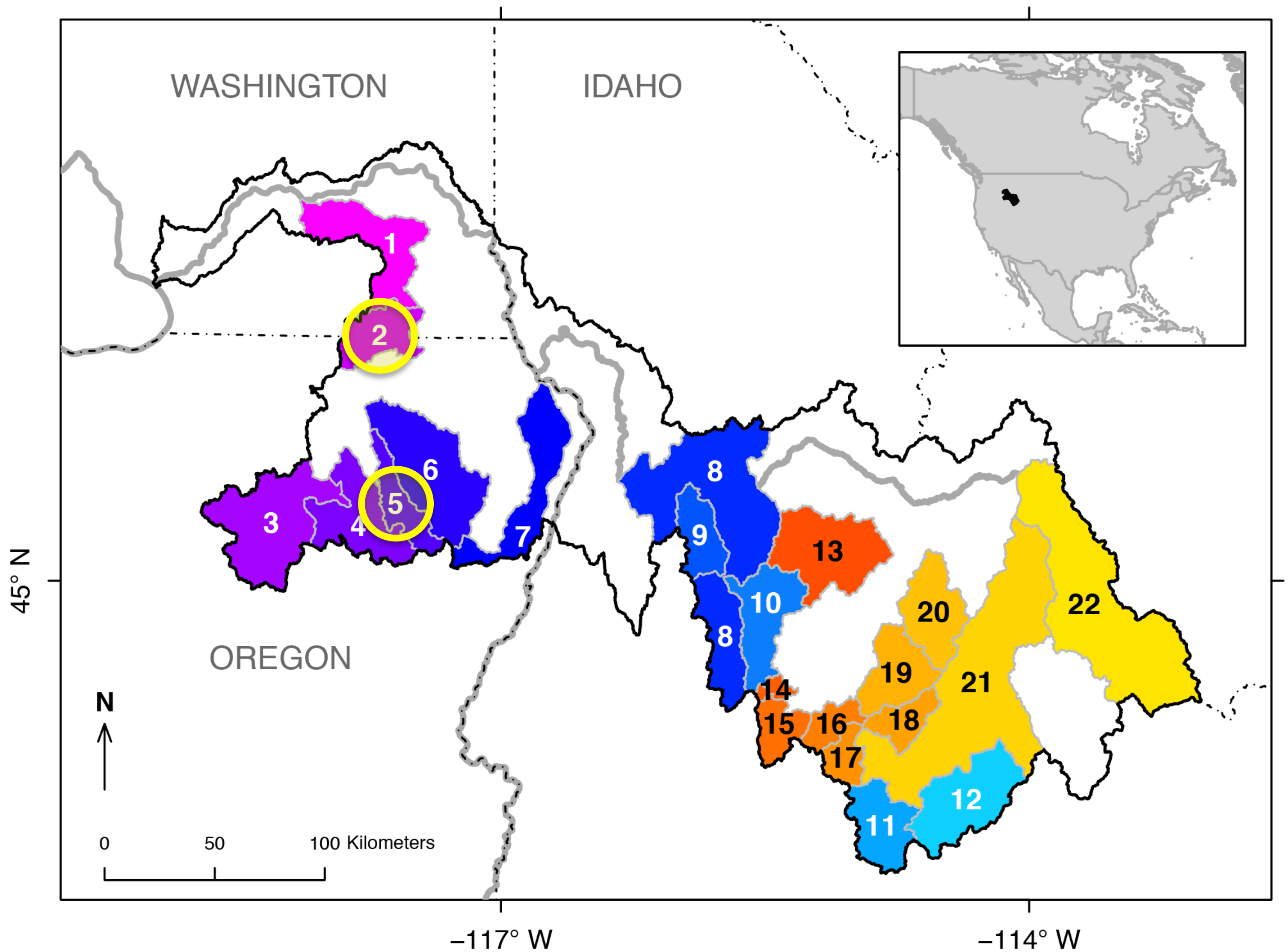
**No supplementation effect on process or obs. variance*

# Distribution of intervention sizes

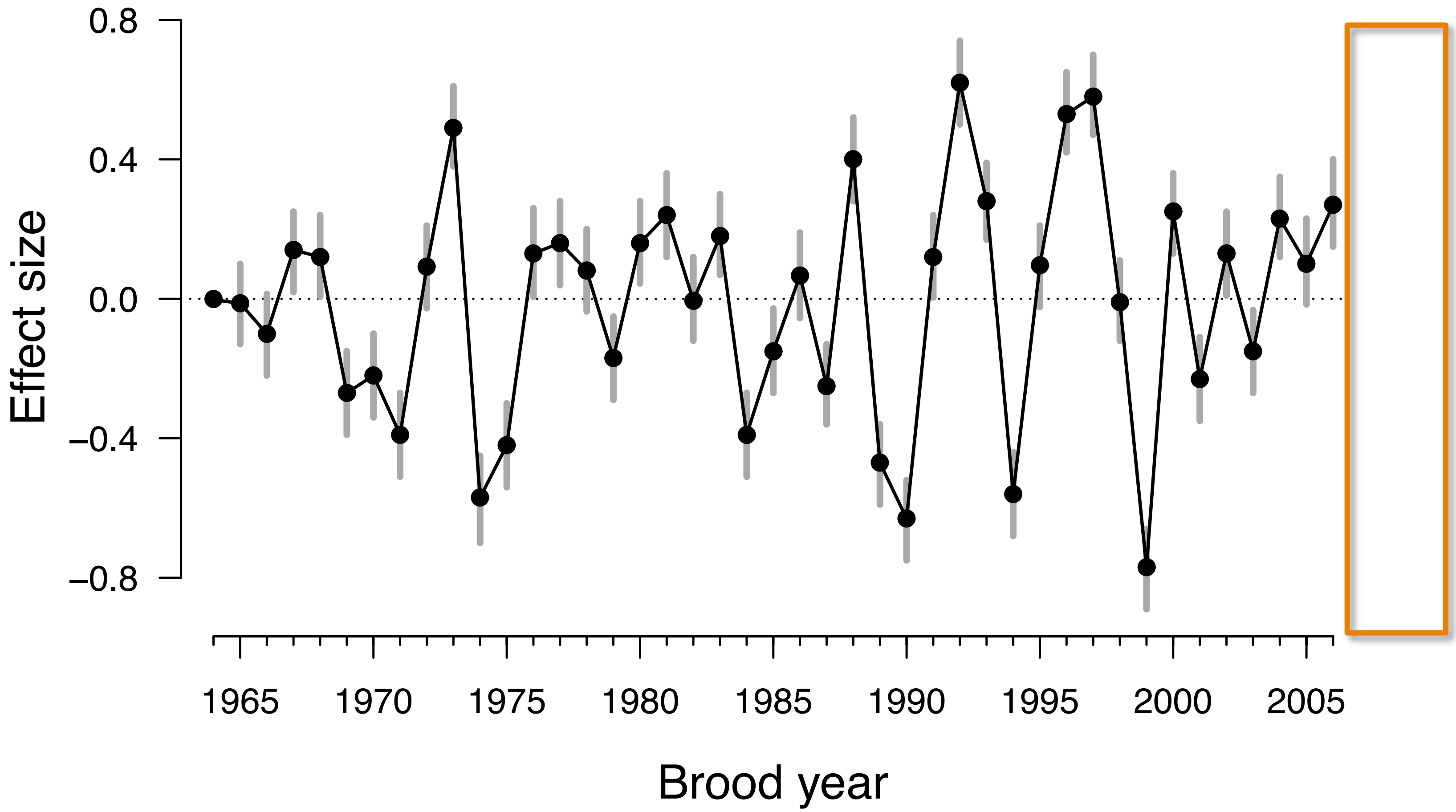
| ESU-level: | Mean | 95% CI | Pr(+) |
|---|---|---|---|
| | 0.033 | (-0.077, 0.15) | 0.73 |



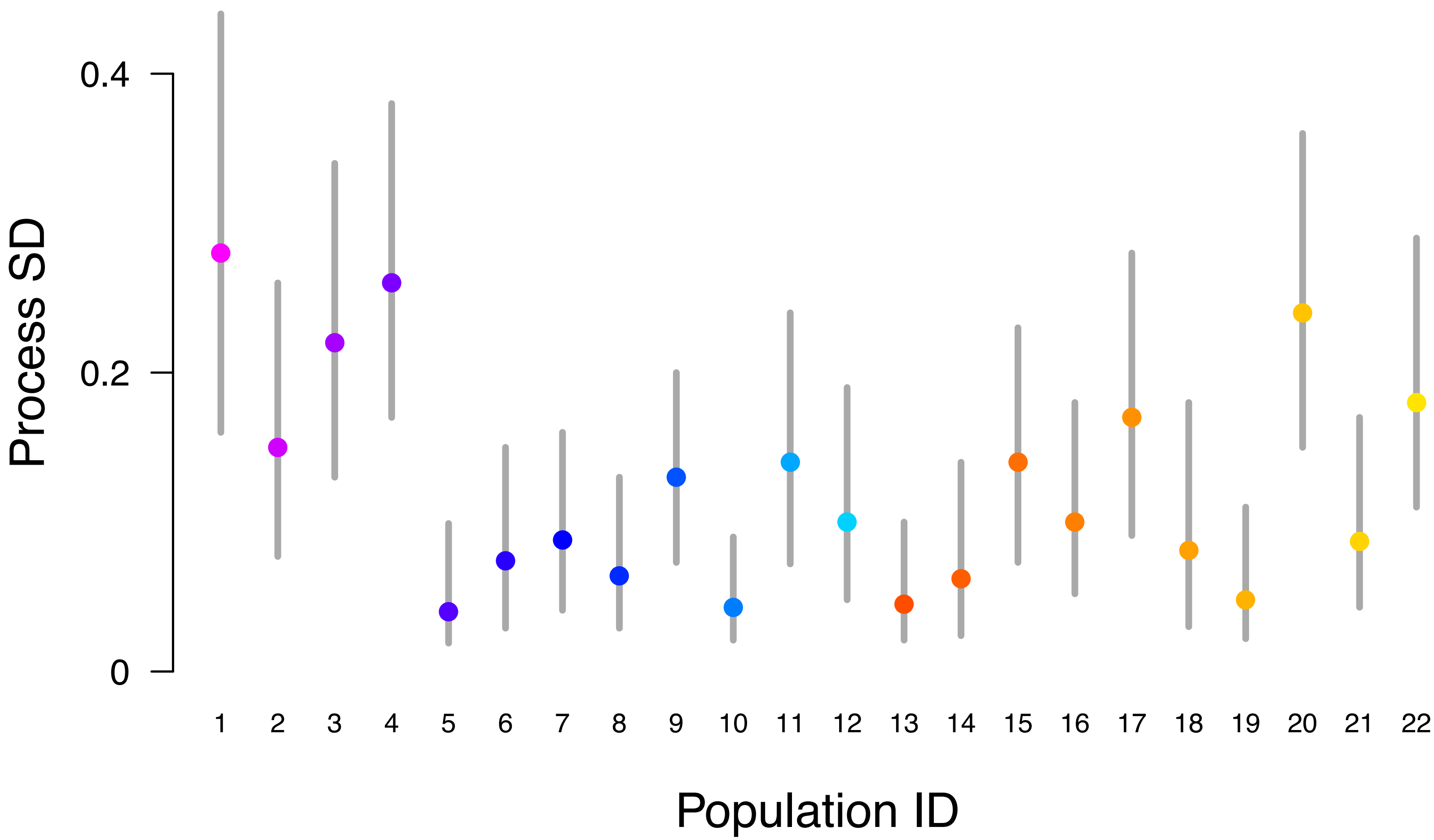
# Unintended supplementation



# Year effects are much stronger



# Spatio-temporal variation



# Summary

- Intervention models are used in many fields
- Intervention models can take many forms