



**NOAA  
FISHERIES**

# Stock Assessments in Support of U.S. Fisheries

**Patrick D. Lynch**

National Stock Assessment Coordinator  
NOAA Fisheries Office of Science & Tech.  
Silver Spring, MD

**Richard D. Methot**

NOAA Senior Scientist for Stock Assessments  
Seattle, WA

## Objectives

- Describe the context for stock assessments in fisheries management
- Describe the assessment process and associated components of that process
- Complete a training exercise where you interpret scientific advice from stock assessments to make management decisions

# Presentation Outline



- **Mandate for Stock Assessments**



- **Supporting Fishery Management Plans**



- **Stock Assessment Process**



- **Harvest Control Rules**



# Mandate for Stock Assessments



## Magnuson-Stevens Act (MSA)

- The MSA does not explicitly mandate assessments  
(In contrast to the MMPA)



## However,

- MSA language *implies* that assessments are necessary



# Mandate for Stock Assessments

## MSA: National Standards 1, 2, 3

**NS1**

- “...prevent overfishing while achieving...optimum yield”

**NS2**

- “...best scientific information available”

**NS3**

- “...an individual stock ...shall be managed as a unit throughout its range”

# Mandate for Stock Assessments

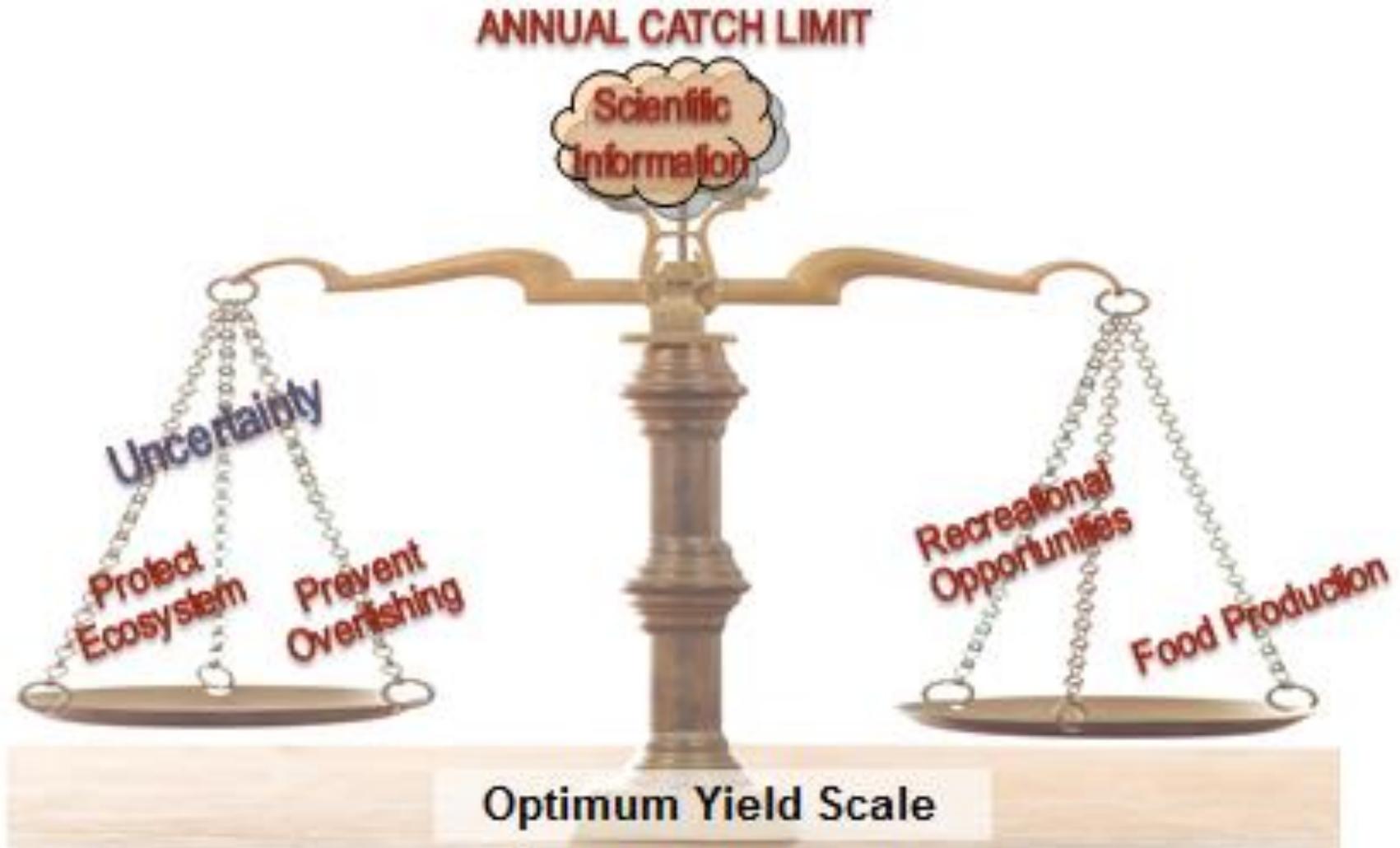
## MSA: Fishery Management Plans

*“...annual catch limits...such that overfishing does not occur...including measures to ensure accountability.”*

*“...objective and measurable criteria for identifying when the fishery ... is overfished...related to reproductive potential of stock”*

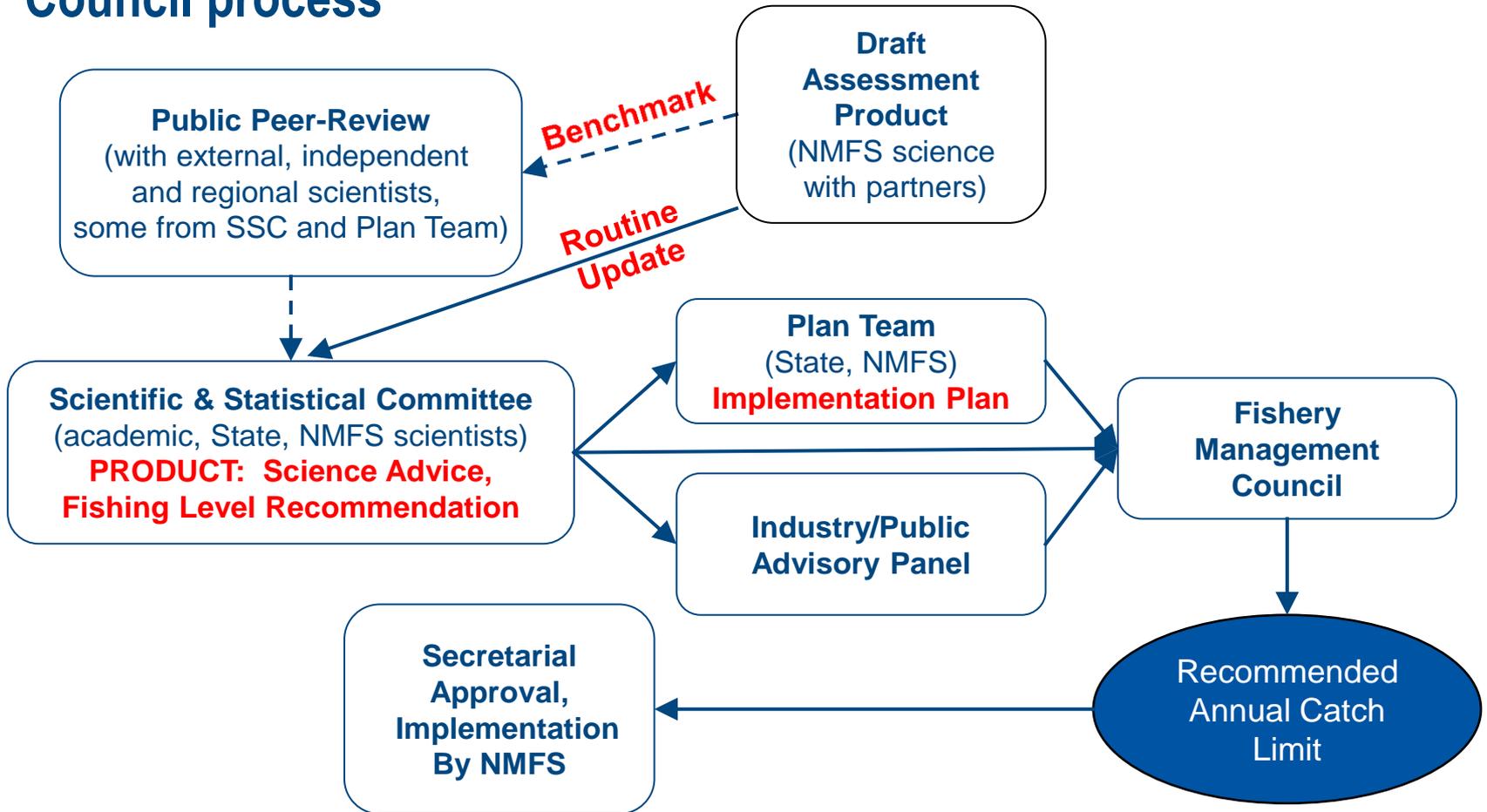
*...ACLs may not exceed Scientific and Statistical Committee’s fishing level recommendation...based on best scientific information available”*

# Mandate for Stock Assessments



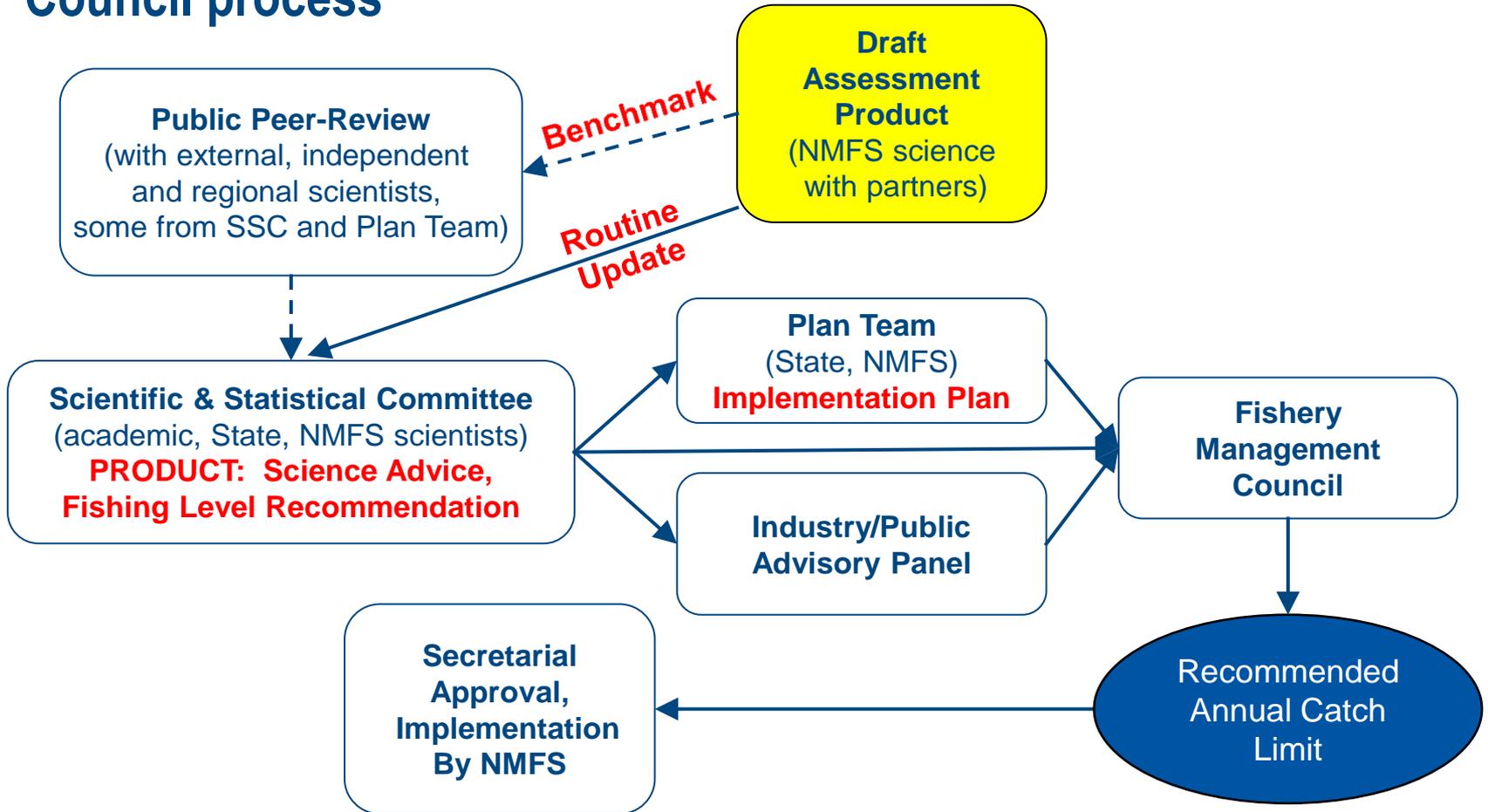
# Supporting Fishery Management Plans

NMFS stock assessments: a collaborative effort that supports the Council process



# Supporting Fishery Management Plans

NMFS stock assessments: a collaborative effort that supports the Council process



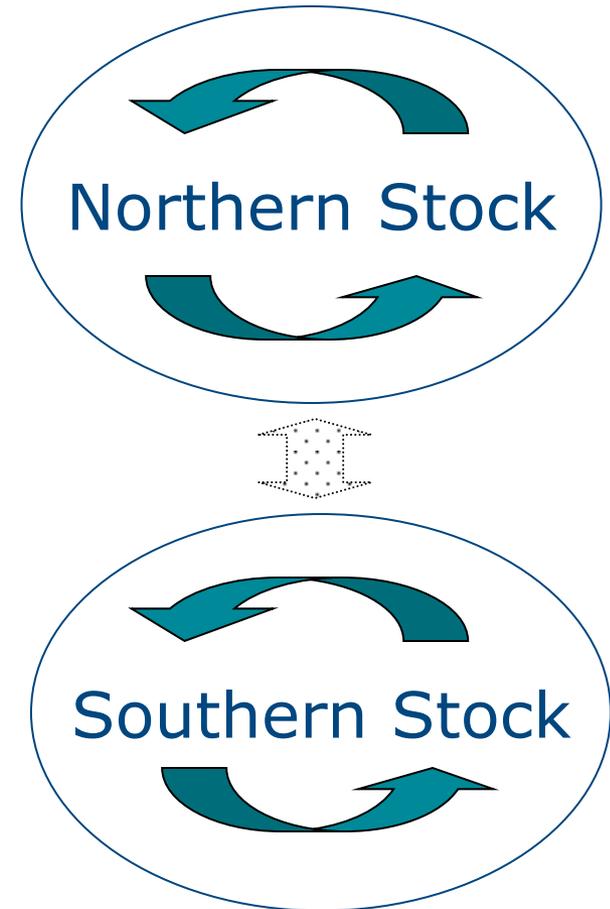
# What is a “Stock”?

## A biological stock

- Group of individuals of the same species
- That inhabit the same geographic region
- That mix and interbreed when mature

## A management stock

- Often a biological stock
- Sometimes not:
  - Multispecies complex
  - Geopolitical boundaries



# What is a Stock Assessment?

The process of collecting, analyzing, and reporting demographic information to determine the effects of fishing (and other drivers) on fish populations and, to the extent possible, predict future catch and stock status.

# Stock Assessment Process

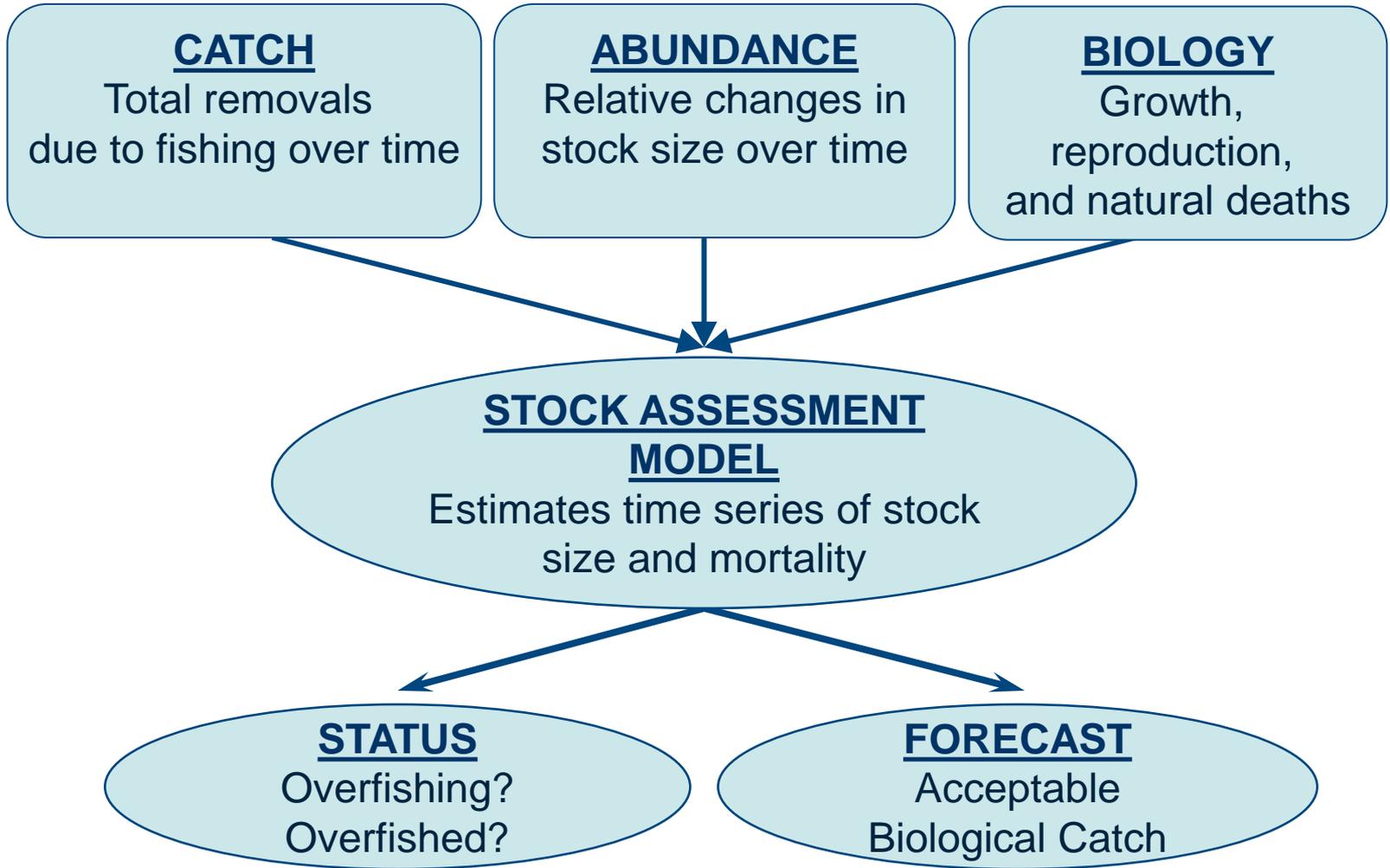
**Data collection &  
processing (DCP)**

**Stock Assessment  
Modeling (SAM)**

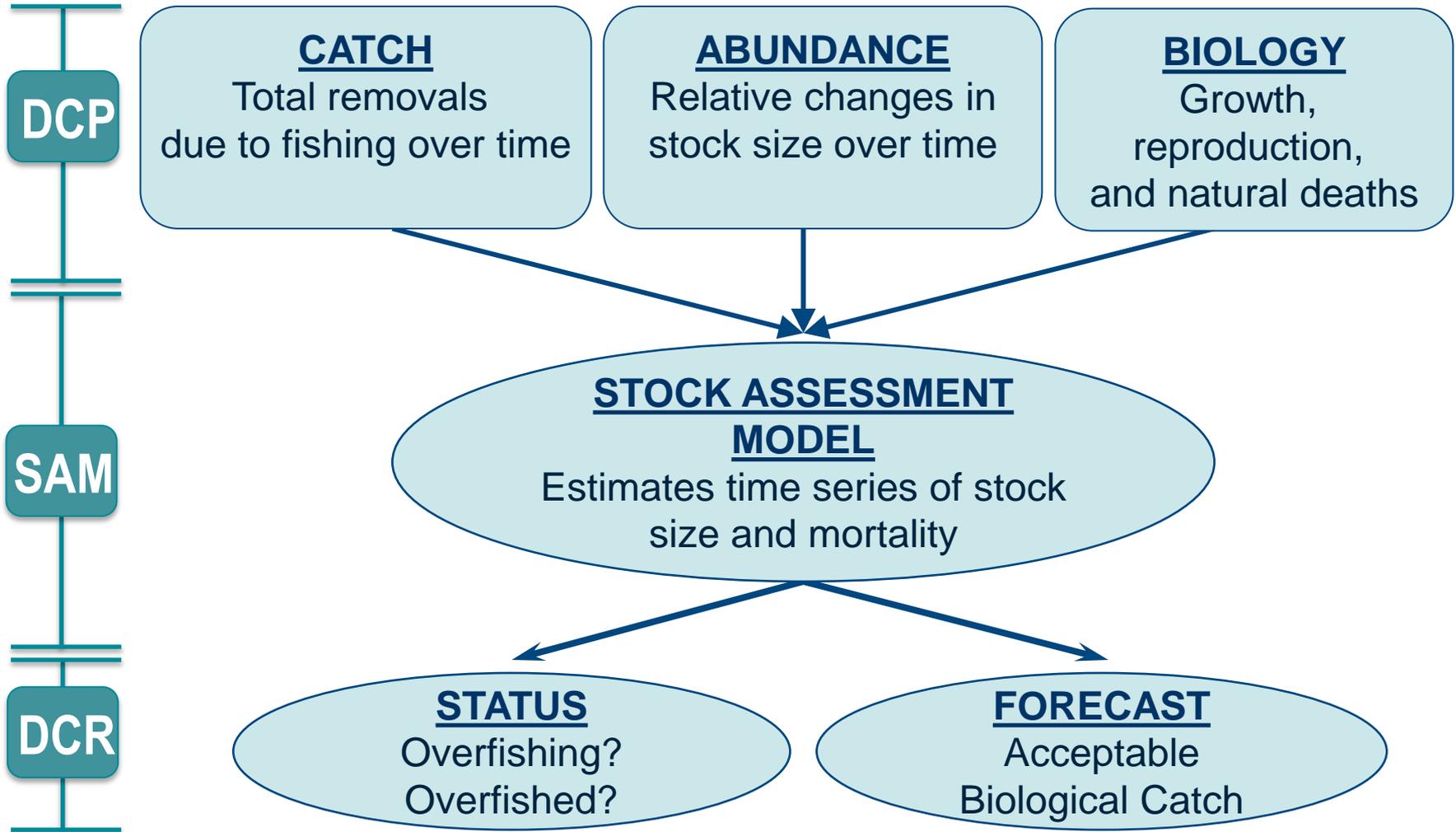
**Developing &  
Communicating  
Recommendations  
(DCR)**



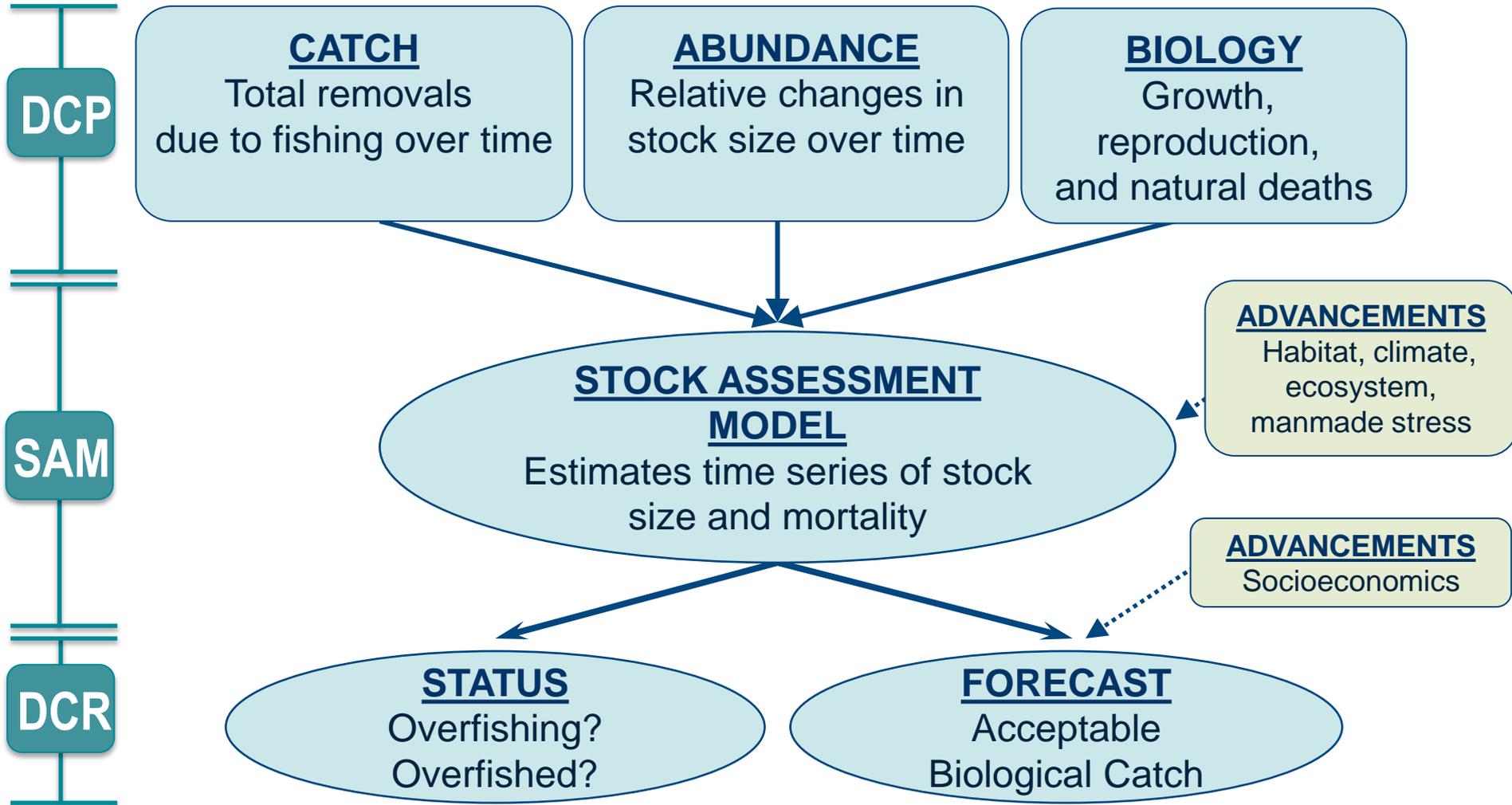
# Stock Assessment Process



# Stock Assessment Process



# Stock Assessment Process



# Stock Assessment Process

## Data Collection & Processing: historical to present

### Catch

- Commercial landings
- Recreational landings
- Commercial/recreational discards & releases (% survival)
- Research removals

### Catch Data Sources

- Fishery Information Networks (state-federal-commission)
- Fishery statistics
- Observer programs
- Marine Recreational Information Program

# Stock Assessment Process

## Data Collection & Processing: historical to present

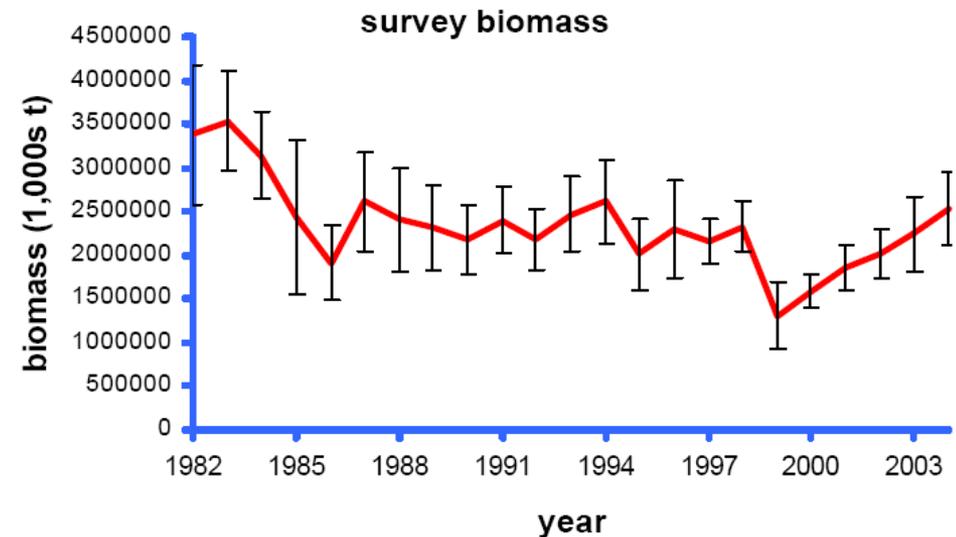
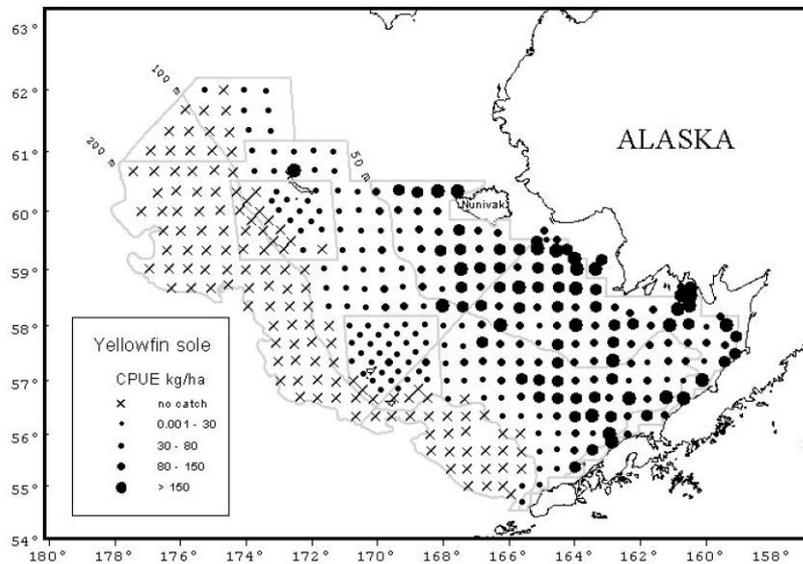
### Abundance

- Fishery-independent: scientific surveys
  - Statistical sampling design (minimize bias)
  - Full stock range (even low density areas)
  - Standardized gear and practices
- Fishery-dependent: commercial/recreational catch per unit of effort (CPUE)
  - May not reflect abundance — market dynamics and changing practices

### Survey Methods (NOAA & charters)

- Extractive: trawl, longline, hook and line, pot, seine, gill net, dredge, etc.
- Non-extractive: acoustic, picture/video, aerial, diving, tag and release, etc.

# Extractive Example: Bering Sea bottom trawl survey



- Fish counted & measured at 100s of sites per year

- Average biomass (w/error) for each survey year

- Multiple stocks sampled simultaneously
- Other regions w/ similar surveys: NE, Gulf of AK, Pacific coast, Gulf of Mexico

# Non-extractive Example: Northeast Scallop Survey



- **Advanced sampling technology**
  - Towed camera system
  - Automated recognition software for abundance estimates
  - Non-lethal, hence no samples for biological measurements
- **Similar techniques being tested and applied across regions**

# Stock Assessment Process

## Data Collection & Processing: historical to present

### Biology

- Age, Length, Weight, Maturity, Fecundity, Natural Mortality
- Diverse characteristics across stocks

### Biology Data Sources

- Scientific surveys
- Observer programs
- Port sampling
- Research & tagging studies

# Which of these is NOT a Critical Assessment Data Component?

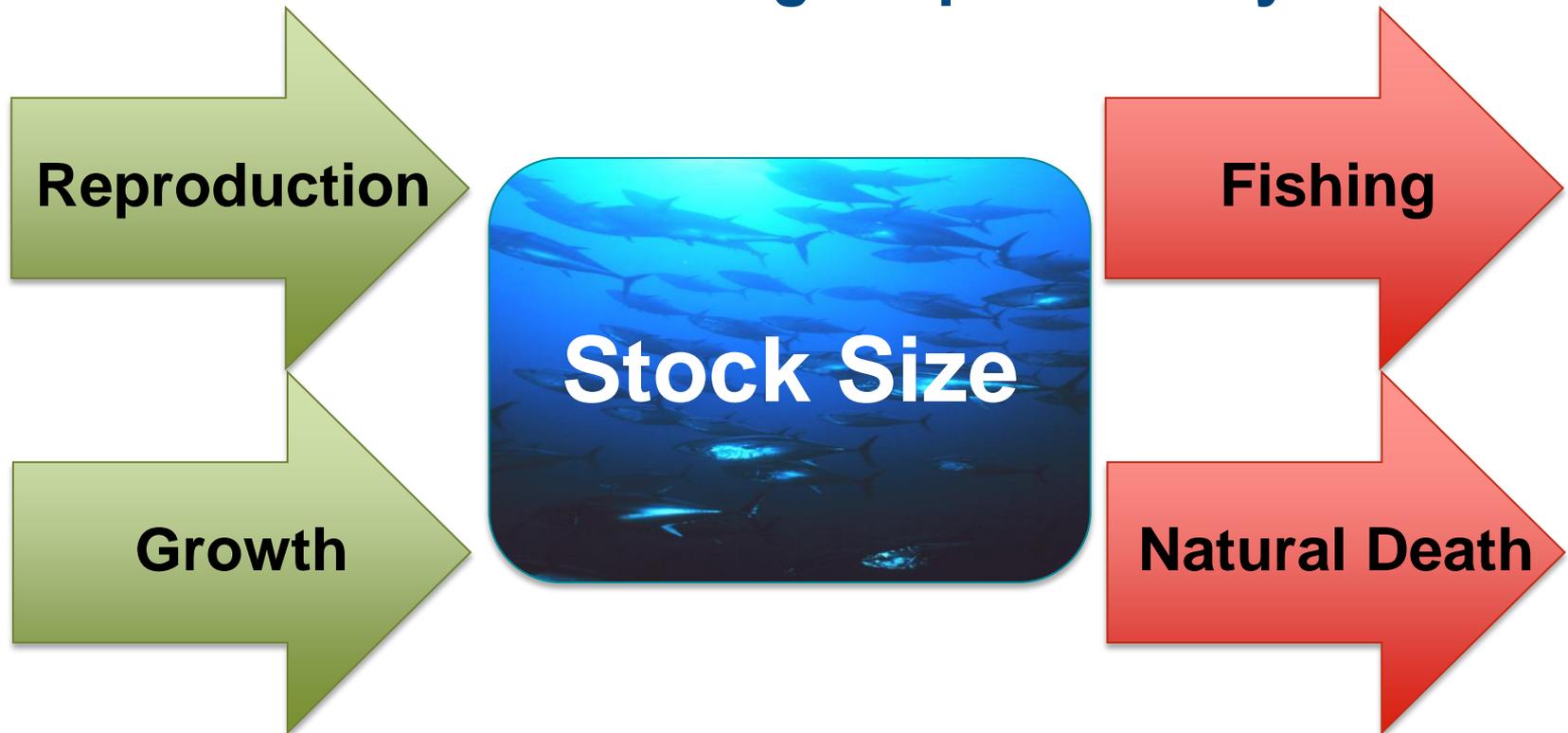
- Catch
- Environmental data
- Abundance survey
- Fish Biology

# Which of these is NOT a Critical Assessment Data Component?

- Catch
- Environmental data
- Abundance survey
- Fish Biology

# Stock Assessment Process

## Stock Assessment Modeling: Population dynamics



# Stock Assessment Process

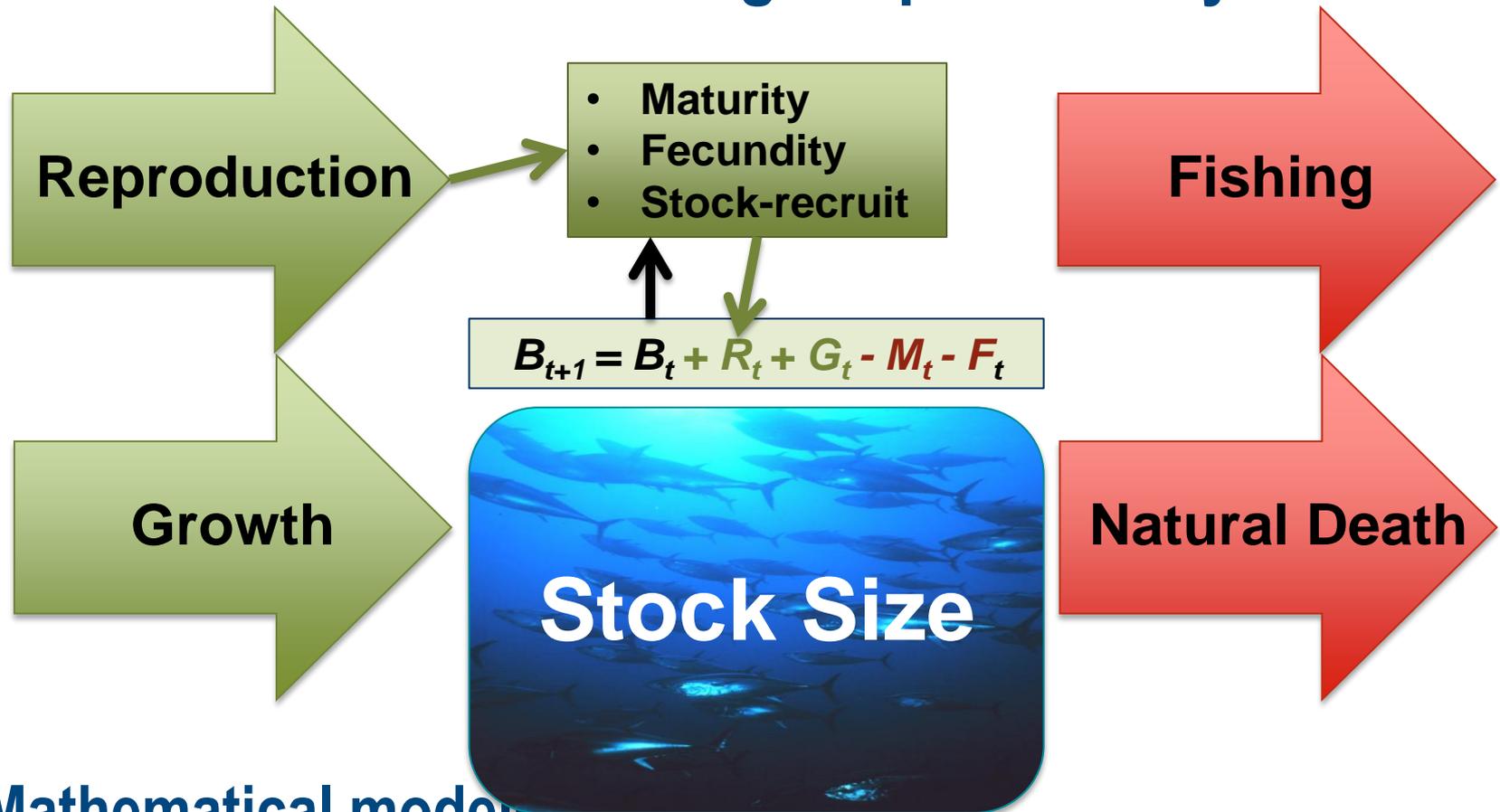
## Stock Assessment Modeling: Population dynamics



- **Mathematical models**

# Stock Assessment Process

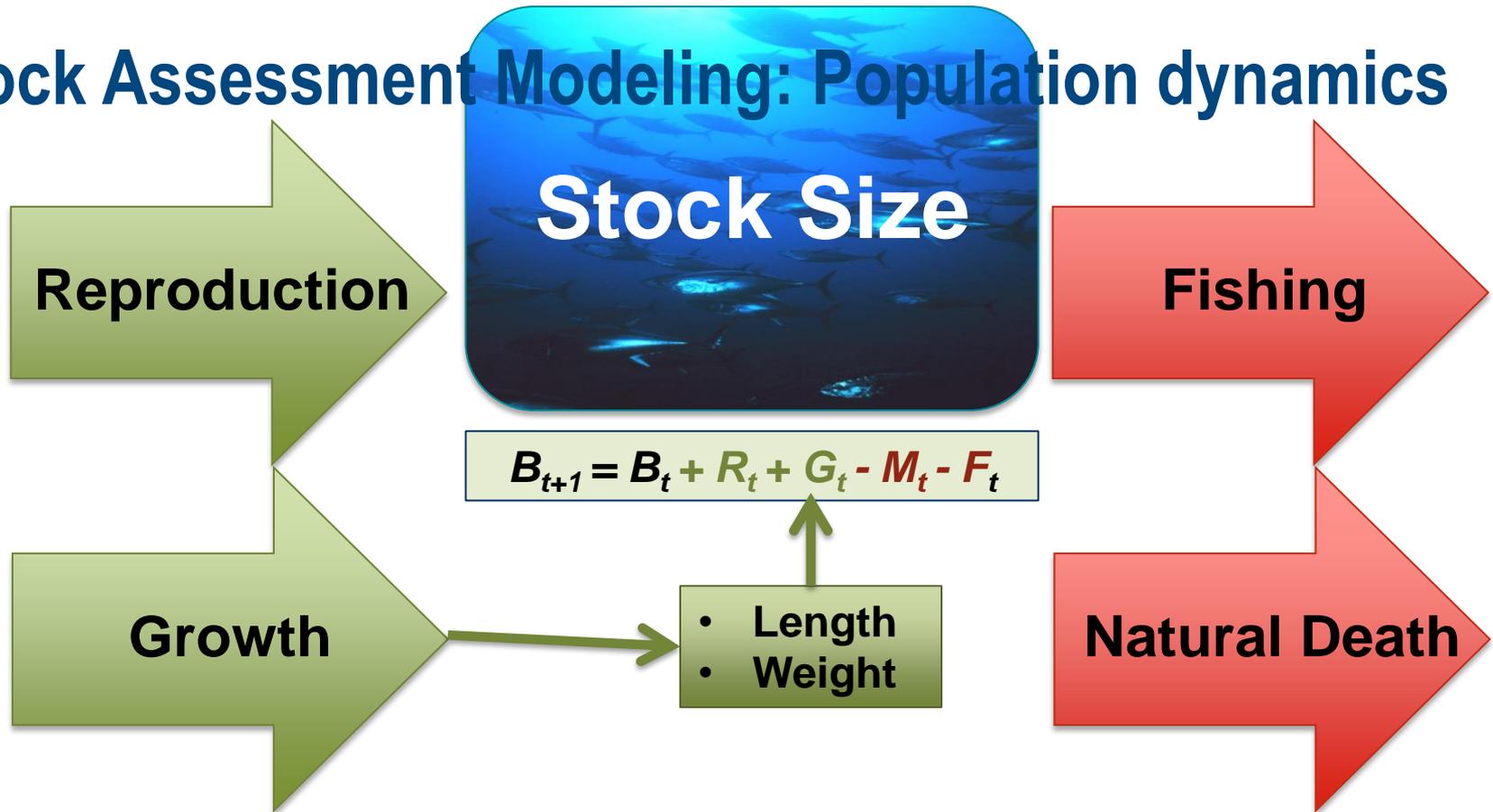
## Stock Assessment Modeling: Population dynamics



- Mathematical models

# Stock Assessment Process

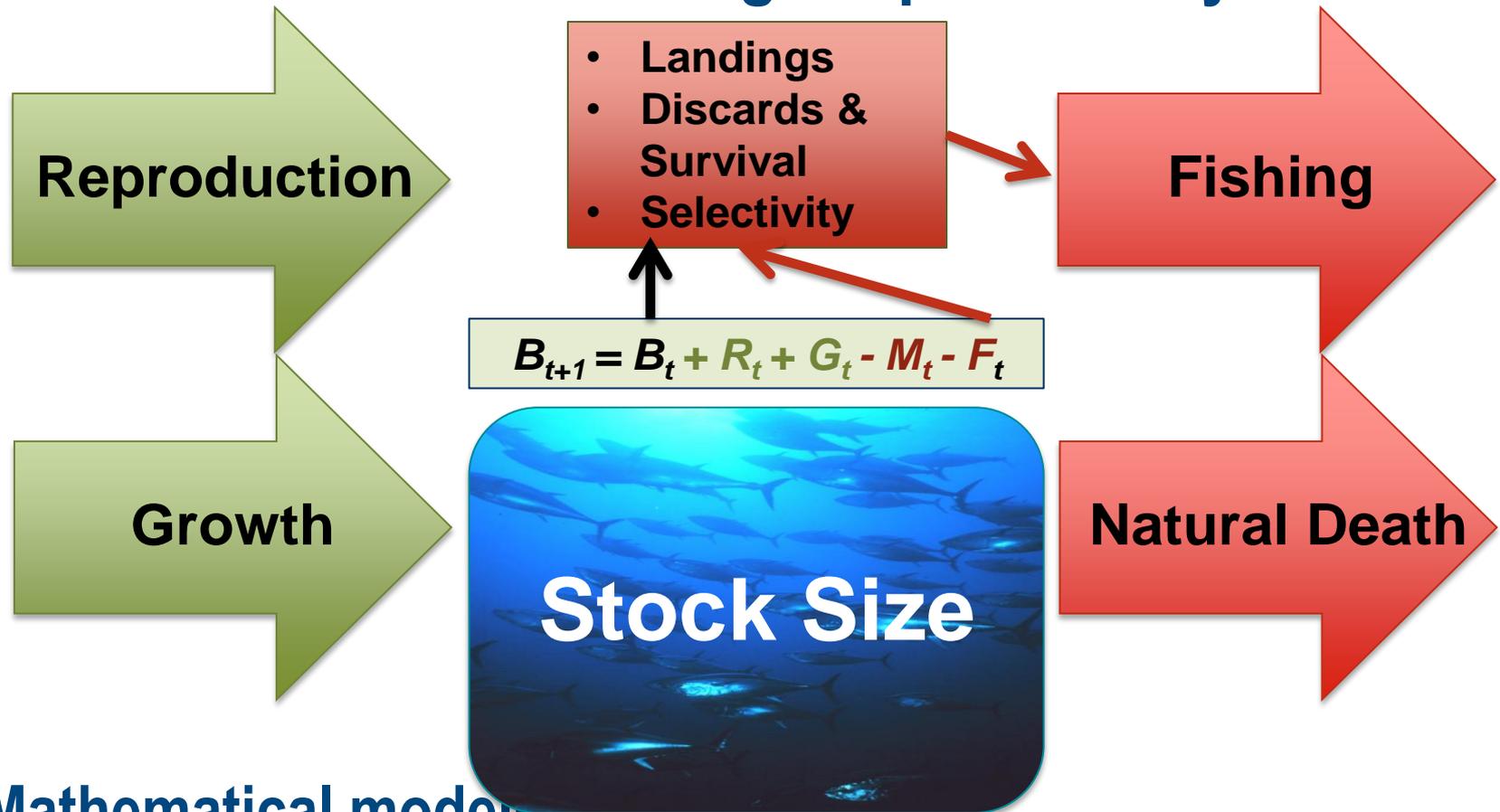
## Stock Assessment Modeling: Population dynamics



- Mathematical models

# Stock Assessment Process

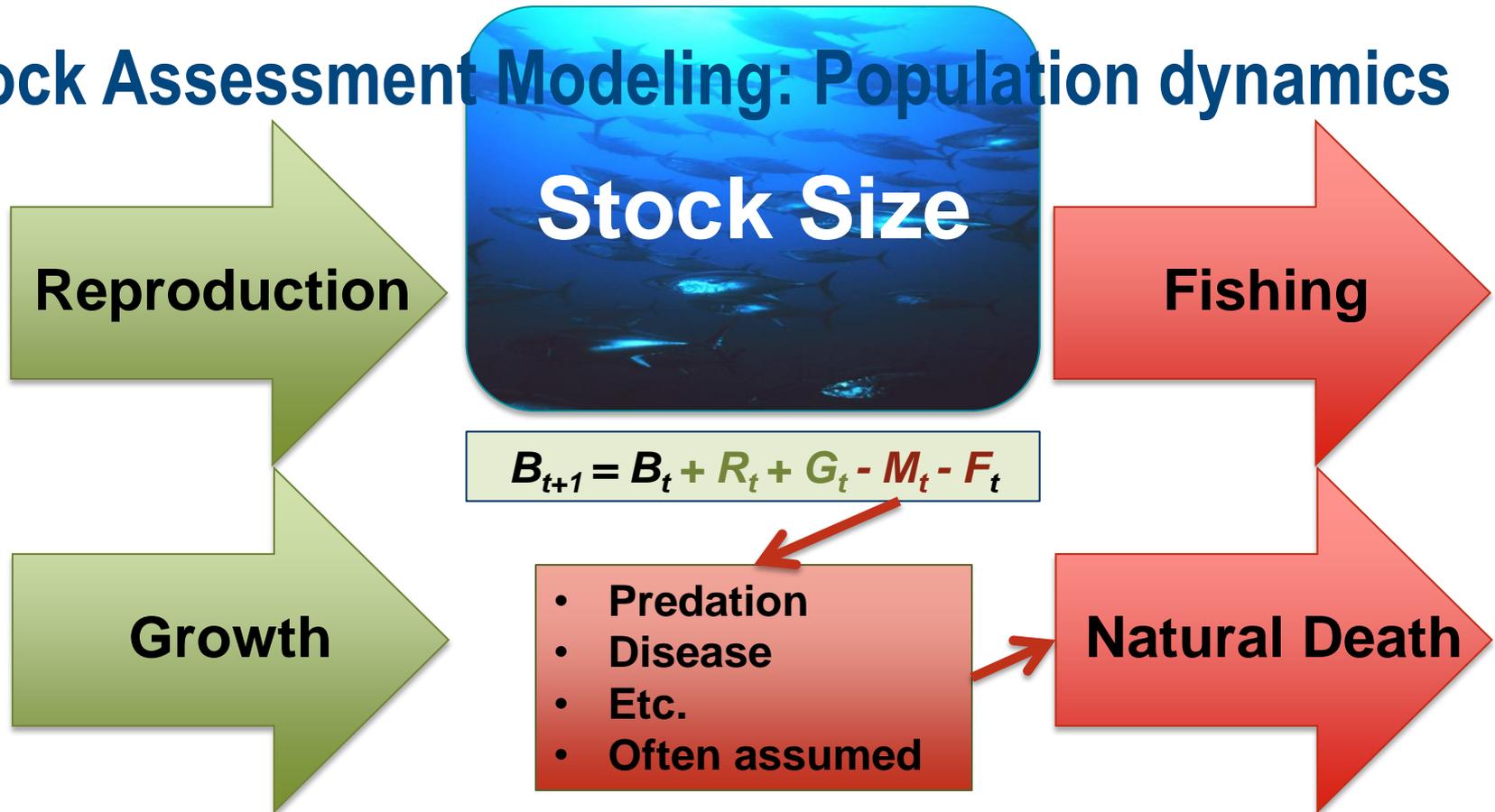
## Stock Assessment Modeling: Population dynamics



- Mathematical models

# Stock Assessment Process

## Stock Assessment Modeling: Population dynamics



- **Mathematical models**

# Stock Assessment Process

## Stock Assessment Modeling: Statistics



- Observations, estimation, & forecasts

# Stock Assessment Process

## Stock Assessment Modeling: Statistics



- Observations (data): landings & discards (LD)

# Stock Assessment Process

## Stock Assessment Modeling: Statistics



- Observations (data): landings & discards (LD), index of abundance (IA)

# Stock Assessment Process

## Stock Assessment Modeling: Statistics



- Observations (data): landings & discards (LD), index of abundance (IA), biology (B)

# Stock Assessment Process

## Stock Assessment Modeling: Statistics



- Observations (data): landings & discards (LD), index of abundance (IA), biology (B)

# Stock Assessment Process

## Stock Assessment Modeling: Statistics



- Estimation: observations compared with model predictions
  - Identify dynamics that best represent patterns in data

# Stock Assessment Process

## Stock Assessment Modeling: Statistics

- Forecasts: use model(s) & knowledge about the future to project dynamics and identify sustainable practices

"It's hard to make predictions, especially about the future."

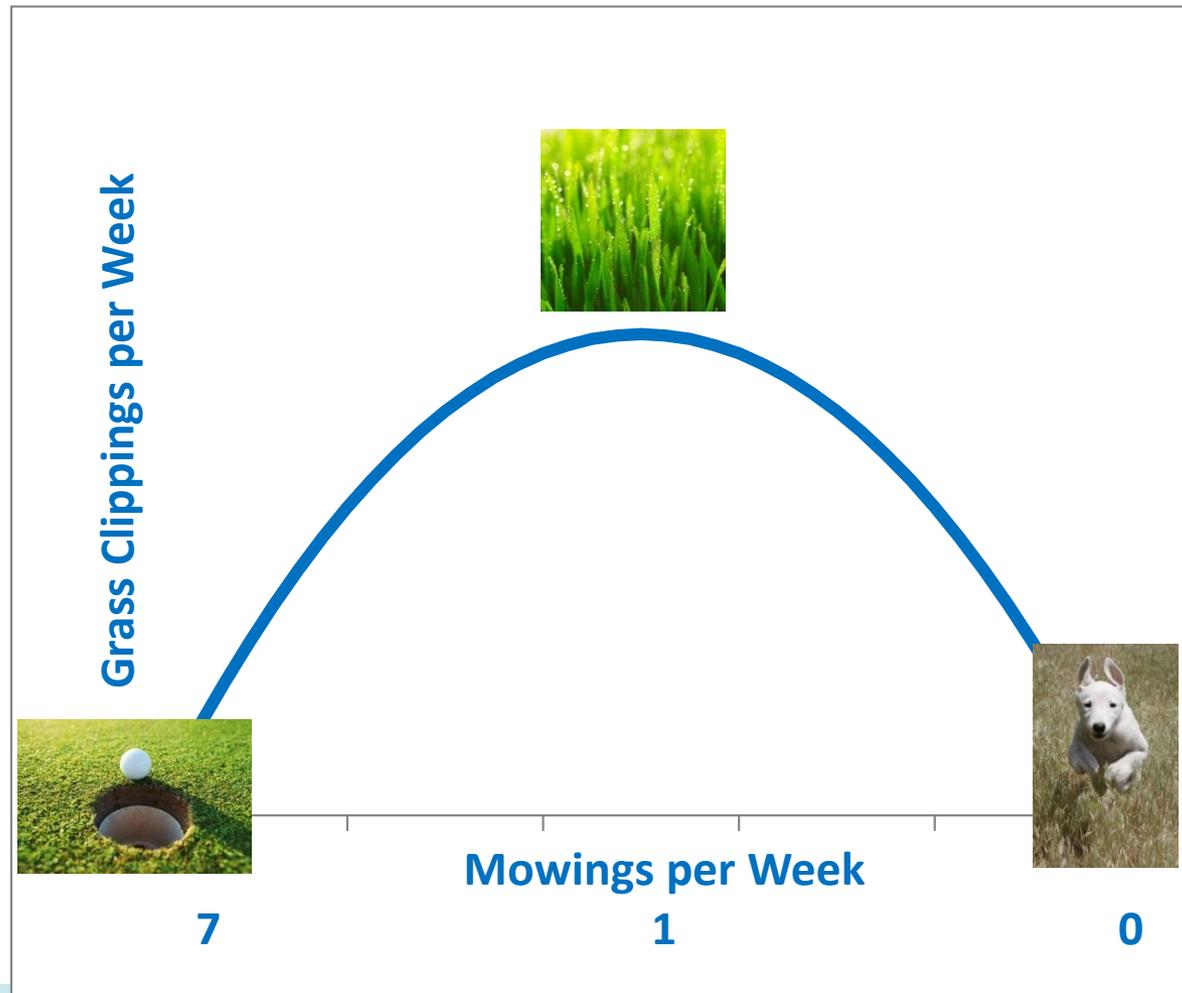


*Yogi Berra (c. 1925–2015)*



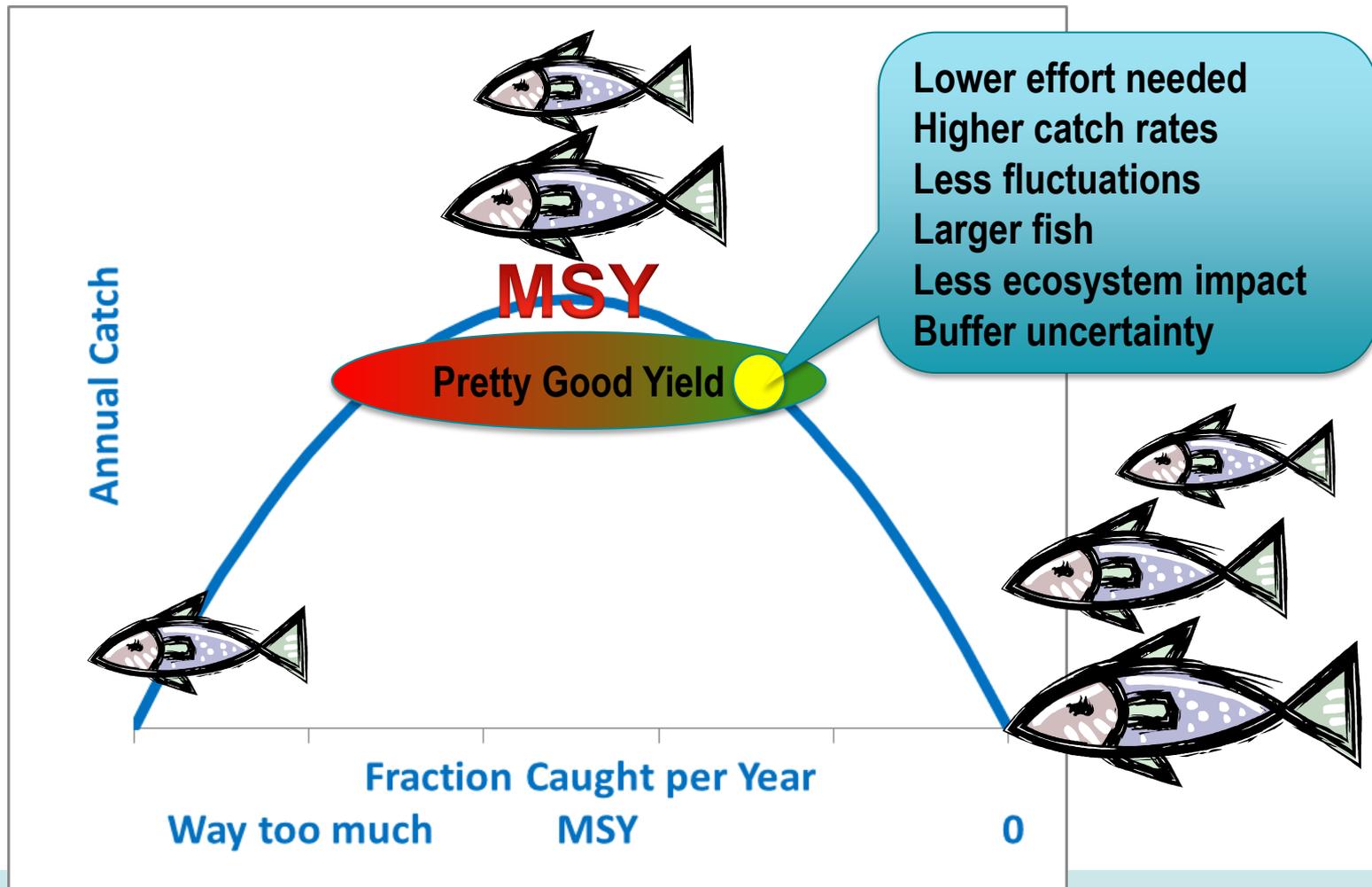
# Stock Assessment Process

## Stock Assessment Modeling: What is sustainable?



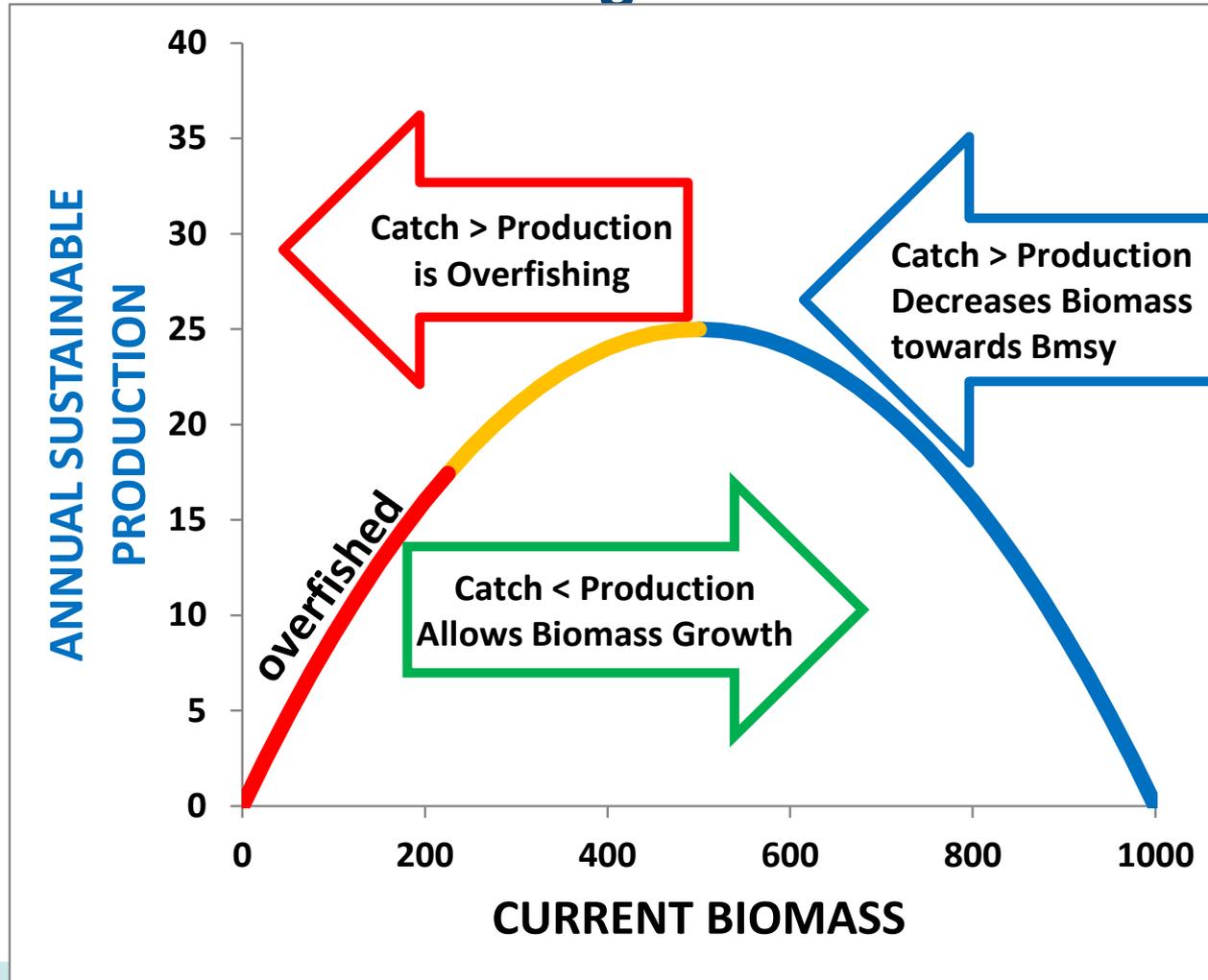
# Stock Assessment Process

## Stock Assessment Modeling: What is sustainable?



# Stock Assessment Process

## Stock Assessment Modeling: What is sustainable?

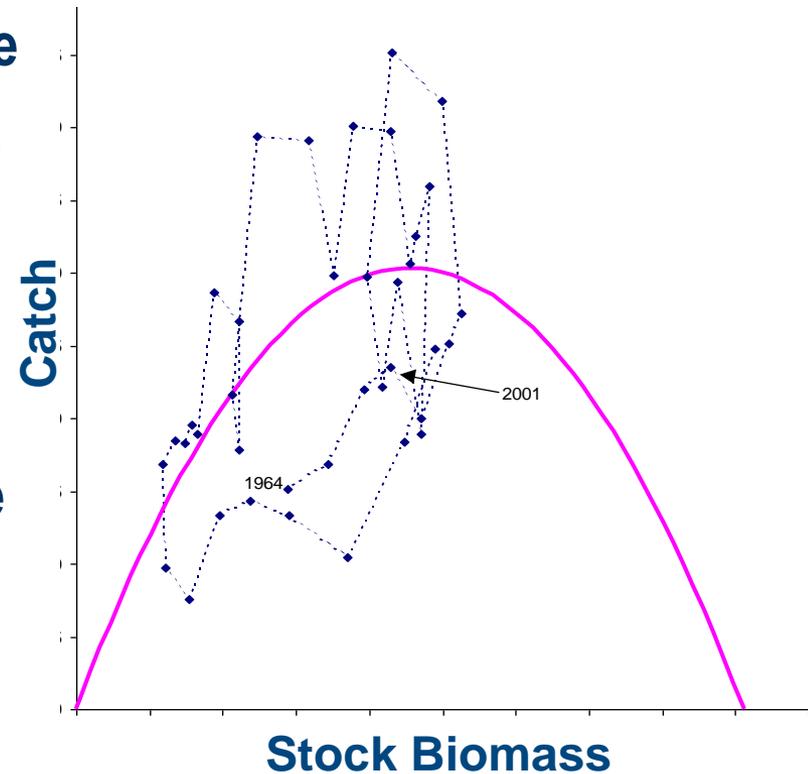


# Stock Assessment Process

## Stock Assessment Modeling: What is sustainable?

### Surplus production reality

- Biology dictates sustainable fishing rate
  - Short life & fast growth = higher rates
- Uncertainty in calculating curve
  - Natural variation
  - Sampling error
- Contrast – observations across range of biomass
- Observed biomass is usually relative (age data helps w/scale)



# Stock Assessment Process

## Stock Assessment Modeling: Types of models

### Statistical catch-at-age/length (SCAA)

- Detailed data (catch, abundance, & biology including tagging) – most complete dynamics
- Project forward from start year

### Virtual Population Analysis (VPA)

- Backward projecting from end year
- Often less flexible/more assumptions than SCAA

### Biomass dynamics (production models)

- Not age-specific (catch and abundance index only)
- MSY can be calculated directly

### Equilibrium

- Data-limited approaches
- Life-history (biology) based

### Index-based

- Time series analysis of fishery or survey trends
- Rumble strip approach between more complete types



# Stock Assessment Process

## Stock Assessment Modeling: Which method to use??

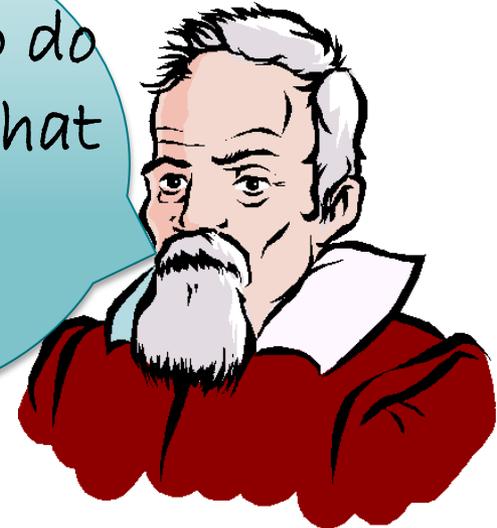
- Models are a simplification of the real world that aim to capture the essence of how a piece of the world works



"All models are wrong, but some are useful."

*George E. P. Box (c. 1919–2013)*

"It is vain to do with more what can be done with fewer."



*William of Ockham (c. 1287–1347)*



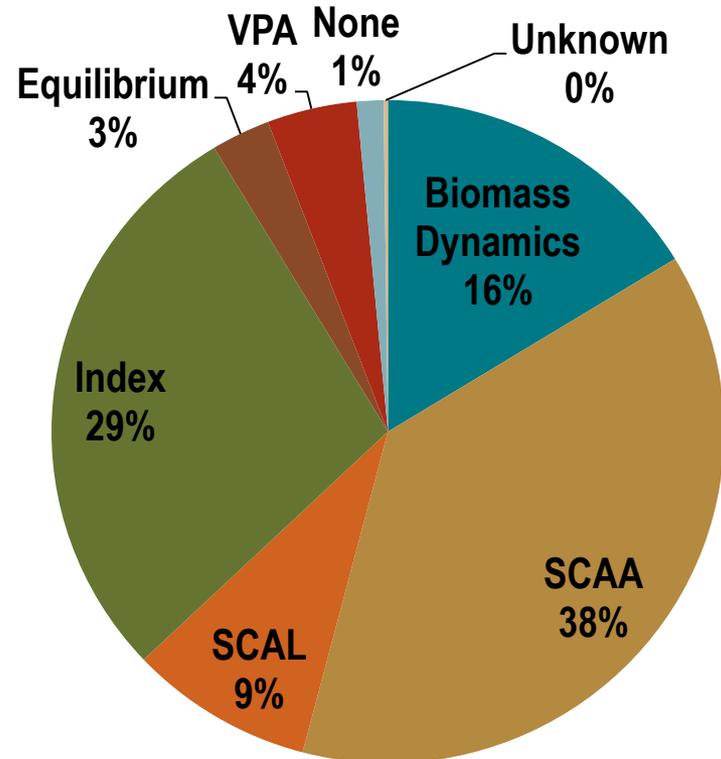
# Stock Assessment Process

## Stock Assessment Modeling: Which method to use??

### Model choice:

- Data available
- What's appropriate for a given stock
- Multiple models may be appropriate

\*NMFS Stock Assessment Approaches 2005-2014



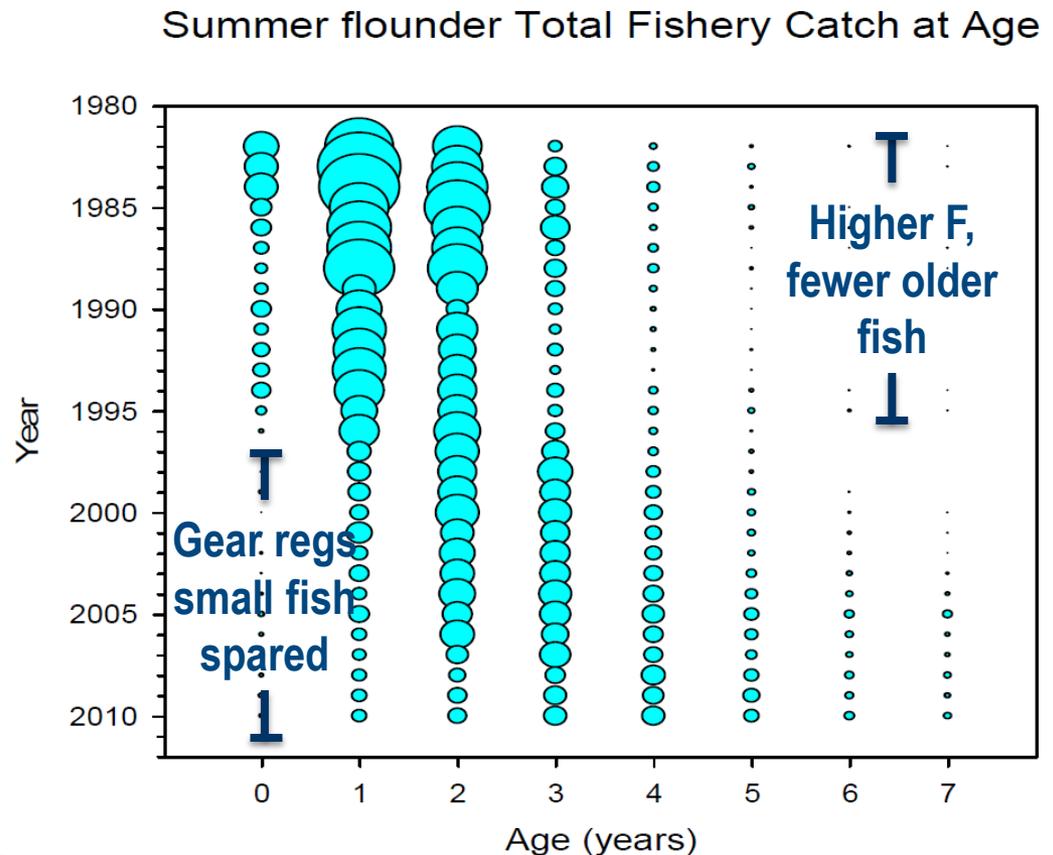
\*Data not inclusive of all NMFS assessments

# Stock Assessment Process

## Stock Assessment Modeling: Which method to use??

Age data provide important details on fishing effects

- Encouraged for valuable or important stocks
- Fishing effects
  - Higher total mortality
  - Age & size structure
  - Generation time
  - Growth rates
  - Other attributes...

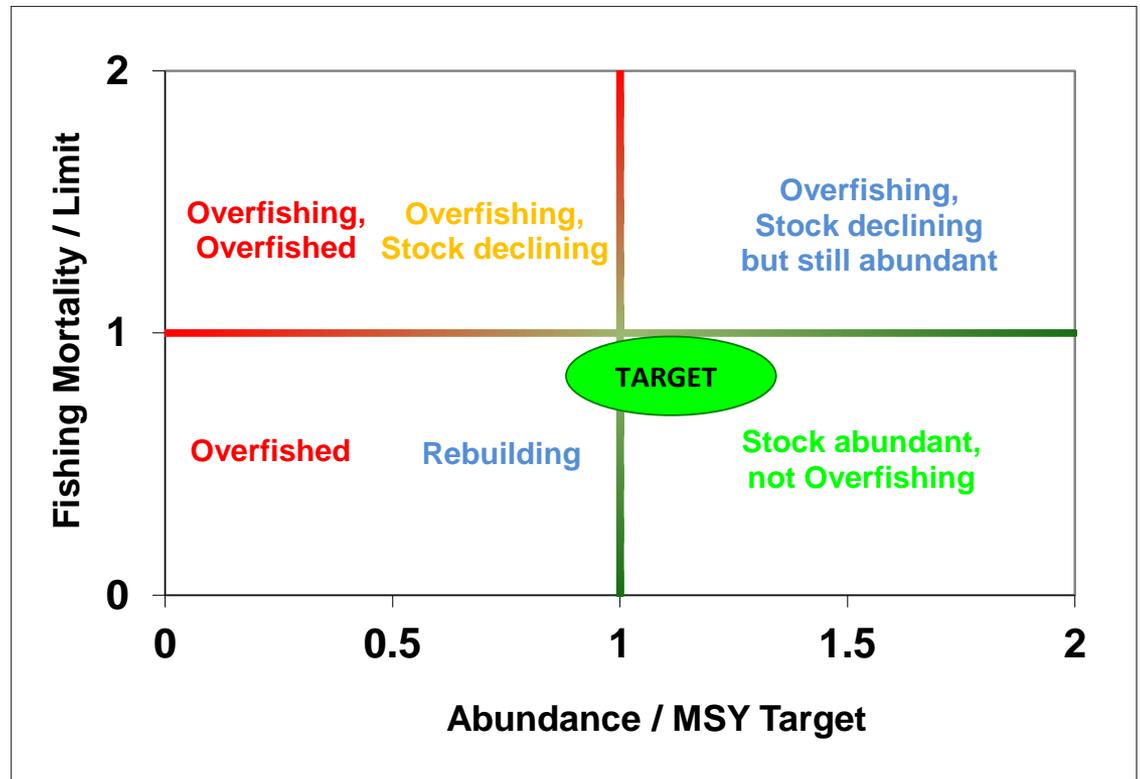


# Stock Assessment Process

## Developing & Communicating Recommendations

### Stock status

- Current fishing rate and biomass levels relative to mgmt. reference points

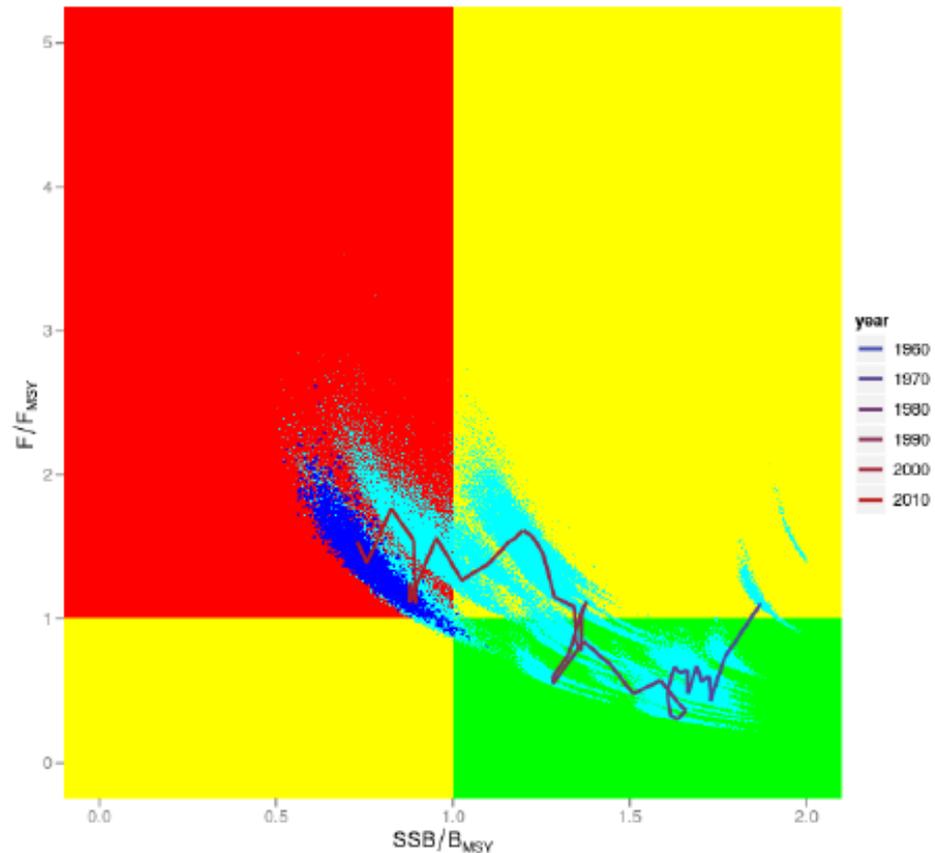


# Stock Assessment Process

## Developing & Communicating Recommendations

### Stock status

- Current fishing rate and biomass levels relative to mgmt. reference points
- Example time series

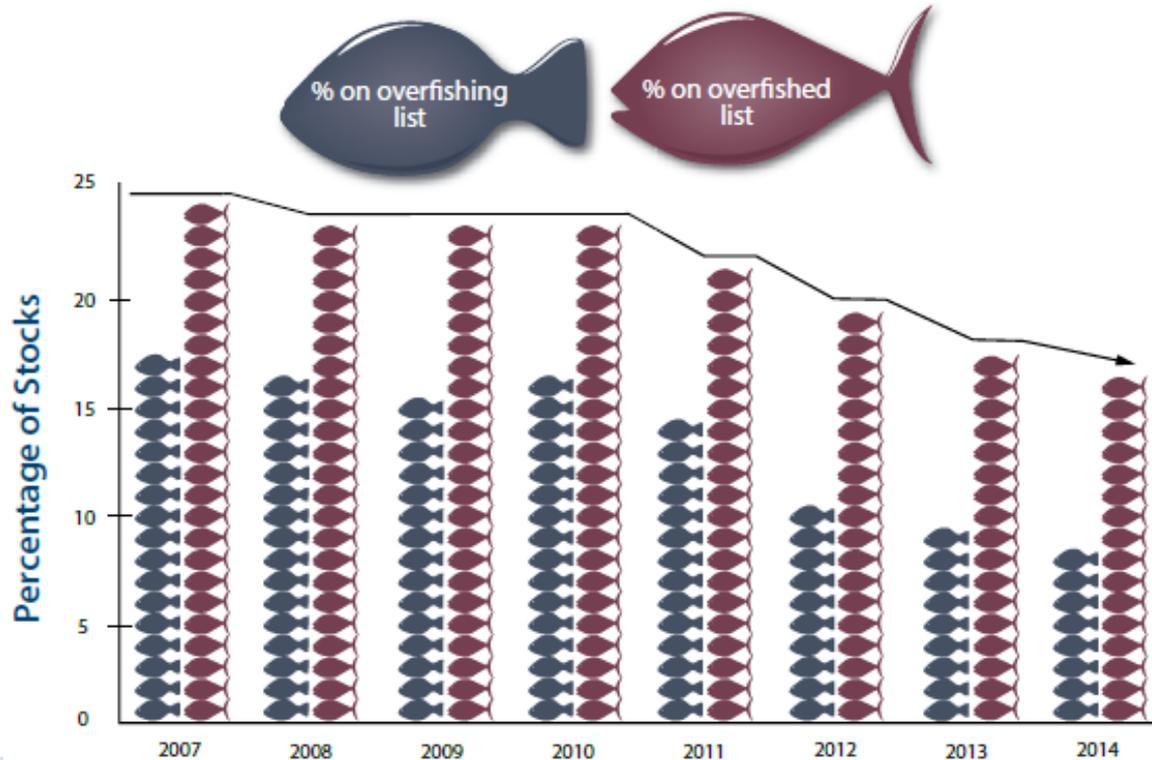


# Stock Assessment Process

## Developing & Communicating Recommendations

### Stock status – national summary

Stock Trends 2007 - 2014



# Stock Assessment Process

## Developing & Communicating Recommendations

### Proactive short-term advice: catch levels

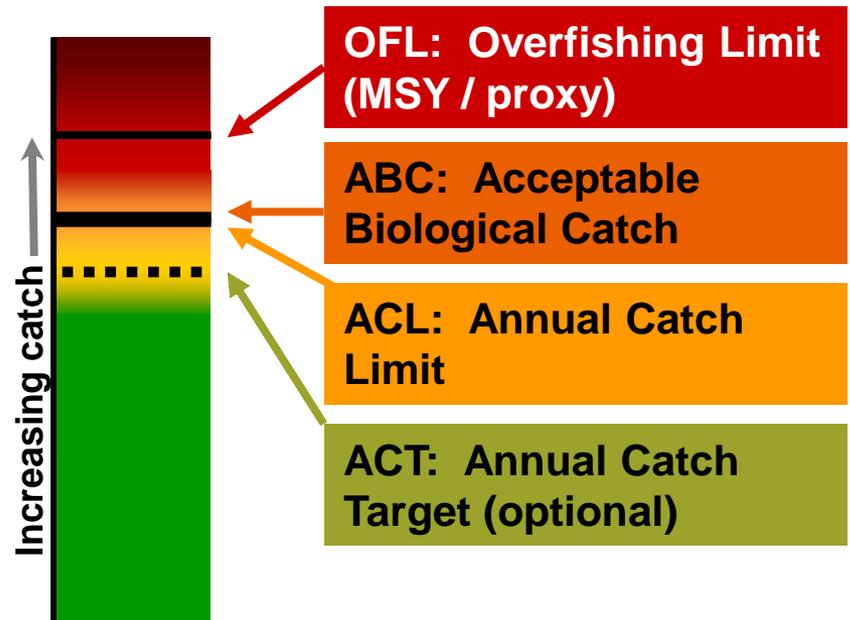
- In accordance with harvest policy
  - No more than specified ( $\leq 50\%$ ) chance of overfishing
  - Rebuild overfished stocks
  - Maximize benefits while protecting marine ecosystems
- Control rule: formula that calculates future catch level from forecasted biomass

# Stock Assessment Process

## Developing & Communicating Recommendations

### Proactive short-term advice: catch levels

- NS1 Guidelines (2009)
- ABC accounts for scientific uncertainty
- If ABC = OFL, no uncertainty
- ABC = ACL is OK (science mgmt. handoff)
- ACL triggers accountability
- ACT accounts for mgmt. uncertainty

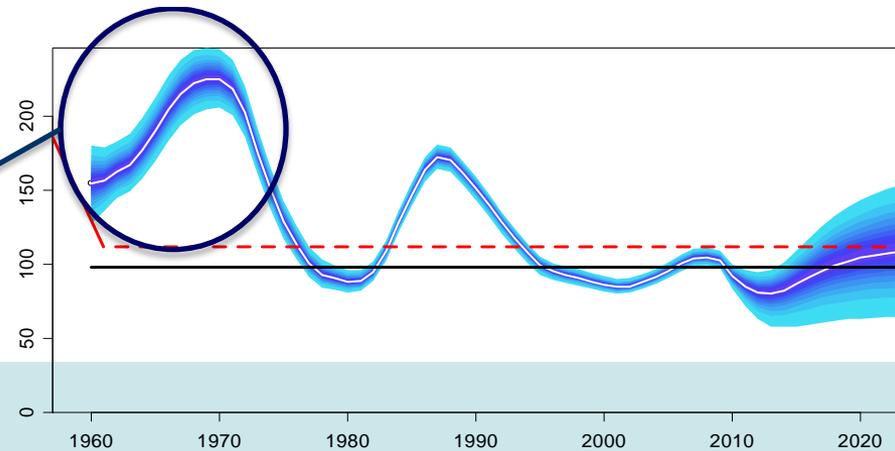
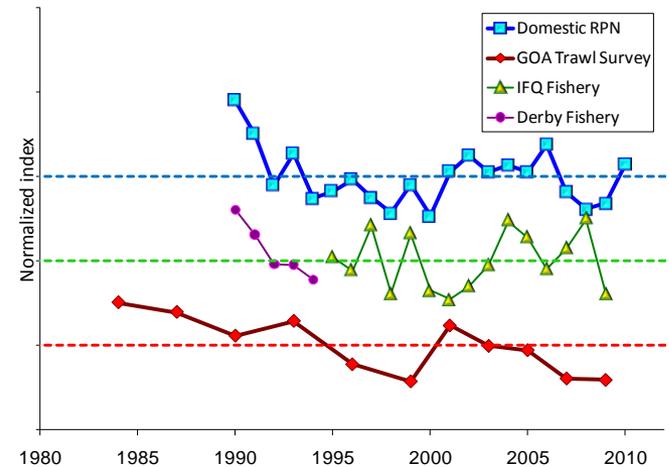


# Stock Assessment Process

## Developing & Communicating Recommendations

### Proactive short-term advice: uncertainty

- Uncertainty is the reality
  - Models are simplifications & data are incomplete
  - Uncertainty  $\neq$  bad science
- Example: Sablefish
  - Multiple indices of abundance
  - Catch monitoring predates abundance tracking
  - Higher uncertainty in years w/out surveys

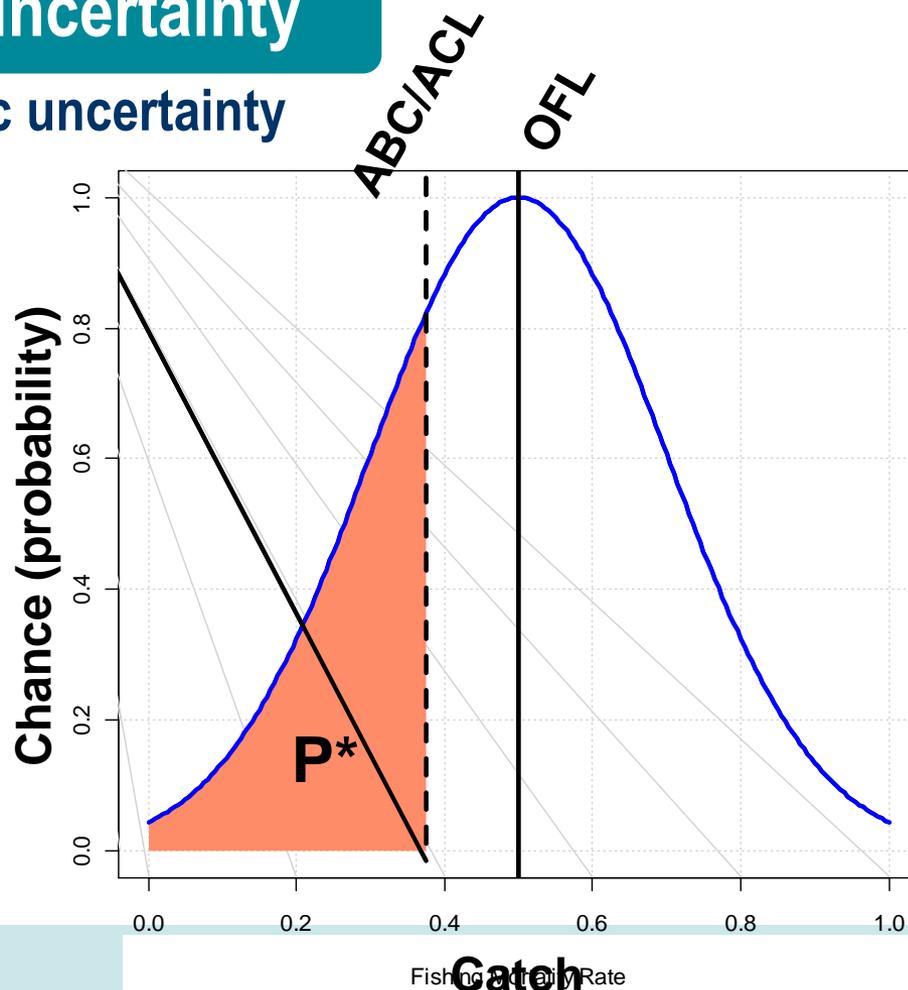


# Stock Assessment Process

## Developing & Communicating Recommendations

### Proactive short-term advice: uncertainty

- SSCs expected to address scientific uncertainty with ABCs (safety buffer)
- One approach:  $P^*$ 
  - Fig: uncertainty around OFL
  - $P^*$  = chance that true OFL < ABC (overfishing)
  - Using  $P^* = 40\%$  identifies an ABC that has 40% chance of exceeding true OFL

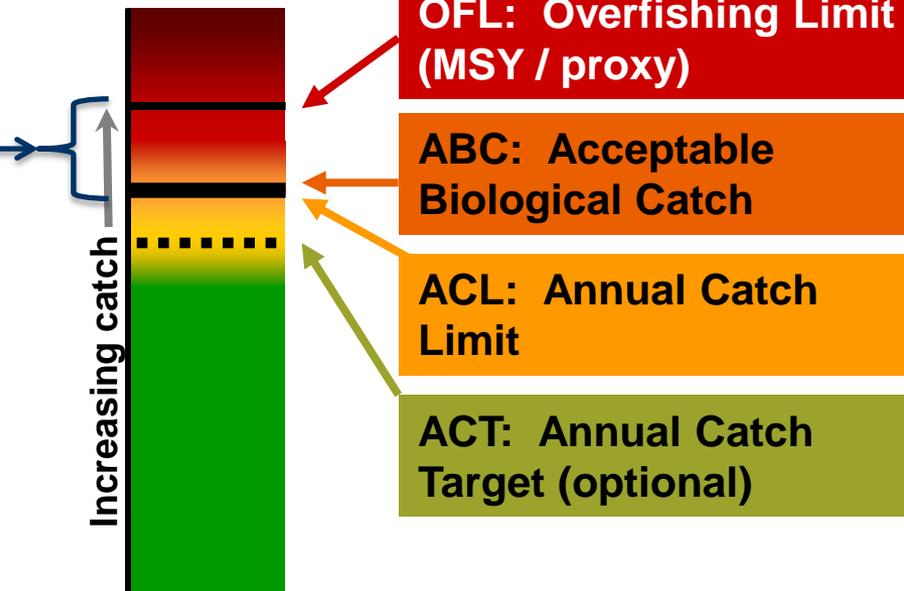


# Stock Assessment Process

## Developing & Communicating Recommendations

### Proactive short-term advice: uncertainty

- Trade-off: How much catch is foregone to achieve an acceptably low chance of overfishing?

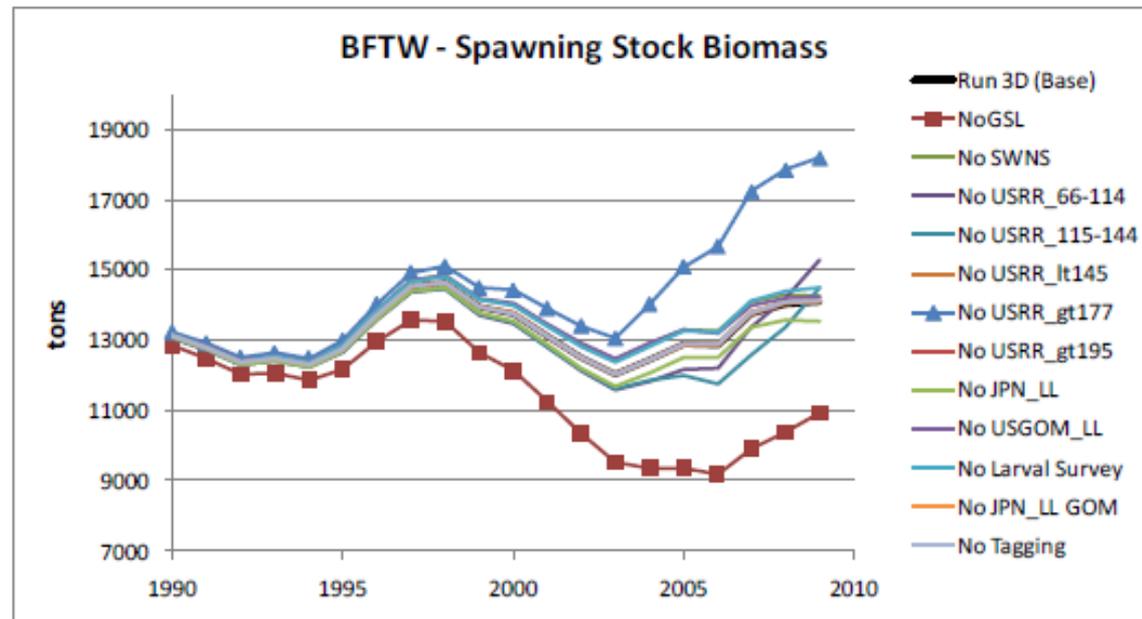


# Stock Assessment Process

## Developing & Communicating Recommendations

### Proactive short-term advice: uncertainty

- Methods for characterizing uncertainty:
  - Statistical error
  - Sensitivity analysis →
  - Multiple models
  - Retrospective analysis
  - Management strategy evaluation

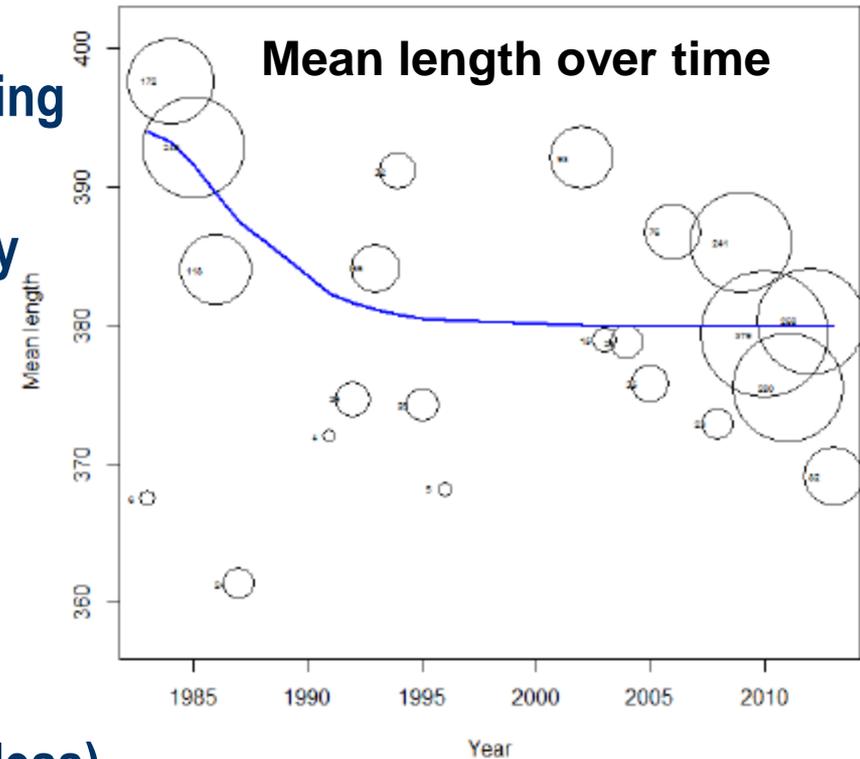


# Stock Assessment Process

## Developing & Communicating Recommendations

### Uncertainty and the data poor situation

- MSY or proxies cannot be calculated
  - Catch level that constitutes overfishing is unknown
- Statistical uncertainty may be relatively low with data-poor methods
- However, should decrease with more information
  - Need to account for unmeasured (*likely*) uncertainty
  - Size of buffer can be “borrowed” from similar species (should not be less)



# When assessments cannot calculate uncertainty, SSCs should set ABC:

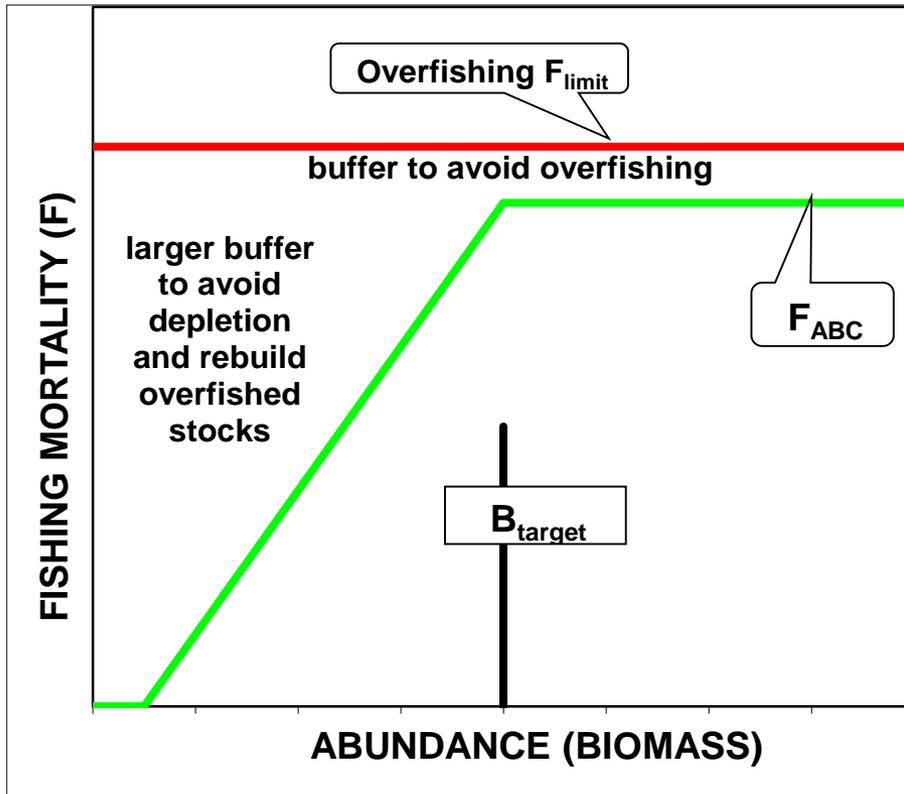
- At the overfishing limit, OFL
- Below the OFL using uncertainty proxy from other stocks
- Refuse to set an ABC

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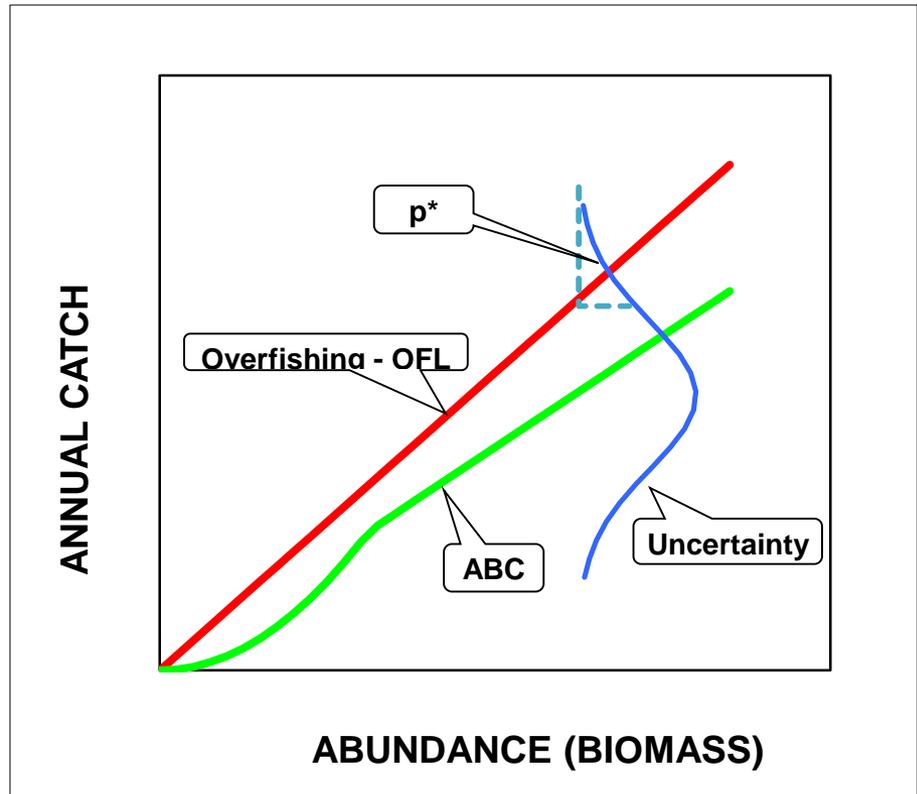
- At the overfishing limit, OFL
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- Refuse to set an ABC

# Harvest Control Rules

F is the fraction caught

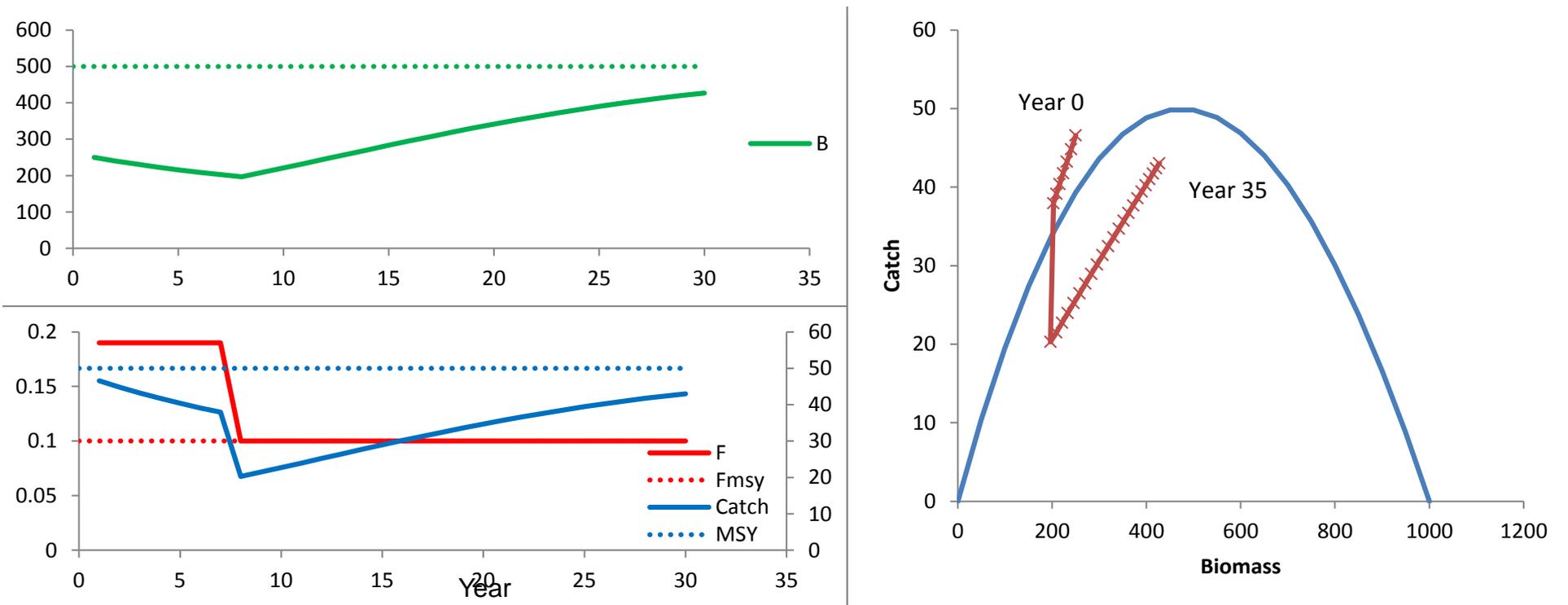


Annual Catch = F times B



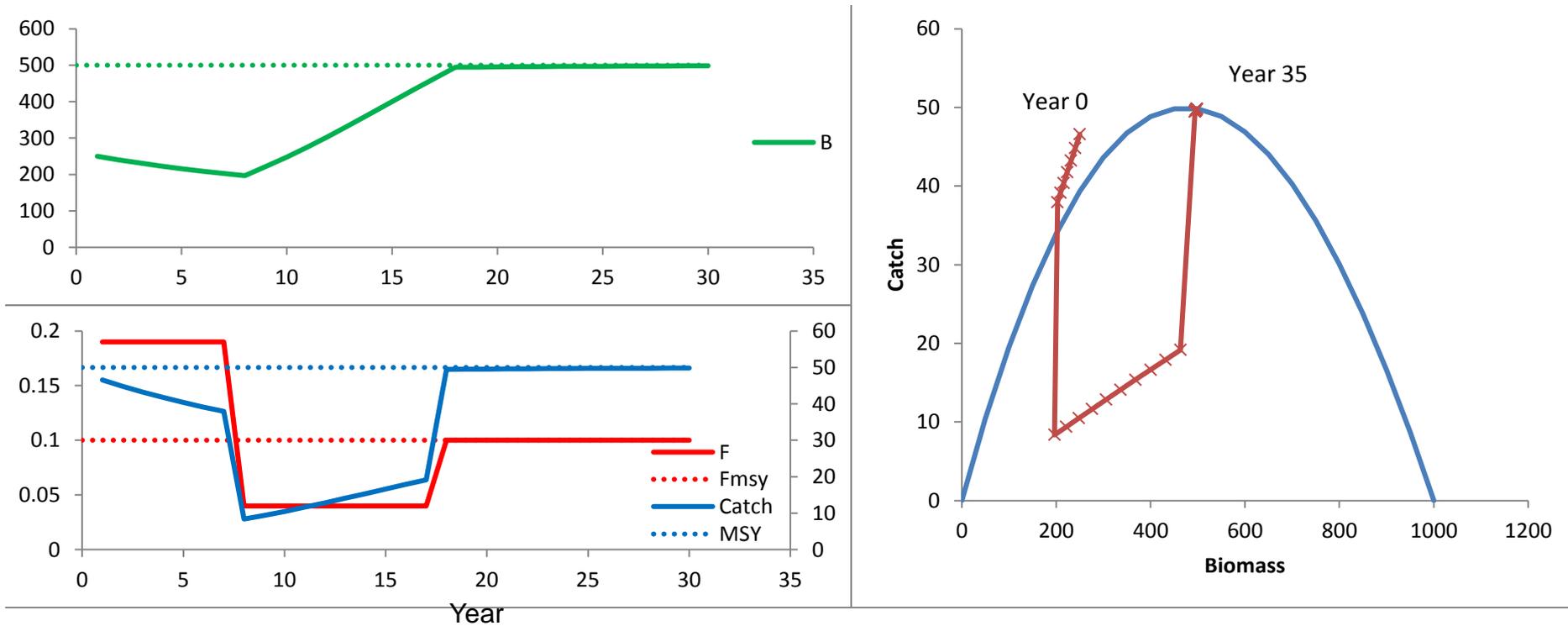
# Harvest Control Rule Scenarios

## 1. Jump to $F_{MSY}$ ; rebuild slowly



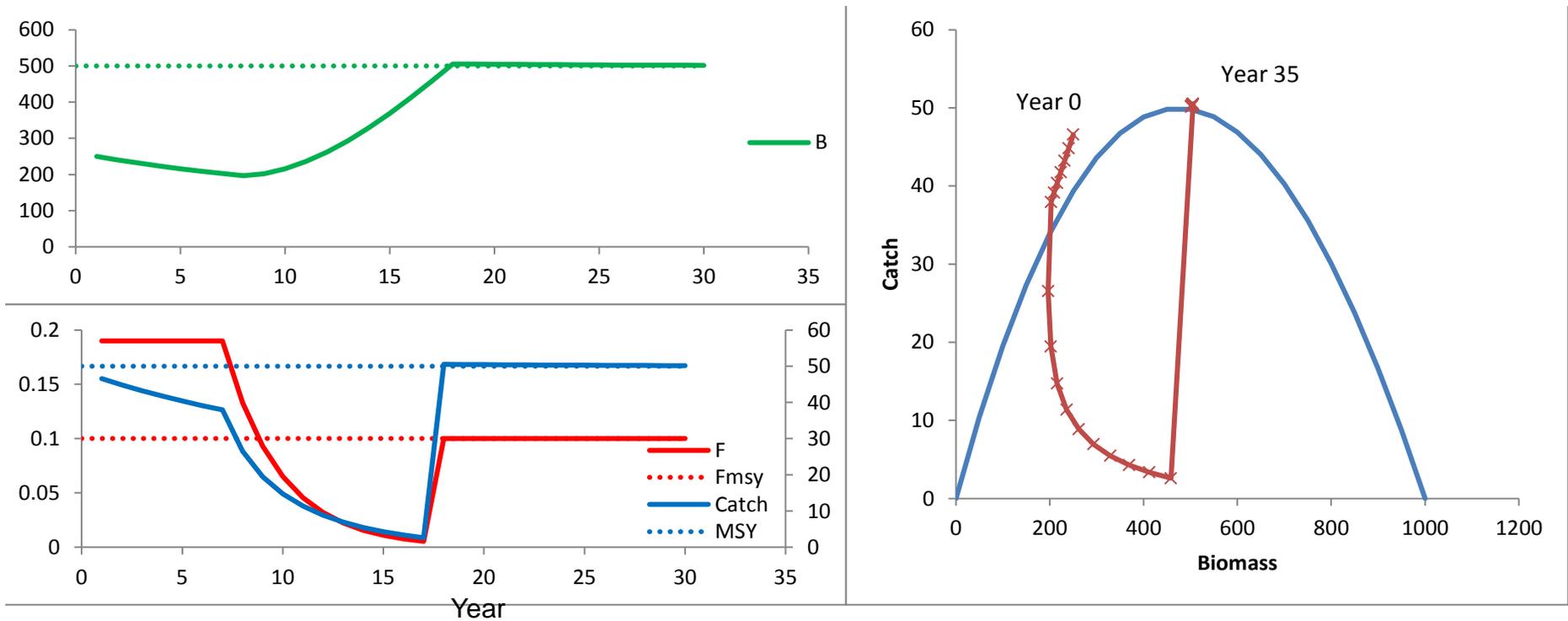
# Harvest Control Rule Scenarios

## 2. 10 year rebuilding plan



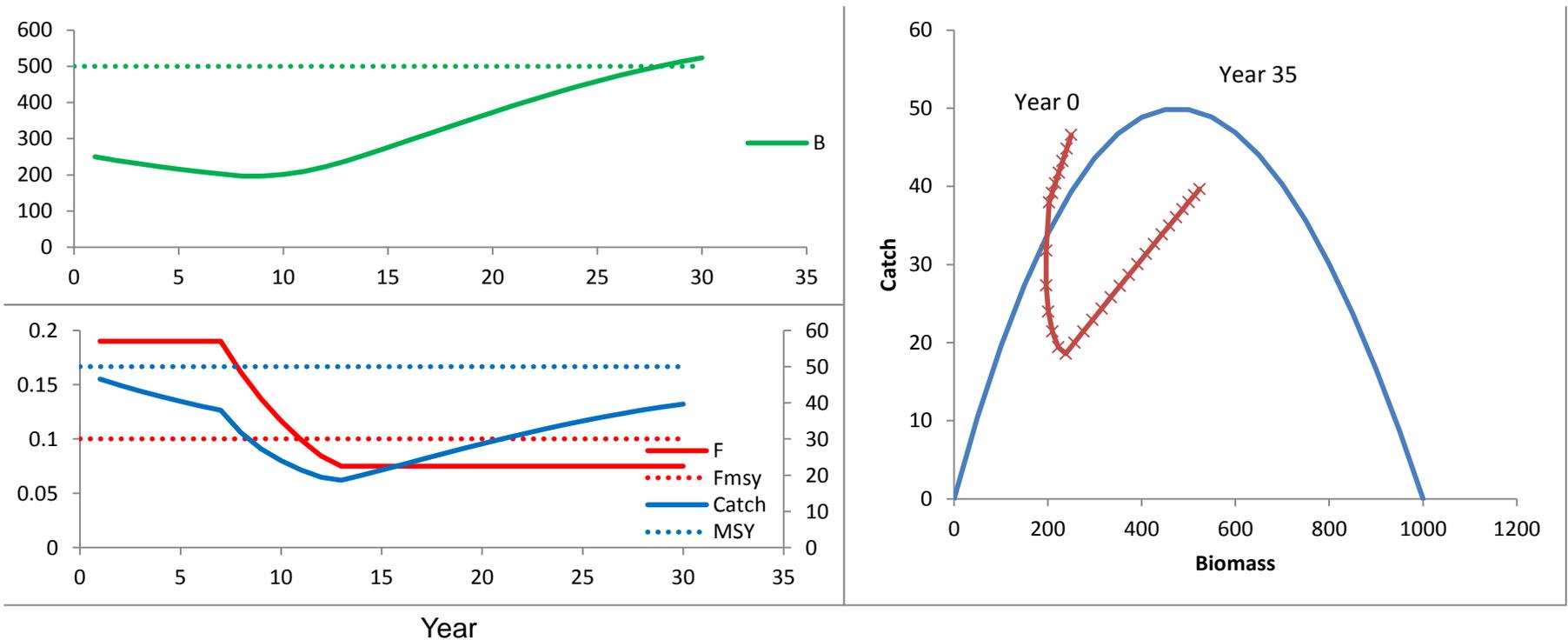
# Harvest Control Rule Scenarios

## 3. Delay the pain; still rebuild in 10 years



# Harvest Control Rule Scenarios

## 4. Long-term buffer; 5 year phase in



- Several options: socioeconomics can guide selection
- Buffer is important for effective management

# Summary

- **Assessments designed to answer mgmt. questions**
- **Catch, abundance, & biology are key inputs**
- **Variety of advanced technical methods tuned to diverse data availability scenarios**
- **Assessments produce estimates of stock abundance, fishing mortality, and productivity**
- **Stock forecasts provide technical basis to guide setting Annual Catch Limits**



## For More Information

### NMFS stock assessment site

<http://www.st.nmfs.noaa.gov/stock-assessment/index>

### FishWatch

<http://www.nmfs.noaa.gov/fishwatch/>

### Status of Fisheries and FSSI Quarterly Reports

<http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm>

### Species Information System for stock assessment and status determination data

<https://www.st.nmfs.noaa.gov/sisPortal/sisPortalMain.jsp>

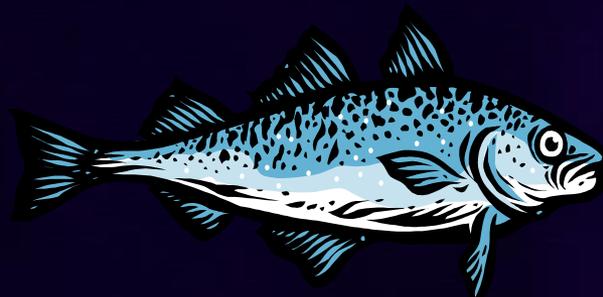
# Thank You



NOAA FISHERIES

# BACK-UP SLIDES

# Differences Between Fishery Catch Rates and Survey Trends for Yellow-eyed Cod



SSC Presentation

# “Hyperstability”

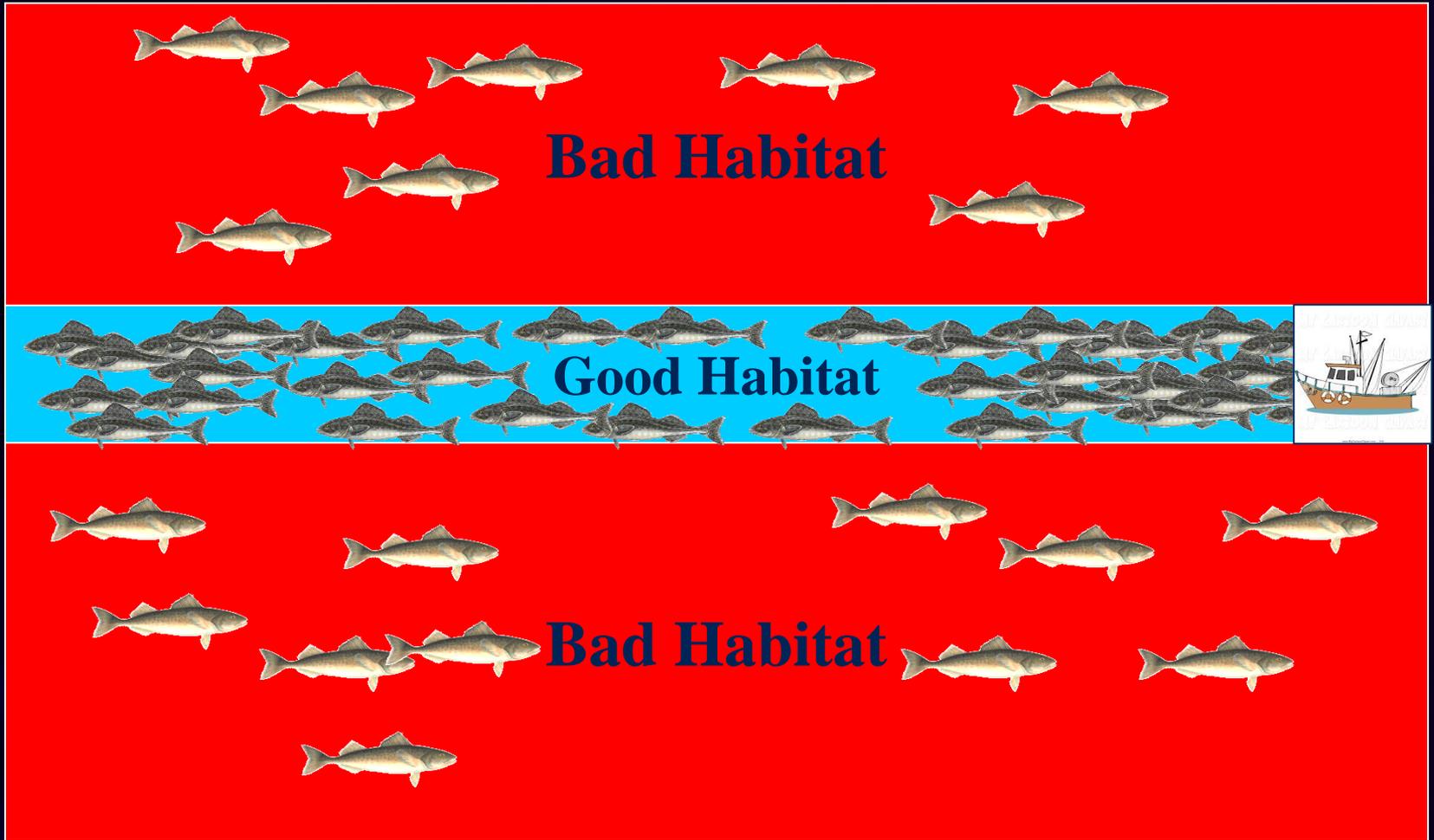
- “If abundance is down, why are catch rates still good?”
- Fishery catch rates are a lagging indicator
- Surveys trends decline before catch rates
- Fishery catch rates are “hyperstable”

# “Hyperstability”



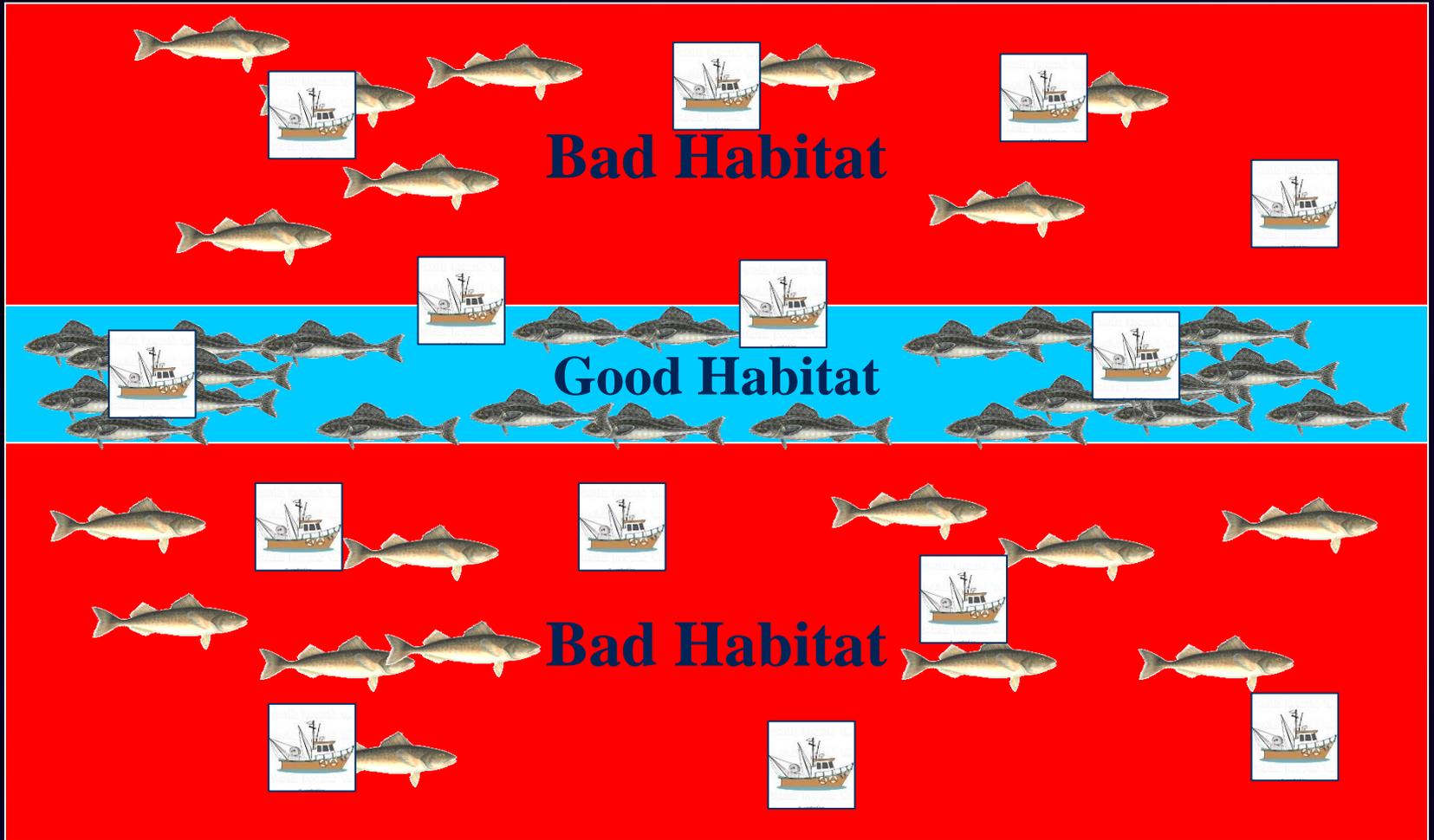
# “Hyperstability”

Depth

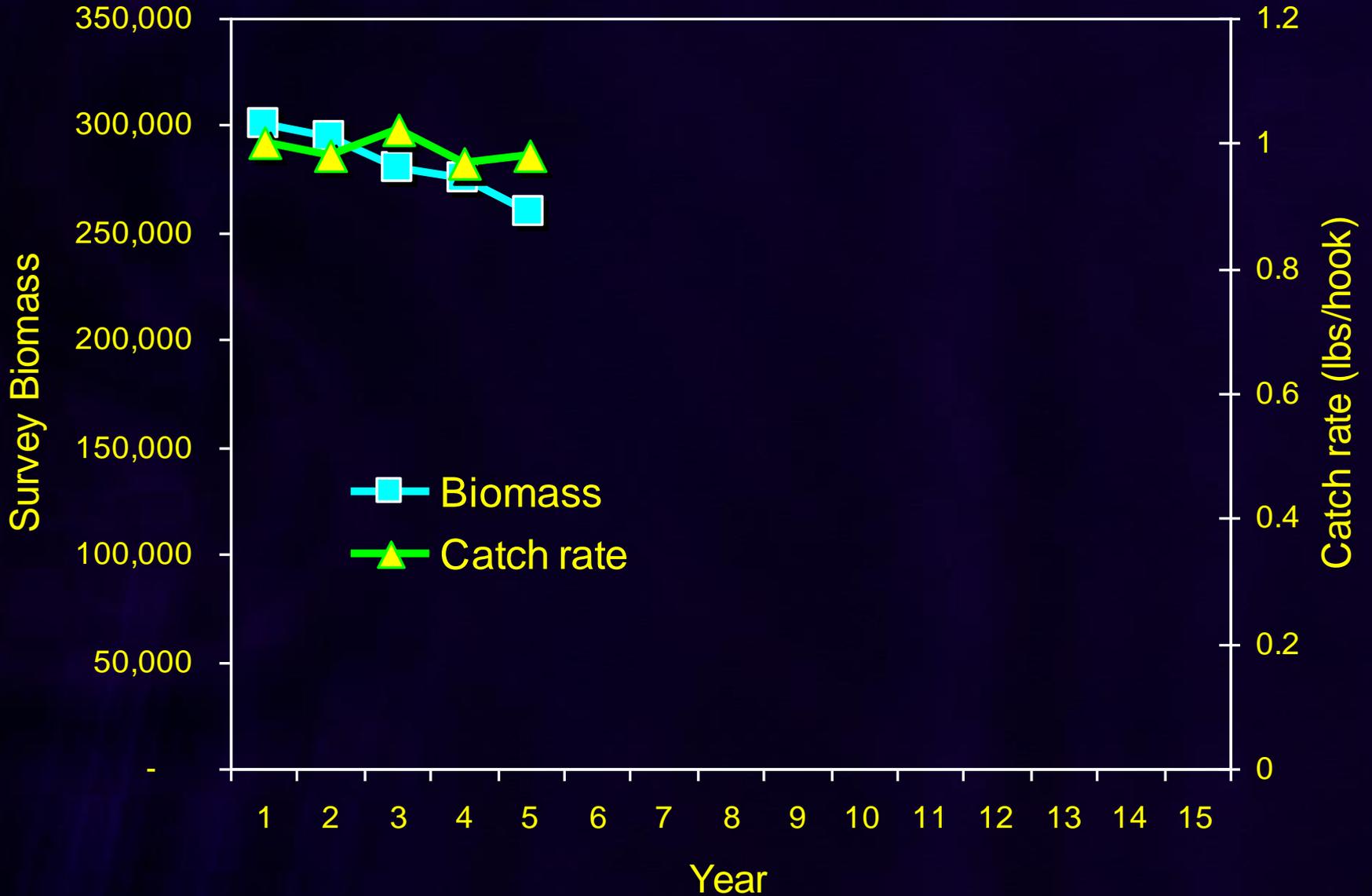


# “Hyperstability”

Depth



# “Hyperstability”



# “Hyperstability”

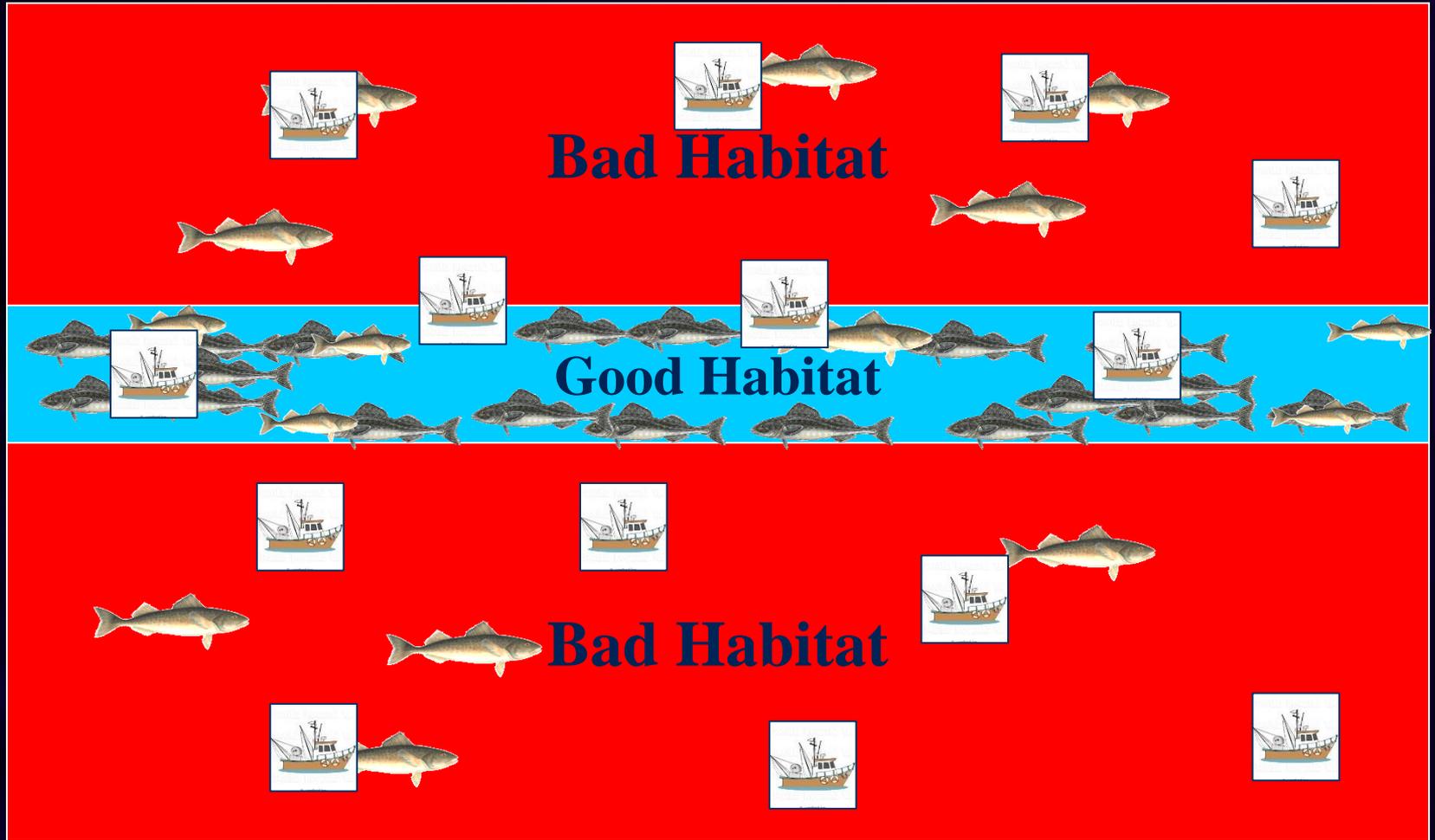


# “Hyperstability”



# “Hyperstability”

Depth



# “Hyperstability”



# “Hyperstability”

Depth

**Bad Habitat**

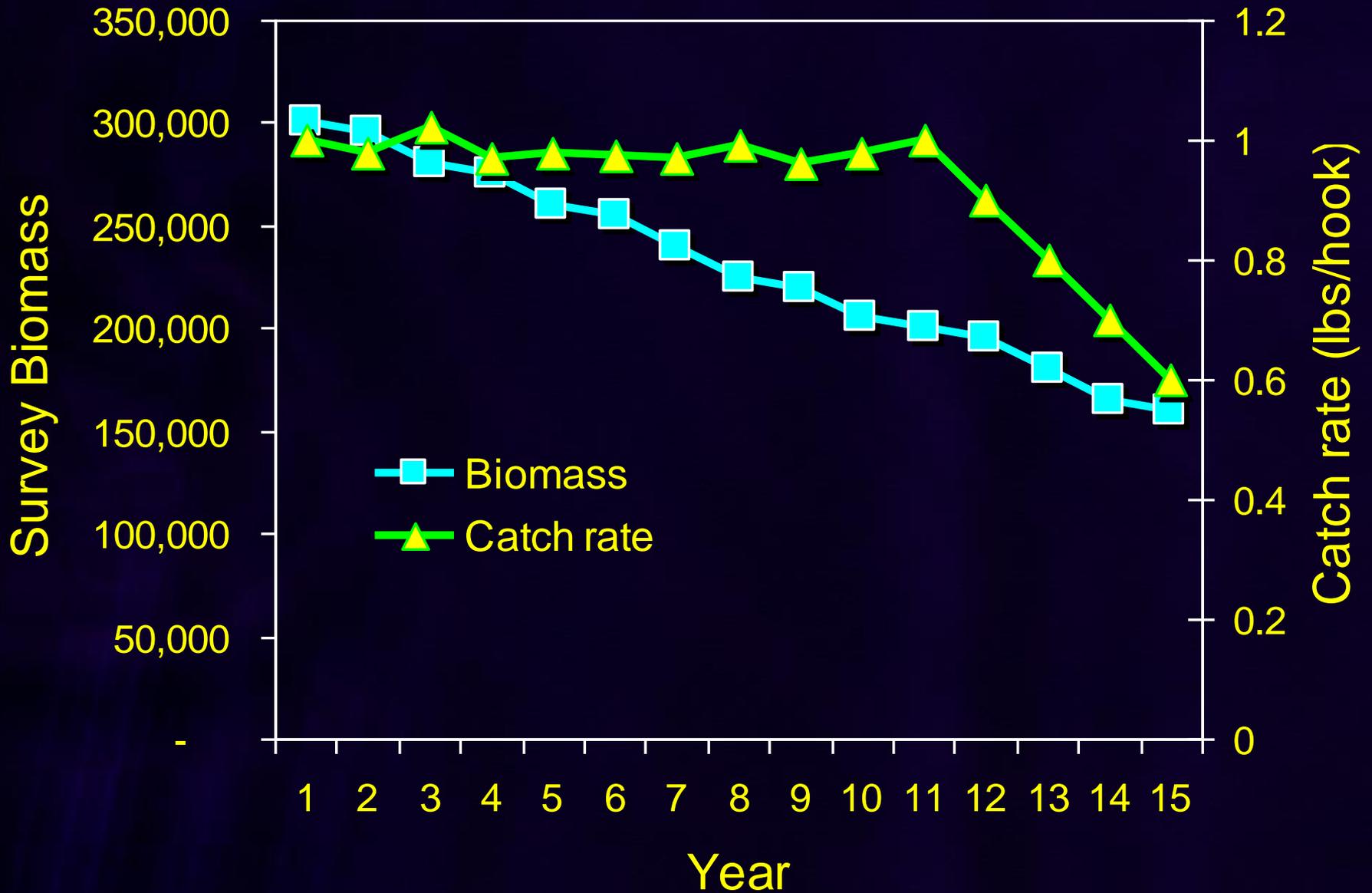


**Good Habitat**



**Bad Habitat**

# “Hyperstability”

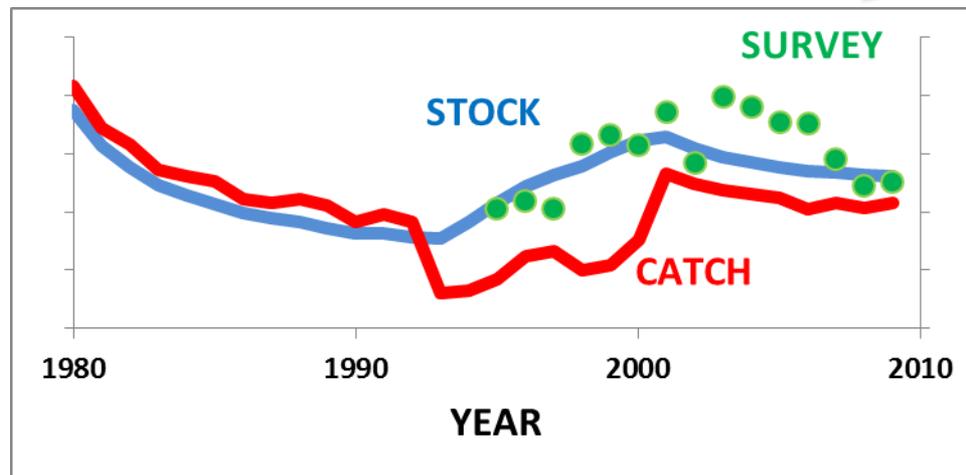
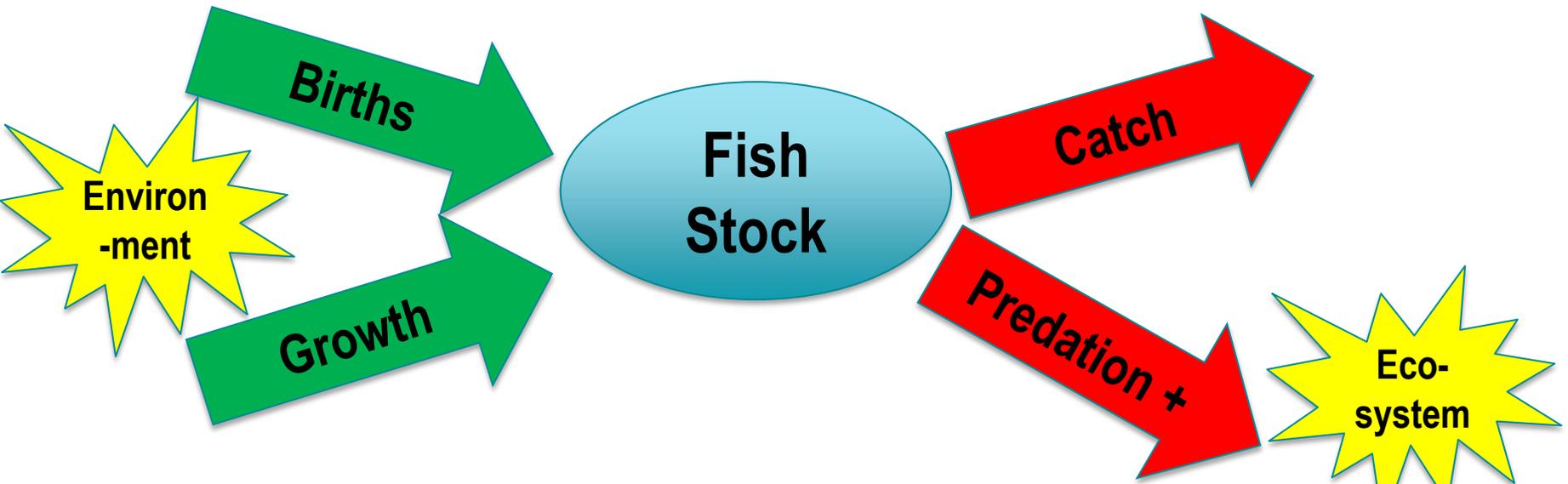


# Assessment Jargon

- **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) = (recommended F) times (Current Biomass)**
- The maximum long-term average catch that the stock can produce is **MSY**

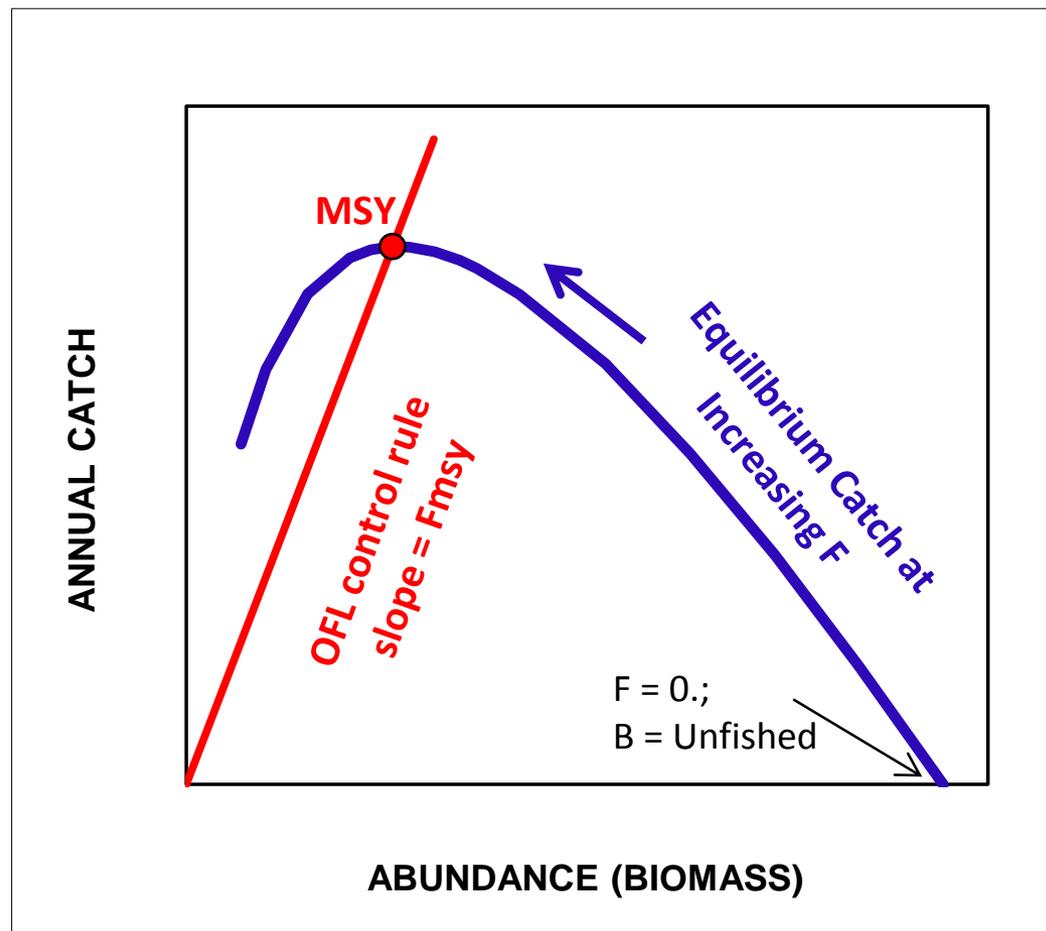


# What is a Stock Assessment?



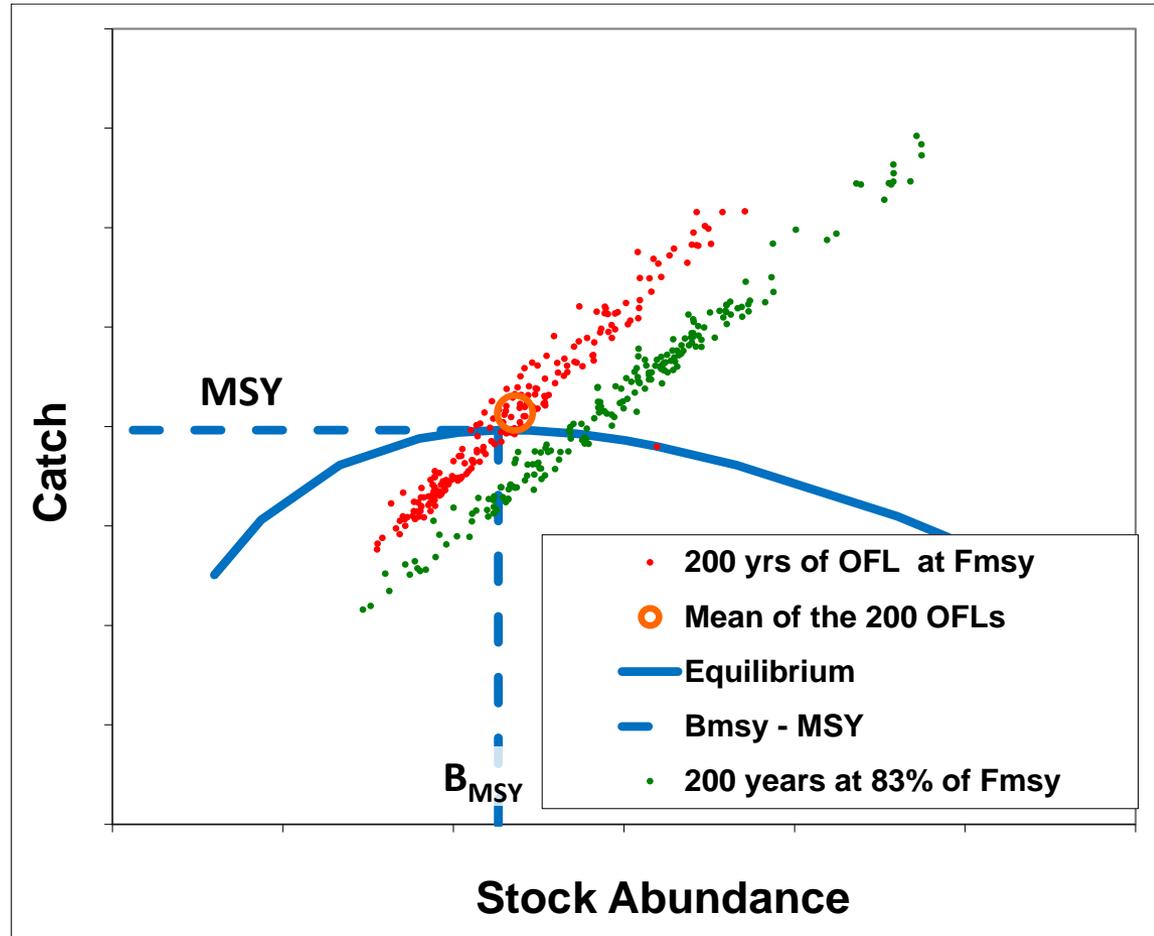
# OFL Control Rules

- Now focus on pro-active; using the control rule to prevent overfishing
- But, info is never as definitive as implied by this neat figure
- Scientific uncertainty



# Management Strategy Evaluation

- OFL is the annual catch when fishing mortality is at the rate that gives MSY
- OFL varies above and below the MSY level depending on fluctuations in abundance.
- Over the long term, average OFL close to equilibrium MSY
- ABC: Fishing at slightly less than  $F_{MSY}$  gets less catch from given abundance level, but higher abundance and similar catch over long-term



# What does it mean to prevent overfishing?

- Intentional overfishing; i.e. setting a target that is beyond the best estimate of the overfishing limit. In principal, the US has ended this type of overfishing.
- Management shortcoming: this occurs when fishery management procedures fail to keep the catch below the overfishing limit. This could be accidental (procedures were in place but they didn't work), or structural (no credible accountability measures were in place to keep catch under control within the fishing season).
- Science uncertainty: this leads to retrospective revision of calculated historical abundance and fishing mortality such that the revised historical level now appears to have exceeded the limit, even though the catch was not over the ACL. This may happen every few years as major updates of assessments occur.
- Ecosystem overfishing: this occurs when the model/paradigm under which the tactical estimates of overfishing limits are calculated is wrong/biased/inadequate. We may not find out about this until decades later.



# How/When is overfishing measured?

## Catch compared to OFL

- ❖ Can be done each year, no new assessment needed
- ❖ High transparency for public, consistent with the ACL paradigm
- ❖ Forecast of ACL and OFL from past assessment does not account for recent recruitments, so need frequent assessment updates to keep ACL and OFL current
- ❖ Overfishing determination is only sensitive to management uncertainty
- ❖ Subsequent estimation of  $F$  by assessments does not result in overfishing determination

## F compared to Flimit

- ❖ Requires assessment to calculate current  $F$  and update  $F_{limit}$
- ❖ Low transparency for public, keeping catch  $<$  ACL does not mean that new estimate of  $F$  will be  $<$   $F_{limit}$
- ❖ Because this is a hindcast, it is not sensitive to recent recruitments, but associated ACLs are sensitive
- ❖ Overfishing determination could be caused by management uncertainty or scientific uncertainty

