

**NOAA**  
**FISHERIES**

# **Fishery Management Process: From Data to Quotas**

**Application of Seasonal to Decadal Climate Predictions  
for Marine Resource Management Workshop**

**June 3-5, 2015**

**Princeton, NJ**

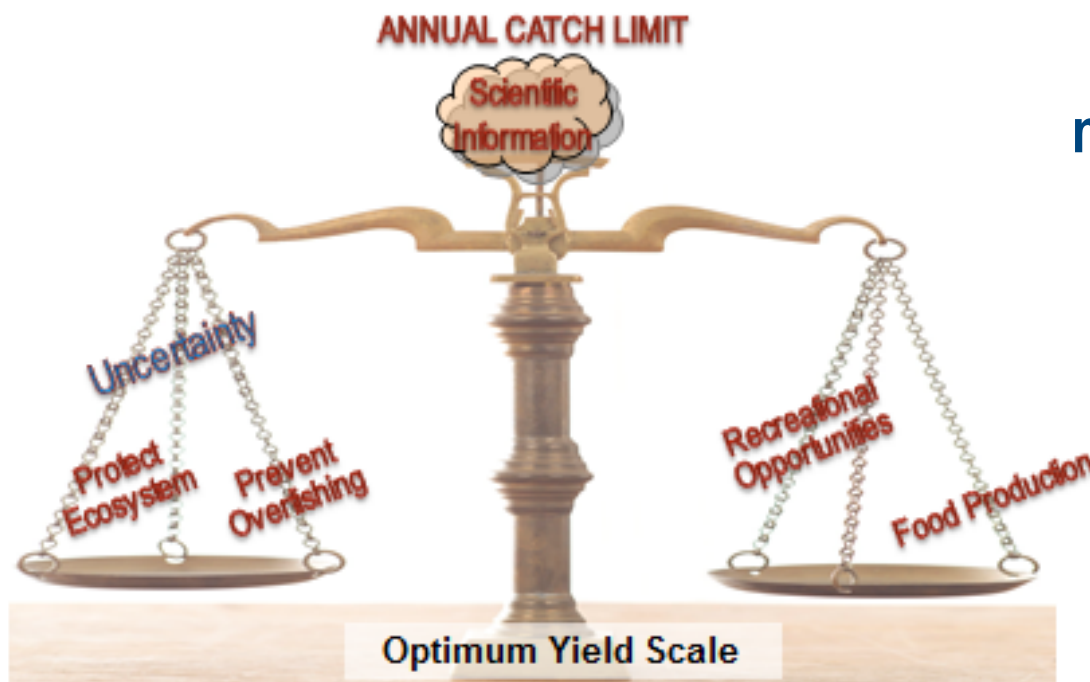
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## MSFCMA: National Standards 1, 2, 3

NS1: “Conservation and management measures shall **prevent overfishing** while achieving, on a continuing basis, the **optimum yield** from each fishery for the United States fishing industry.”



NS2: “Conservation and management measures shall be based upon the **best scientific information available.**”

NS3: “...an individual **stock** of fish shall be managed as a unit throughout its **range....**”

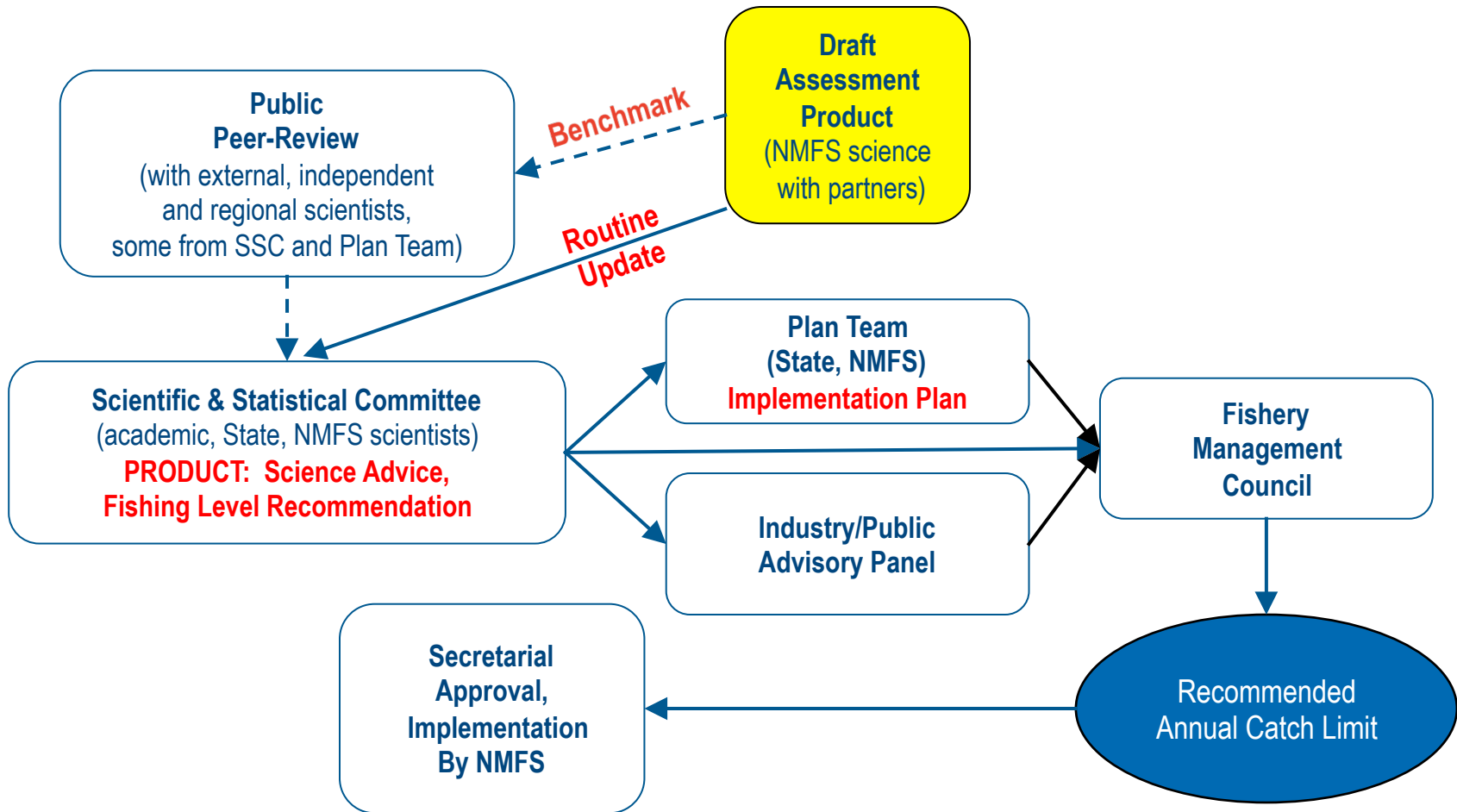


## Fishery Management Plans

- *Establish a mechanism for specifying **annual catch limits** ... at a level such that **overfishing does not occur** in the fishery, including measures to ensure **accountability**.*
- *Specify **objective and measurable criteria** for identifying when the fishery ... is overfished*
  - *Related to reproductive potential of stock*
- *Annual Catch Limits (ACLs) may not exceed Council's Scientific and Statistical Committee's **fishing level recommendation***
  - *Based on best **scientific information** available*



# Stock Assessment / Council Process



<http://www.nrc.noaa.gov>



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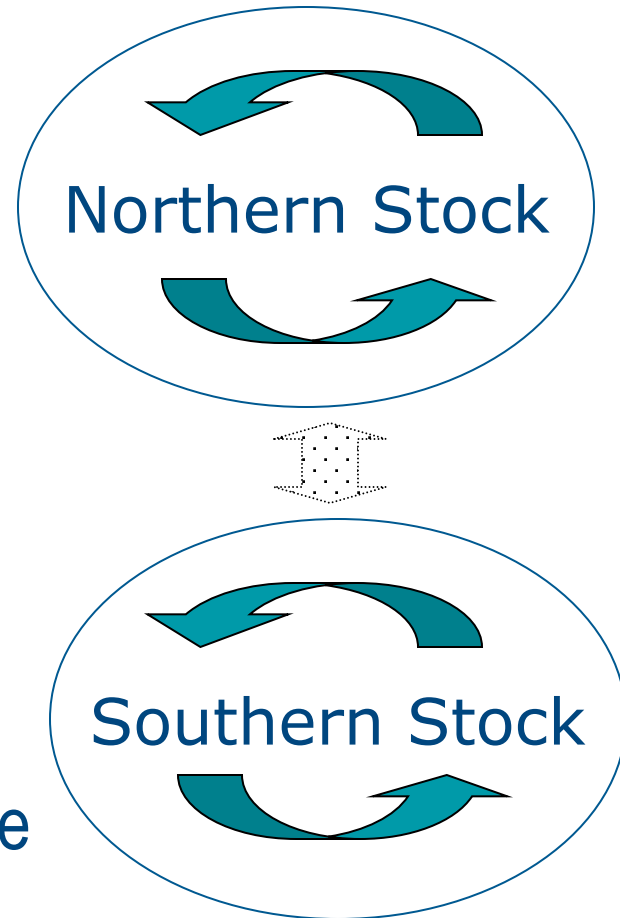
# Assessment Jargon

- **Stock; Population**
  - Biological unit being analyzed, and its fishery
- **Abundance; Biomass (B)**
  - how many fish out there; total weight of the stock
- **Reproductive potential; Spawning biomass (B, SB, SPB)**
  - Produce 1000s of eggs per female, small fraction survive to be young fish
- **Recruitment; Year-class; Cohort (R)**
  - numbers of young fish entering stock each year
- **Natural mortality (M)**
  - Fraction dying each year due to natural causes
- **Fishing mortality (F); Exploitation rate**
  - fraction caught each year by the fishery increases overall mortality
- **Annual Catch Limit (ACL)  $\approx$  (recommended F) times (Current Biomass)**
- The maximum long-term average catch that the stock can produce is **MSY**

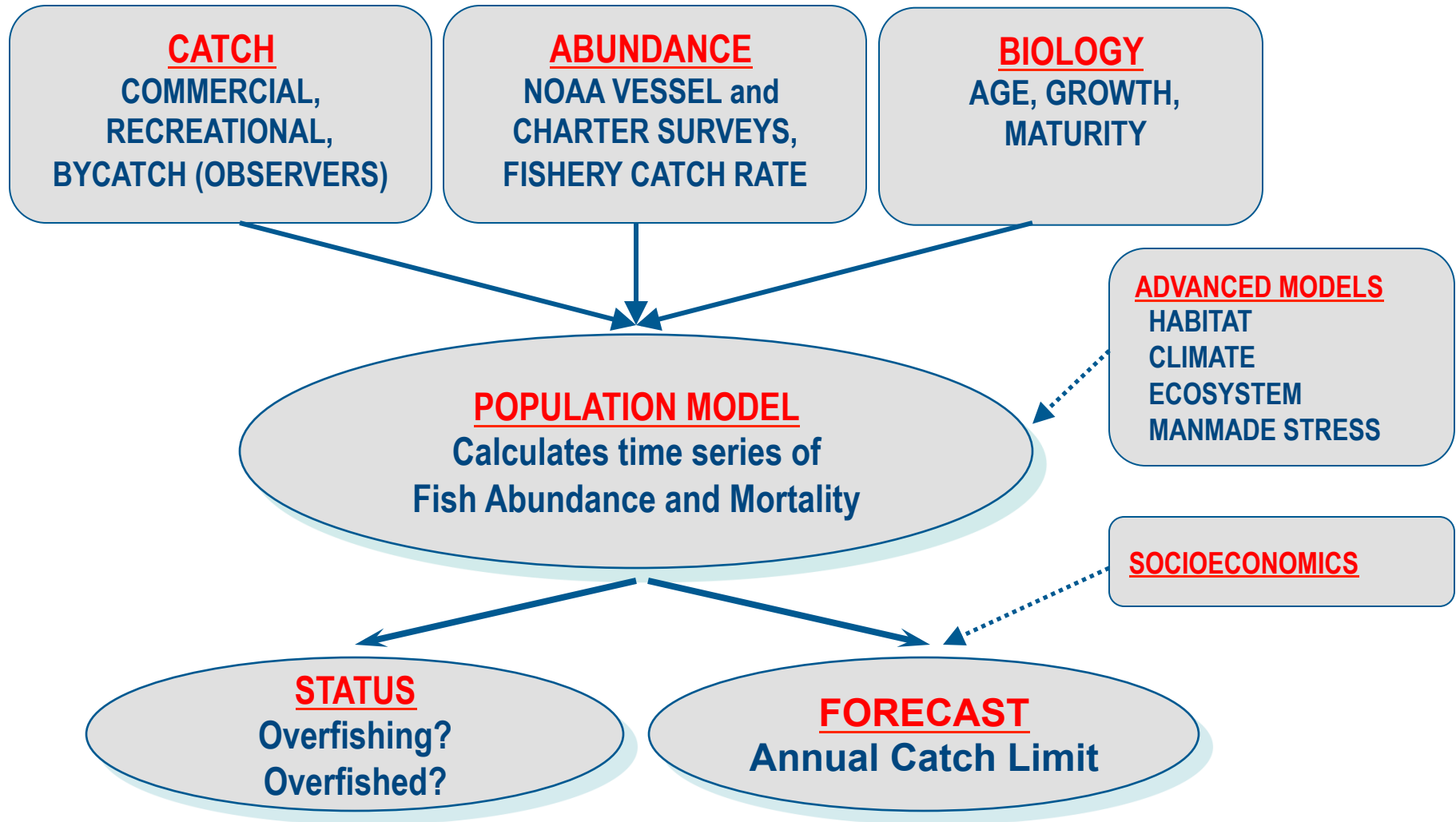


# What is a “Stock”?

- A group of individuals of the same species
- That inhabit the same geographic region
- And that interbreed when mature
  
- Most Models: Instantaneous diffusivity within stock; idealized free distribution



# Stock Assessment: Data, Models, Output



# Total Catch

- **A dead fish is a dead fish; count 'em all**
  - Commercial retained
  - Recreational kept
  - Commercial & recreational discard/release
    - %Survival of discard & released
  - Research take
- **Data Sources**
  - **Fishery Information Networks: State-federal-Commission**
  - **Fishery Statistics**
  - **Observer Programs**
  - **Marine Recreational Information Program**



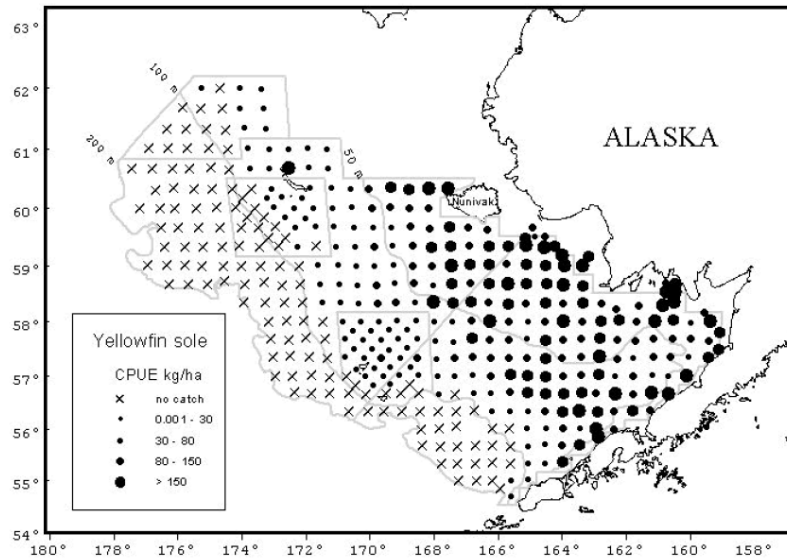


# Why Fishery-Independent Surveys?

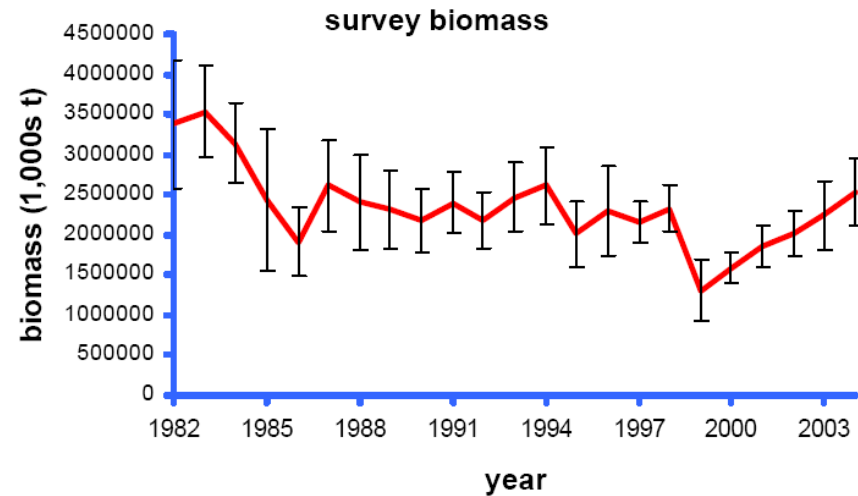
- **Fishery catch rates**
  - **Should go up and down with fish abundance**
    - **But, fishermen are businessmen seeking profits**
    - **Adjust fishing methods & locations**
  - **Difficult to be confident that calibration of catch rate to fish abundance doesn't drift over time**
- **Fishery-independent surveys of abundance**
  - **Cover range of the stock (even areas with lower abundance)**
  - **Select sample locations with statistical plan**
  - **Use highly standardized sampling methods**
  - **With advanced technology (acoustics, optical, robotics, smart tags) can achieve even higher degrees of calibration**



# Example: Bering Sea bottom trawl survey



Count fish at 100s  
of locations each year



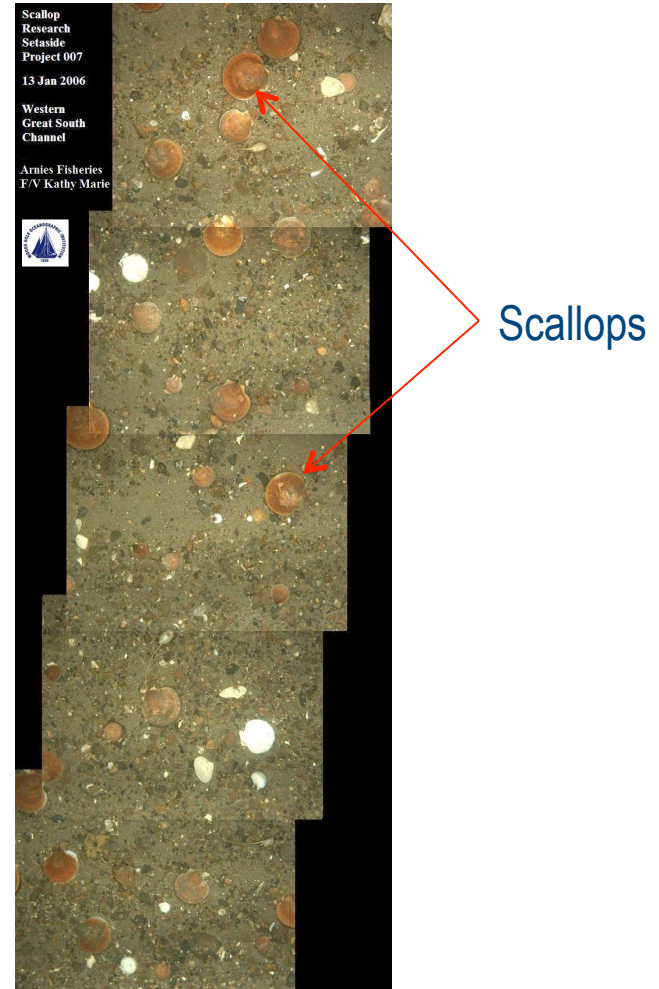
Average count with error bars  
for each year of survey

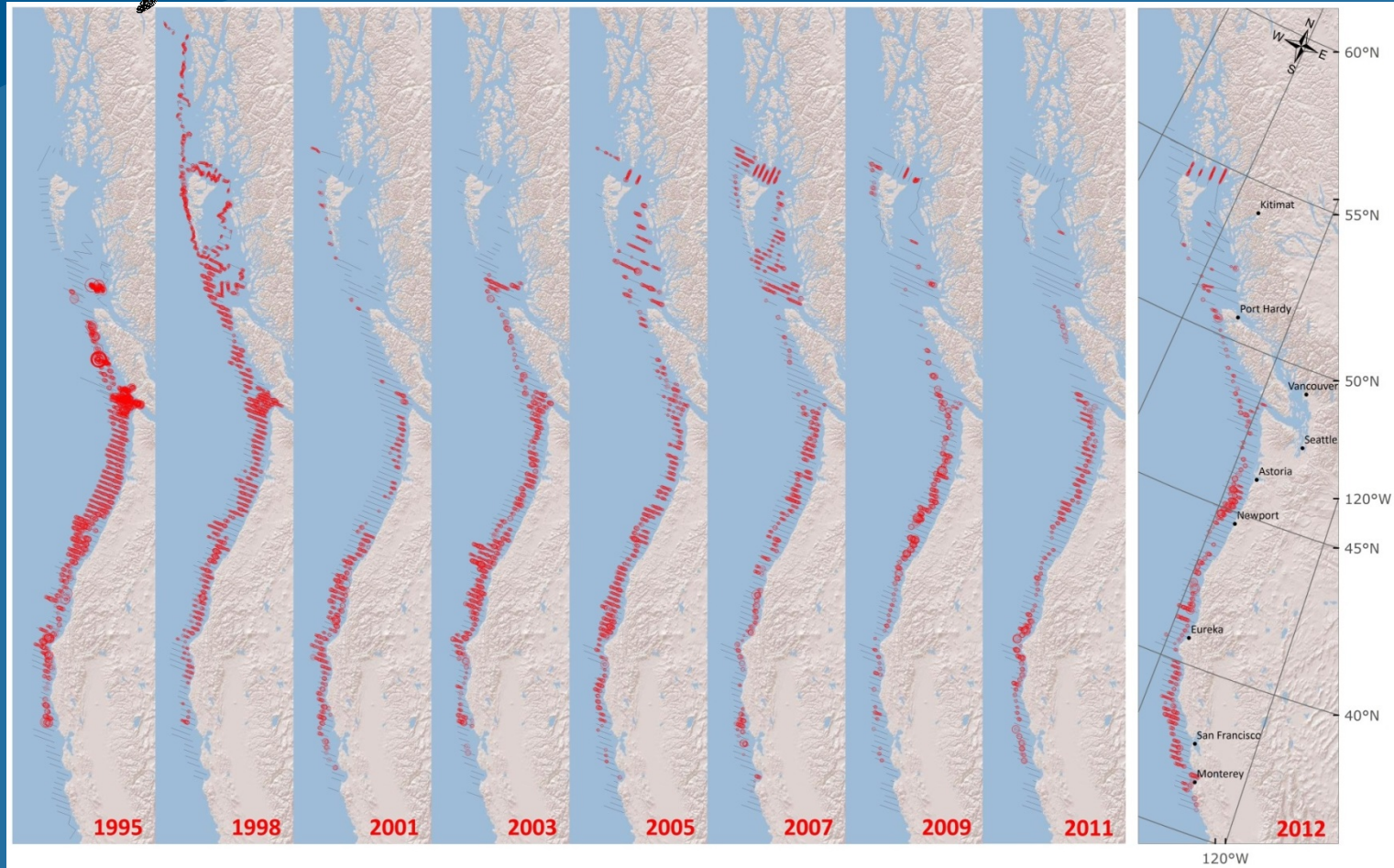
- Comparable bottom trawl surveys in Northeast, Gulf of Alaska, Pacific Coast, Gulf of Mexico provide data for assessment of many stocks
- Other survey methods provide data for additional stocks



# Advanced Technology

- **Optical surveys for non-lethal absolute abundance estimates**
- **Northeast Scallop Survey now using towed camera system with automated optical recognition software for abundance estimates**
- **Towed and robotic systems being tested for reef-fish surveys in GOM, west coast, Pacific Islands and elsewhere**





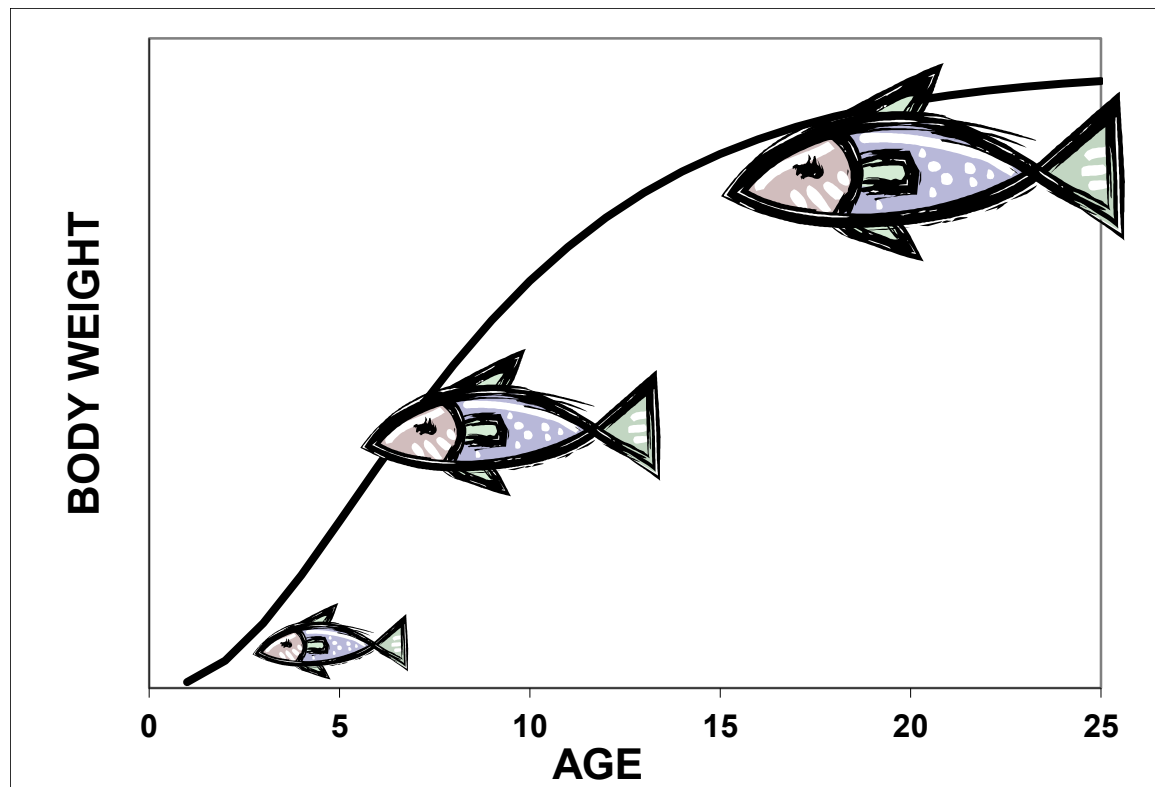
Acoustic sA attributed to adult hake, 1995 - 2012



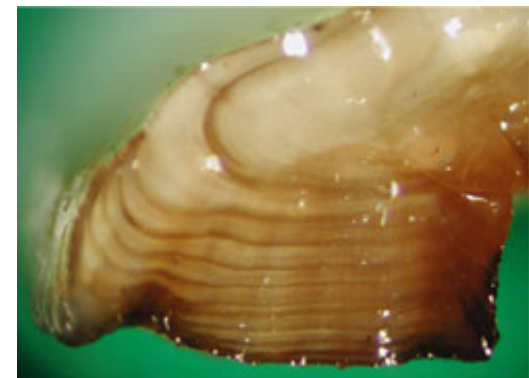
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# Fish Biology and Life History

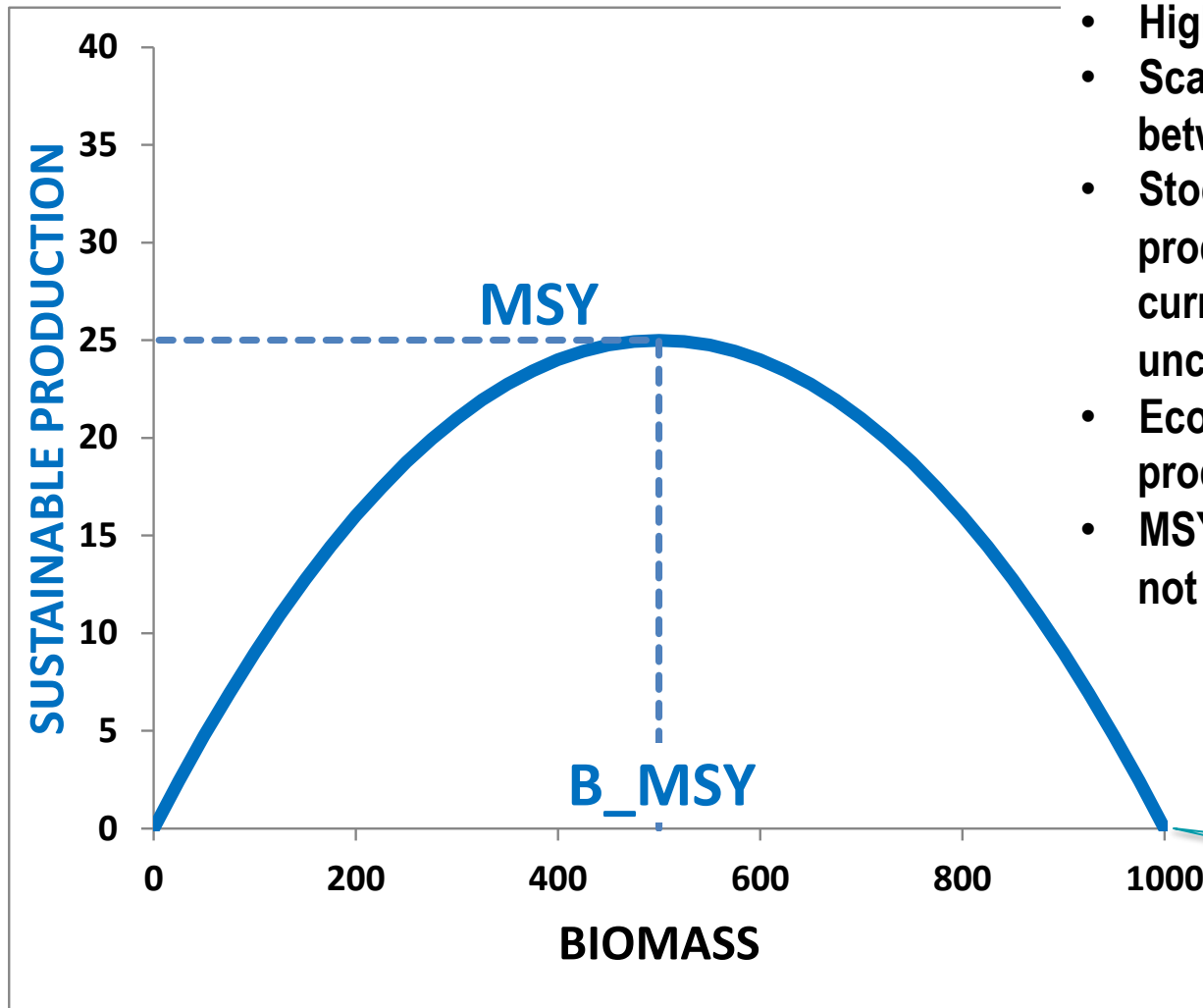
- Age, length, weight, maturity, fecundity, natural mortality



Otolith (ear bone) with annual marks



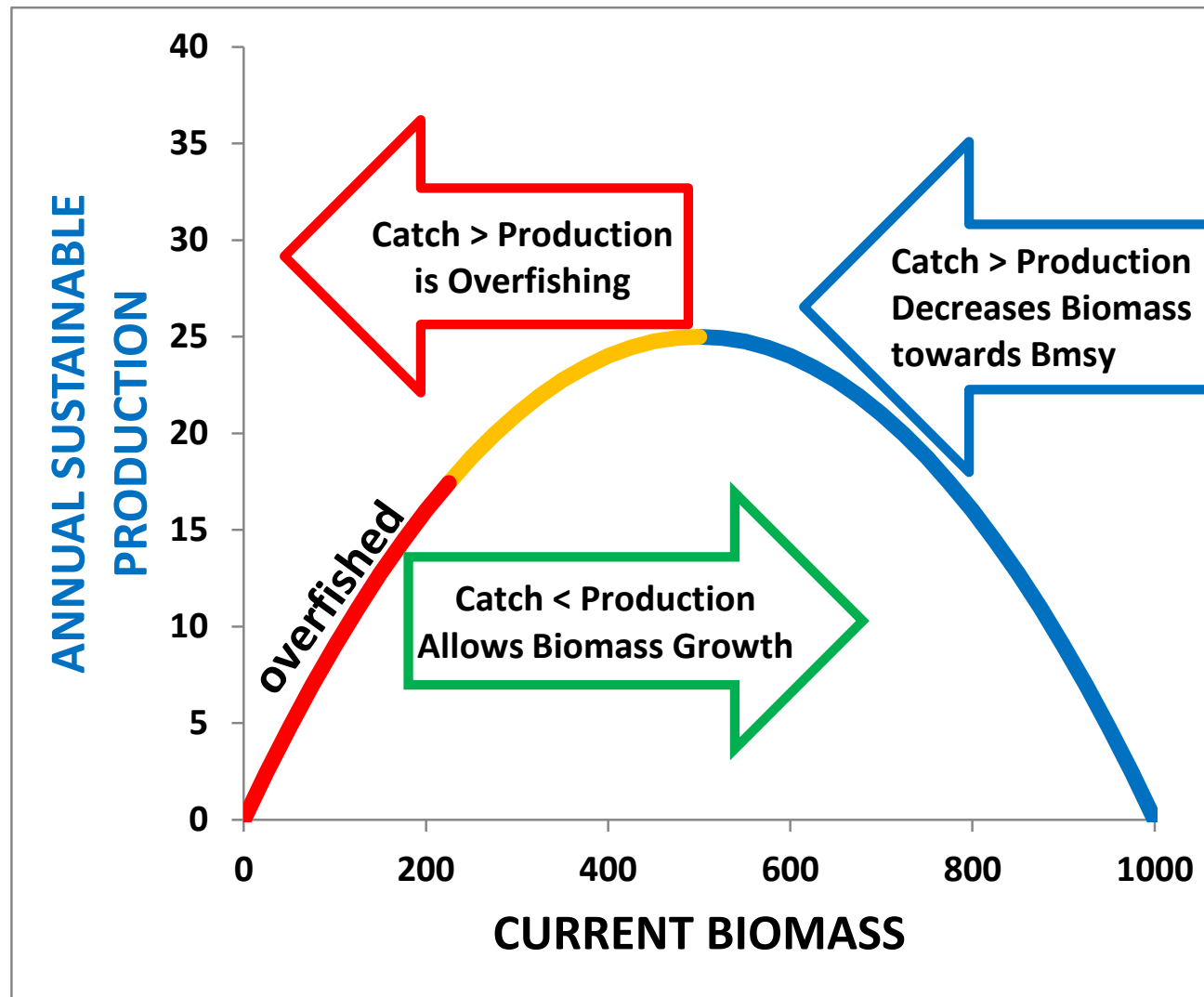
# Theory of Fishing



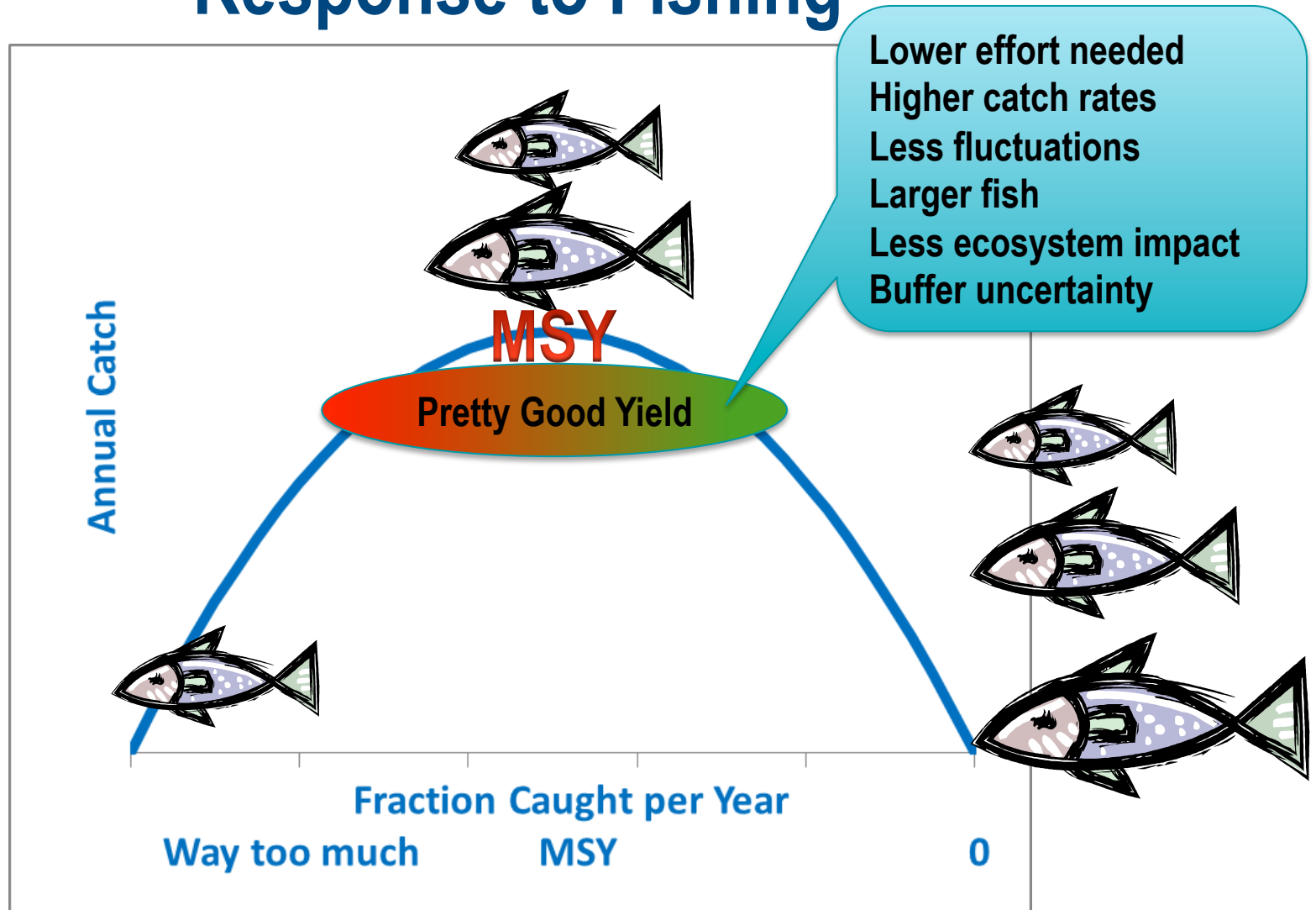
- Highly simplified
- Scale, level, and shape varies between species
- Stock assessments calibrate the production curve and measure the current biomass, all with some uncertainty
- Ecosystem and climate shift production curve over time
- MSY is useful theoretical limit, but not realistically attainable

Unfished,  
Carrying Capacity

# Fishery Production Concepts

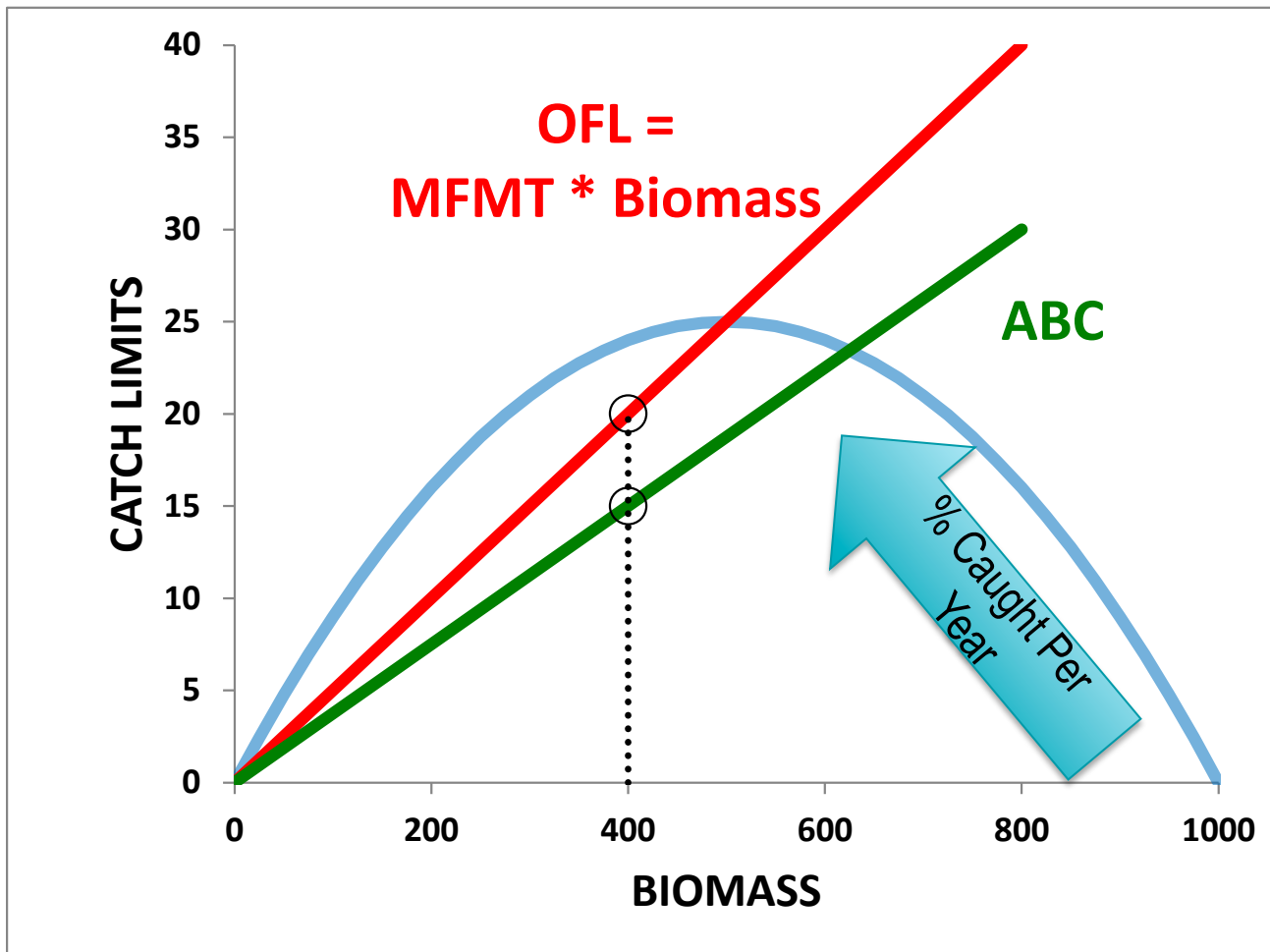


# Response to Fishing



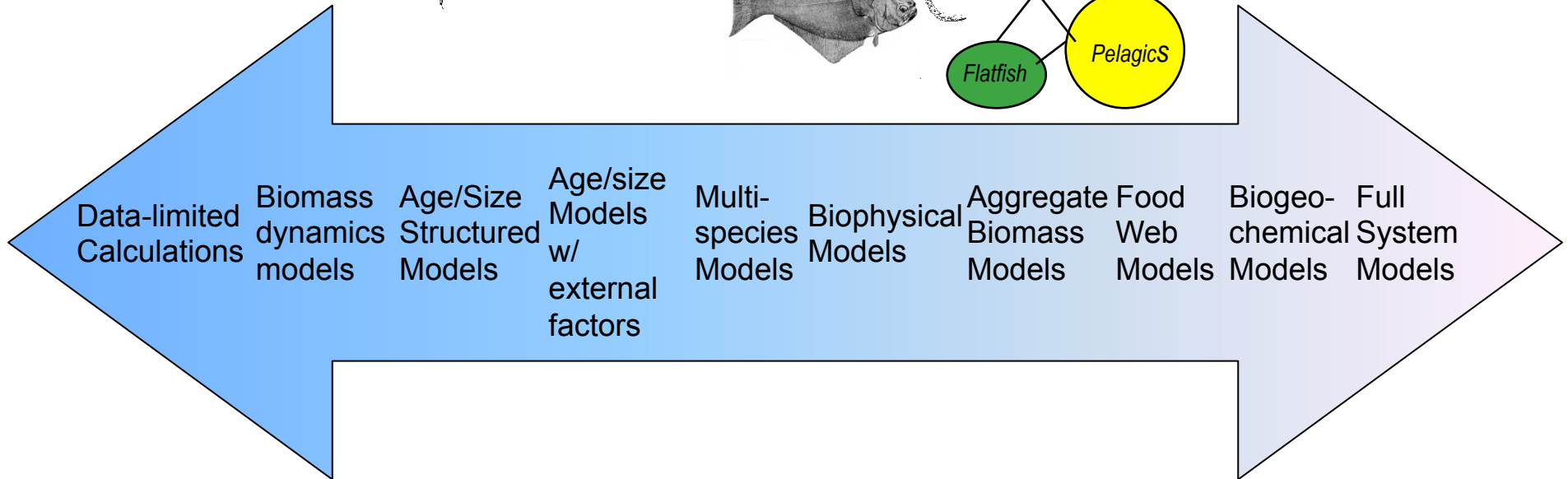
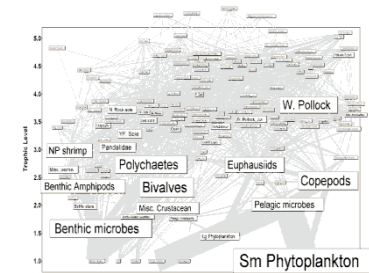
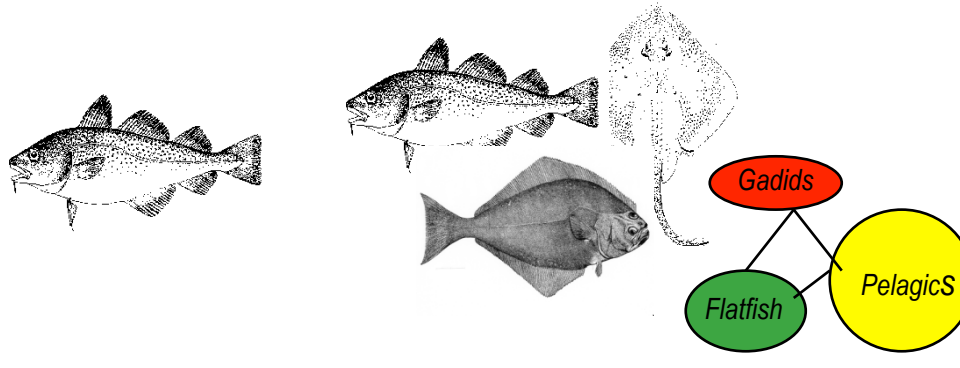
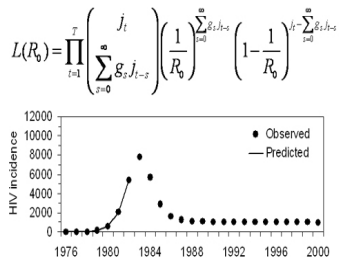


# Fishery Control Rules



- Updated stock assessment forecasts biomass for next fishing year
- Slope of control rule is  $F$ , the fishing rate,
- OFL control rule sets annual overfishing catch level
- ABC control rule is lower to account for uncertainty in assessment

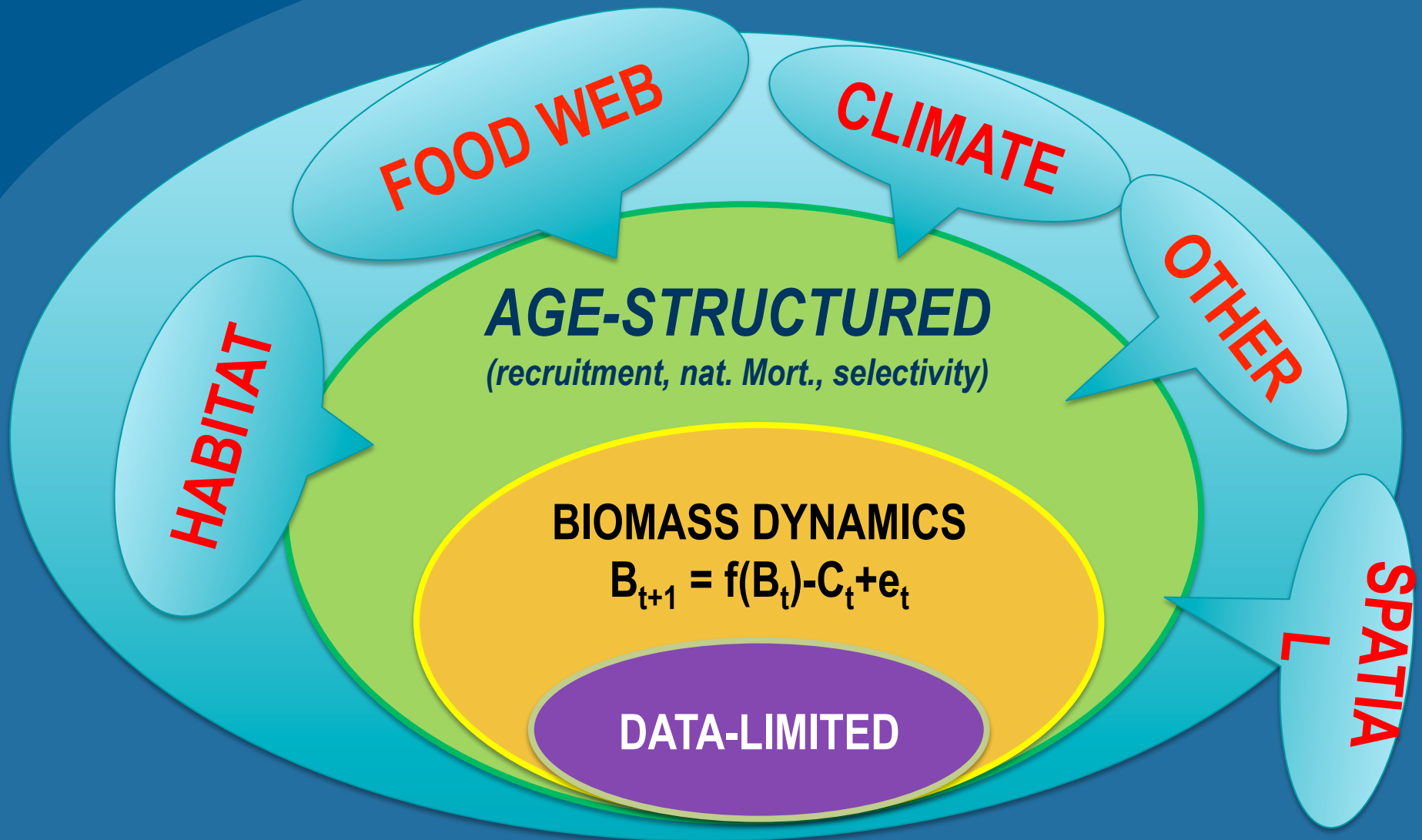
# Spectrum of Modeling



Stock Assessment/Single Species Models

Ecosystem Assessment/Multi-species model

# Onion of Model Simplifications

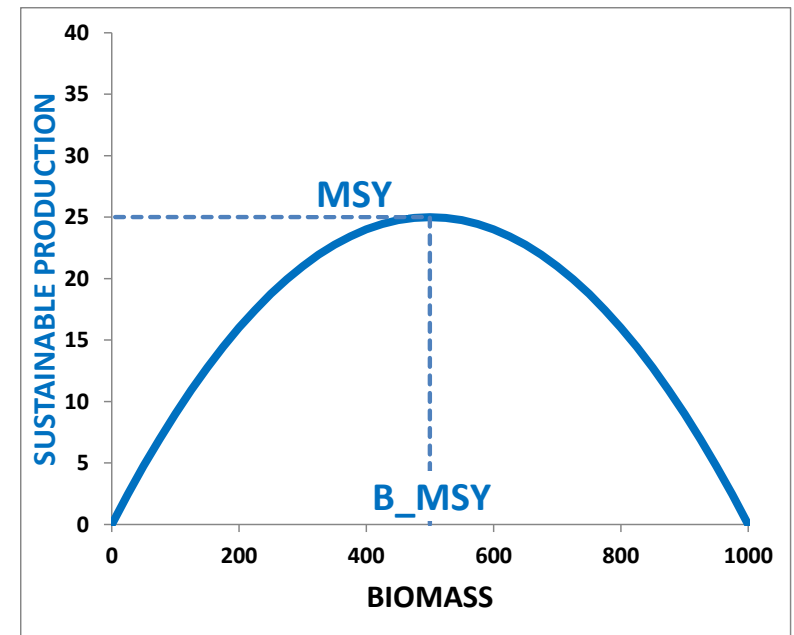


# Stock Assessment Models

- Data-Limited
  - Cumulative catch history
  - Current snapshot of stock status
- Biomass Dynamic
  - Based on catch history and an indicator of trends in total stock abundance
  - Can work well if age-structure factors minimal
- Age/Size-Structured
  - Built upon annual recruitment of young fish
  - Age-specific fishery impacts and survey observations

# Biomass Dynamics

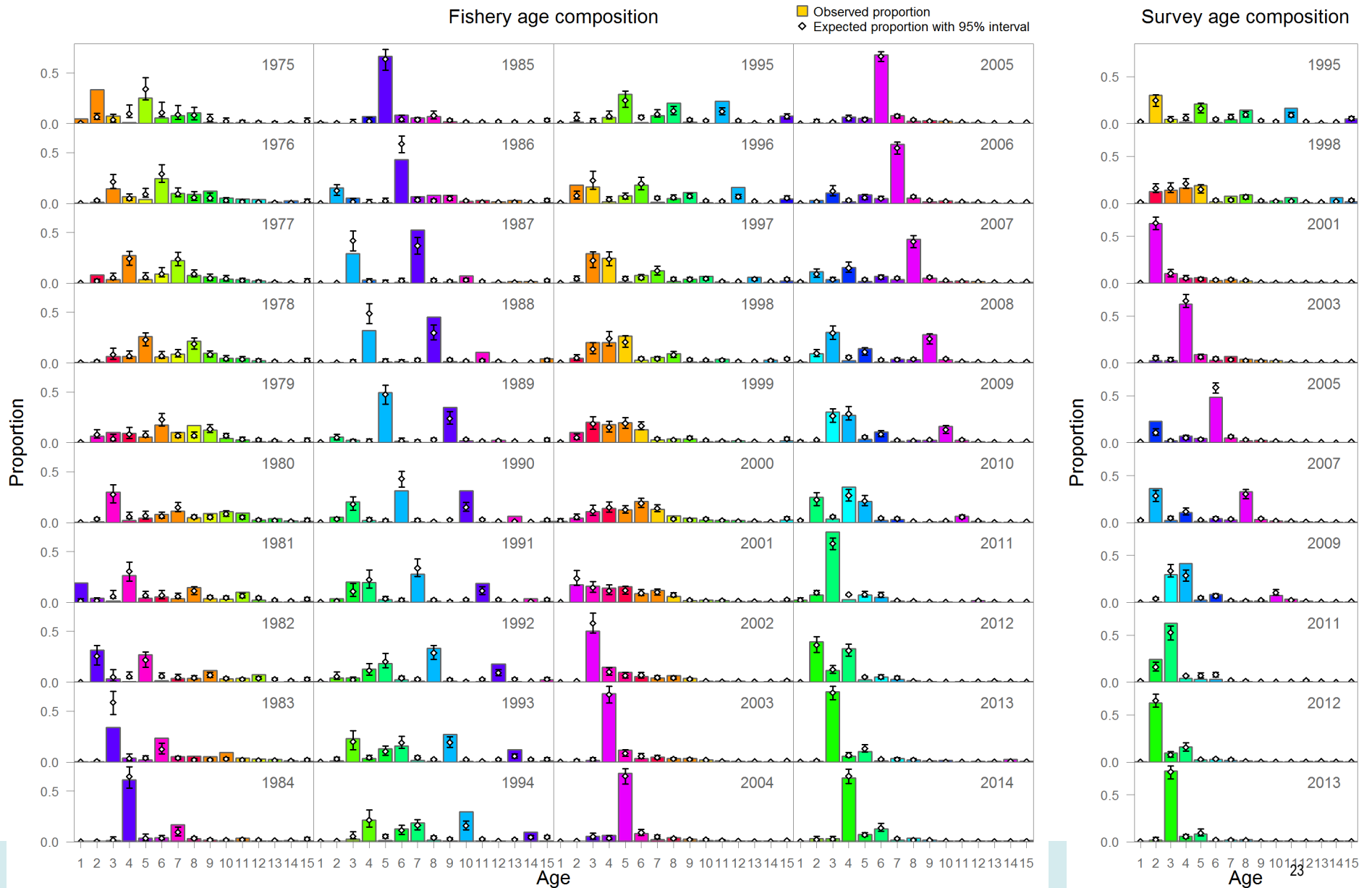
- $B_{t+1} = f(B_t) - C_t + e_t$
- Uses time series of Catch and an indicator of abundance (B)
- $f(B)$  generally 2-3 parameters
- $e_t$  can be treated as random effect
- Works fine if:
  - B indicator is good measure;
  - good contrast in B over time in response to changing levels of C, and
  - $\text{var}(e)$  is not too large



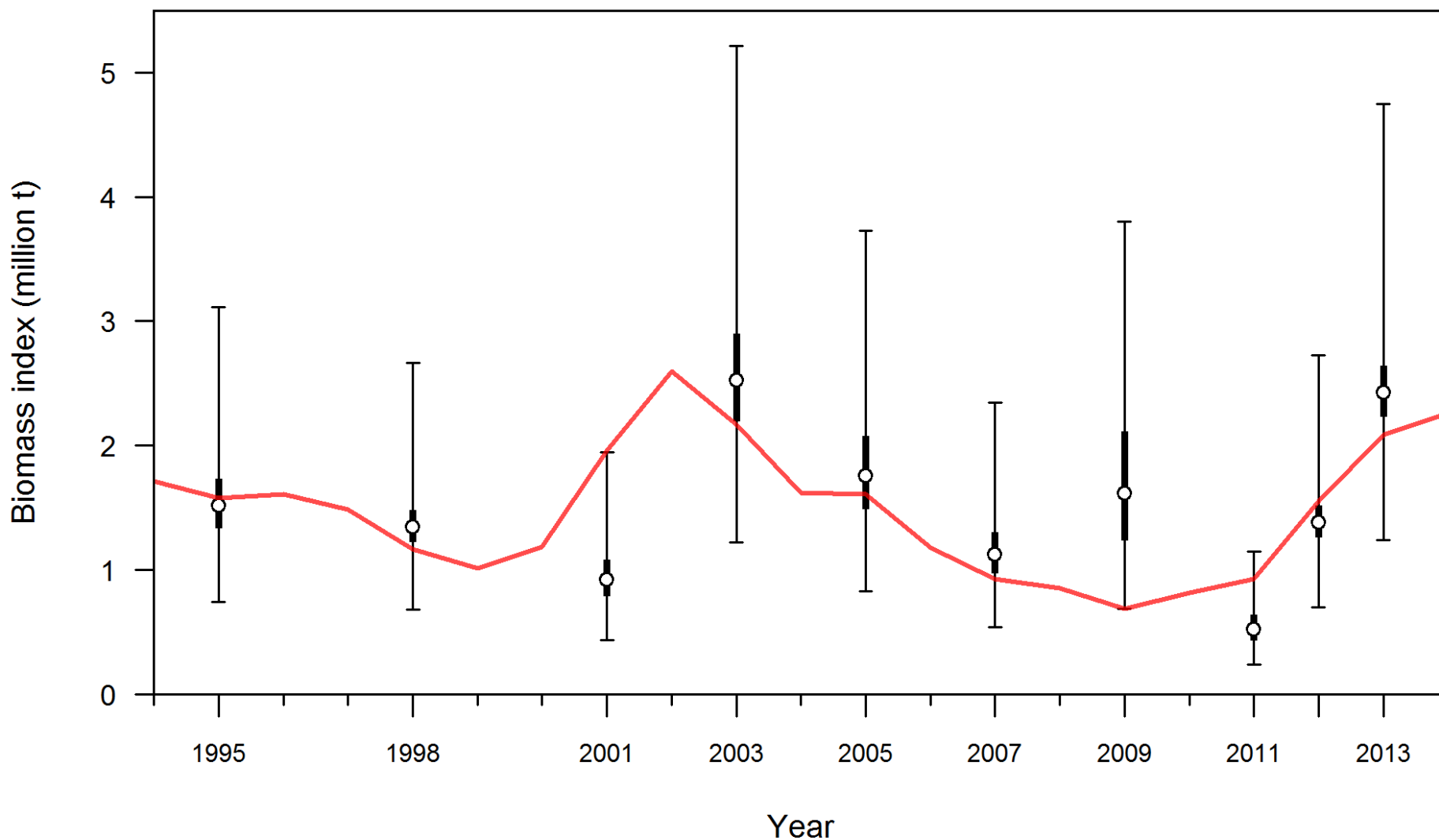
## Age-Structured Models

- Annual recruitment of young fish accounts for a lot of the var(e) from the biomass dynamics, so age-structured is better at forecasting changes;
- Explicit body size-at-age, natural mortality, age-specific vulnerability to fisheries and surveys;
- State-space, data-assimilation models;
- Minimize  $-\log(\text{Likelihood})$ ; often Bayesian;
- Iterative estimation of 10s to 100s of parameters

# Age composition – Pacific hake

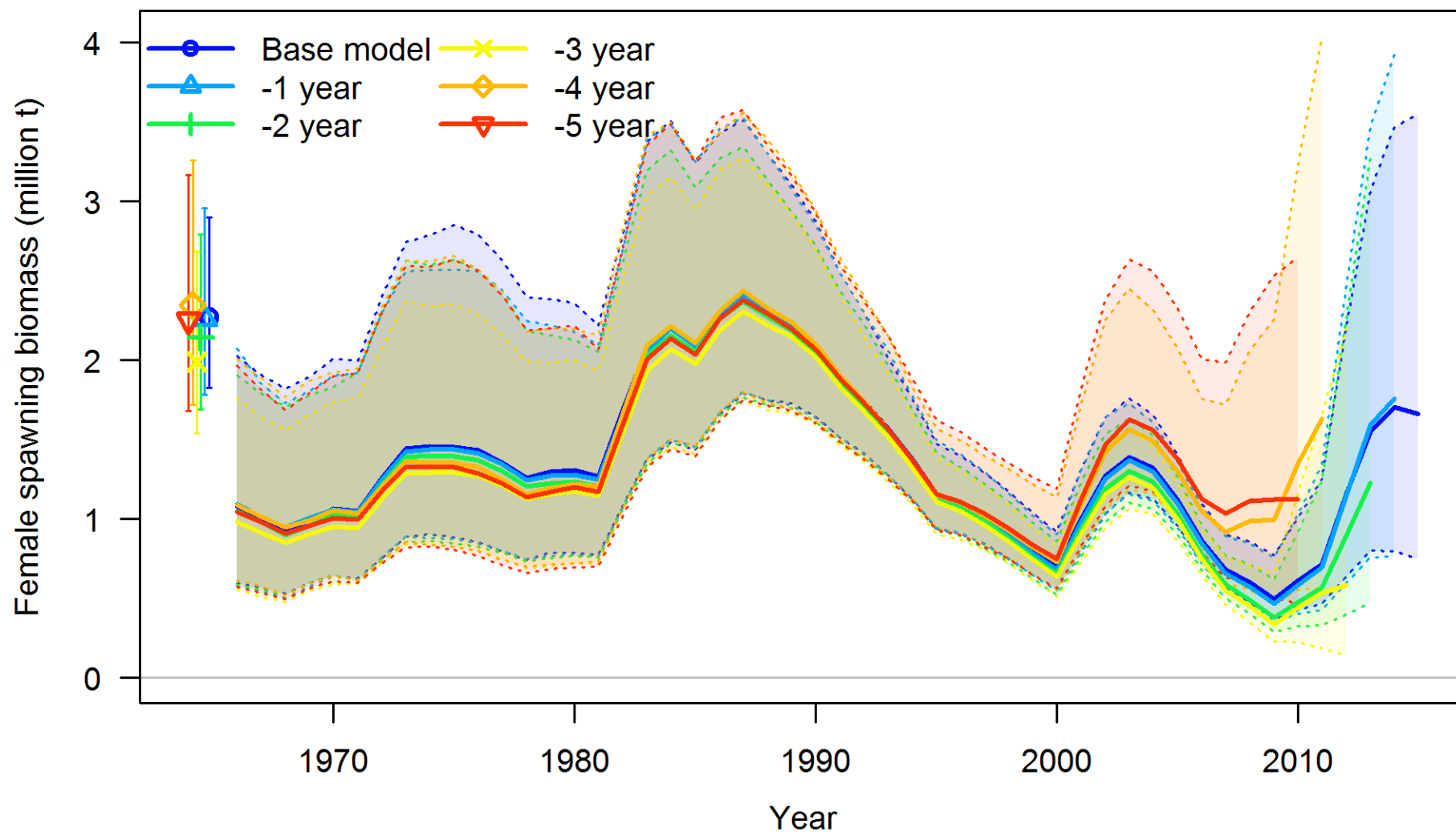


# Acoustic Survey Abundance

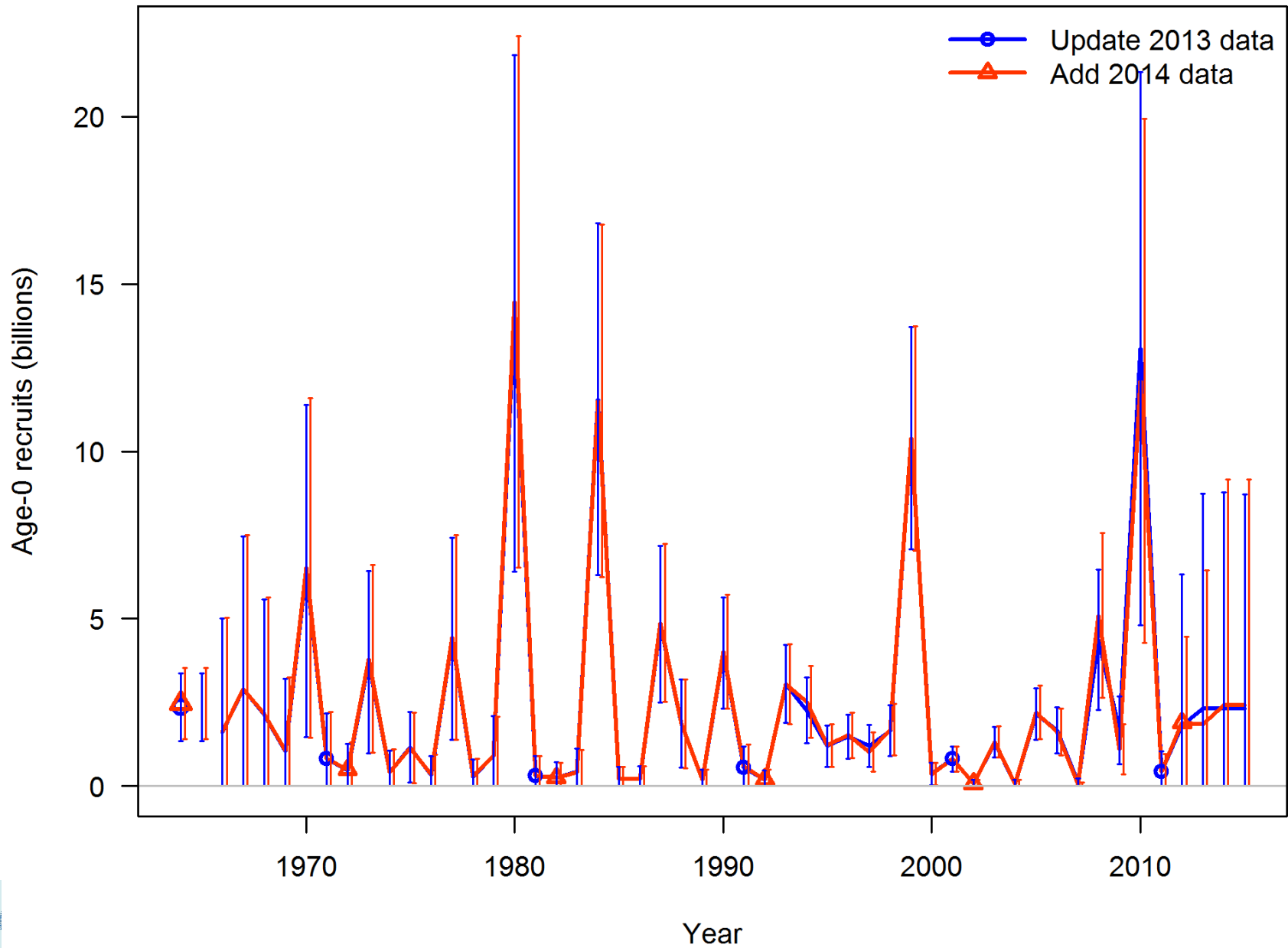




# Spawning Biomass

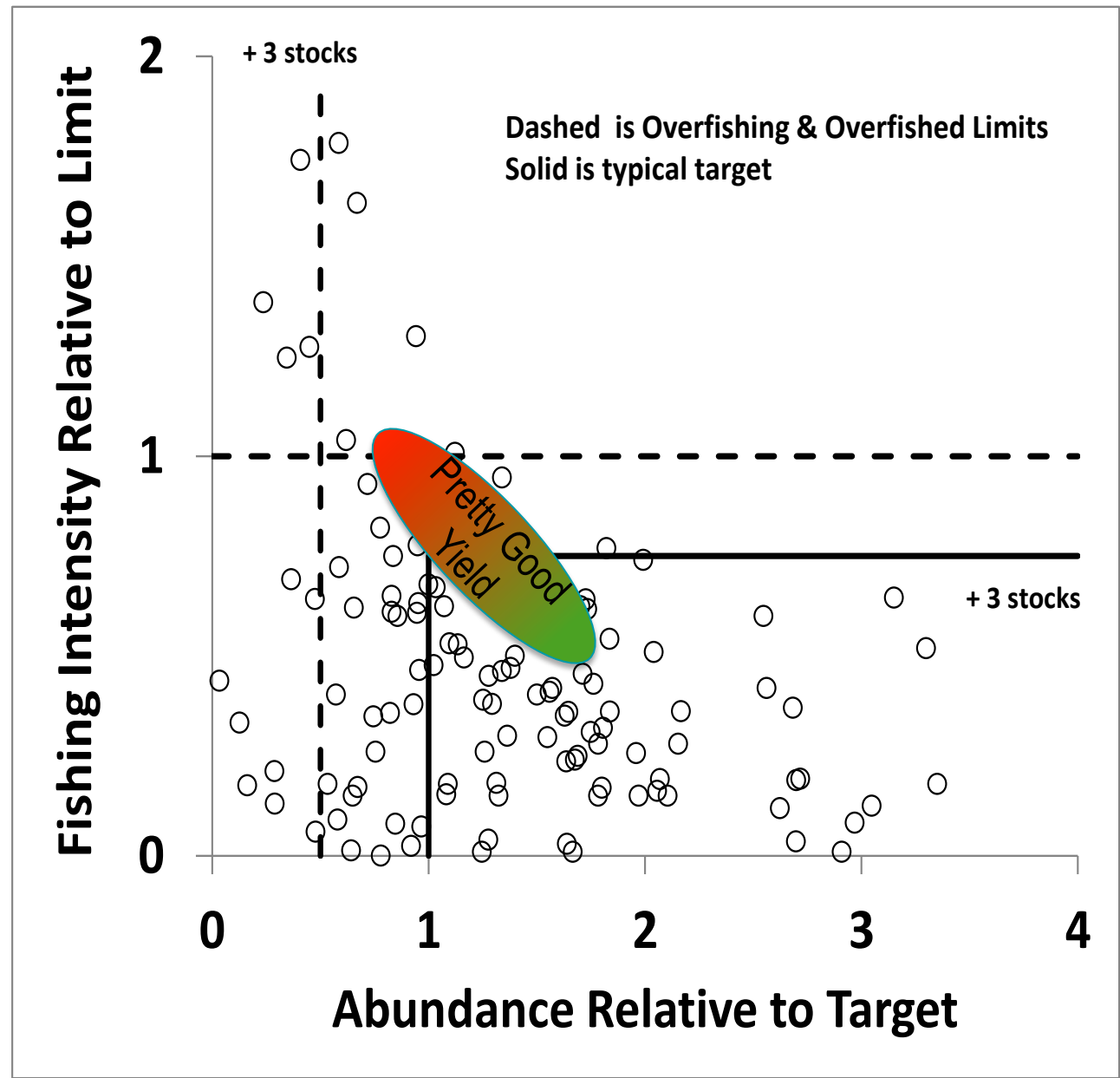


# Annual Recruitment



# How are we doing?:

## Status of 130 Assessed Stocks



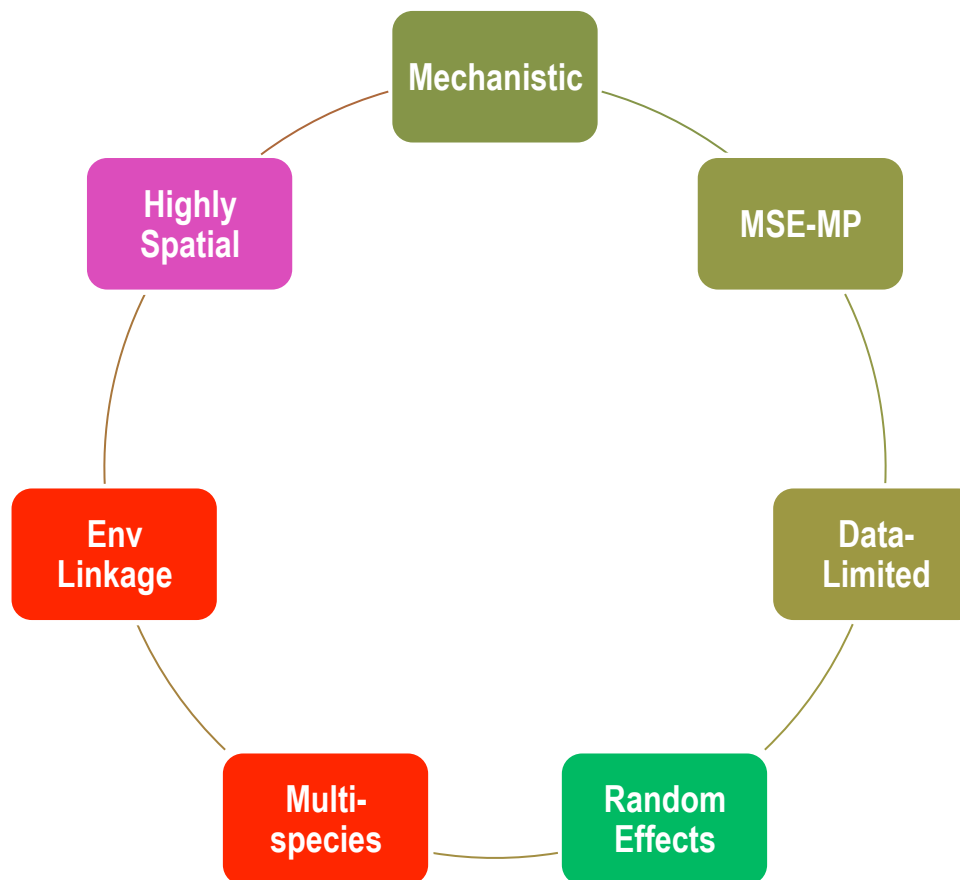
# Assessment Model Research Foci

- Highly mechanistic, detailed data, quasi-likelihood

- More than a few spatial cells

- Environmental influences on model processes

- Ecosystem linkages among species



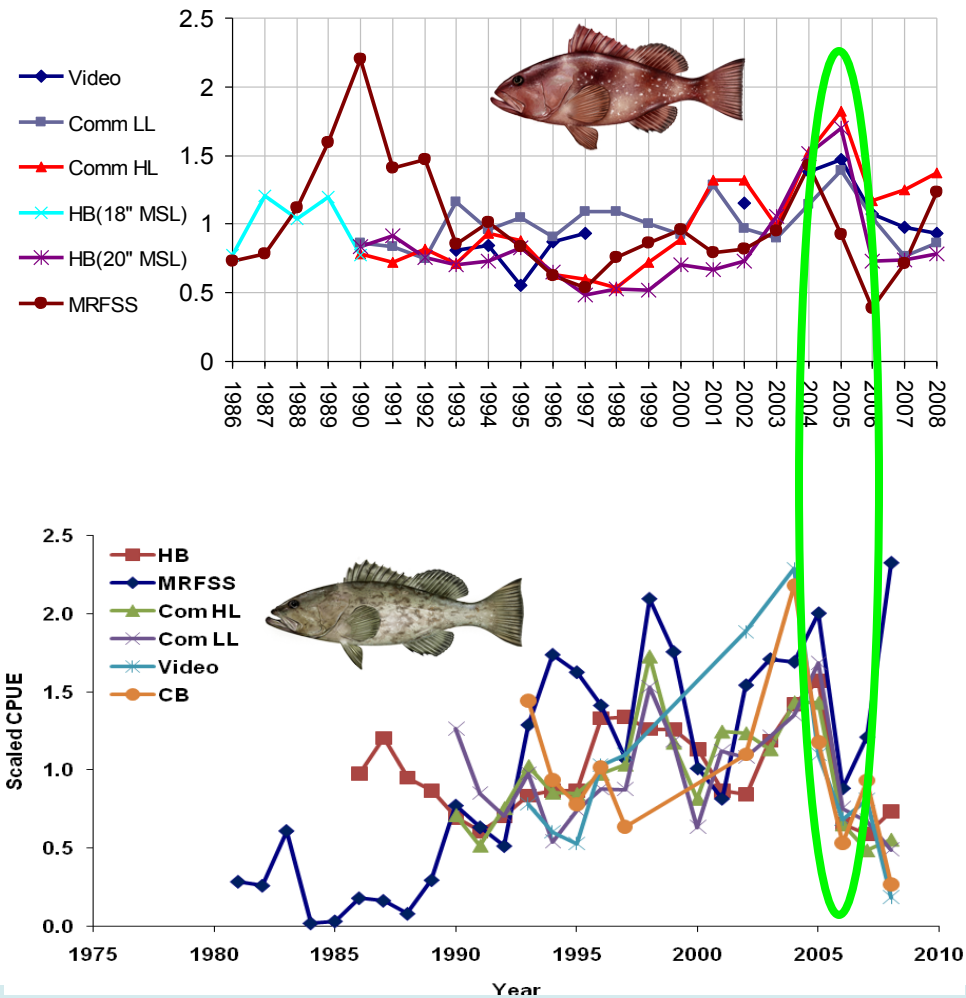
- MSE tested management procedure with simple data

- Data-limited

- Integration across random effects

# Environmental Effects

Observed decline in stock indicators with red tide in 2005  
 Incorporated in assessment model as modifier on natural mortality that year



## Message Recap

- Fish assessment models support regulatory actions: status determinations and quotas
- Models empirically focus on fish population dynamics; external drivers are implicit, not explicit
- Advances in knowledge of how ecosystem and environmental factors affect fish popdy allow explicit inclusion of an ever increasing number of factors