# "Uncertainties about climatic change and Pacific salmon"

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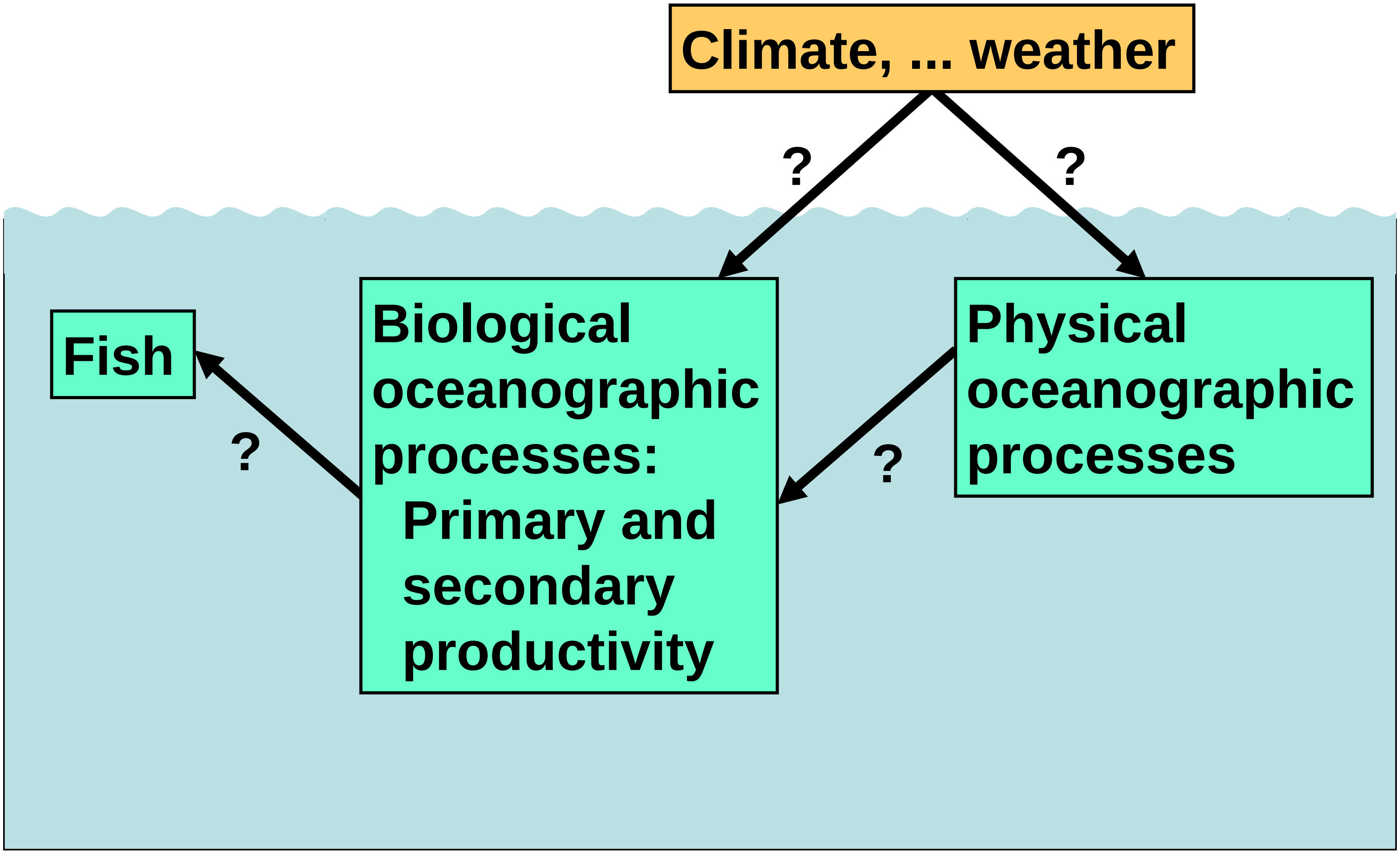
Symposium on "Climate Change Effects and Fisheries", Session P1-D1,
Sendai, Japan, 26 April 2010

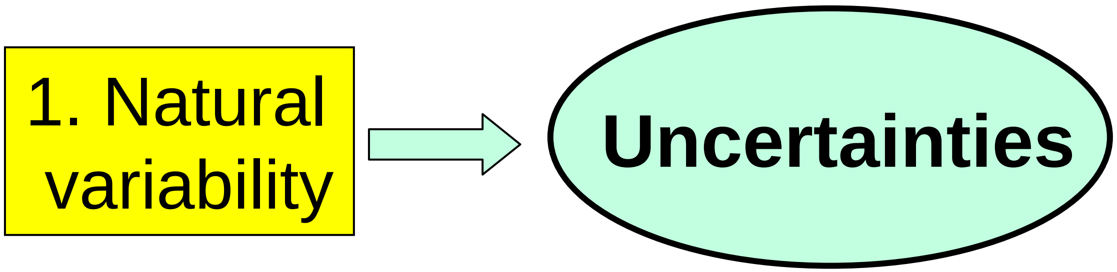
## ***Outline***

- Sources of uncertainty
  - Problems they create
  - What fish stock assessment scientists have done
- Adapting these approaches for forecasting effects of climate on fish
- Recommendations

# Forecasting impacts: From climate to fish



***<u>Sources of uncertainty:</u>***



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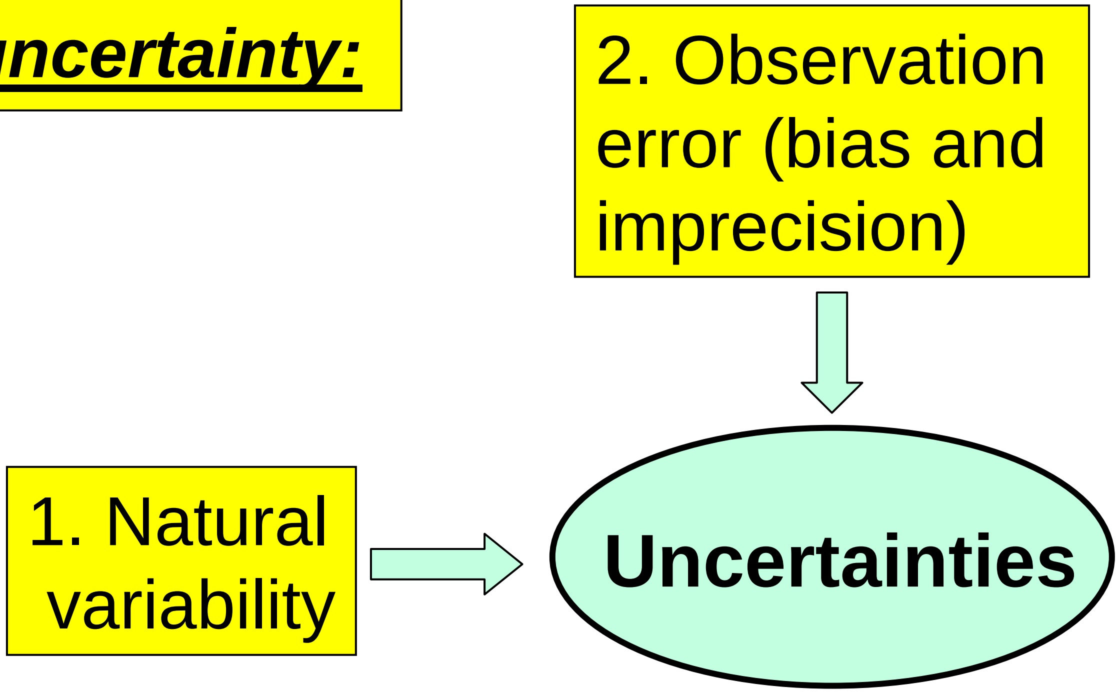

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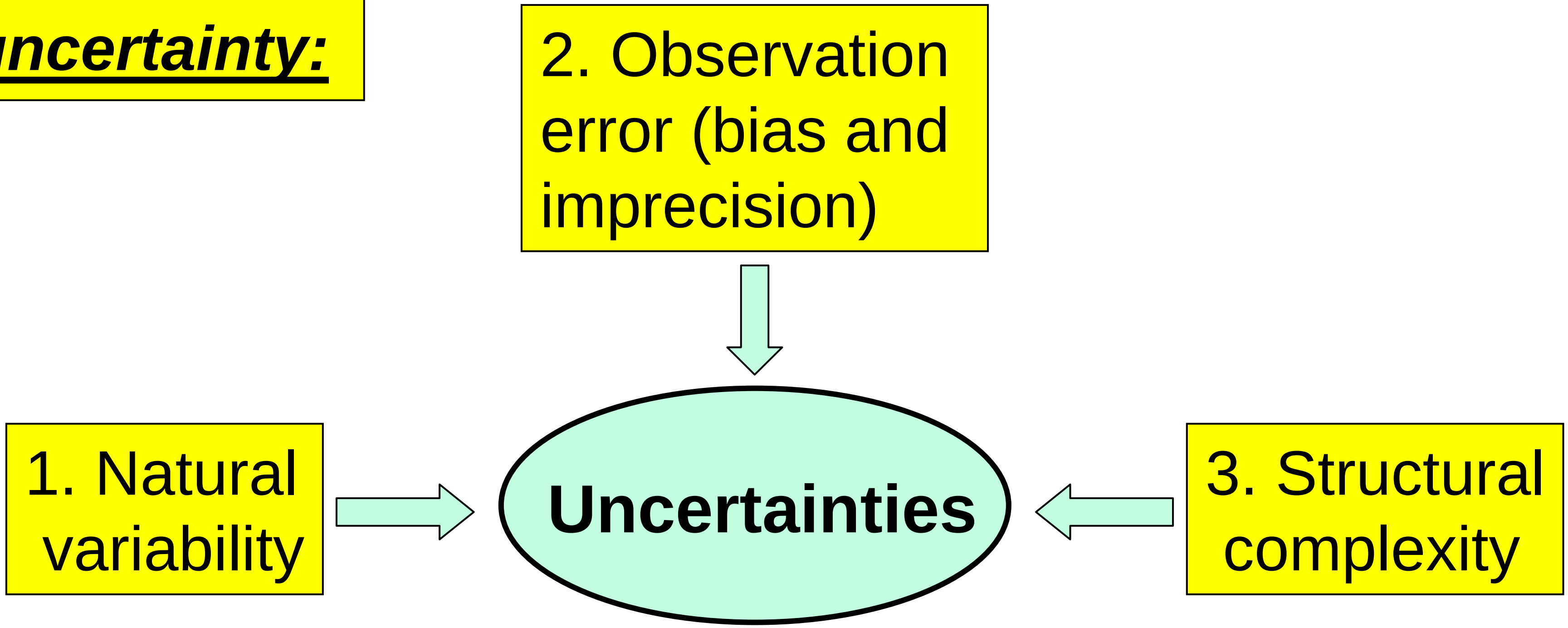

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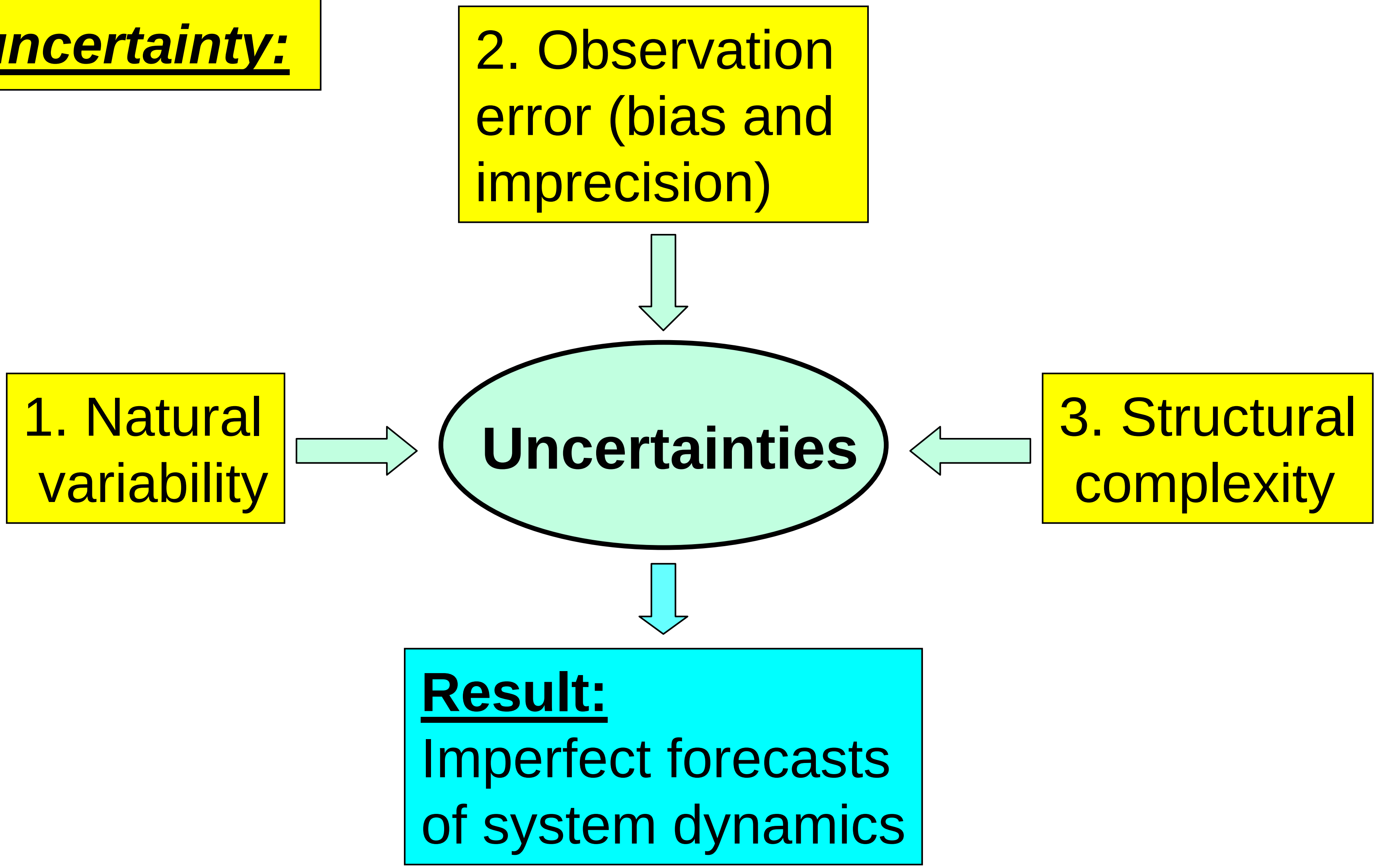
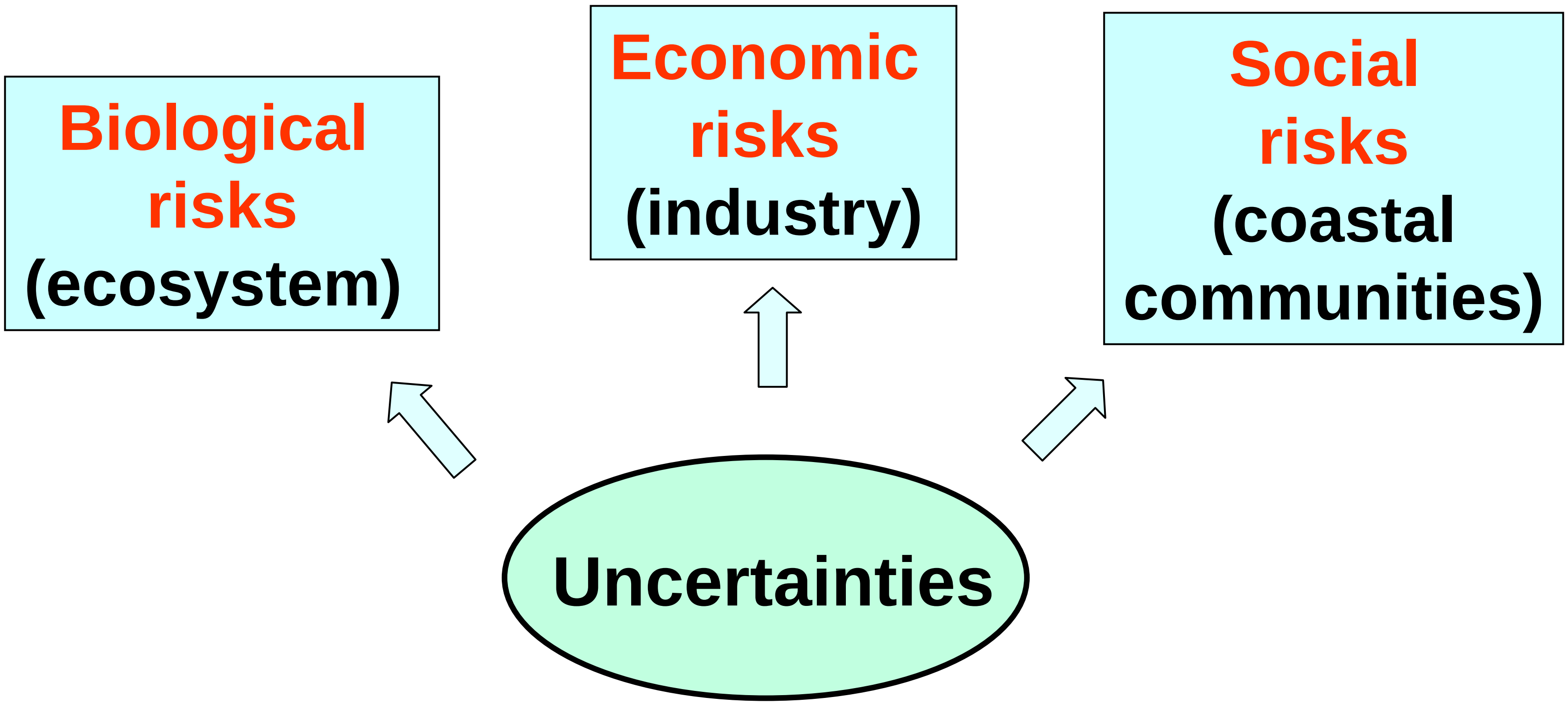



Biological risks
(ecosystem)
Economic risks
(industry)
Social risks
(coastal communities)
Uncertainties

## Sources of uncertainty

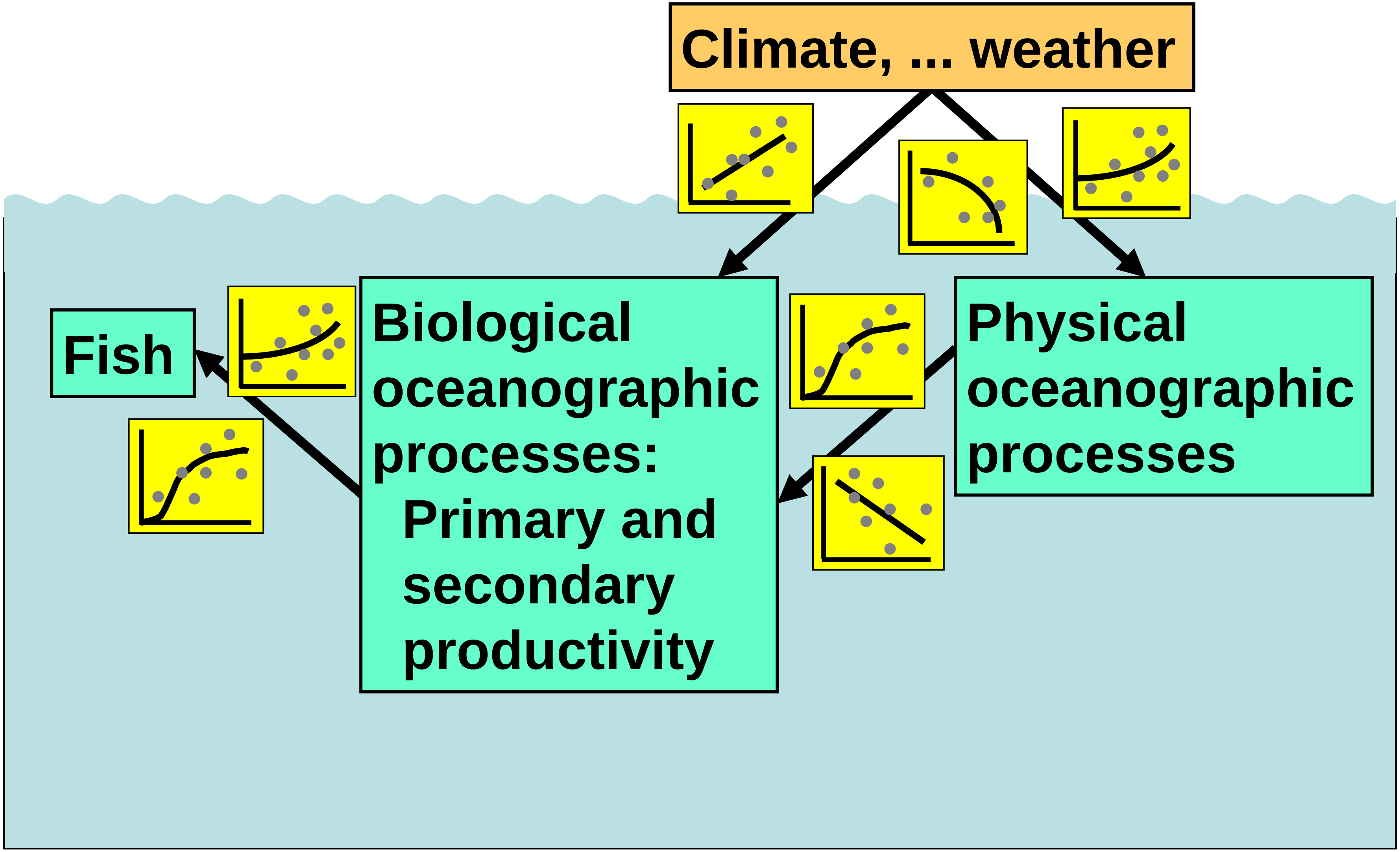
1. Natural variability

2. Observation error

Problems

Resolution

# Forecasting impacts: From climate to fish



| Uncertainty | Problems created |
|---|---|
| **1. Natural variability** at multiple space and time scales<br><br>**2. Observation error** (bias and imprecision)<br><br>• **Both occur simultaneously** | • Biased/imprecise estimates of model parameters<br><br>• Incorrect probability distributions<br><br>• Biased/imprecise output indicators |

**To fit model components to data in presence of both natural variability and observation error:**

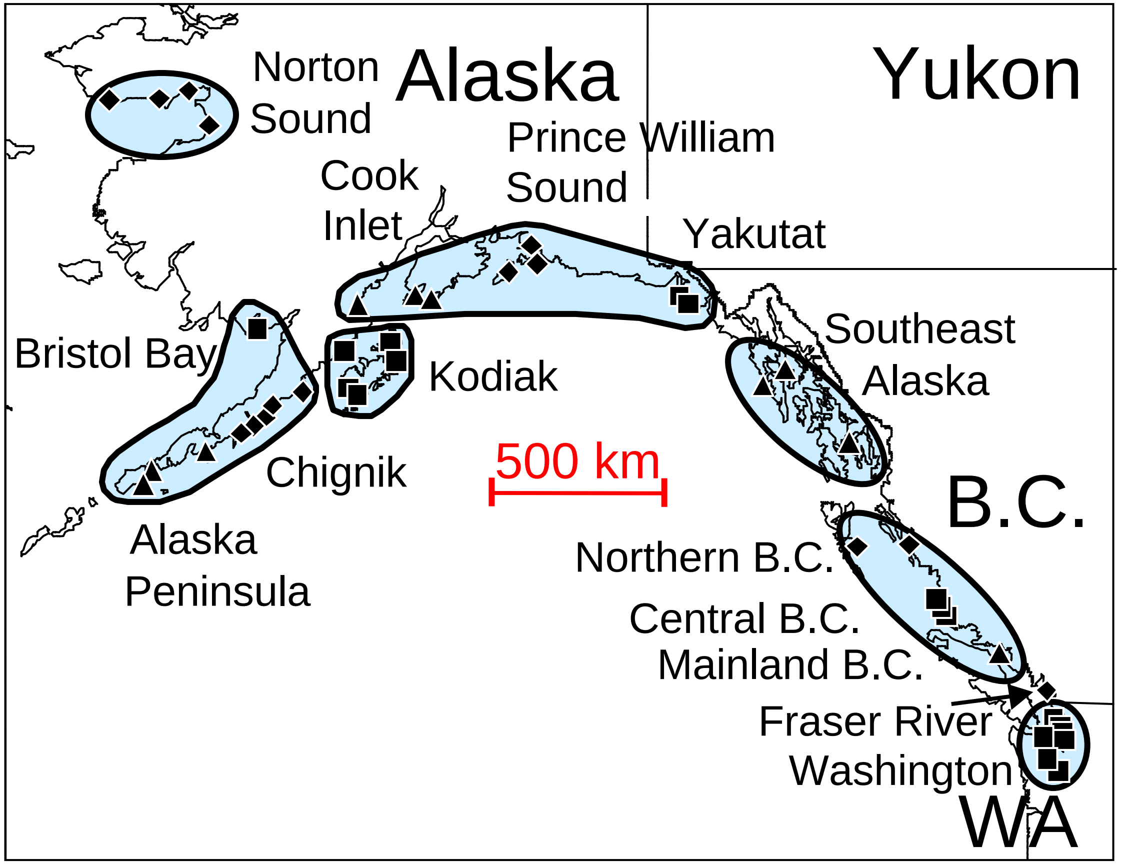
1. Use hierarchical models

    - Data from multiple fish stocks

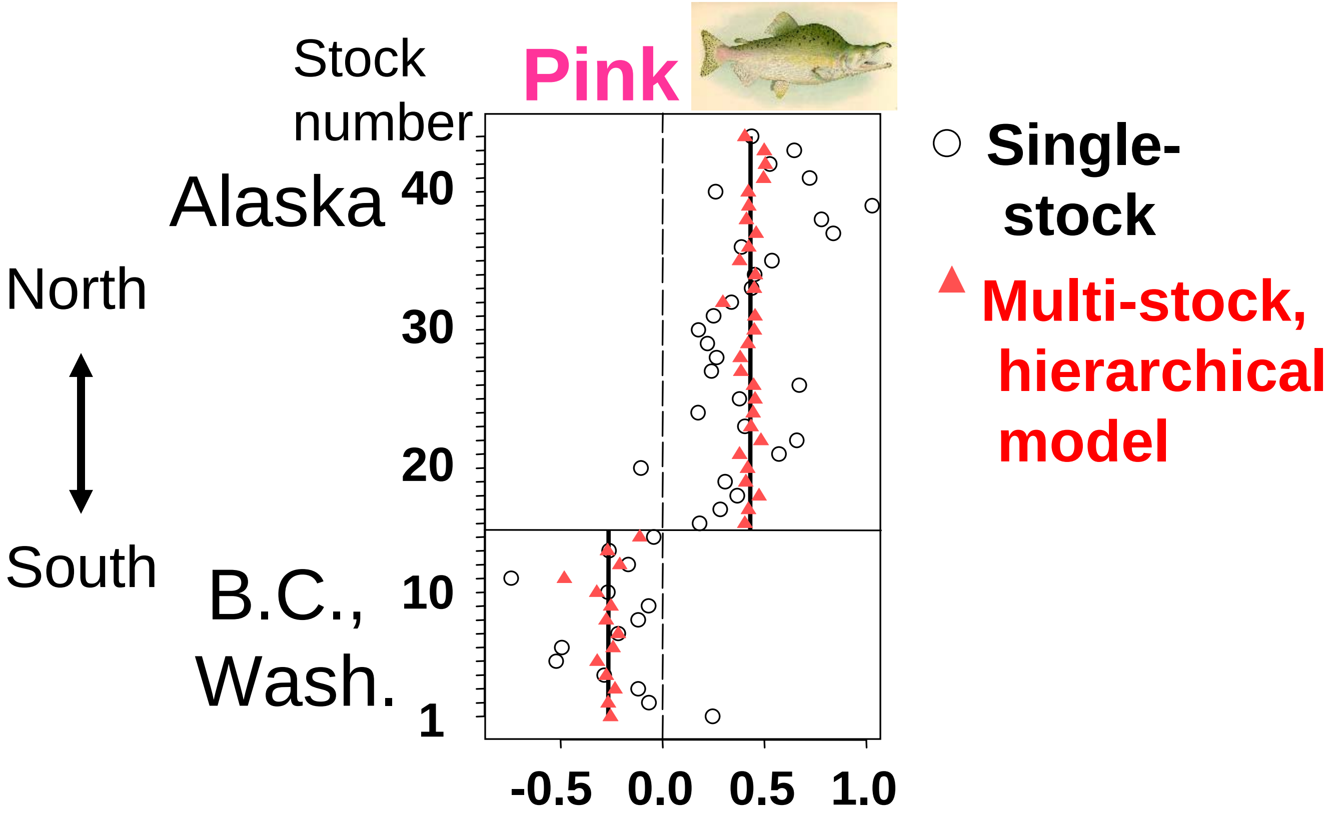
    - Use positive covariation among fish stocks

    - "Average out" annual observation error

# Regions of positive correlation in productivity of pink salmon stocks




Pyper et al. (2001, CJFAS)




**Change in salmon productivity, $\log_e(R/S)$, per $^oC$ increase in stock-specific summer sea-surface temperature (SST coefficient)**

Mueter et al. (2002, CJFAS)

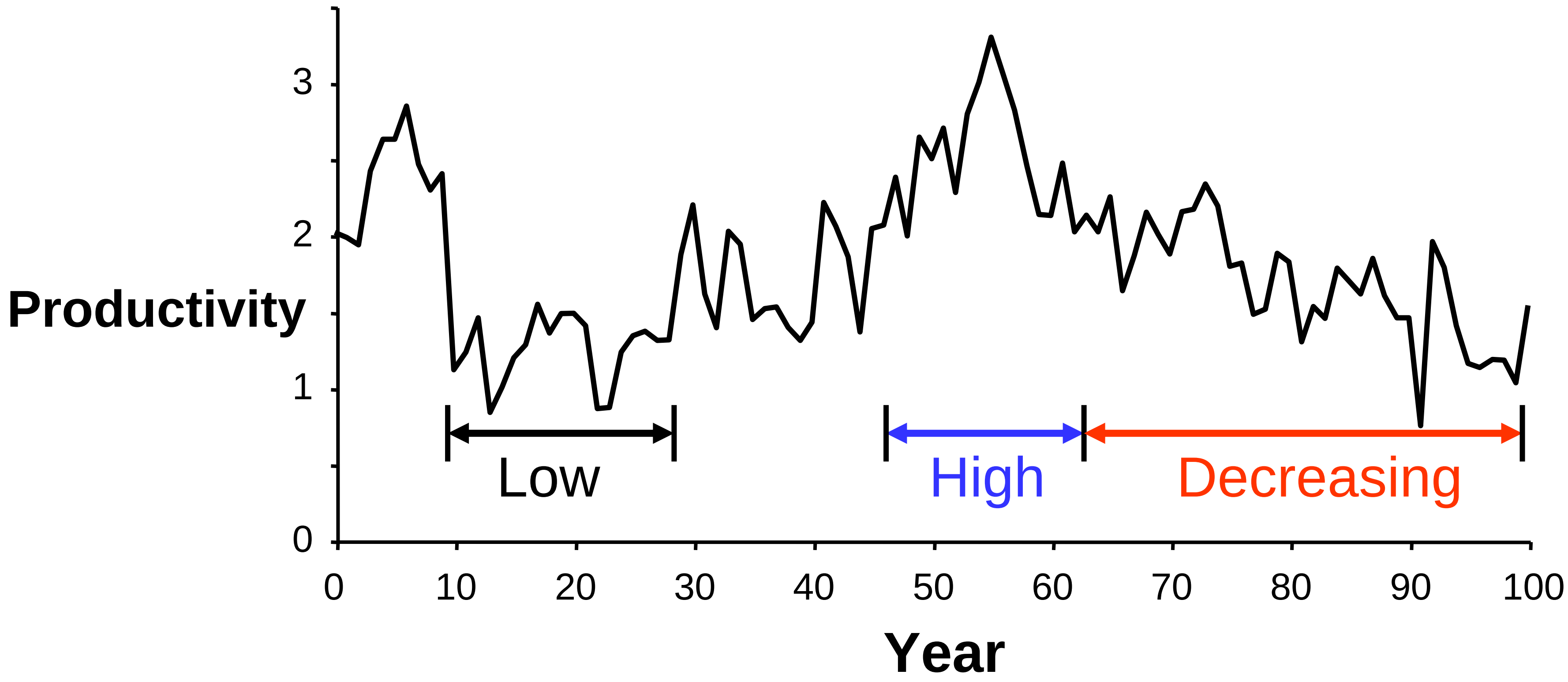
Compared to single-stock analyses, multi-stock models ...

- Improve understanding of environmental effects (e.g., SST) on salmon productivity

2. Separately model natural variation & observation error

- Errors-in-variables models
- State-space models
- Kalman filter

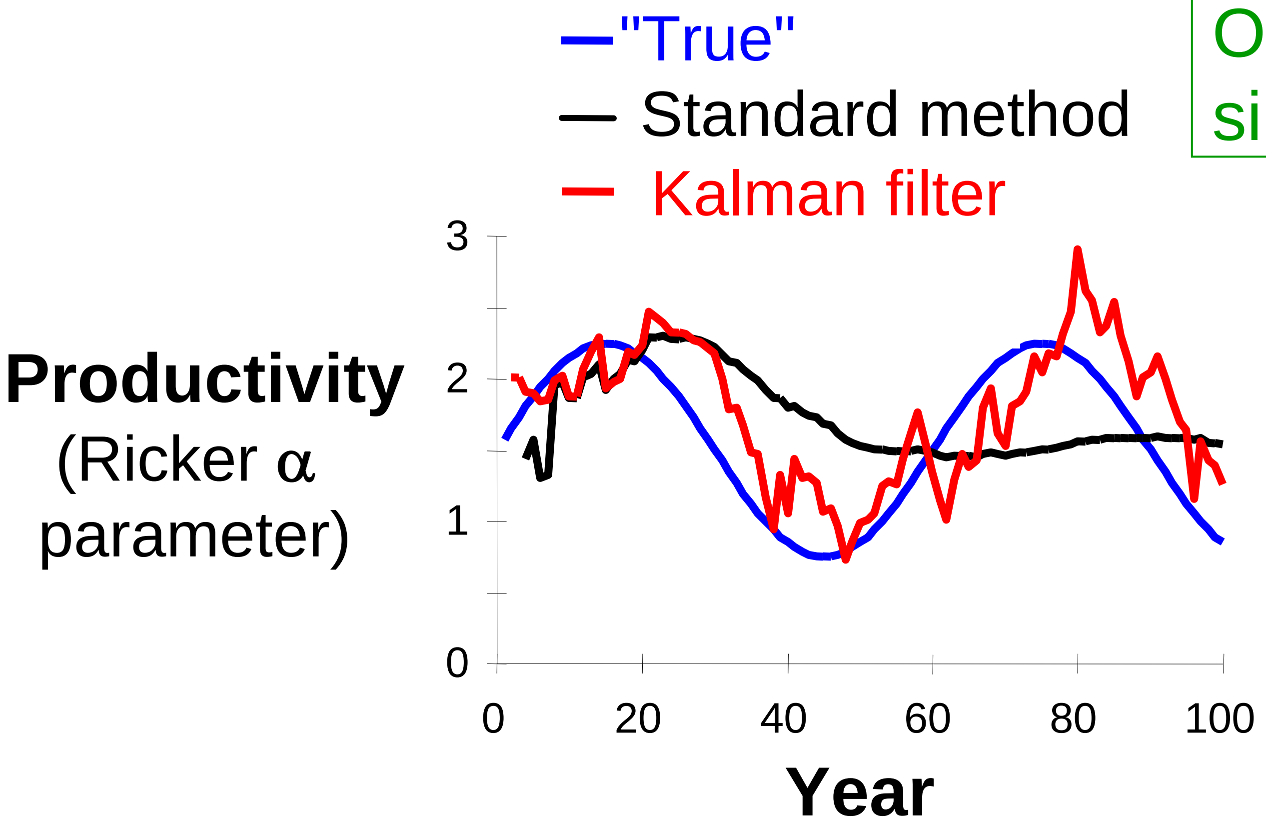
**Example**: Tracking nonstationary productivity parameter (Ricker *a* in stock-recruitment model)




Rather than forecasting changes, try tracking them as they occur.

# "What if?" scenarios for **"true"** Ricker *a* ("signal")

One example simulation trial




Peterman et al. (2000, CJFAS)

## Rather than forecasting effects of climatic change ...

- Extend monitoring programs, and
- Apply advanced statistical models to

  **track changes as they occur**

**Benefits:**

- Avoid large uncertainties in forecasting models

## Sources of uncertainty

1. Natural variability

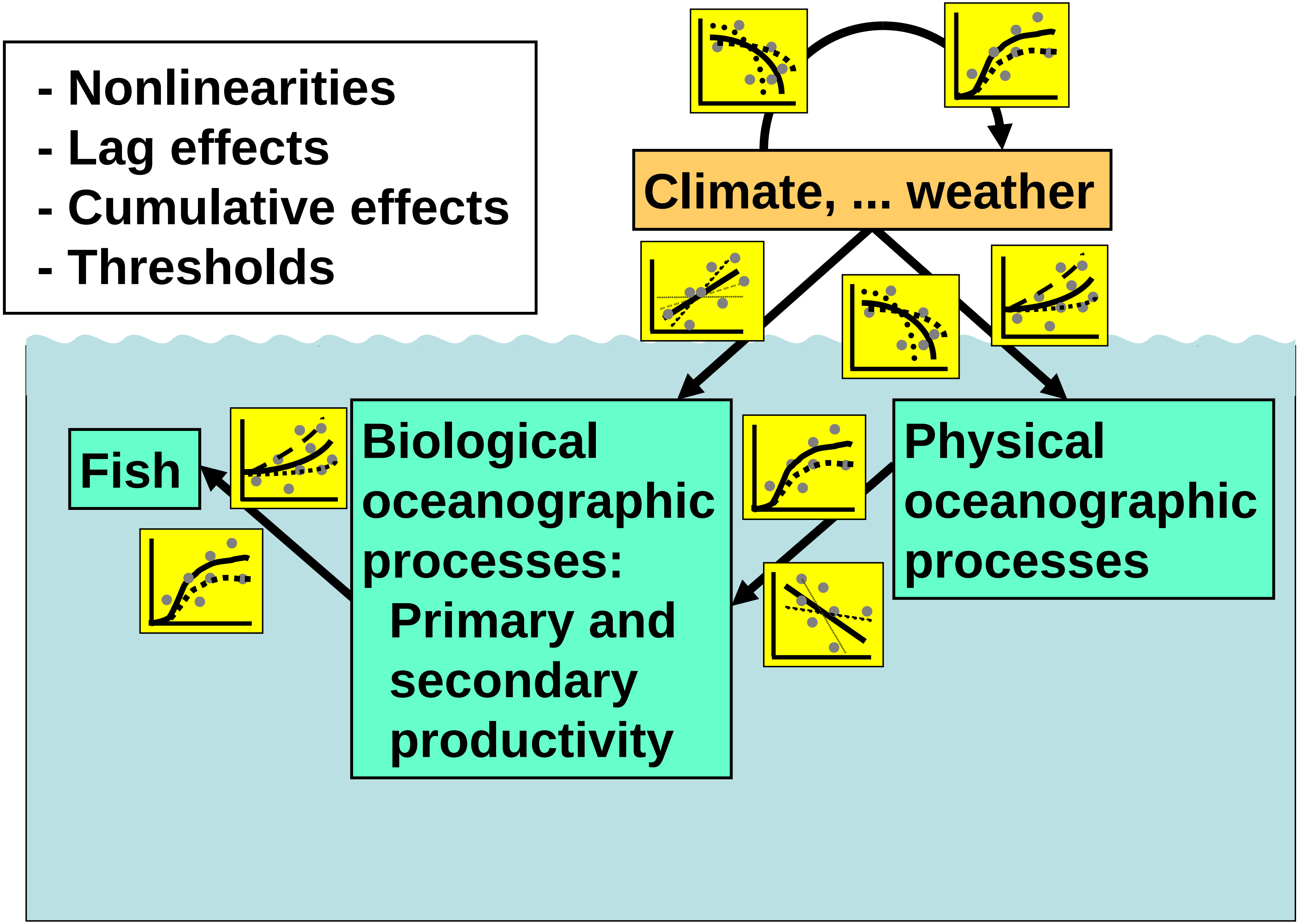
2. Observation error

**3. Unclear structure of system**

| Uncertainty | Problems created |
|---|---|
| **3. Unclear structure** of physical and biological systems ("model uncertainty", "model misspecification" "structural uncertainty") | • Biased/imprecise parameters<br>• Wrong system dynamics<br>• Overconfidence in results if only use <u>one</u> model |

**Structural uncertainty:**

**- Widely recognized as most dominant influence on results of fish stock assessment models**


- Nonlinearities
- Lag effects
- Cumulative effects
- Thresholds
Climate, ... weather
Fish
Biological oceanographic processes: Primary and secondary productivity
Physical oceanographic processes

**- Nonlinearities**
**- Lag effects**
**- Cumulative effects**
**- Thresholds**

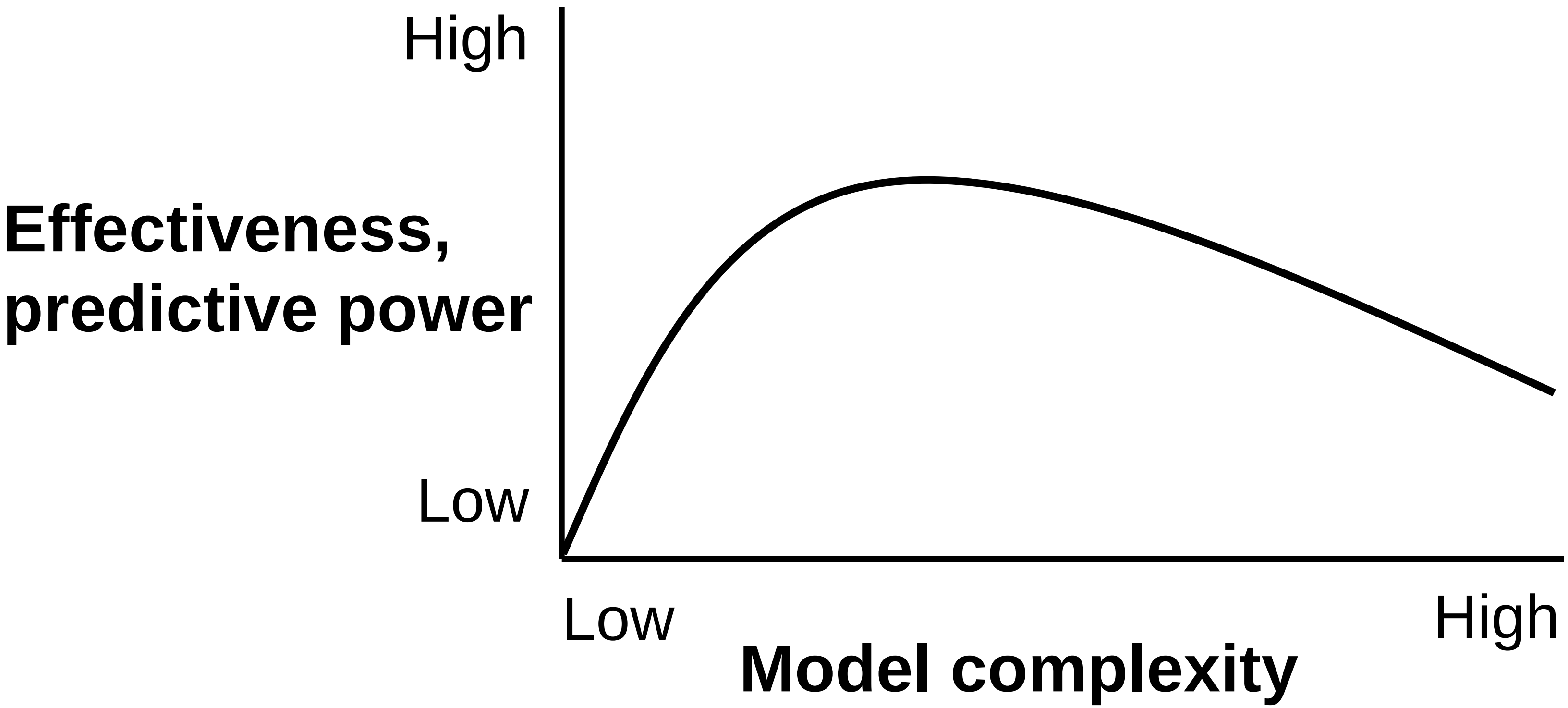
- Unexpected rapid changes (regime shifts)
- New persistent conditions
- Forecasts of climatic effects on fish: highly uncertain

Conduct extensive sensitivity analyses and show uncertainties in forecasts.

But time and money!!

**Standard response:**

**- Build bigger, better, more complex models**




Fulton et al. (2003), others

## 3. To deal with structural uncertainty

1. Consider multiple models, but choose single "best" model among alternatives using $AIC_c$, DIC, or ...

## 3. To deal with structural uncertainty ...

2. Retain multiple models

    2a. Analyze separately

    - Yodzis (1998) could omit 44% of interactions

    2b. Combine forecasts from alternative models

    - With or without weightings, e.g., AIC

## 3. To deal with structural uncertainty ...

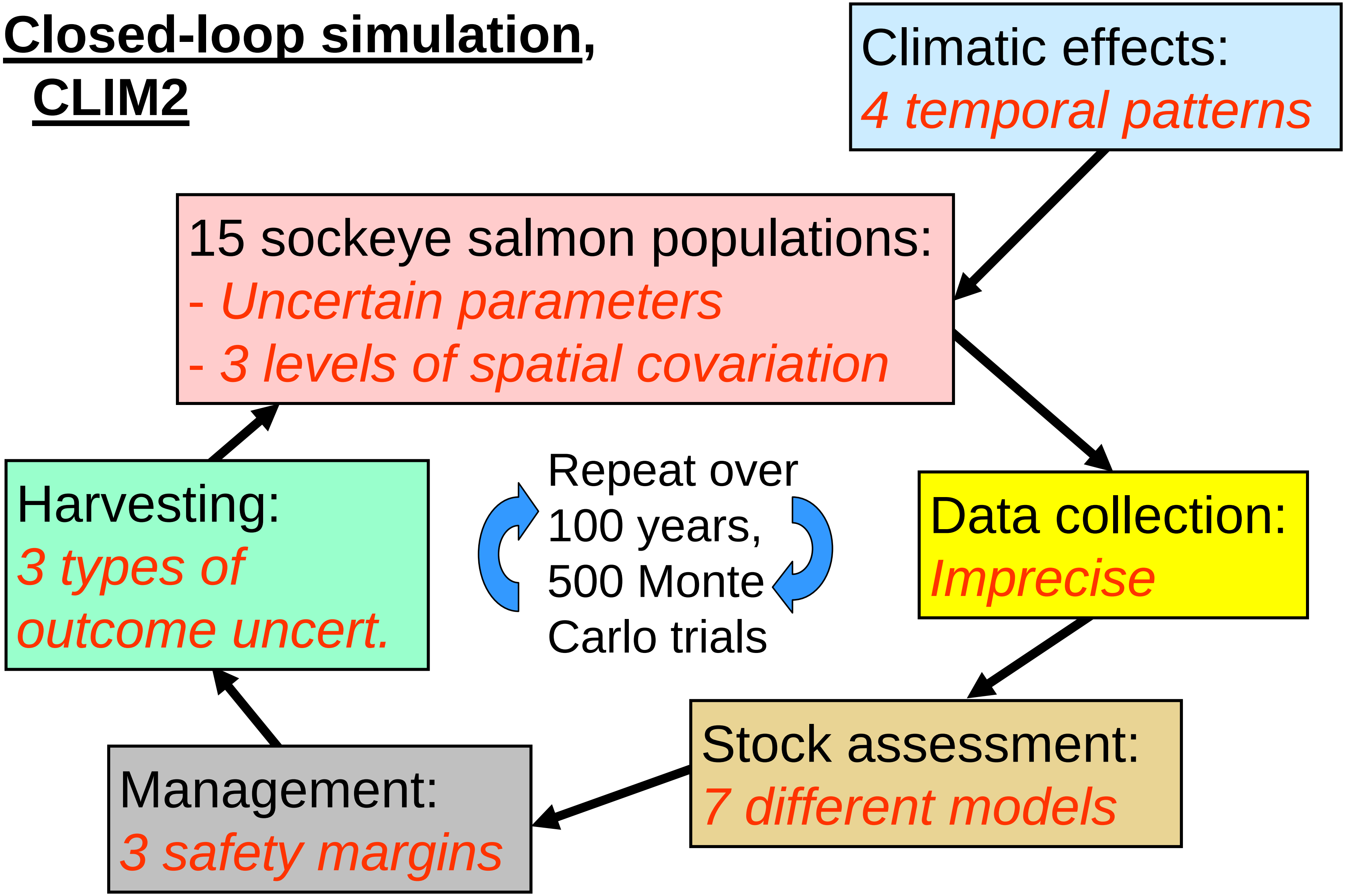
2. Retain multiple models
   2a. ...
   2b. ...
   2c. Change focus to management response:
   Determine most "robust" management procedures by evaluating alternative models within closed-loop simulations or management strategy evaluations (MSEs)
   - "Robust" to wide range of uncertainties

# "Best practices" for evaluating models of aquatic ecosystems

- Tivoli meeting (FAO 2008)
- Plagányi (2007, FAO)
- NMFS NEMoW I & II reports (2008, 2010)


- Multiple models, ranging from simple to complex
- Management Strategy Evaluation is best approach

# Closed-loop simulation, CLIM2

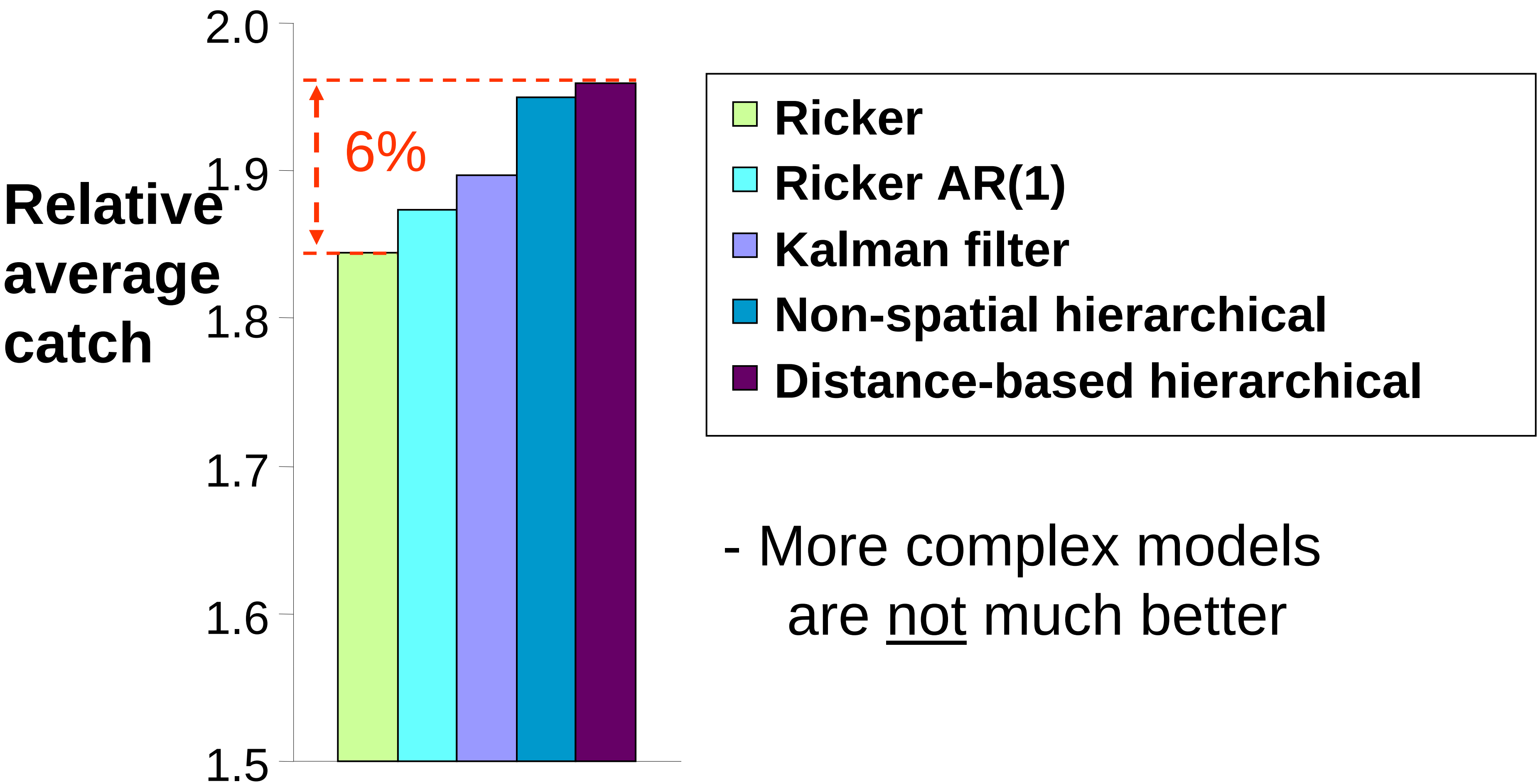



Dorner et al. (2009, CJFAS)

## Performance measures

1. Catch

2. Index of conservation concern
   - Prob.(spawners < 10% of unfished abundance)



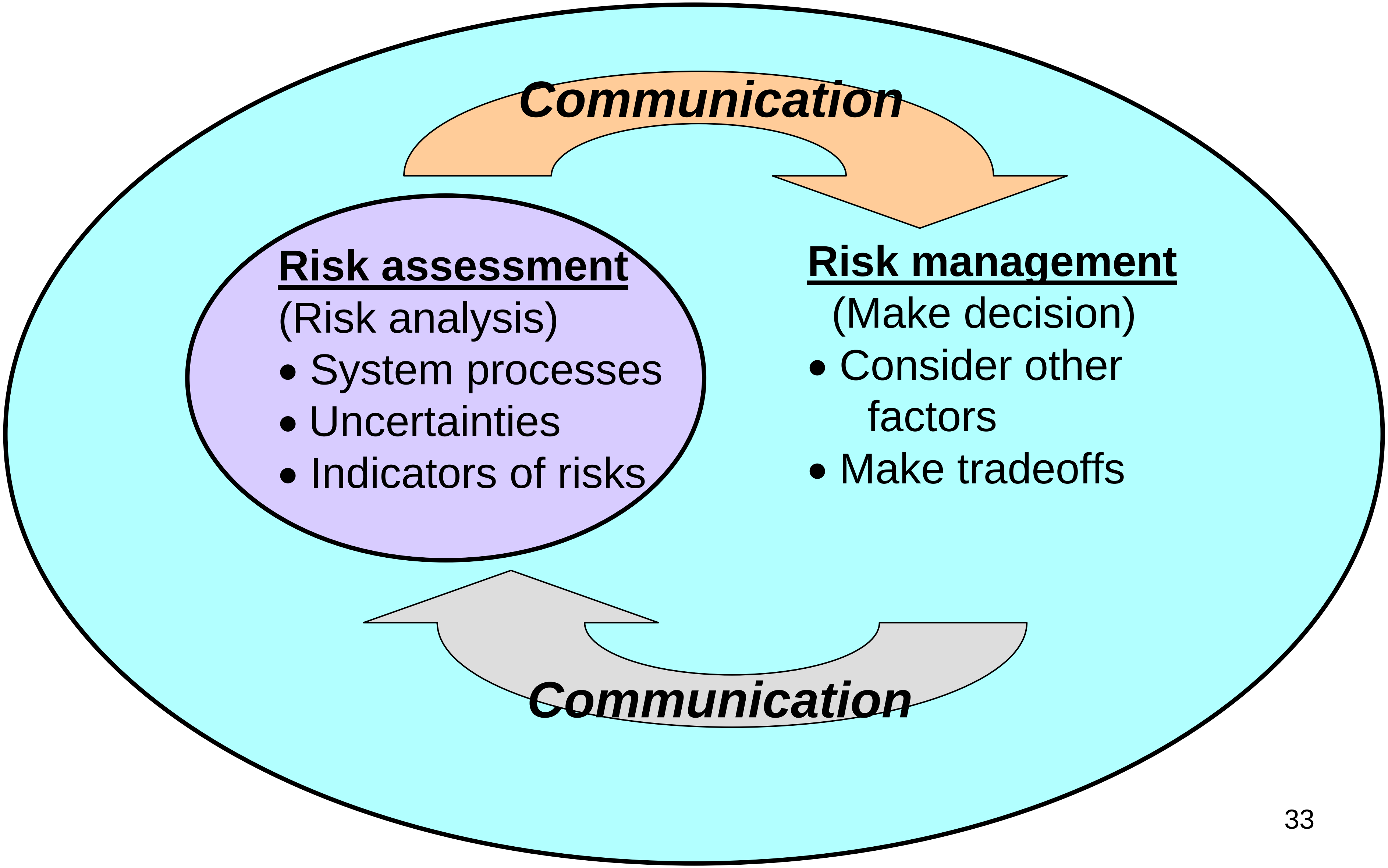

- More complex models are <u>not</u> much better

(Dorner et al. 2009, CJFAS)

**Risk assessment**

(Risk analysis)

- System processes
- Uncertainties
- Indicators of risks


Communication
Risk assessment
(Risk analysis)
• System processes
• Uncertainties
• Indicators of risks
Risk management
(Make decision)
• Consider other factors
• Make tradeoffs
Communication

## Sources of uncertainty

1. Natural variability

2. Observation error

3. Unclear structure of fishery system

**4. Inadequate communication**

| Uncertainty | Problems created |
|---|---|
| **4. Inadequate communication** among scientists, decision makers, and stakeholders | • Misinterpretation<br>• Overconfidence by decision makers if uncertainties not clear |

## 4. To deal with inadequate communication ...

1. Show results of extensive sensitivity analyses

## 4. To deal with inadequate communication ...

2. Use cognitive psychologists' findings about uncertainties and risks

- Cumulative probability distributions

- Frequency format, not decimal probability format
  (due to six interpretations of "probability", only one of which is "chance")

“Chance" of an outcome for a given set of management regulations:

*Probability format*

"There is a probability of 0.2 that spawning stock biomass (SSB) will drop unacceptably low."

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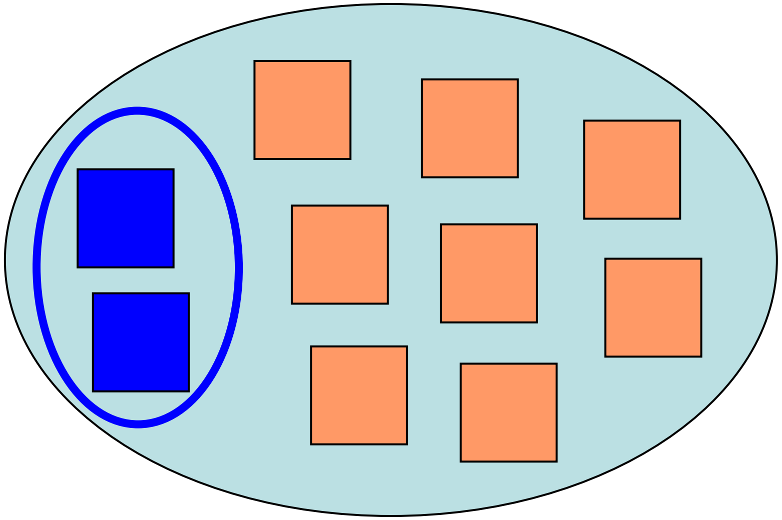

Gerd Gigerenzer et al.

## Recommendations

1. Establish "best practices" for climate-fish modelling; i.e., a standardized protocol to:
   - Estimate uncertainties and take them into account
   - Show effects of uncertainties on outcomes
   - Develop multiple models and compare reliability

2. Evaluate proposed "improvements" to ecosystem models (more complex is <u>not</u> necessarily better)

## Recommendations

3. Change focus to finding management strategies that are robust to uncertainties in models

4. Consider using "tracking" methods instead of building forecasting models

**C.S. Holling:**

> **"The domain of our ignorance is larger than the domain of our knowledge."**