The SS-DL tool as Applied Fisheries Science: Principles and concepts for stock assessment and management

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SS-DL Tool

Welcome to the Stock Synthesis data-limited tool (SS-DL tool)

This tool uses the Stock Synthesis framework to implement a variety of types of models.

Choose data file

Catch time series

Browse...

Length composition

Browse...

Age composition

Browse...

Abundance index

Browse...

Clear data files

Catches | Length | Ages | Index

Use existing model files?

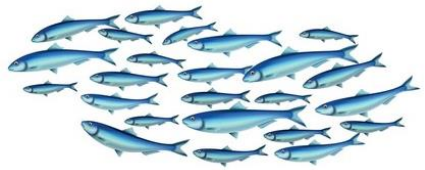
Data and Parameters | SSS Model output | Model efficiency | Jitter exploration | Likelihood profile | Retrospectives | Sensitivity Plots | Ensemble models

Life history

Selectivity

SS-DL Workshop Objectives

- **Get familiar with Stock Synthesis (SS) via the SS-DL tool**
  - **Access SS framework flexibility (using different data types)**
  - **Explore different assessment approaches and how they form a continuum of methods**
- **Learn assessment fundamentals and principles**
  - **Data, inputs, assumptions, uncertainty**
  - **The science and art of stock assessment**
- **Run and explore your own stock assessments using the SS-DL tool**

"Managing  is hard: it's like managing a  , in which the  s are invisible and keep moving around"

-John Shepherd

Managing natural marine resources

- Preventing overfishing
- Rebuilding overfished stocks

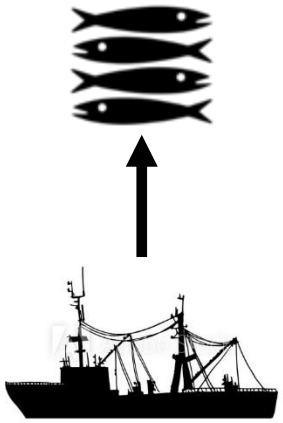
} Setting catch limits?

- Increasing long-term economic and social benefits
- Ensuring a safe and sustainable supply of seafood

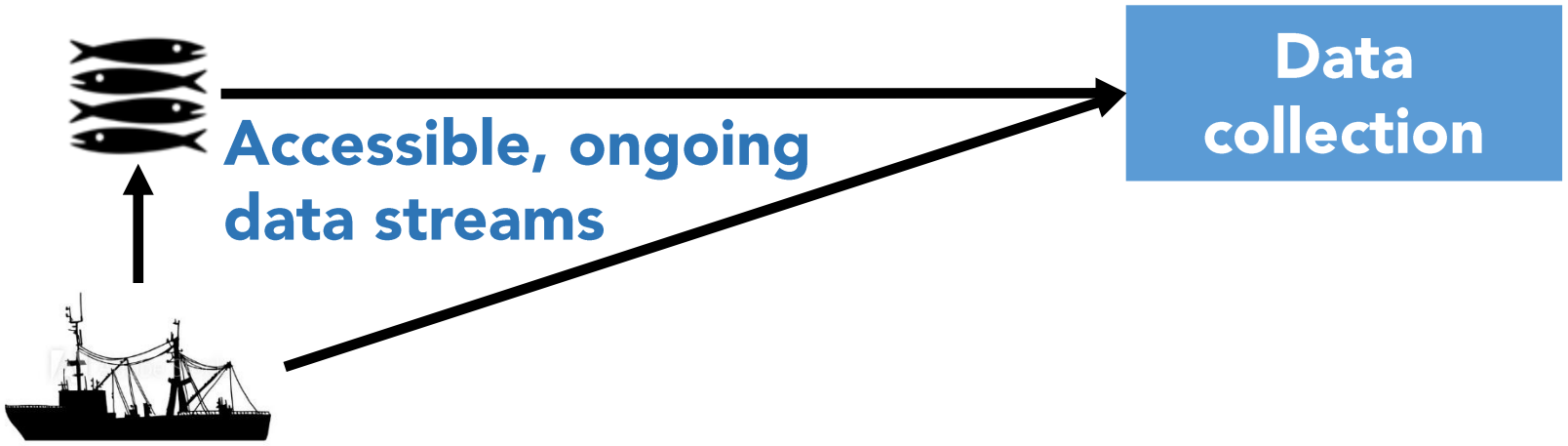
} Provide opportunities

How do we achieve the above?

Adaptive Management System



Adaptive Management System



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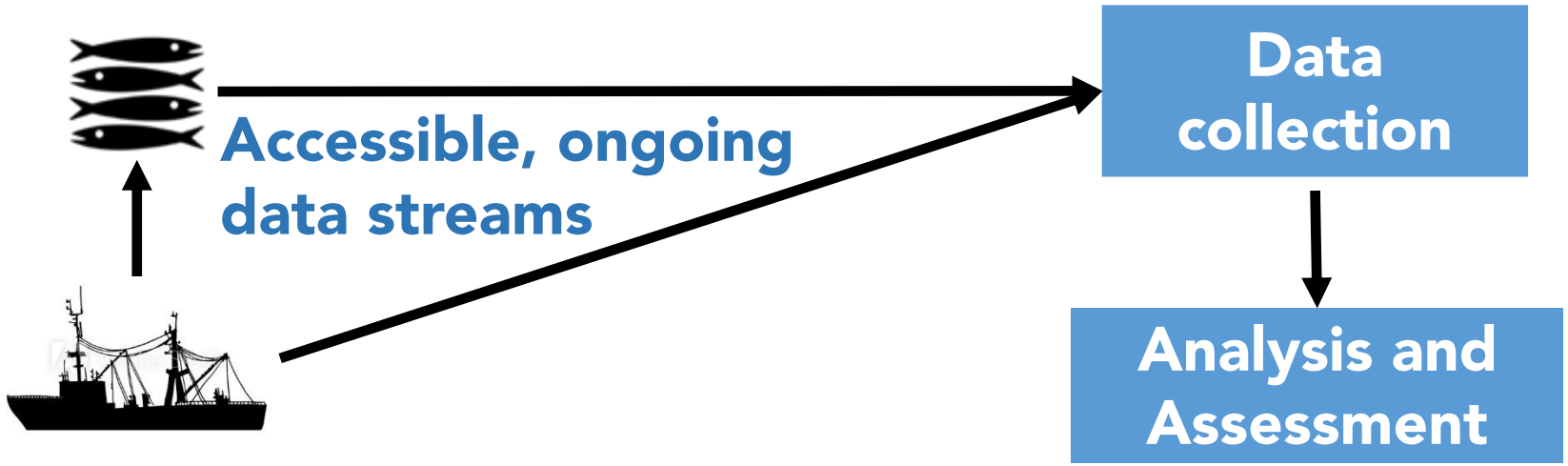

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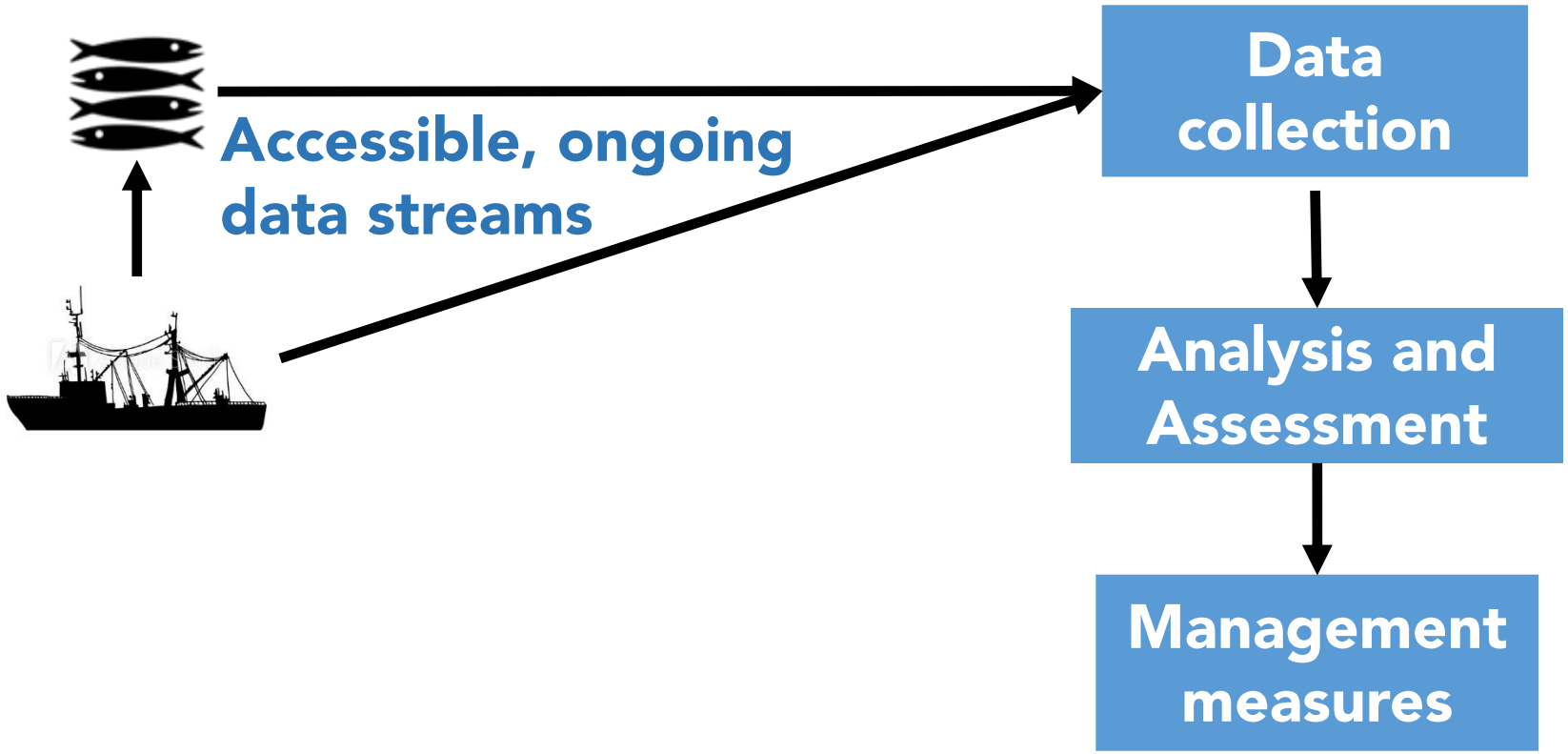
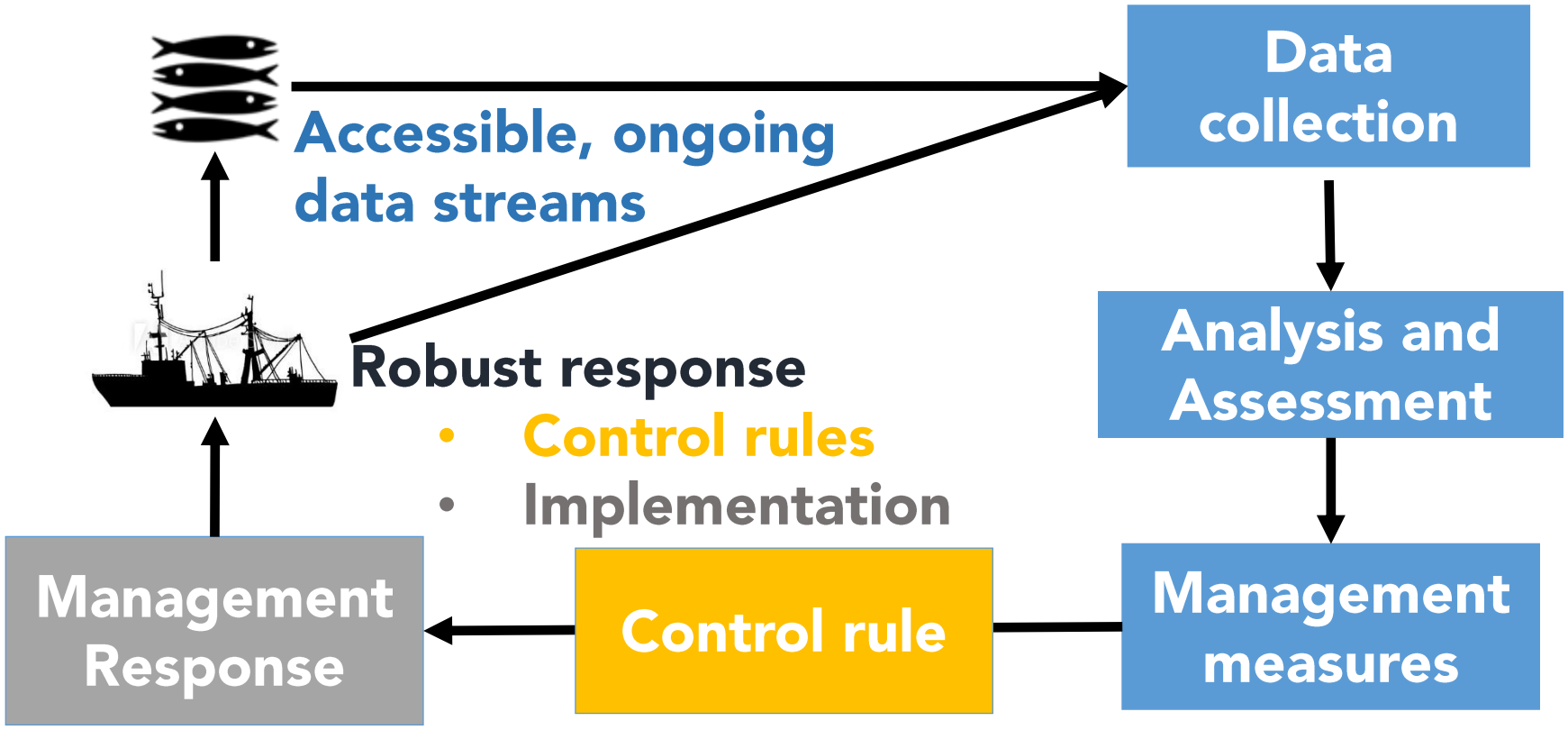
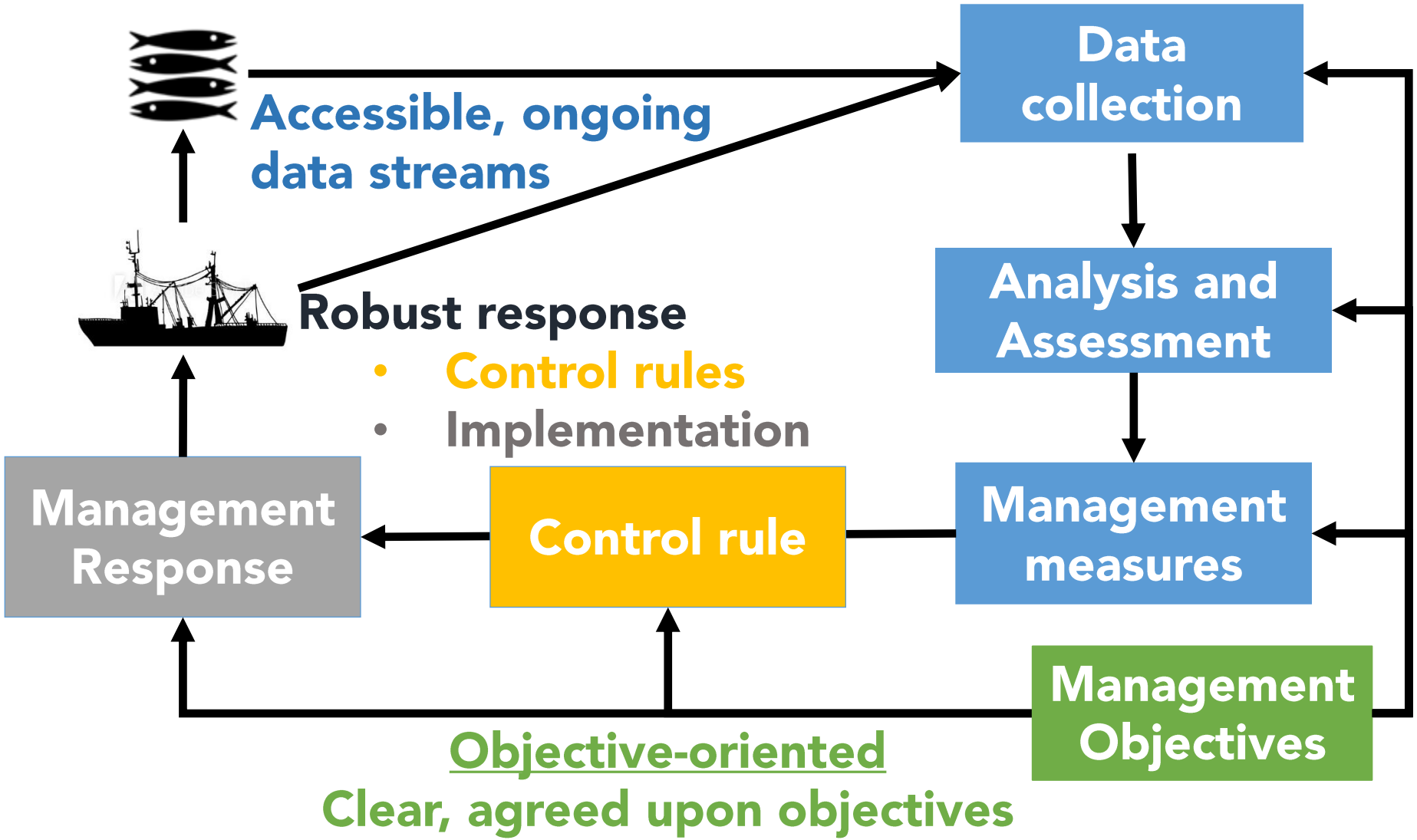


Adaptive Management System

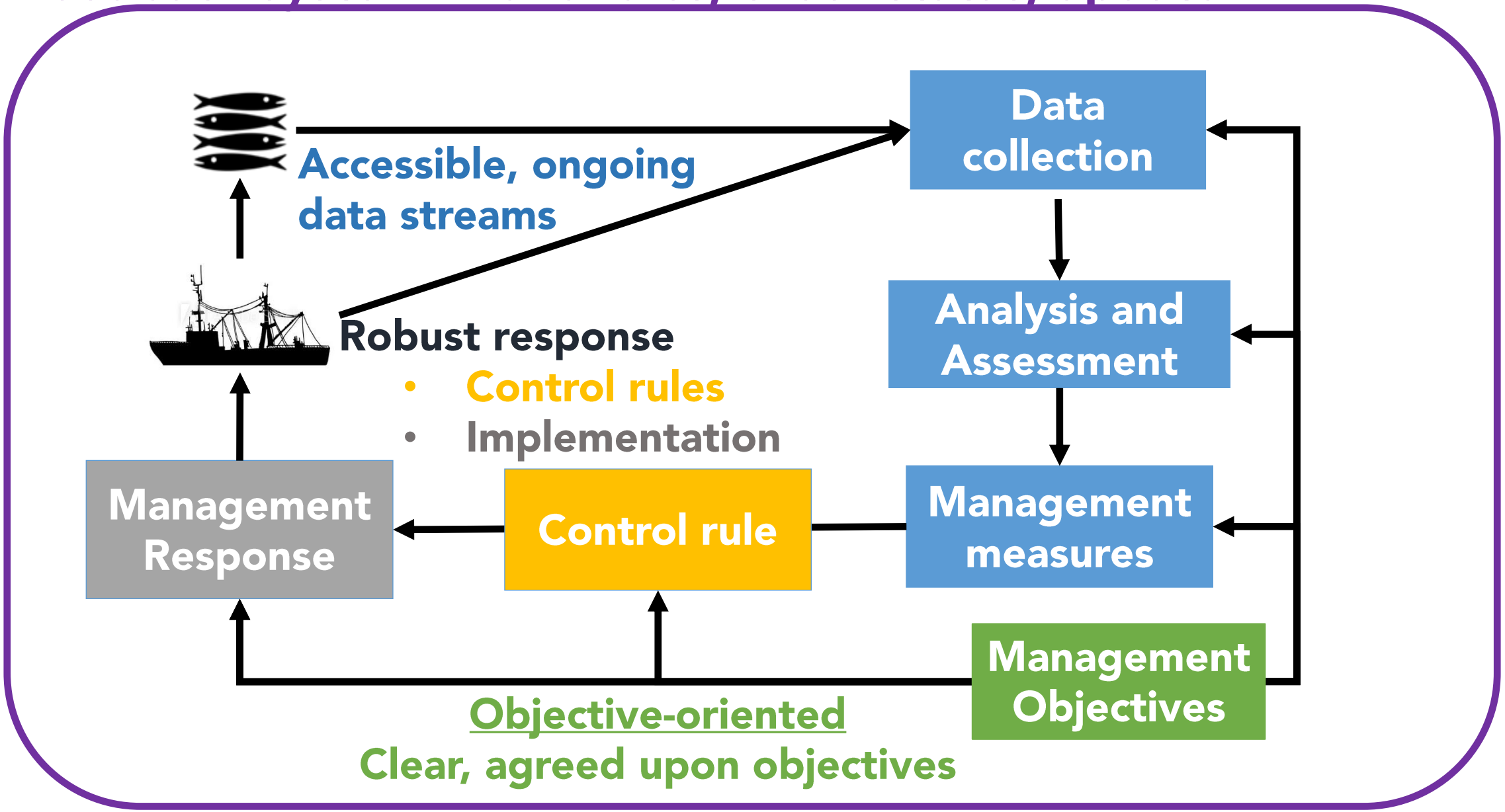


Adaptive Management System



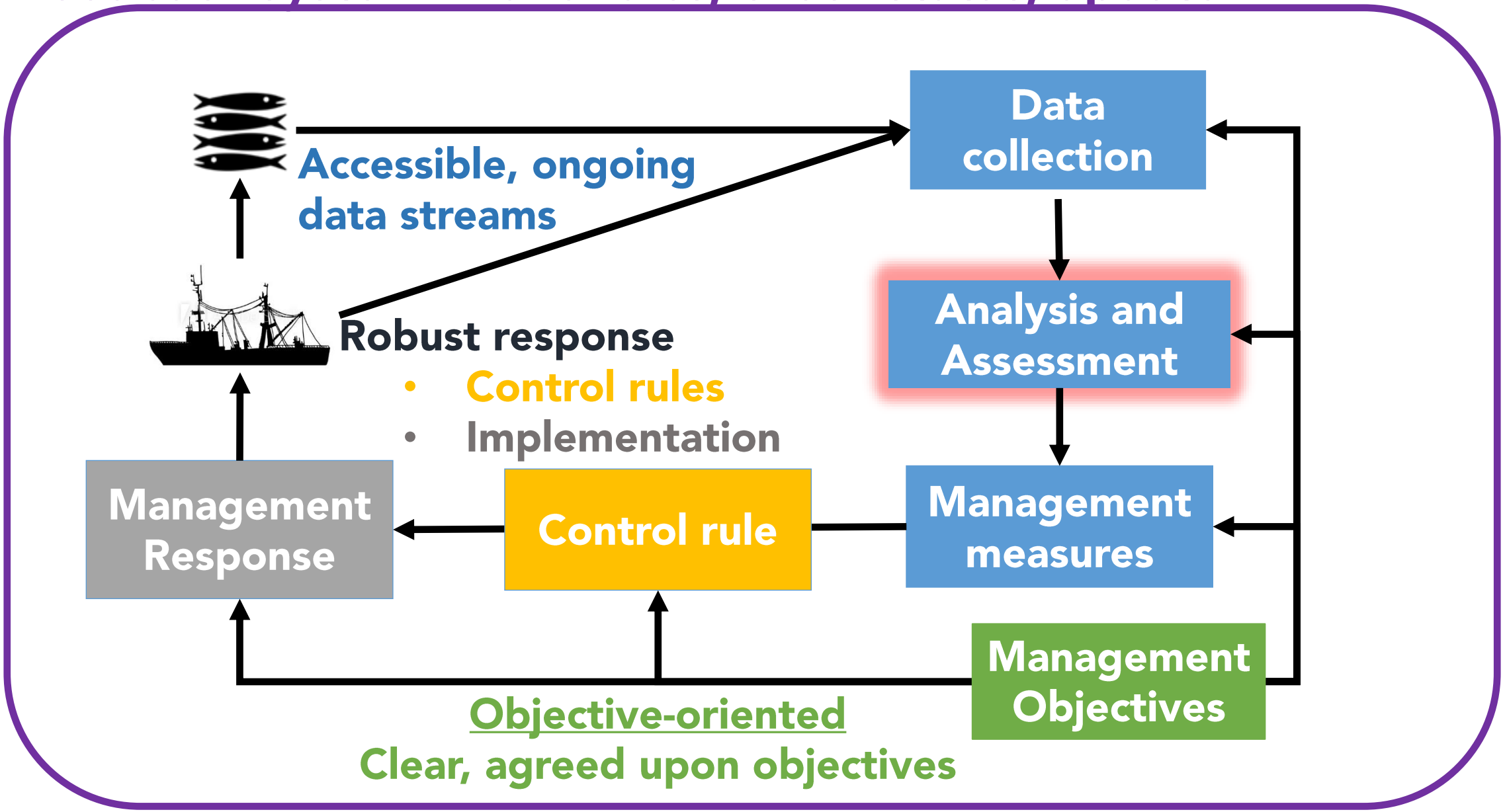
Adaptive Management System

Feedback system: Make rules, check status, update



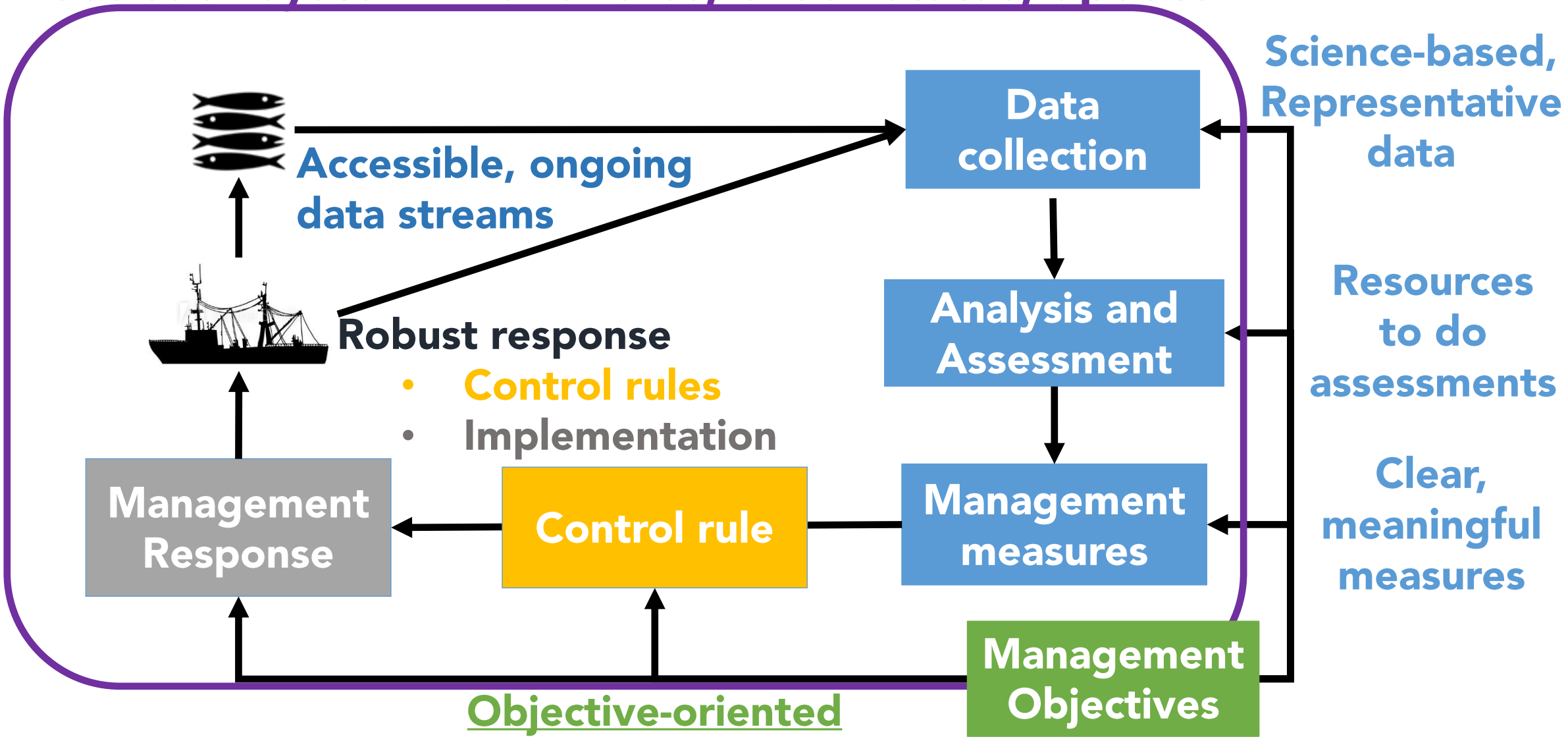
Adaptive Management System

Feedback system: Make rules, check status, update



When does this system work?

Feedback system: Make rules, check status, update

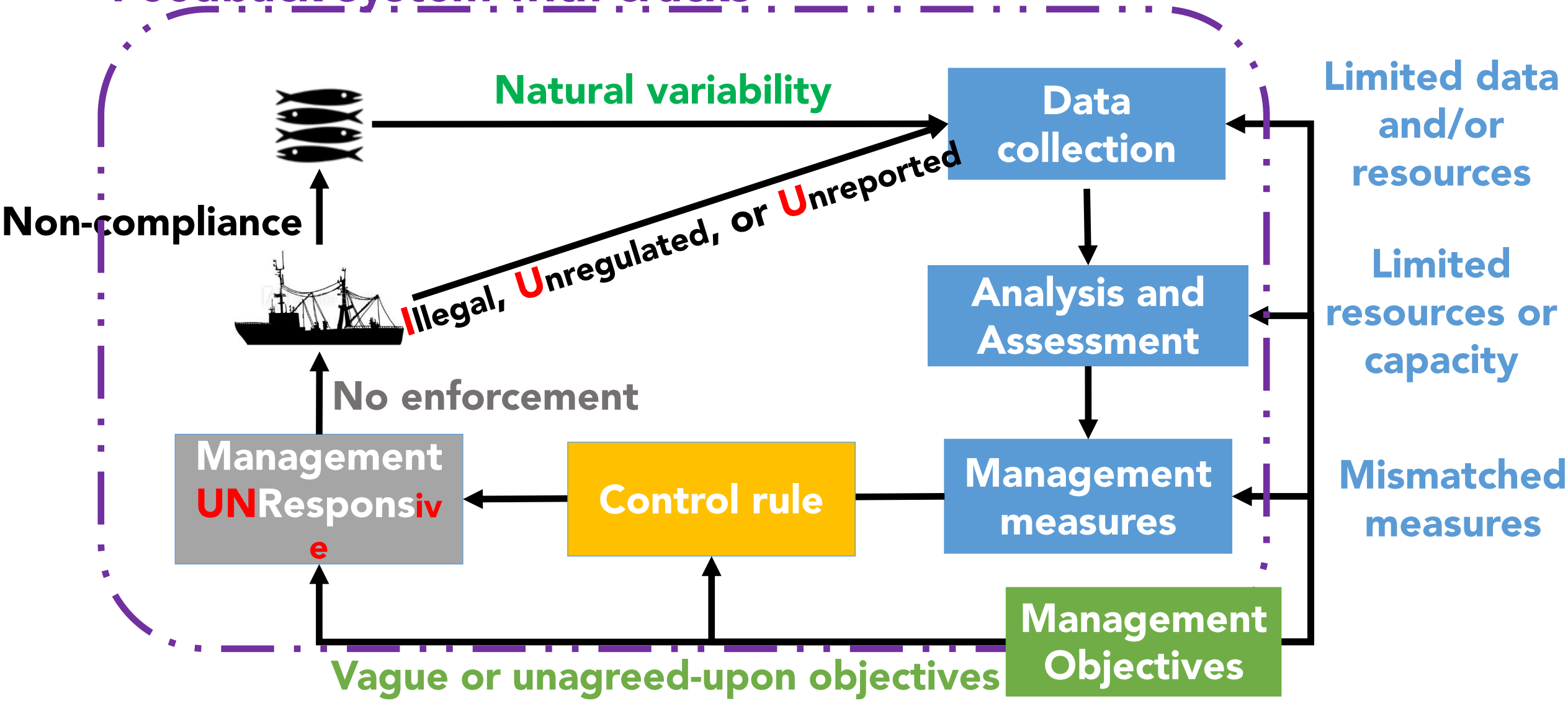


Objective-oriented

Clear, agreed upon objectives

When does it go wrong?

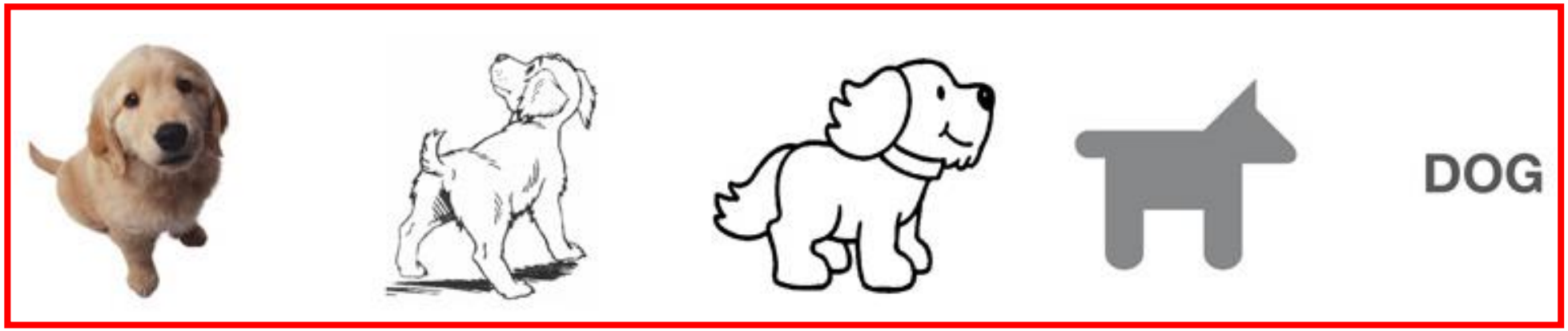
Feedback system with cracks



Models are abstractions of reality

"All models are wrong; some models are useful"- G.E.P. Box

Realistic → Abstract

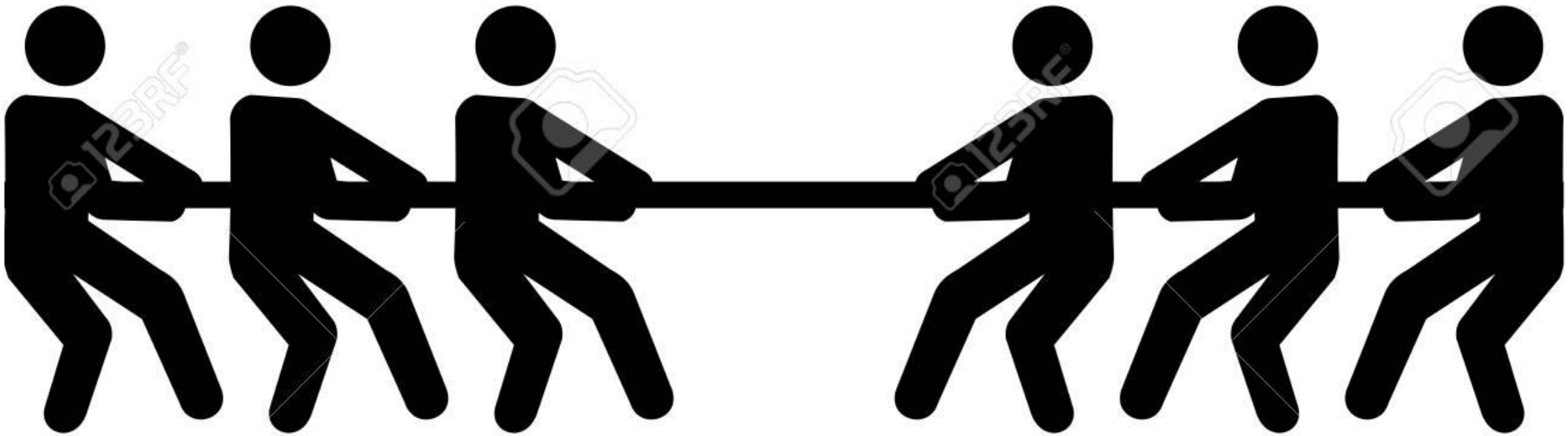


Applying models

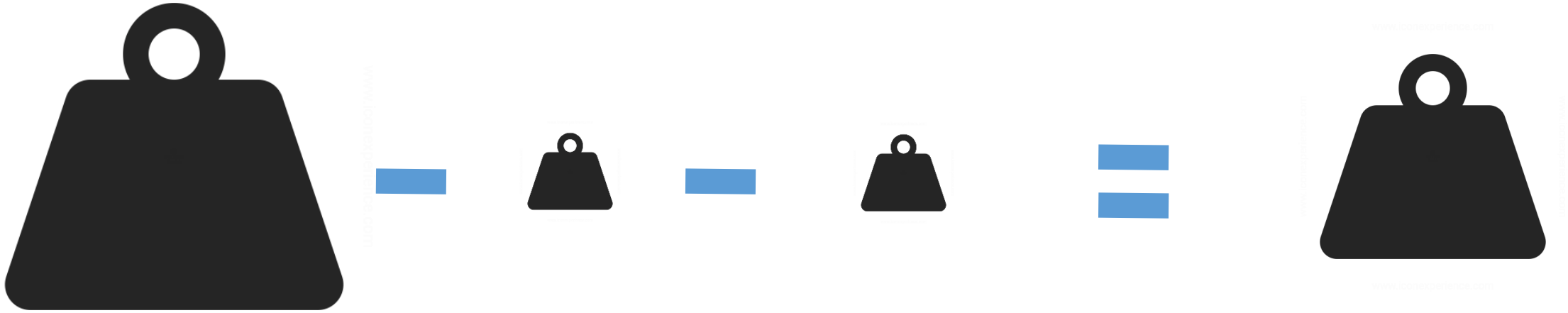
- Provides appropriate output
- Understand simplifications/assumptions

Source: https://sheilapontis.wordpress.com/2013/12/09/visualisations-the-process-of-abstraction/

Data vs. Assumptions



Modelling fish populations



1000 MT
This year's biomass

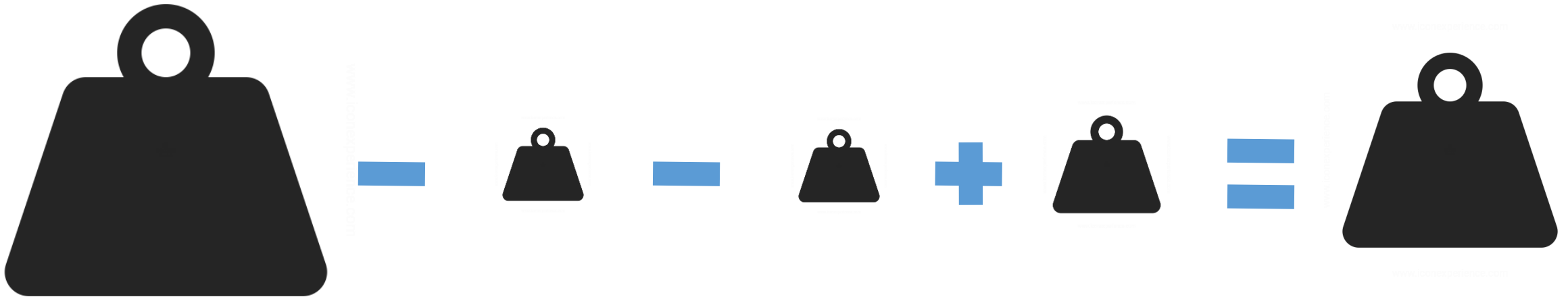
150 MT
Natural mortality

150 MT
Catches

700 MT
Next year's biomass

Modelling fish populations

1. How do you maximize catches?



1000 MT
This year's biomass

150 MT
Natural mortality

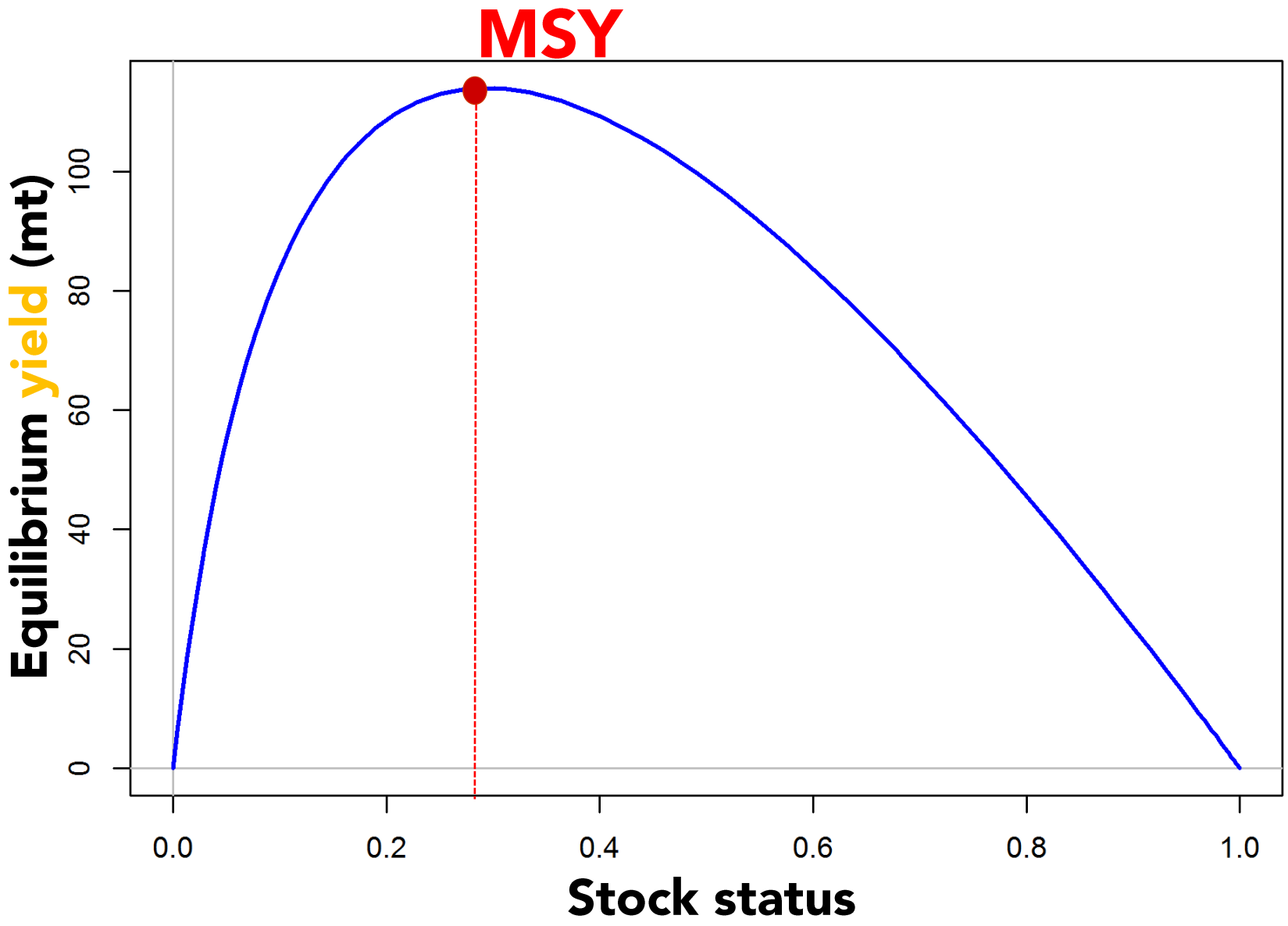
150 MT
Catches

300 MT
Recruitment

1000 MT
Next year's biomass

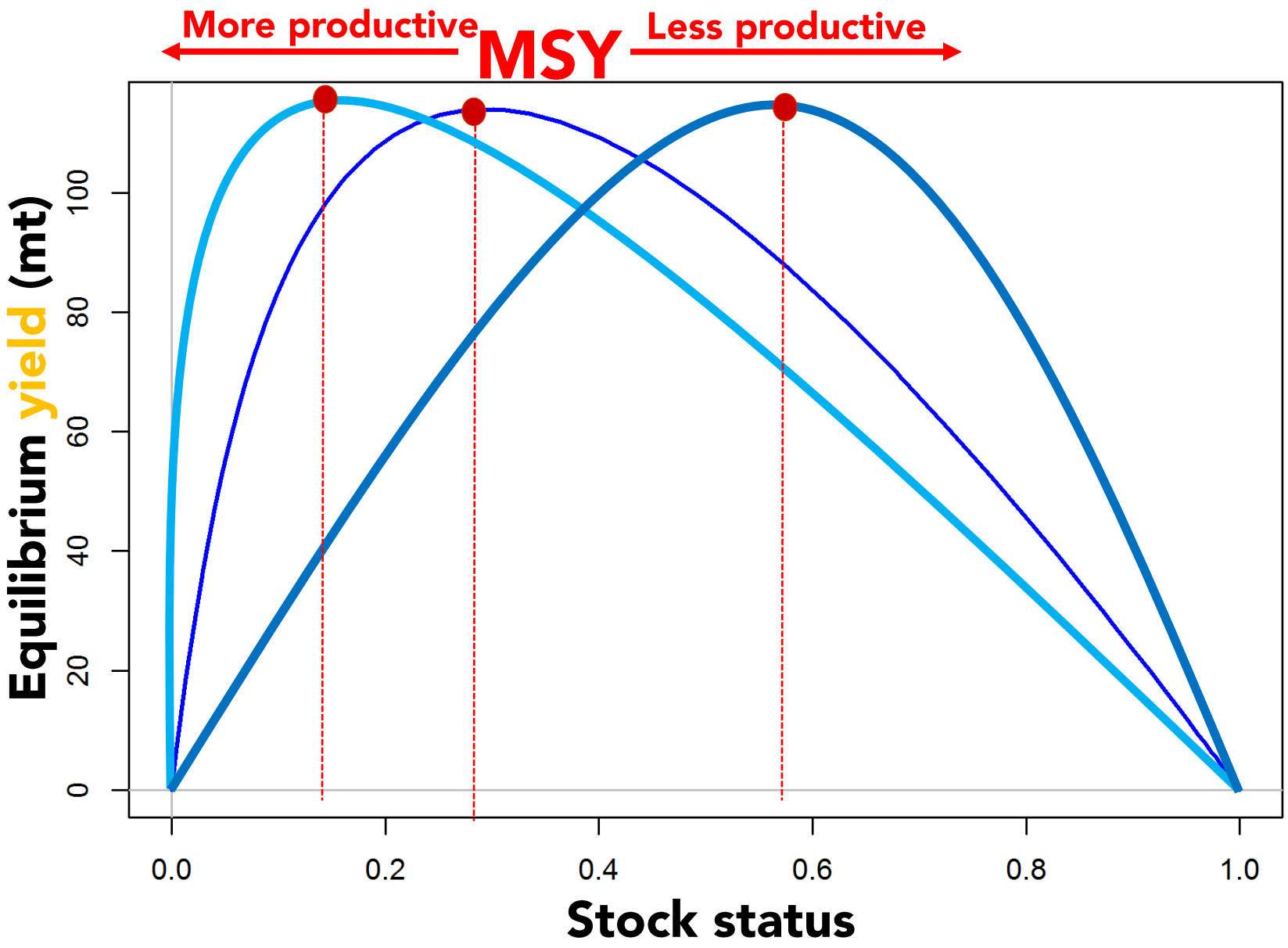
Population models: Yield curve

YIELD = PRODUCTION - REMOVALS



Population models: Yield curve

YIELD = PRODUCTION - REMOVALS



Modelling fish populations

1. How do you maximize catches?

Trade-off between population growth, reproduction and death

1000 MT
This year's biomass

150 MT
Natural mortality

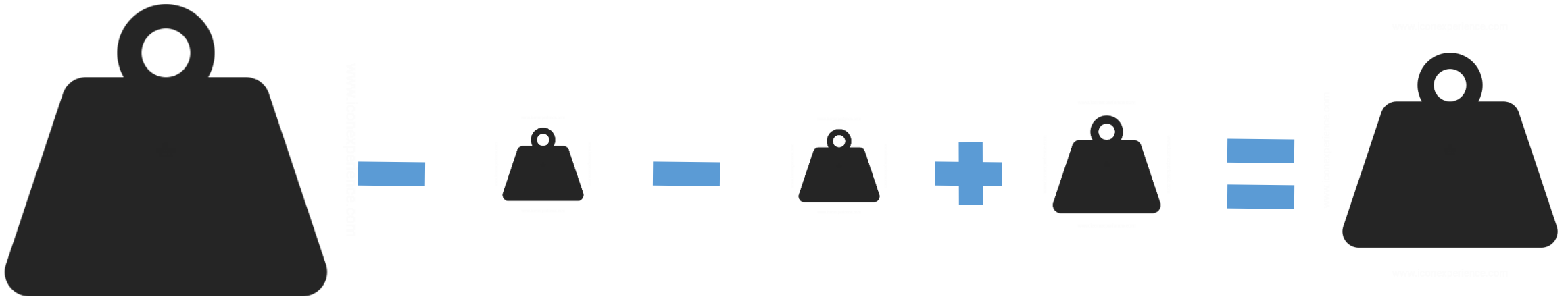
150 MT
Catches

300 MT
Recruitment

1000 MT
Next year's biomass

Modelling fish populations

2. Are fish populations just lumps of biomass?



1000 MT
This year's biomass

150 MT
Deaths

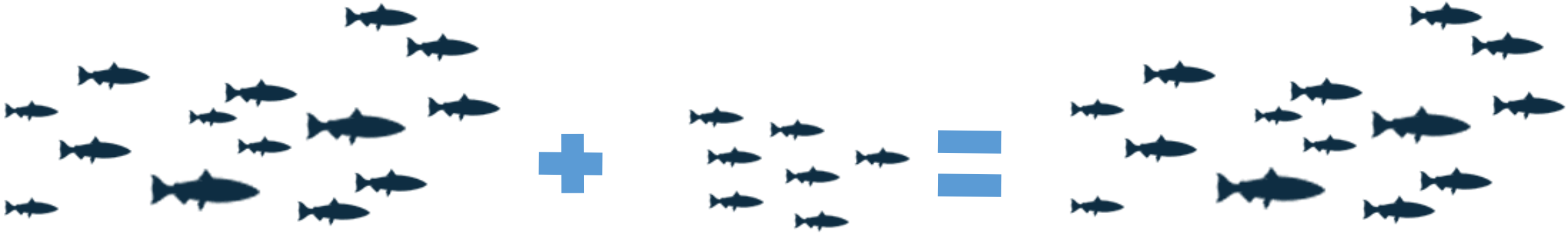
150 MT
Catches

300 MT
Recruitment

1000 MT
Next year's biomass

Modelling fish populations

2. Are fish populations just lumps of biomass? How do individuals grow? When do they mature?



1000 MT
This year's biomass

150 MT
Deaths

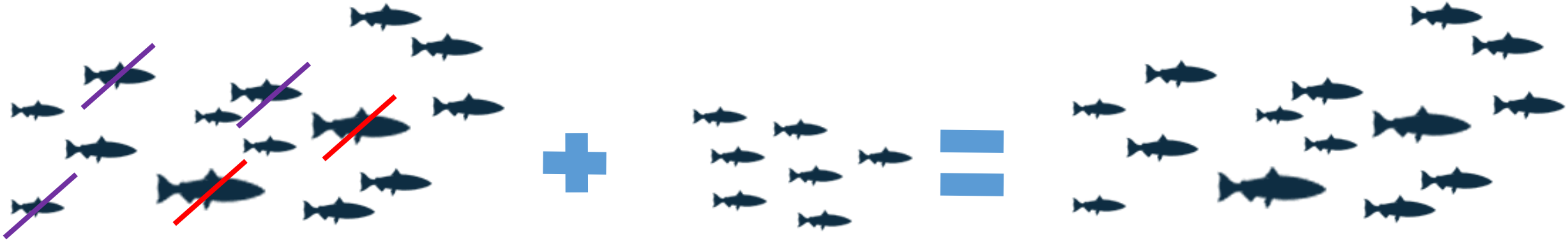
150 MT
Catches

300 MT
Recruitment

1000 MT
Next year's biomass

Modelling fish populations

2. Are fish populations just lumps of biomass? How do individuals grow? When do they mature?



1000 MT
This year's biomass

150 MT
Deaths

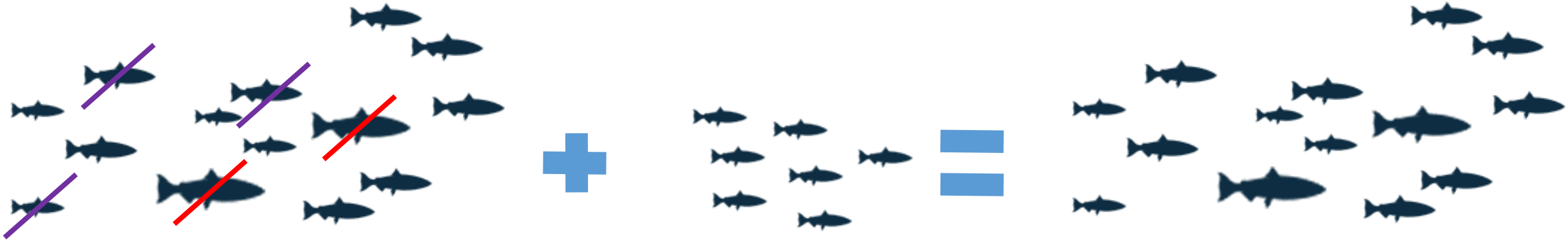
150 MT
Catches

300 MT
Recruitment

1000 MT
Next year's biomass

Modelling fish populations

3. How does the population change with how we fish them?



1000 MT
This year's biomass

150 MT
Deaths

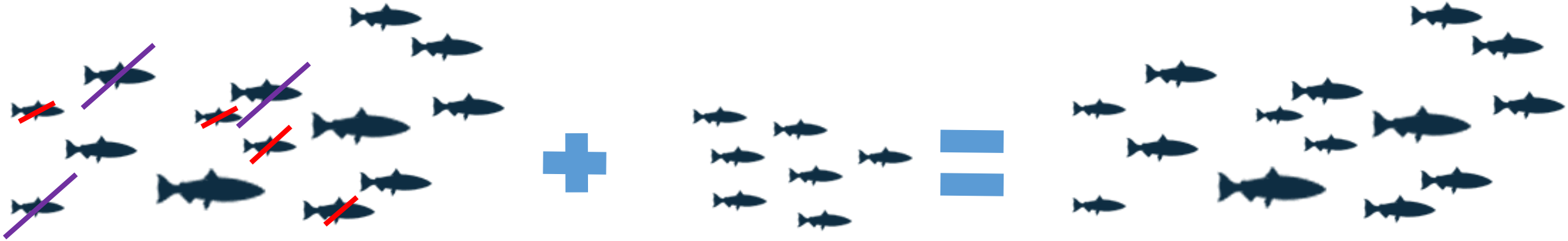
150 MT
Catches

300 MT
Recruitment

1000 MT
Next year's biomass

Modelling fish populations

3. How does the population change with how we fish them? SELECTIVITY



1000 MT
This year's biomass

150 MT
Deaths

150 MT
Catches

300 MT
Recruitment

1000 MT
Next year's biomass

Modelling fish populations: Life history

- Death
- Growth
- Reproduction
- Recruitment

Production
Surplus production is what we can catch

1000 MT
This year's biomass

150 MT
Deaths

150 MT
Catches

300 MT
Recruitment

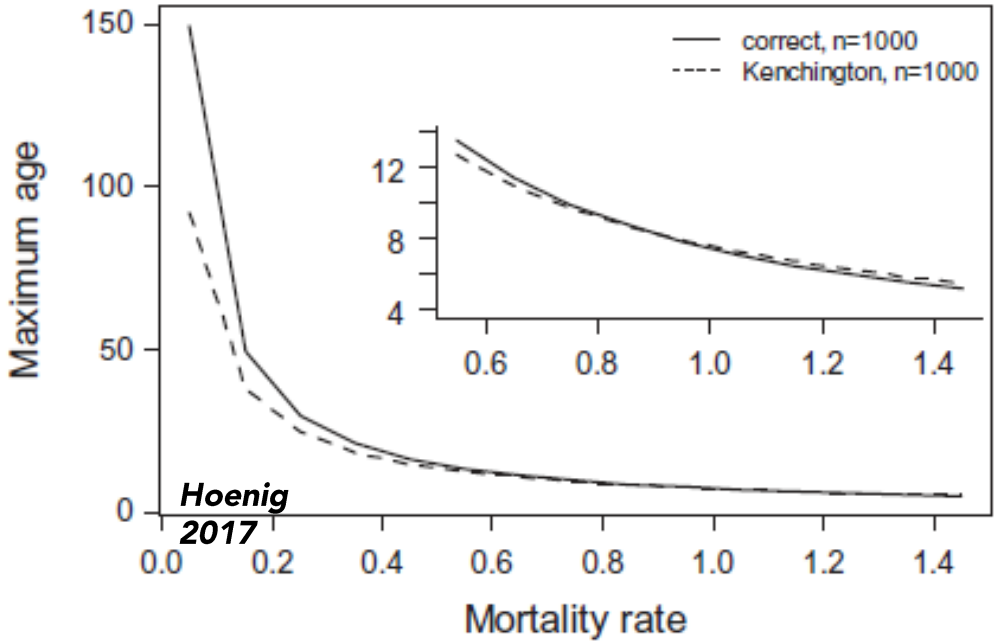
1000 MT
Next year's biomass

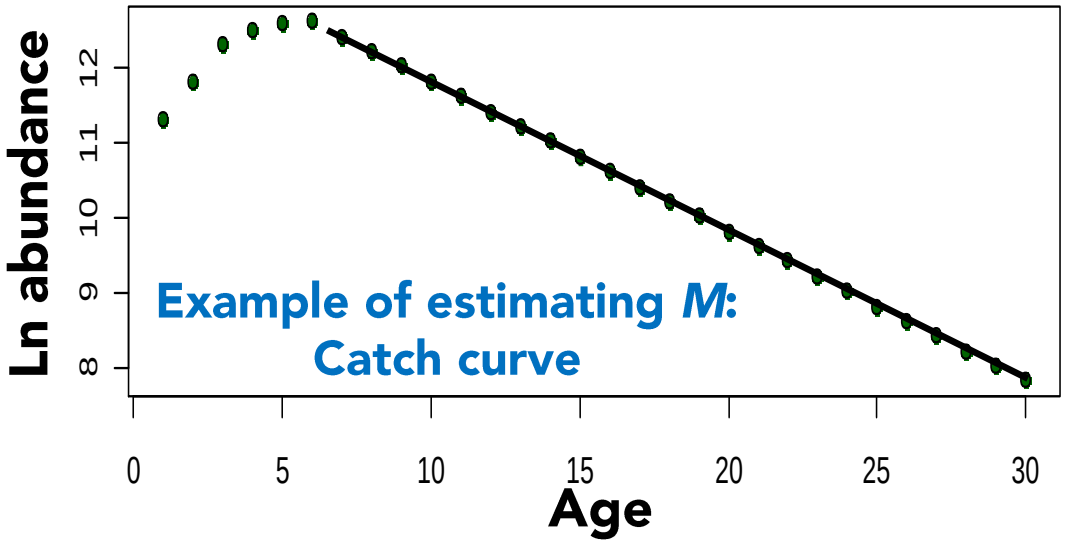
Biology and stock assessment: Mortality

Natural mortality (*M*)

- Death by natural causes
- Not fishing mortality (F)
- Total mortality (Z)= M+F
- Longevity = life expectancy
- Greater longevity, lower *M*
- Directly measuring M is hard

https://github.com/shcaba/Natural-Mortality-Tool
https://connect.fisheries.noaa.gov/natural-mortality-tool/





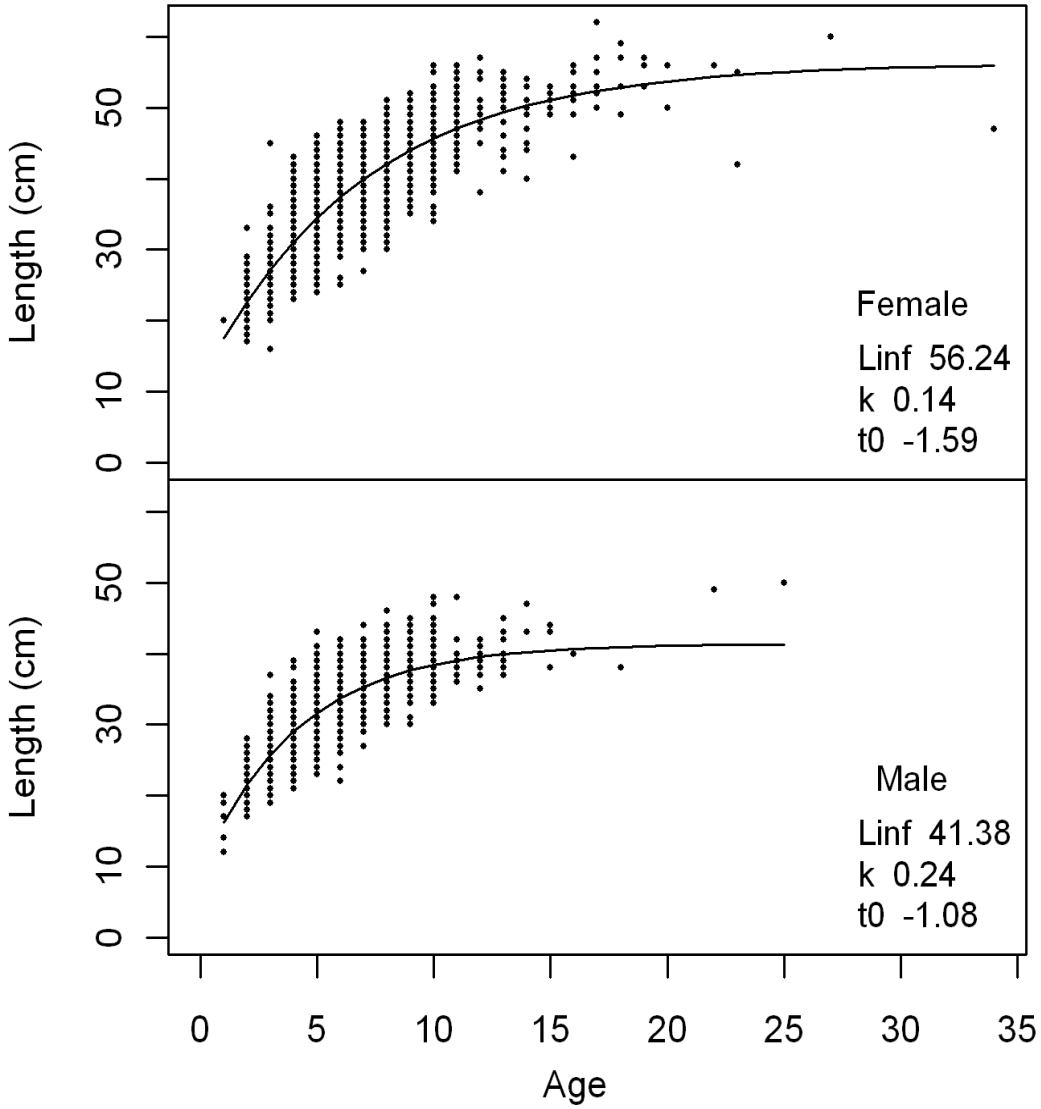
Biology and stock assessment: Growth

Growth

- How size changes by age

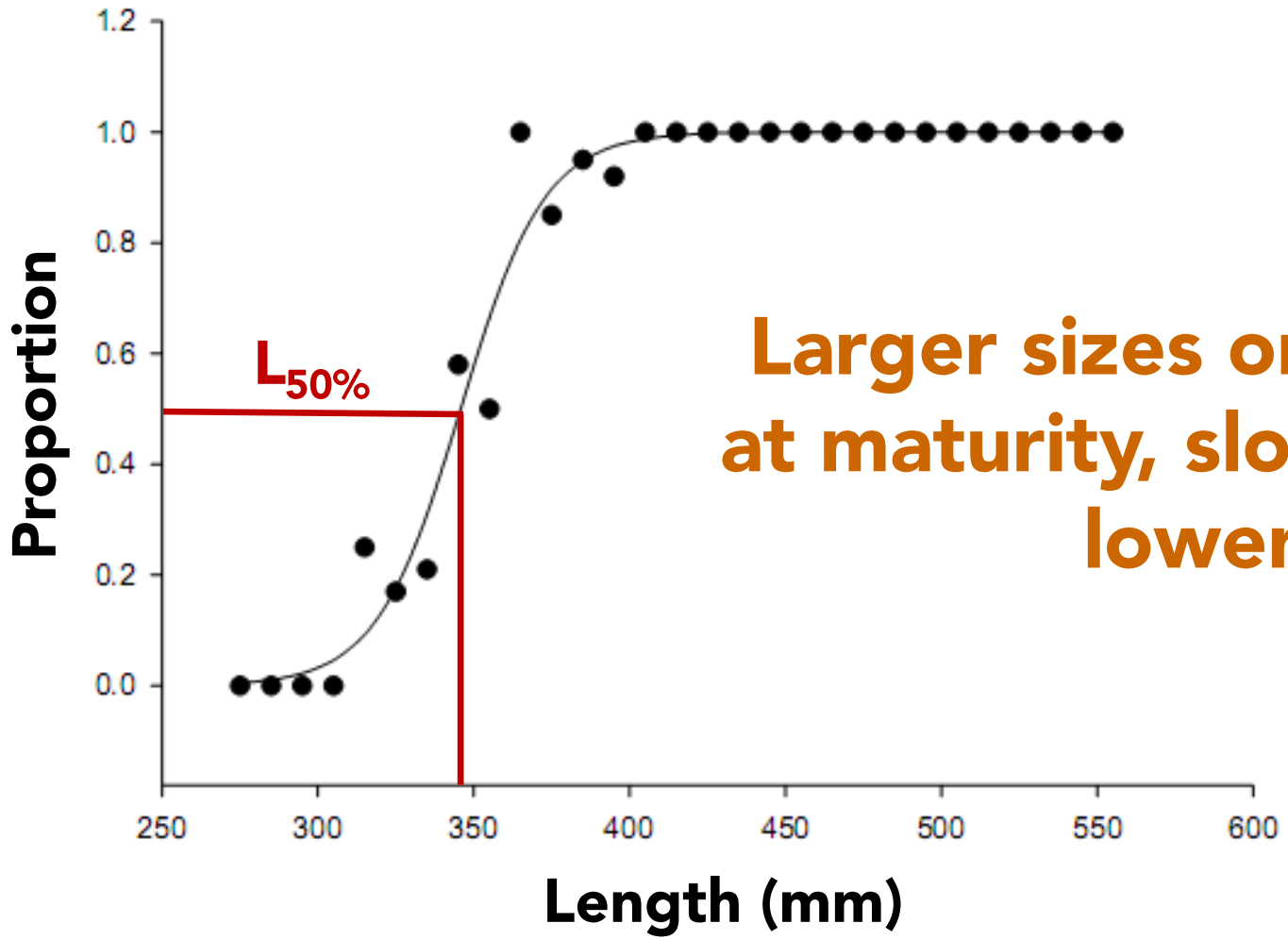
- L_∞: asymptotic size
- k: growth
- t_0: age at size 0

- Longer-lived, lower M, slower growing



Biology and stock assessment: Maturity

Maturity: age or length at reproduction

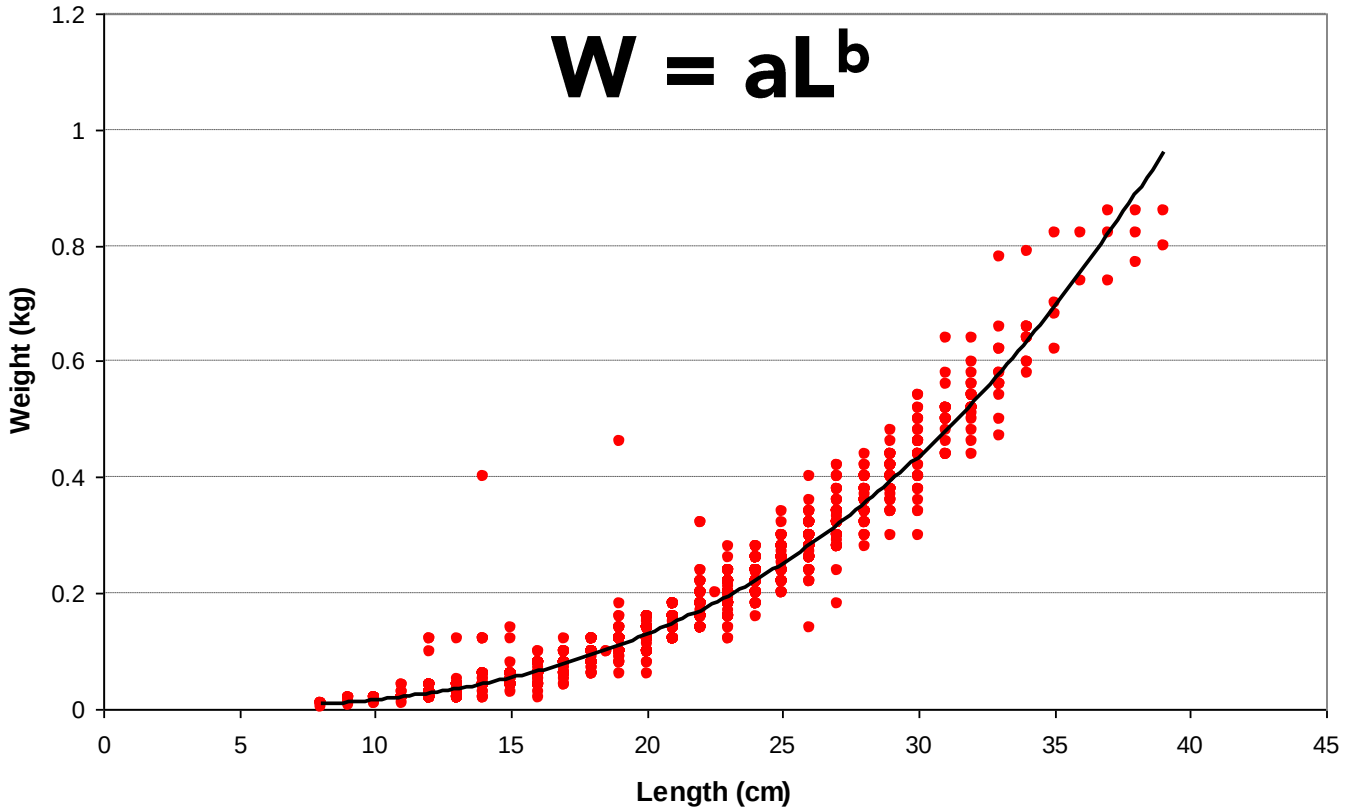


Larger sizes or older ages at maturity, slower growth, lower *M*

Biology and stock assessment: Length-weight

Length-weight relationship

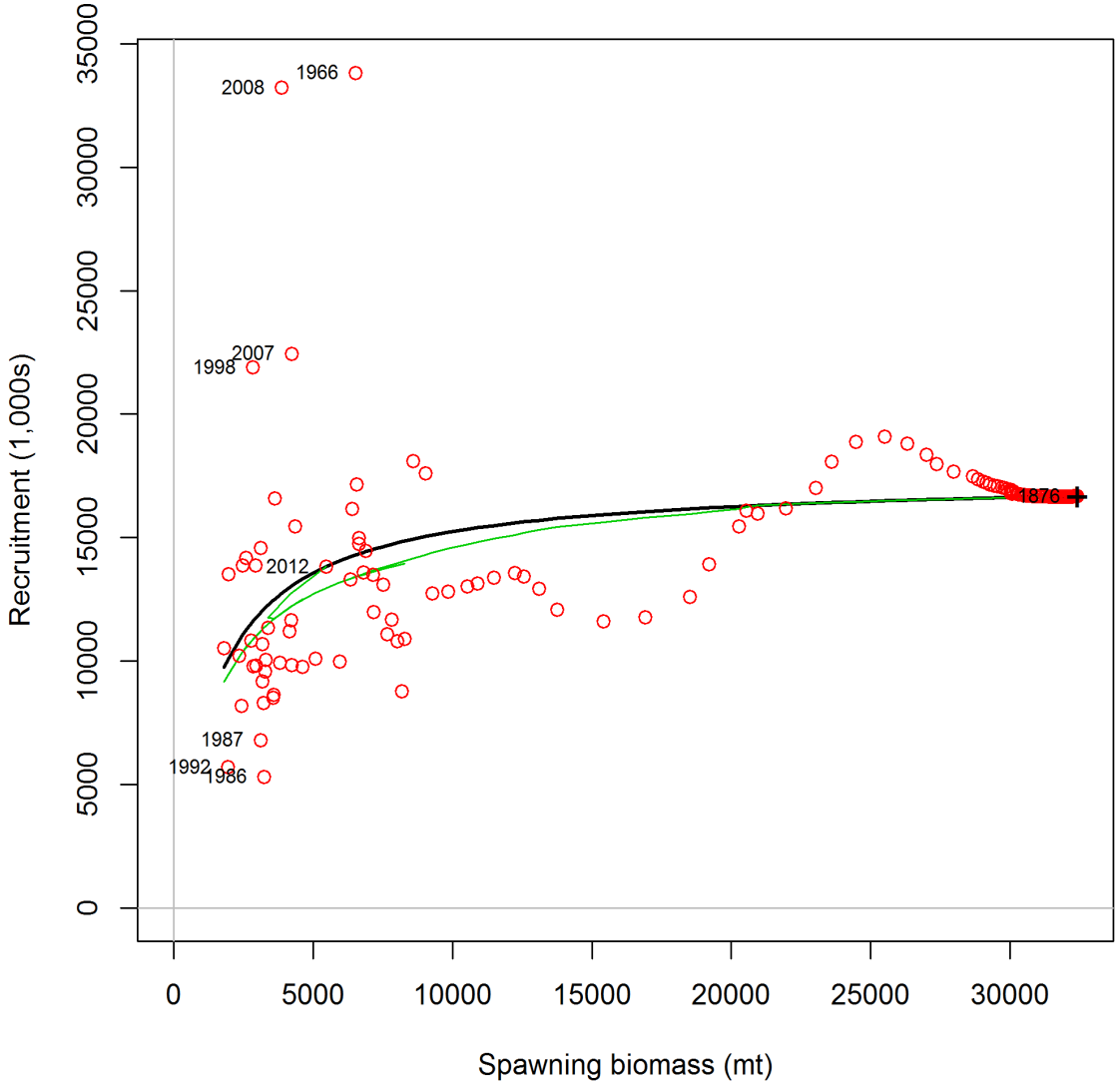
- How weight changes with length
- Provides a measure of scale (i.e., biomass)



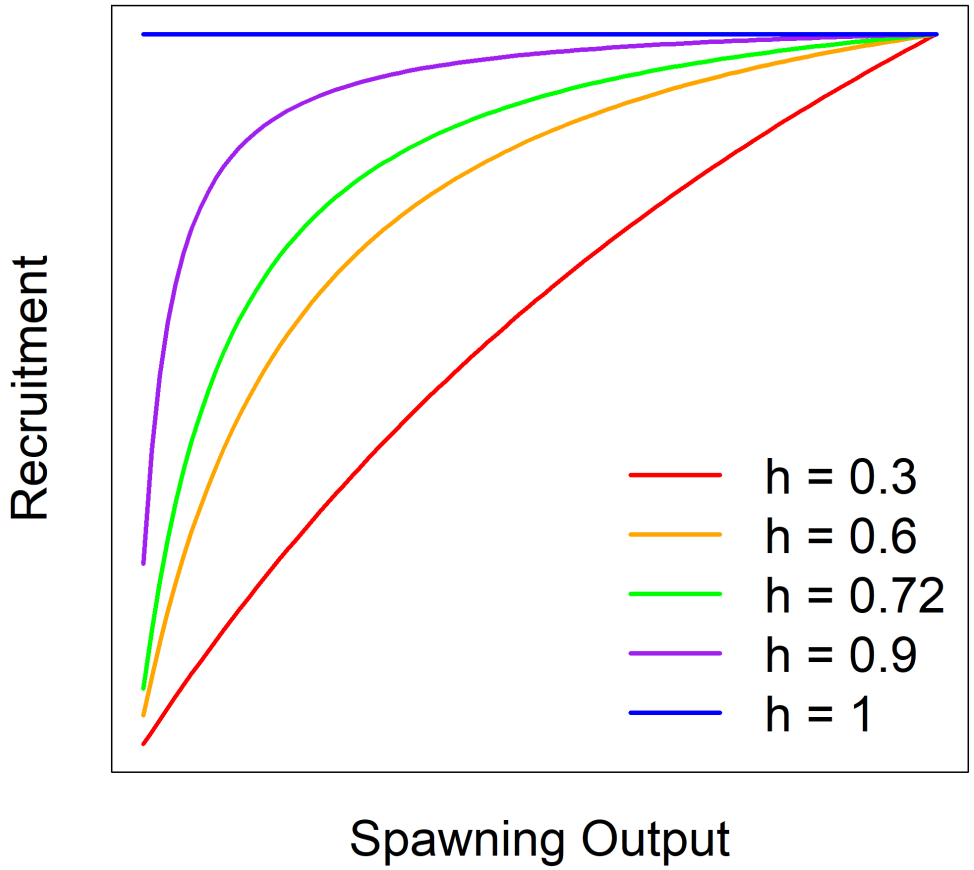
Biology and stock assessment: Productivity

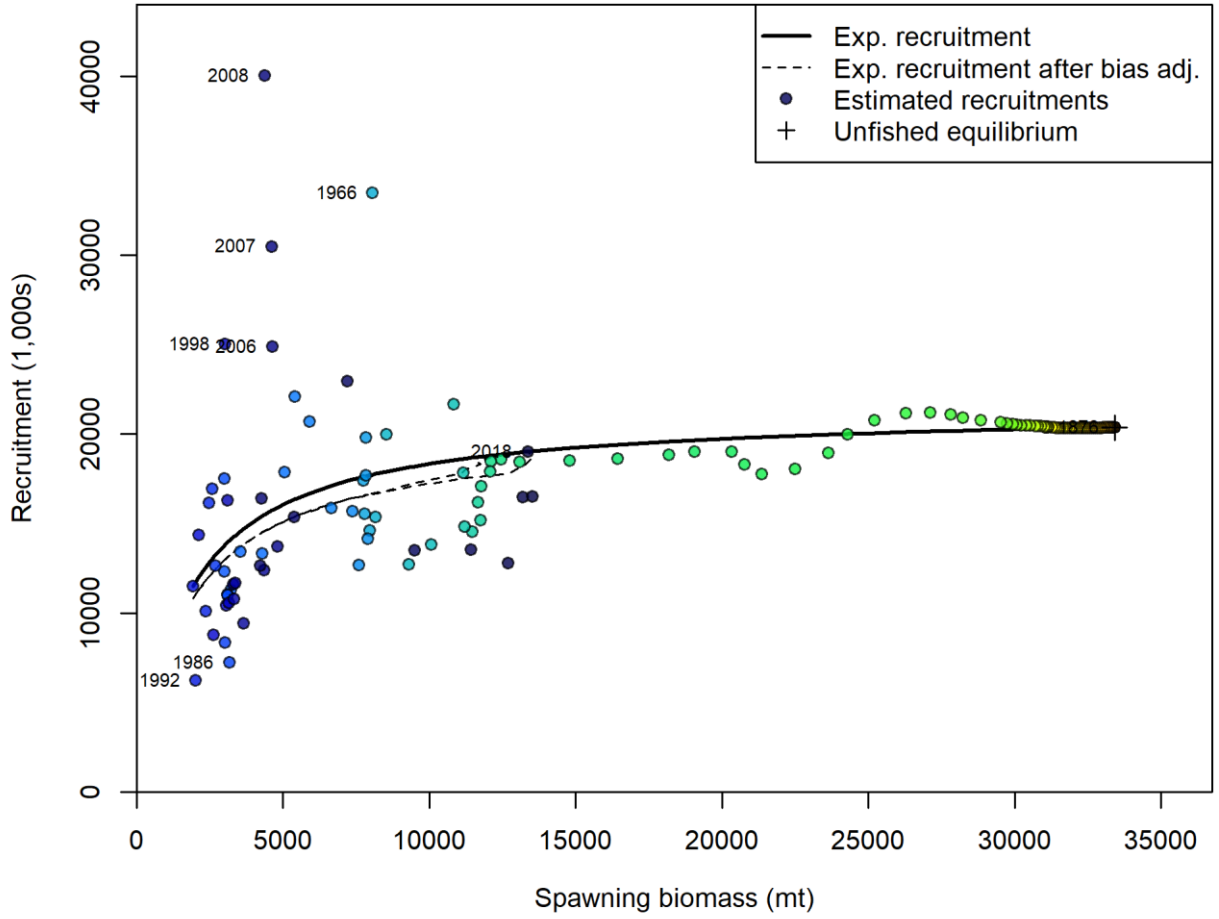
Stock-recruitment relationship

- Number of recruits produced by spawning individuals
- Measure of productivity
- Defines yield curve
- More productive, more relative catch
- Faster growing, shorter-lived, earlier to mature, more productive



Productivity (aka Steepness)

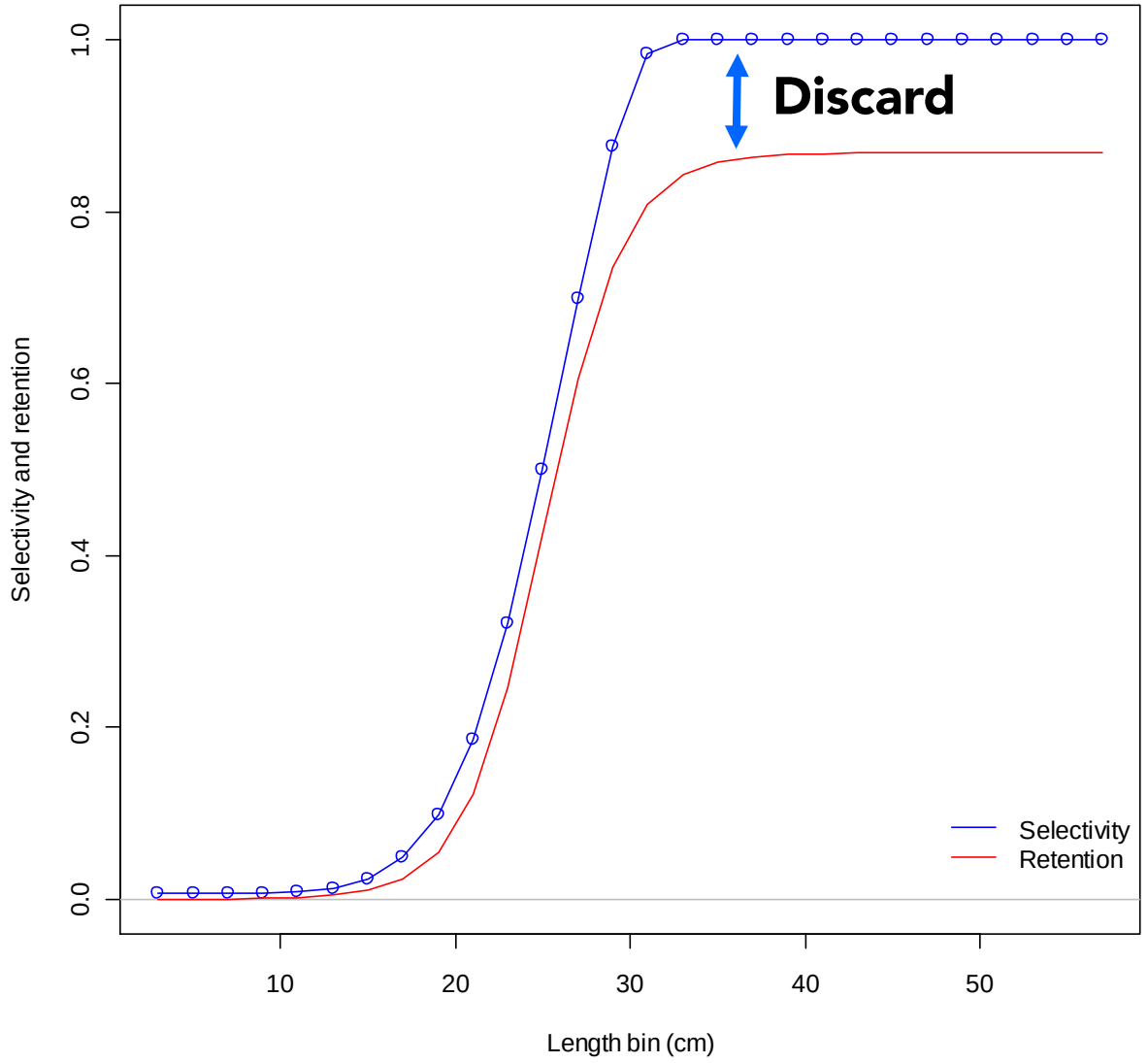




Biology and stock assessment: Selectivity

Selectivity

- Technical interaction of biology and fishery
- What size or age a gear catches
- Determines the interpretation of *F*
- Relation to maturity affects sustainable F



Relationships among life history parameters

"Endpoints" L_∞/T_{max}

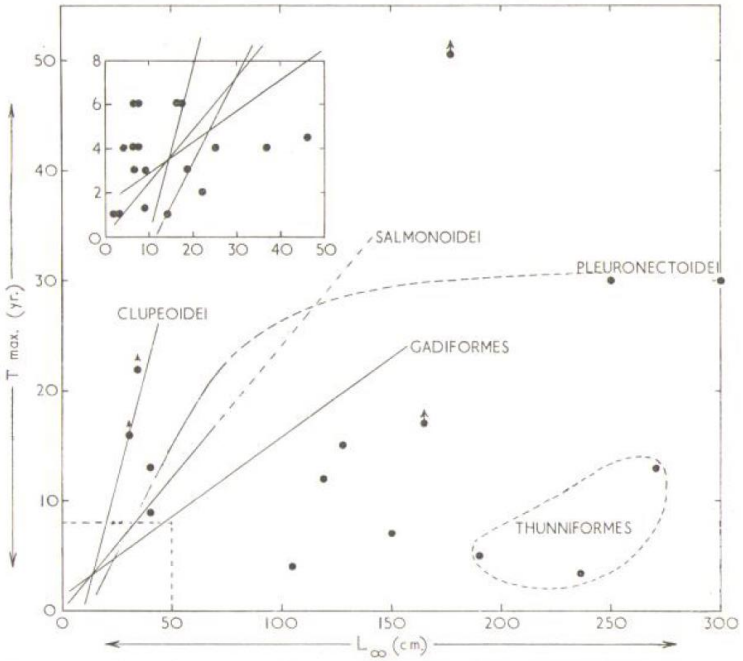


FIG. 5. Relation between maximum age (T_{max}) and asymptotic length (L_∞) in various species not included in Fig. 4 (from Table I). The lines are those for the four groups shown in Fig. 4.

"Course of events" M/K

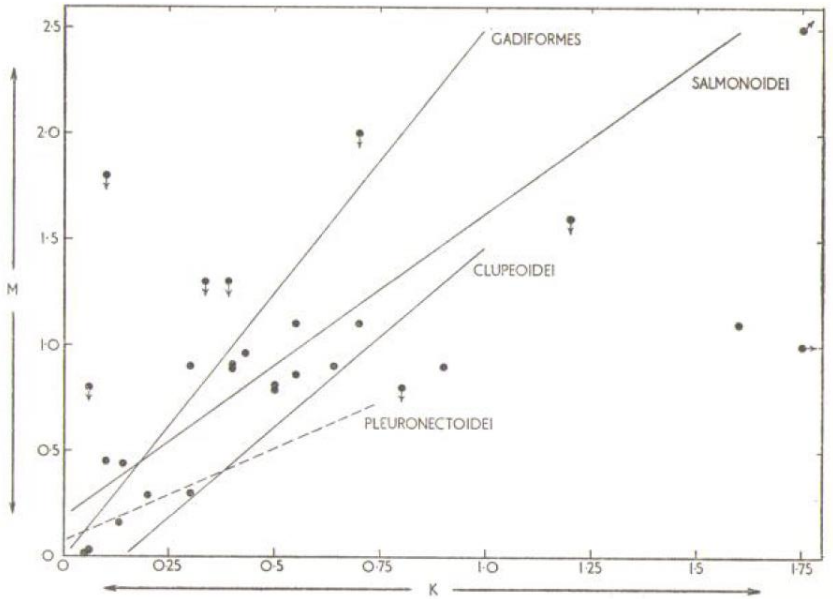


FIG. 7. Relation between natural mortality coefficient (M) and rate of curvature of growth curve (K) in various species not included in Fig. 6 (from Table I). The lines are those for the four groups shown in Fig. 6.

"Reproductive drain?" $[L_{mat}/L_\infty]/T_{max}$

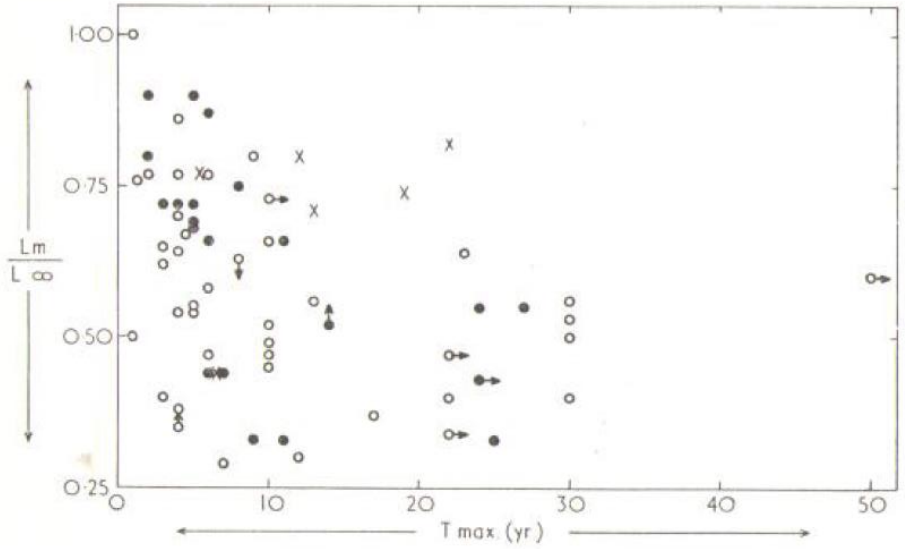
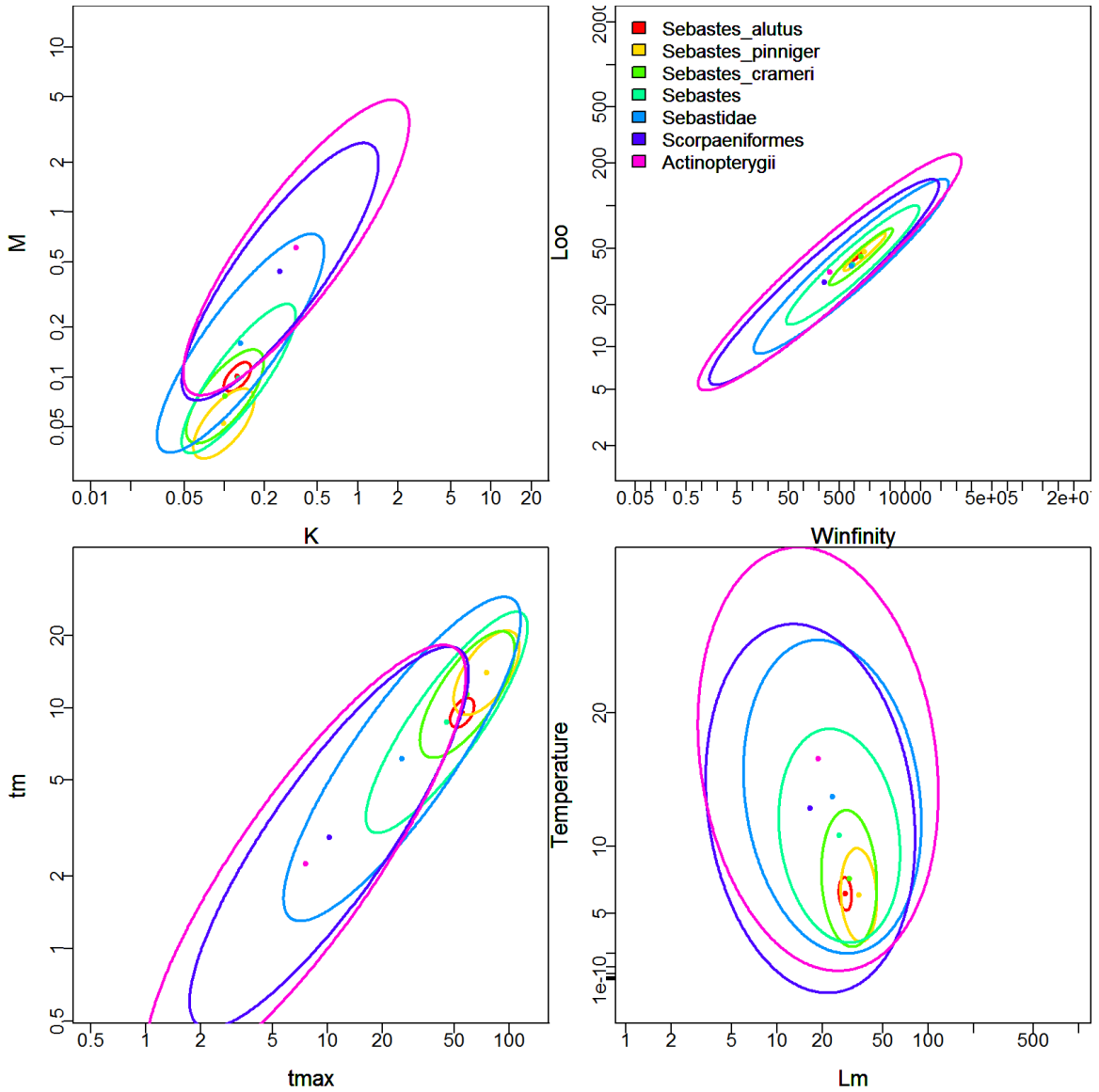


FIG. 8. Size at maturity (L_m) and longevity. Plot of ratio L_m/L_∞ against T_{max}. ● = Salmonoidei, x = Clupeoidei; other species shown as ○.

Source: Beverton and Holt 1959

Building life history rules with taxonomy

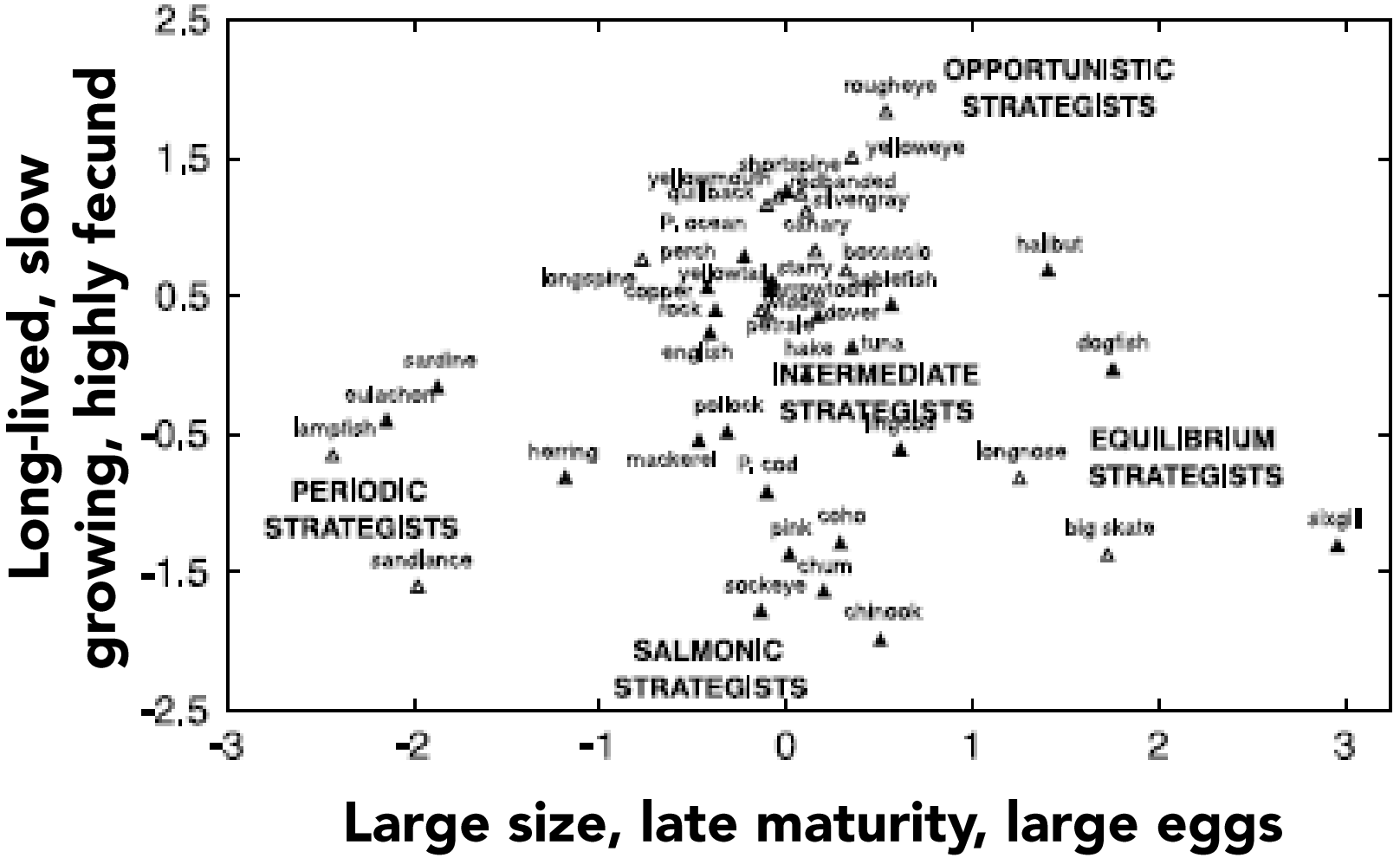


FishLife R library

- **Measurement error- variance on all parameters**
- **Taxonomic considerations- hierarchical relationships**
- **Incomplete data- imputing relationships**
- **Unknown functional form- covariation beyond pairs**

Source: Thorson, Munch, Cope and Gao 2017

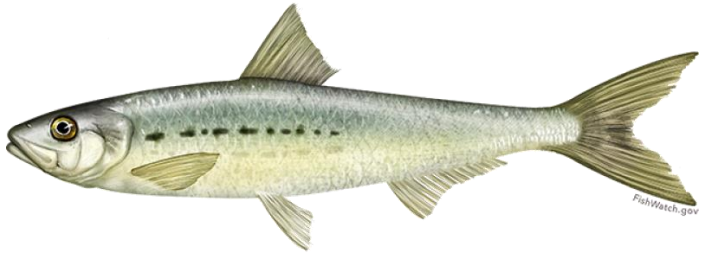
Life history strategies



Understanding these life history strategies along with fishery selectivity and fishing rate can help determine a stocks susceptibility to excessive fishing.
(e.g., Risk assessments)

King and McFarlane 2003

Assessment Goldilocks



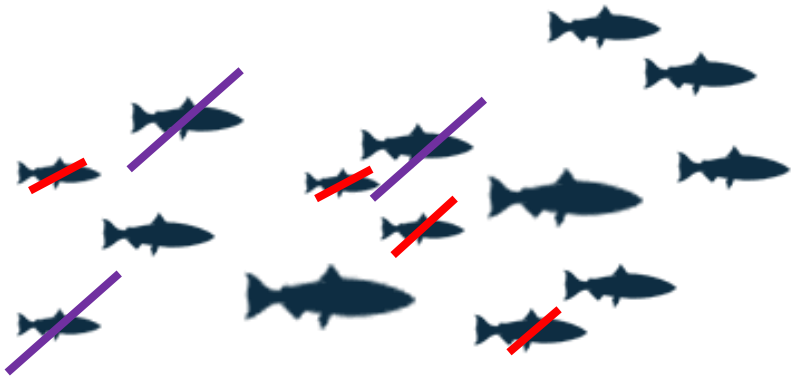
Short-lived, fast growing, quick to mature

Medium-lived, fast growing, late to mature

Long-lived, slow growing, late to mature

Assessment & Management challenge

Modelling fish populations: How do we do it?

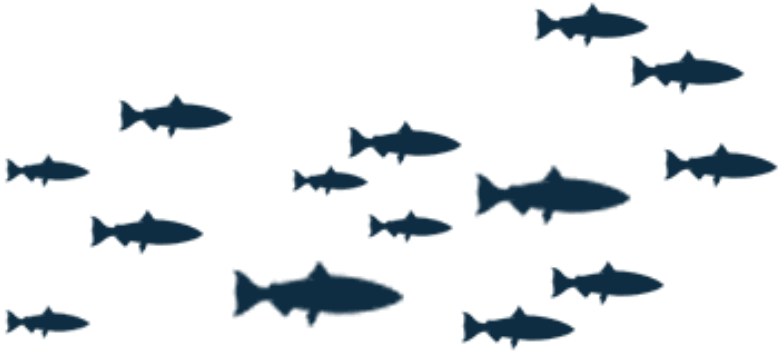


1000 MT
This year's biomass

150 MT
Deaths

150 MT
Catches

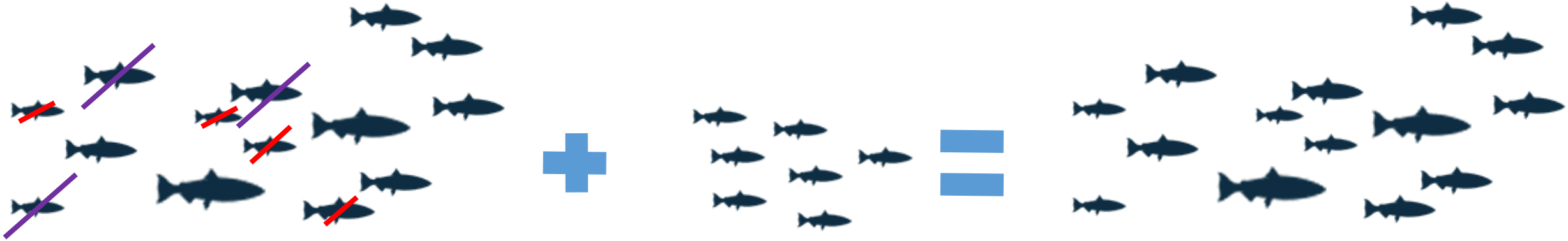
300 MT
Recruitment



1000 MT
Next year's biomass

Modelling fish populations: How do we do it?

WE NEED DATA!



1000 MT
This year's biomass

150 MT
Deaths

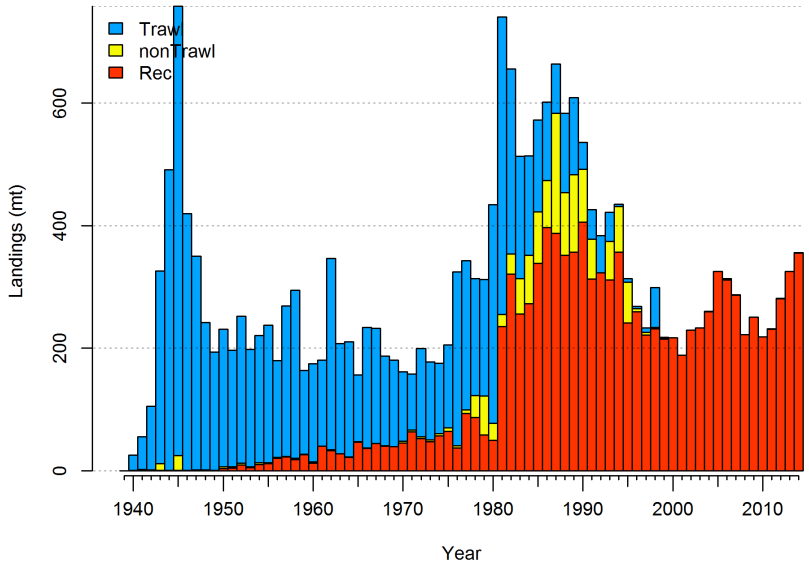
150 MT
Catches

300 MT
Recruitment

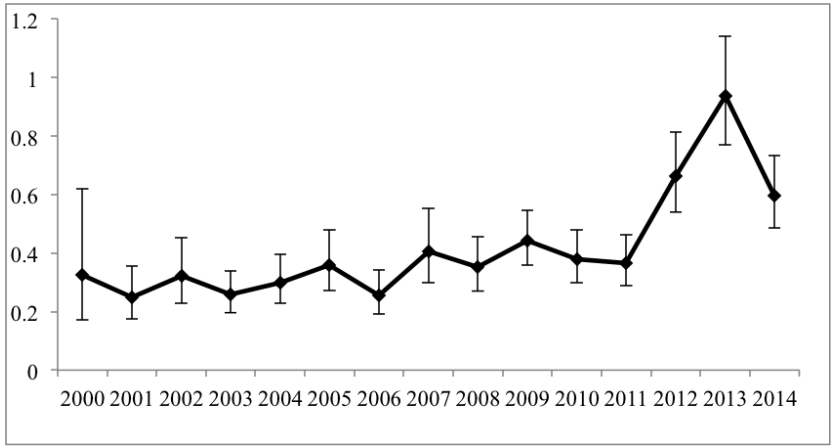
1000 MT
Next year's biomass

Stock assessment inputs: Data

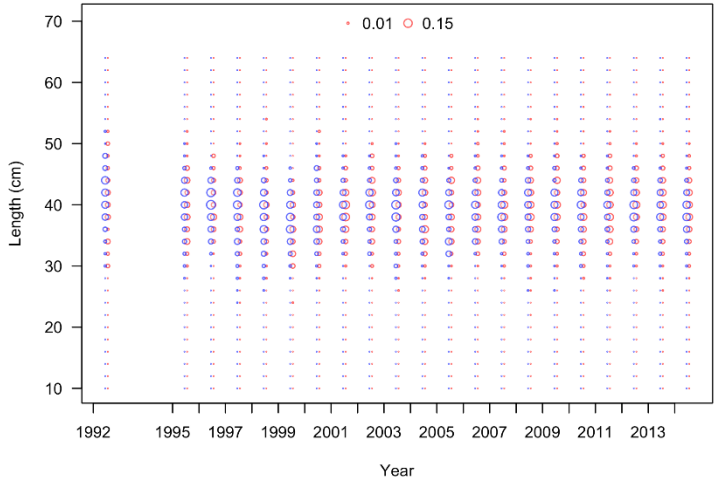
Removals



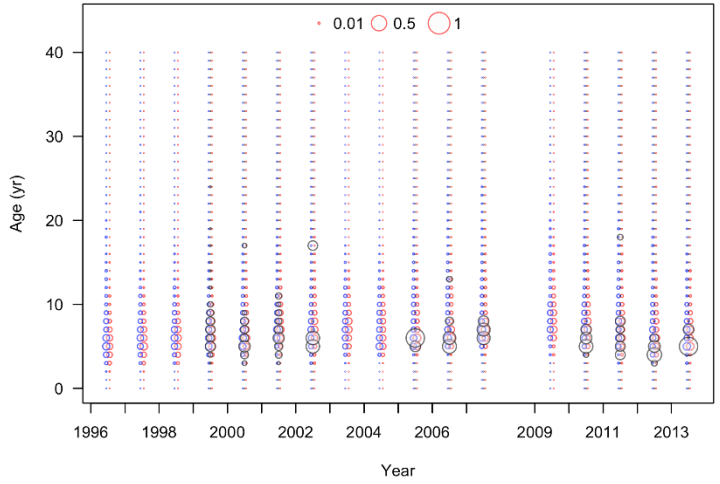
Abundance indices



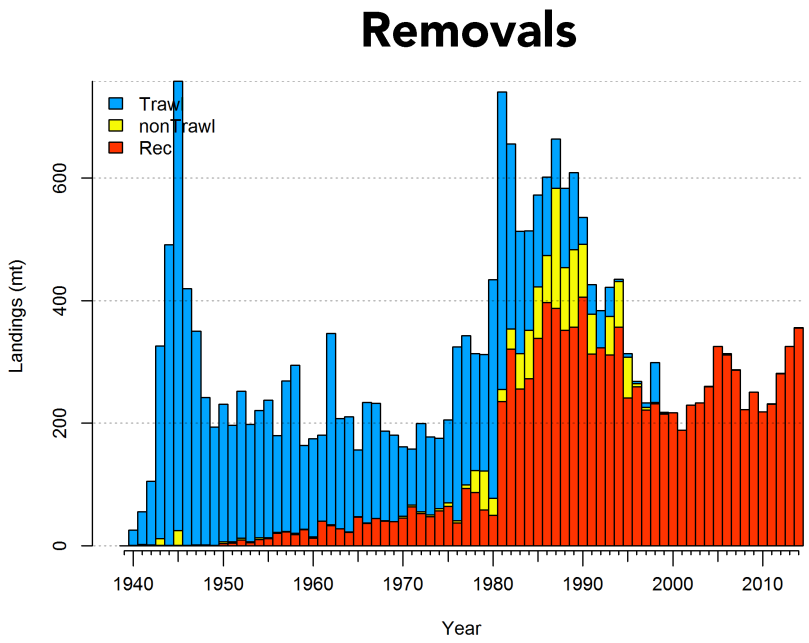
Length compositions



Age compositions



Stock assessment inputs: Removals



Catches, Landings or Removals?

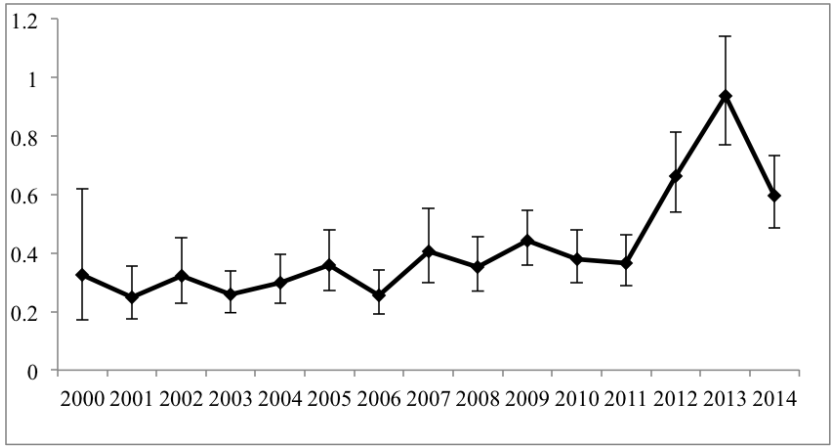
Removals = Landings + dead discards

Stock Synthesis uses metric tons

Stock assessment inputs: Indices

Measuring abundance (e.g., trawl survey, CPUE from fishery)

Abundance indices

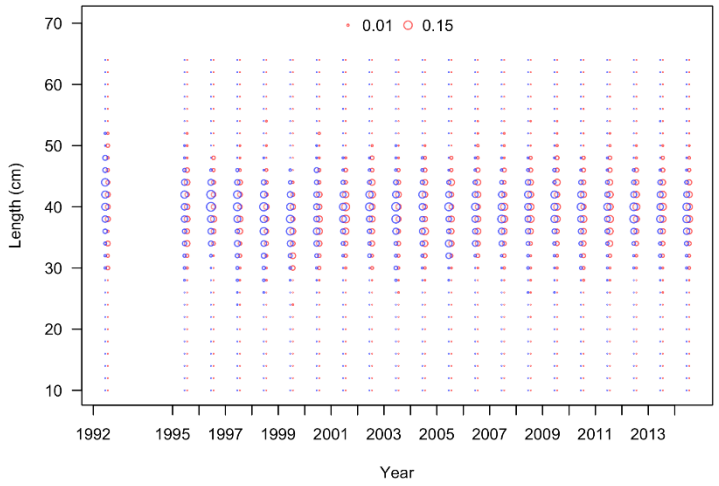


Stock Synthesis allows for multiple fishery-dependent and –independent indices, along with a host of catchability and variance treatments

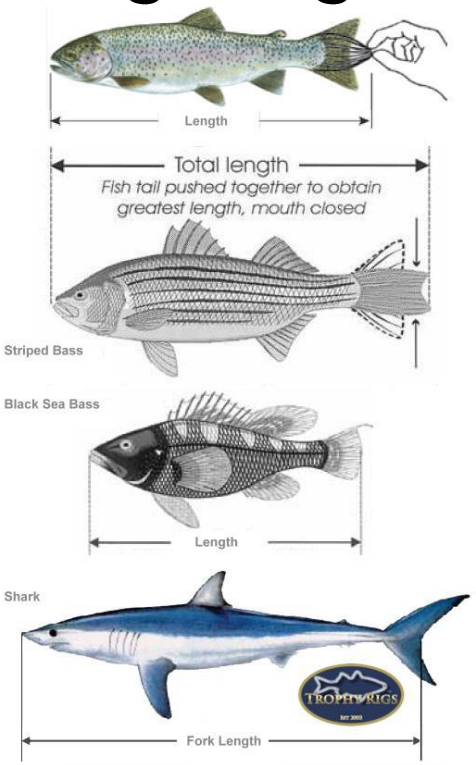
Stock assessment inputs: Lengths

Stock Synthesis use centimeters with user defined binning, effective sample size, and data weighting. Population bins can also be different than data bins

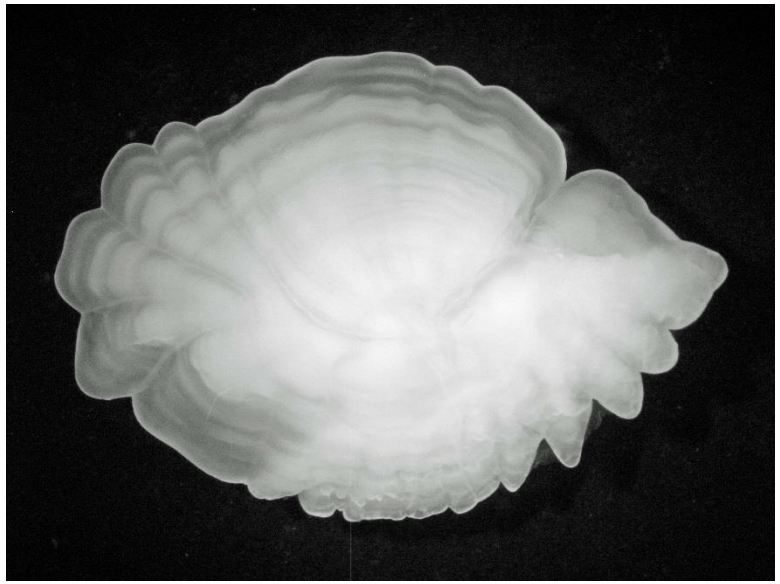
Length compositions



Measuring size structure (e.g., lengths)

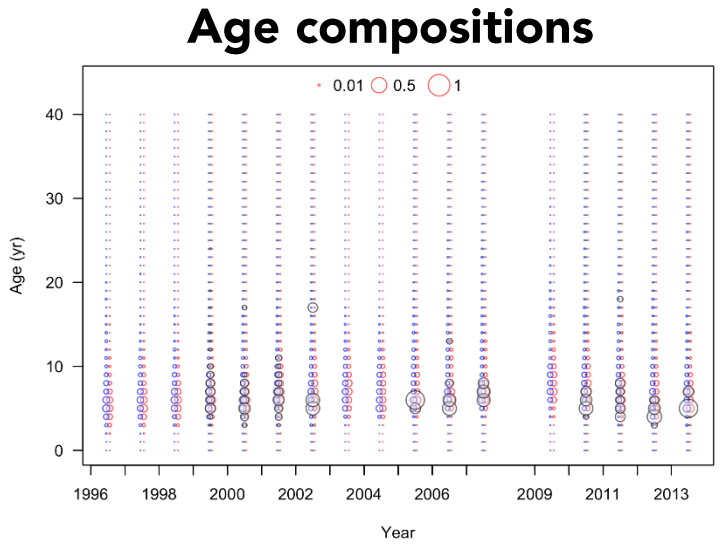


Stock assessment inputs: Ages



Measuring age structure (e.g., ageing otoliths)

Stock Synthesis use years with user defined binning, effective sample size, and data weighting. Marginal and conditional ages can be used. Custom ageing error matrices can also be applied



Data representativeness

- **Do data represent what you want to measure?**
  - Dimensions to consider
    - Time
    - Space
    - Fleets
    - Stocks
    - Sex

- Non-representative data can be a major source of uncertainty
- Always ask how representative data are to your objective.

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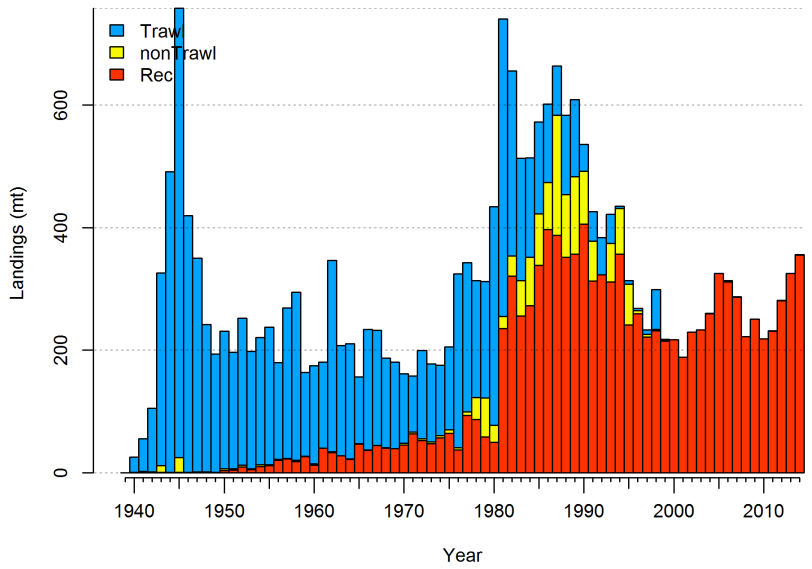

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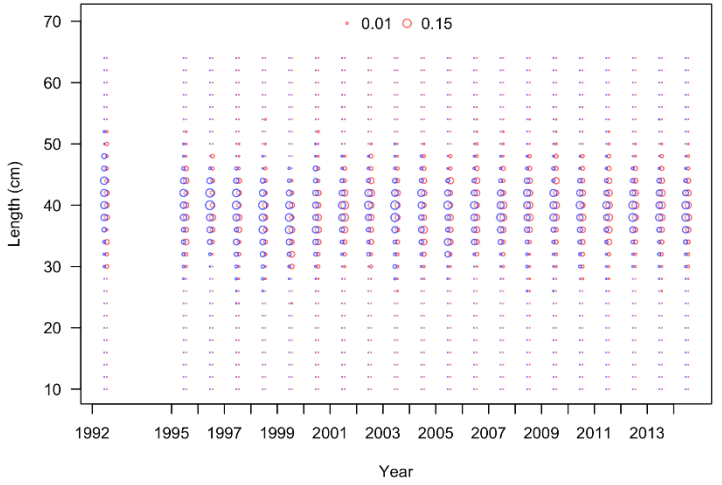

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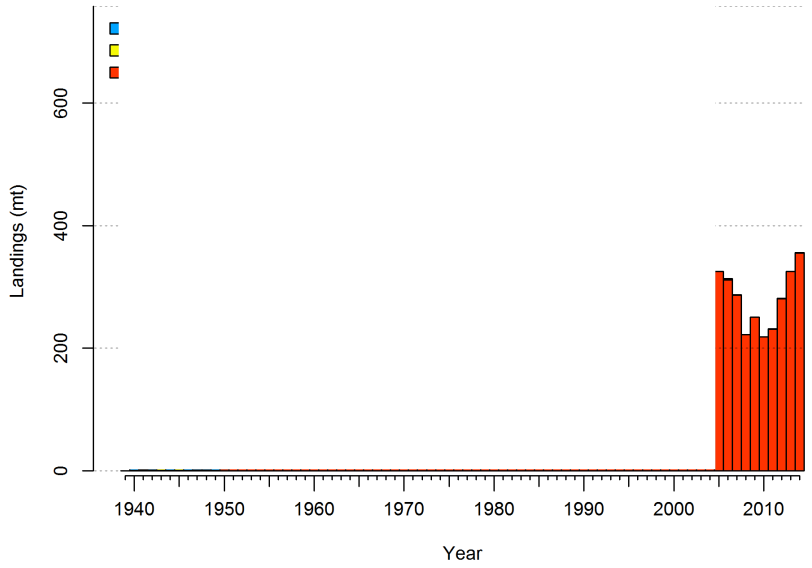

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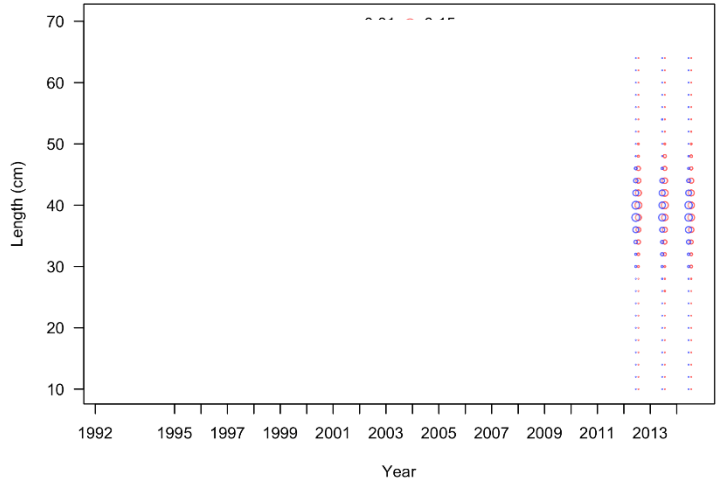

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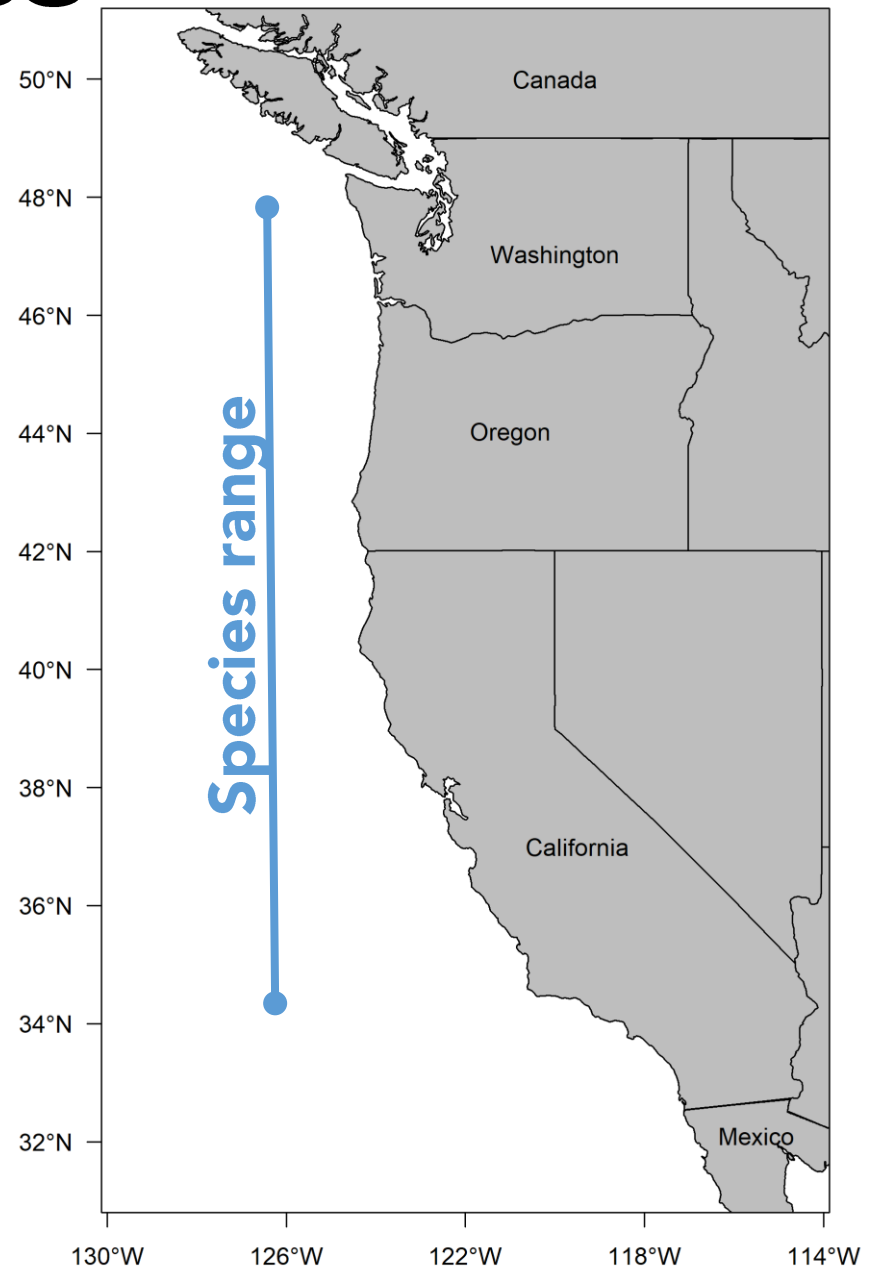

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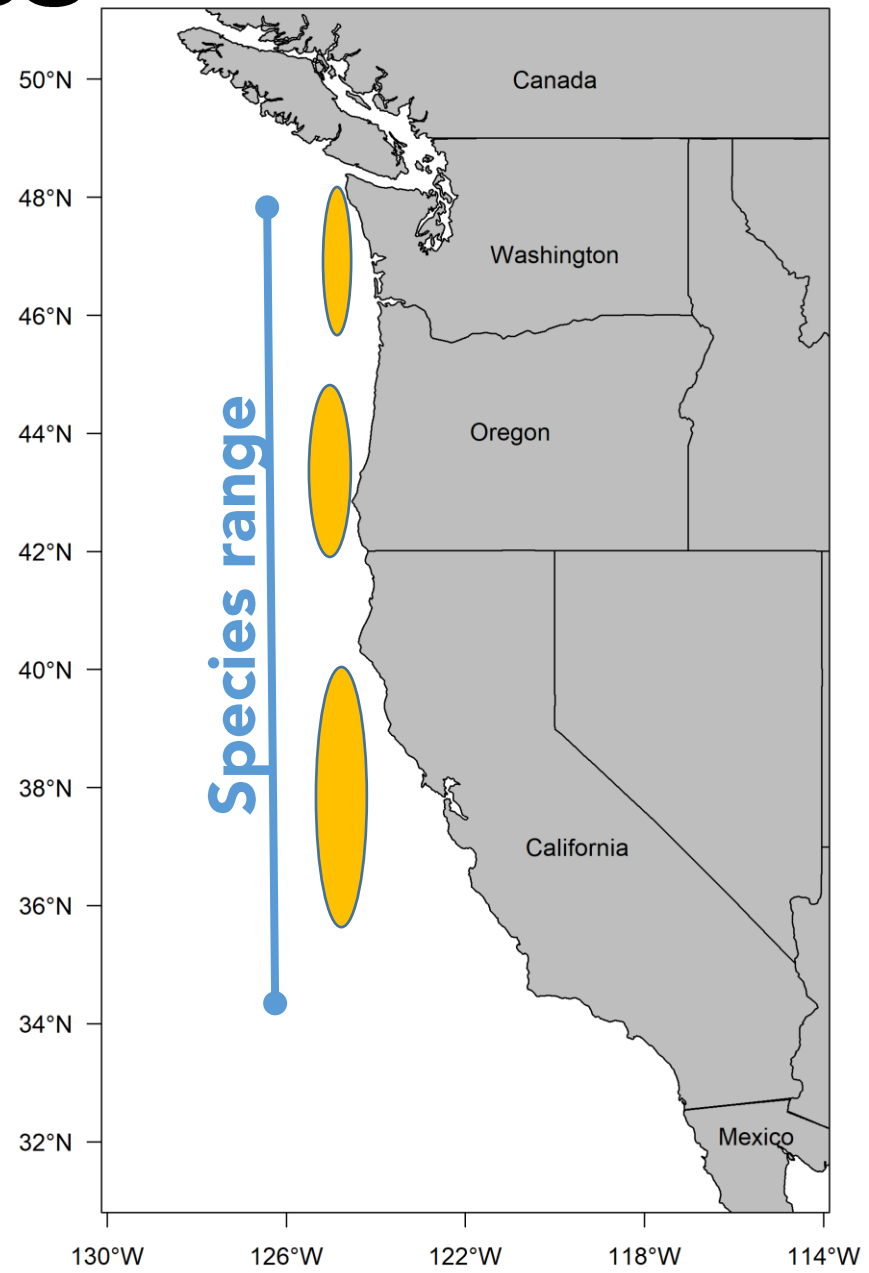

Data representativeness

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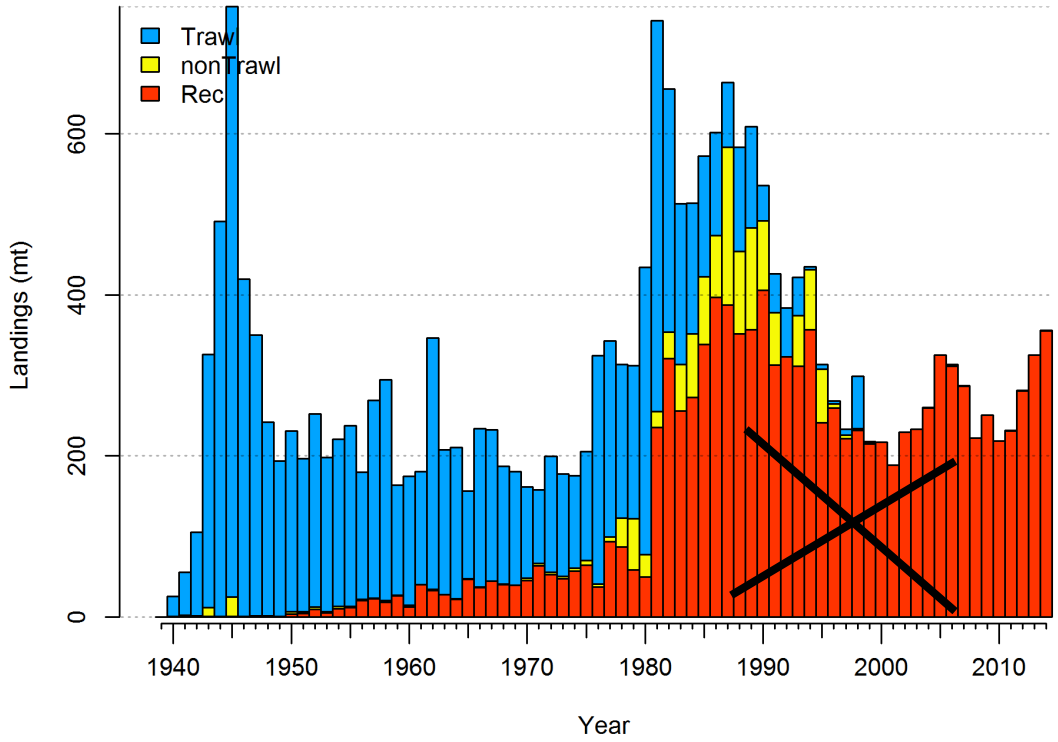
    - Stocks
    - Sex



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Data representativeness

- Do data represent what you want to measure?
  - Dimensions to consider
    - Time
    - Space
    - Fleets
    - Stock identification
    - Sex

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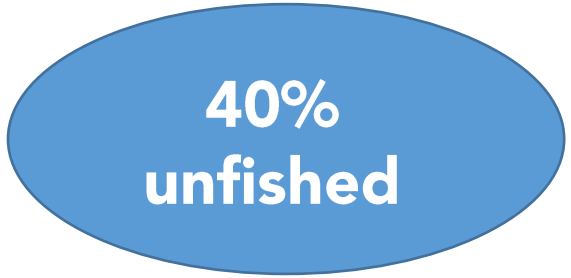
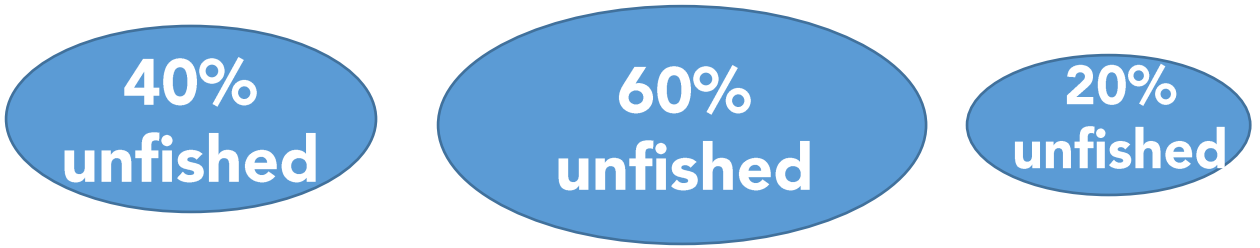
Defining the stock in stock assessment

1 stock



OR

many stocks?

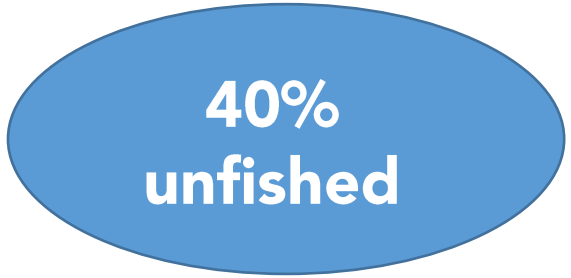


- Genetics
- Biogeography
- Life history
- Political boundaries
- Fishery removal history
- Management
- Data availability

longer — Time scale — shorter

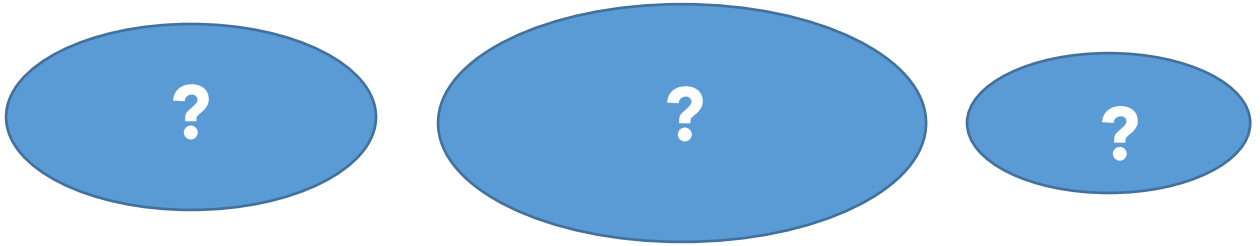
Defining the stock in management units

If 1 stock assessment...



OR

harder to manage many stocks



- Genetics
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Data representativeness

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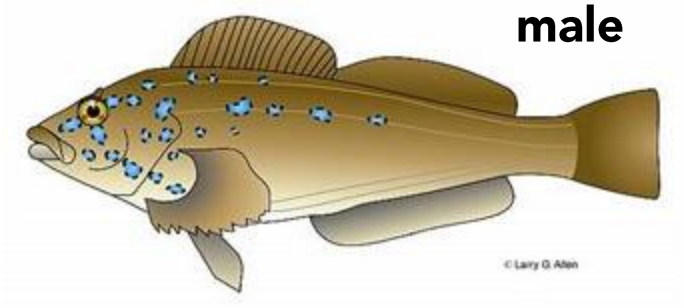
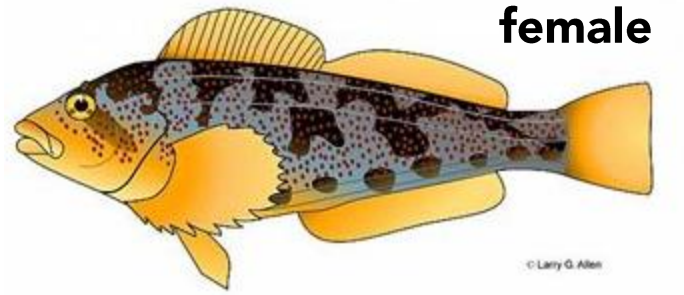


Example

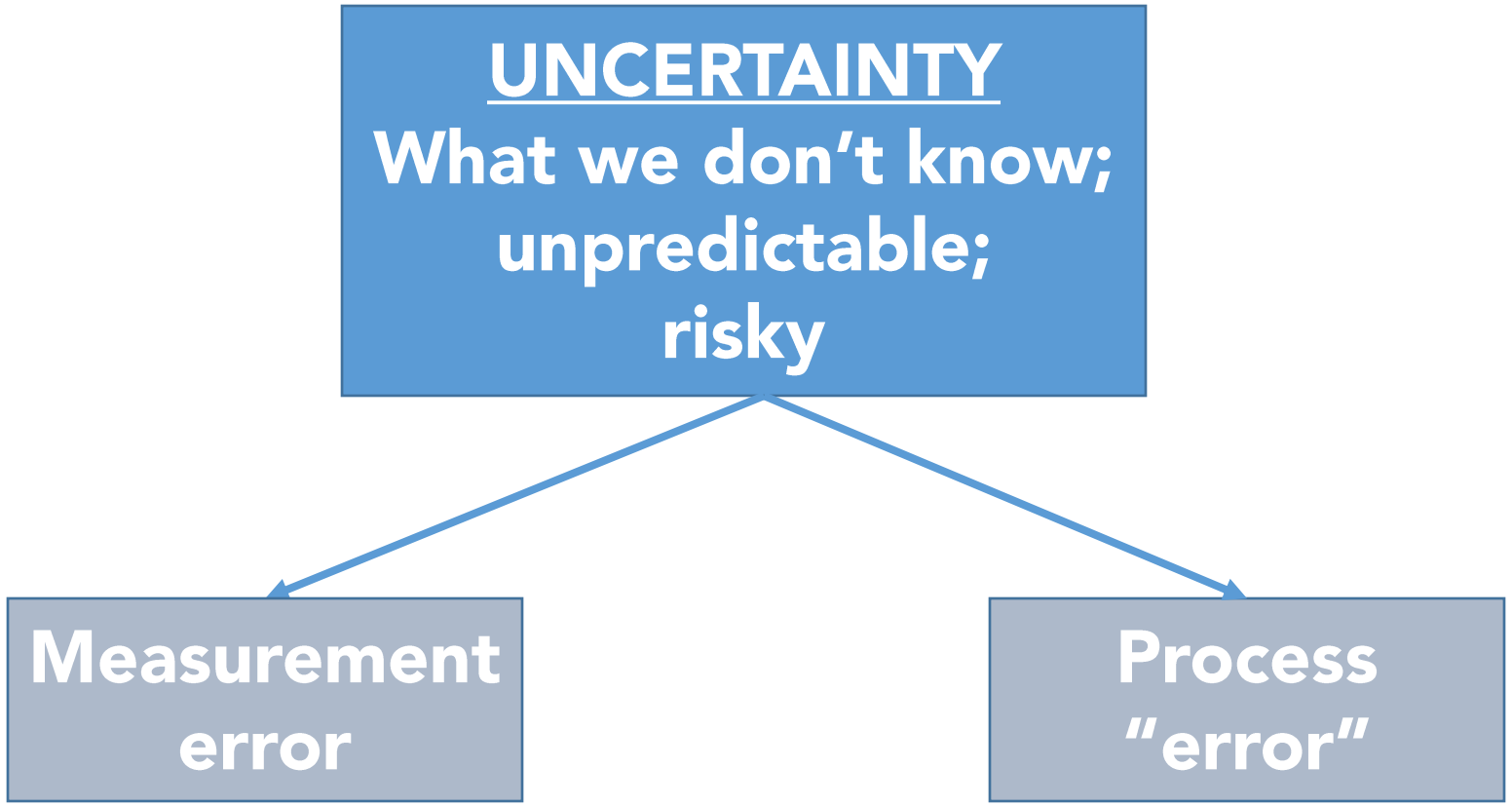
Males and females grow differently, but data do not report sex-specific information

- Non-representative data can be a major source of uncertainty
- Always ask how representative data are to your objective.



Characterizing uncertainty in data and modelling

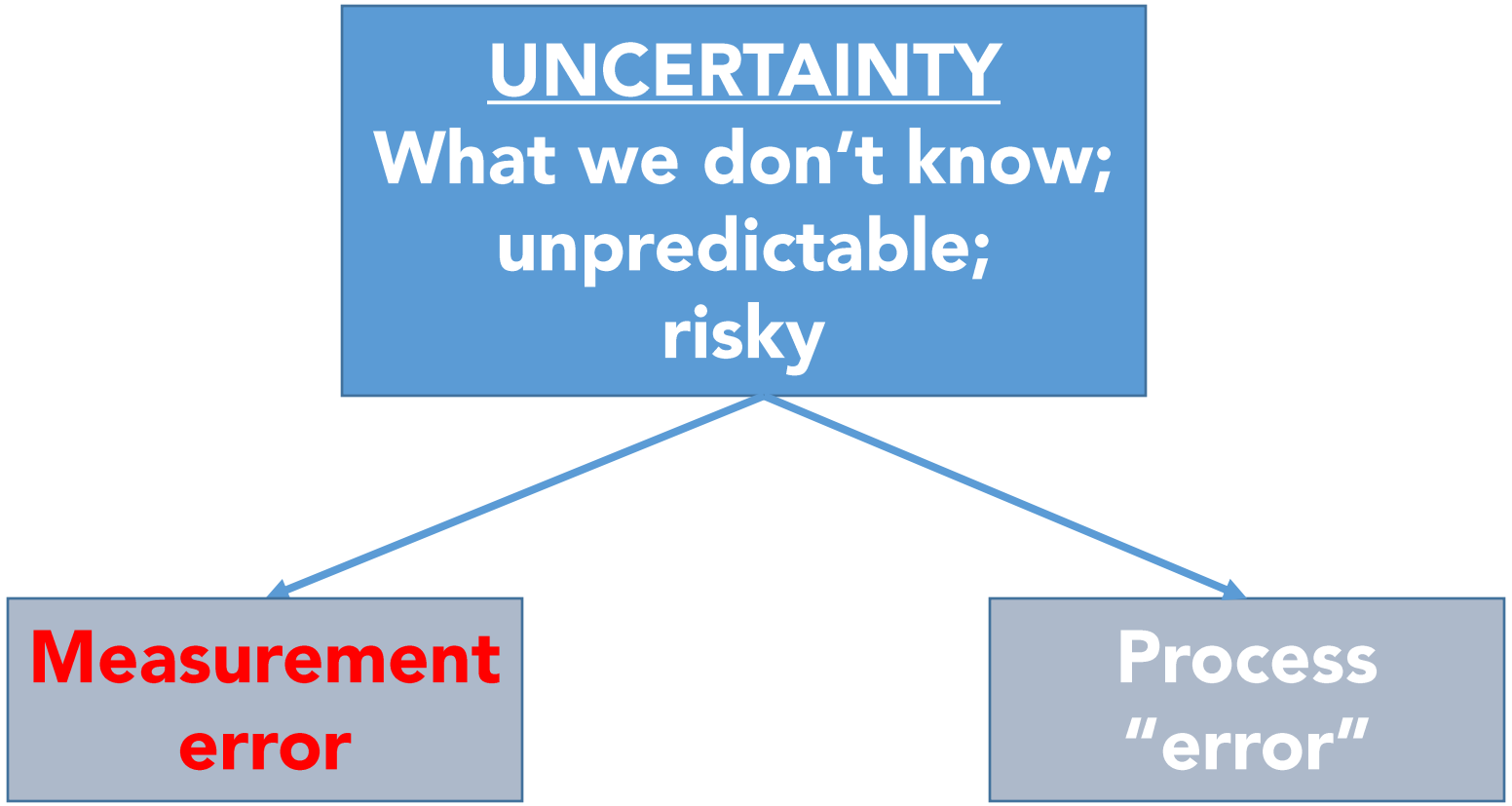
Understanding uncertainty



- **Possibly controllable**
- **Reducible**

- **Naturally occurring**
- **Hard to control**

Understanding uncertainty



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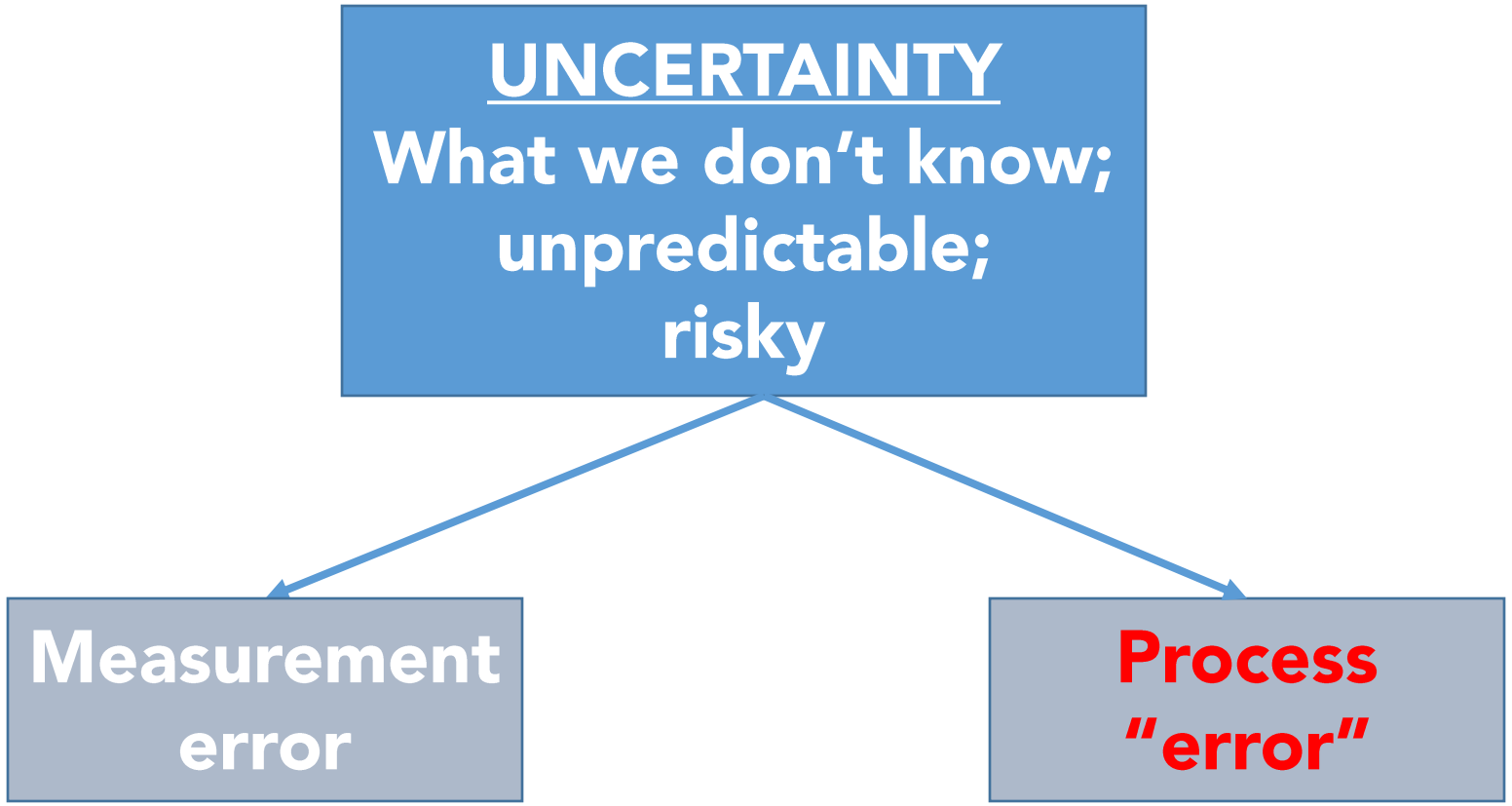


- Possibly controllable
- Reducible

- Naturally occurring
- Hard to control

Understanding uncertainty

Measurement error

- Possibly controllable
- Reducible

Process "error"

- Naturally occurring
- Hard to control

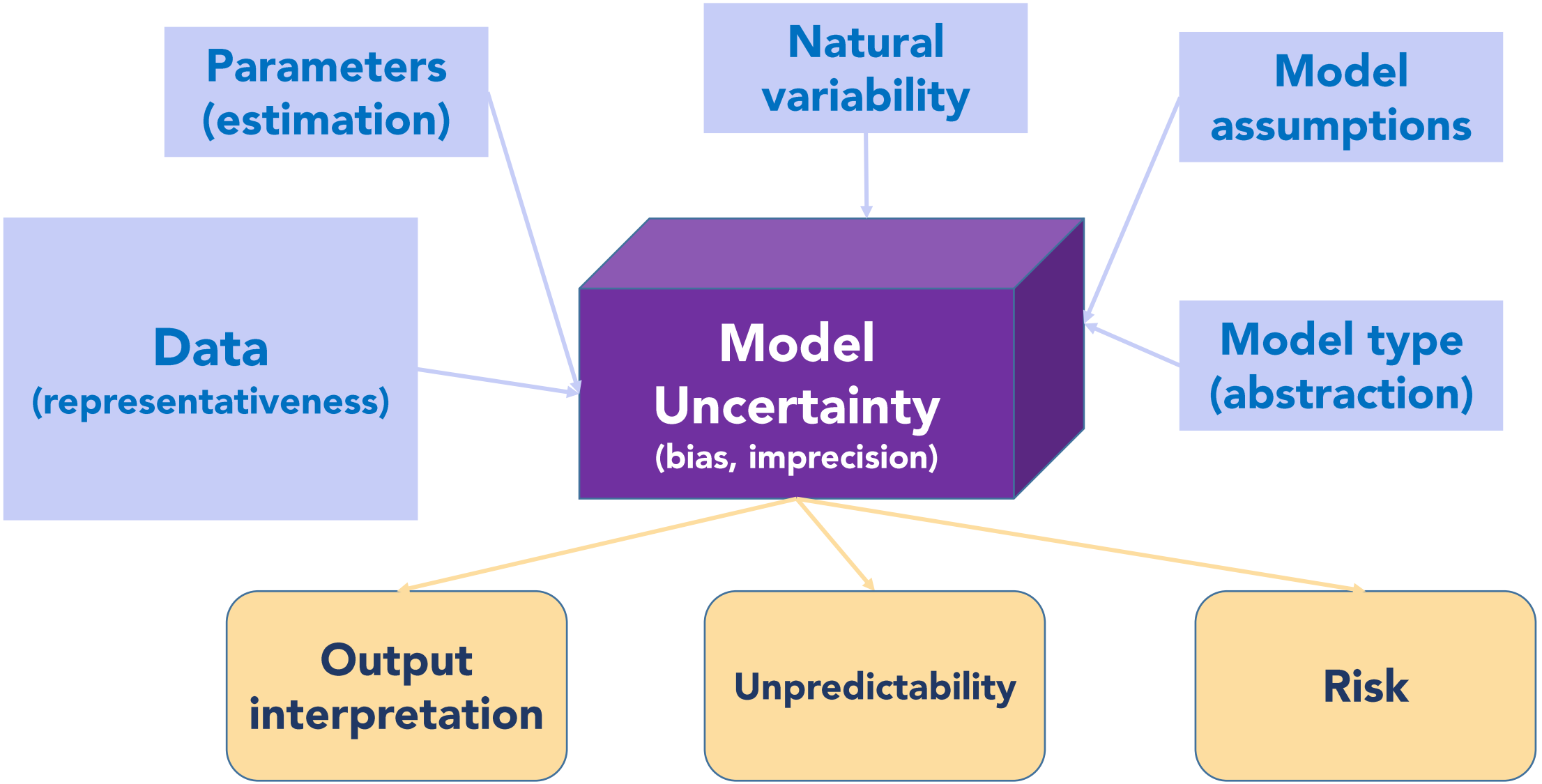
Inaccurate and Imprecise

Inaccurate but Precise

Accurate and Precise

Source:

Understanding uncertainty



How do we reduce uncertainty?

- Better data collection
  - Quality (less bias)
  - Quantity (more precise)

} Measurement error

- Better biological understanding
  - Interpreting when uncertainty matters most
  - Having representative data

} Process error

How do we deal with uncertainty in stock assessments?

Testing multiple hypotheses

"With this method the dangers of parental affection for a favorite theory can be circumvented."

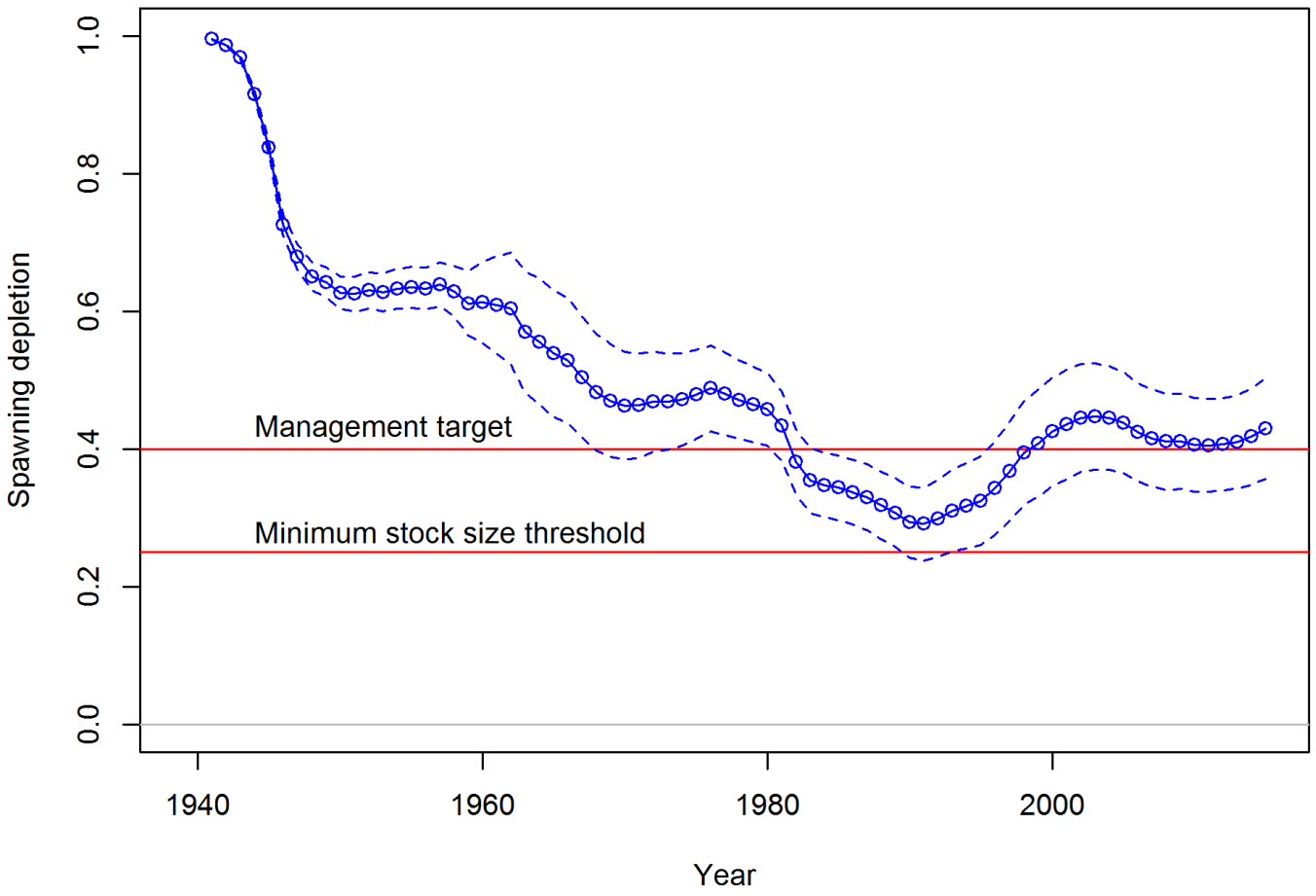
Thomas Chrowder Chamberlin
(1843-1928)

As applied to data limited methods

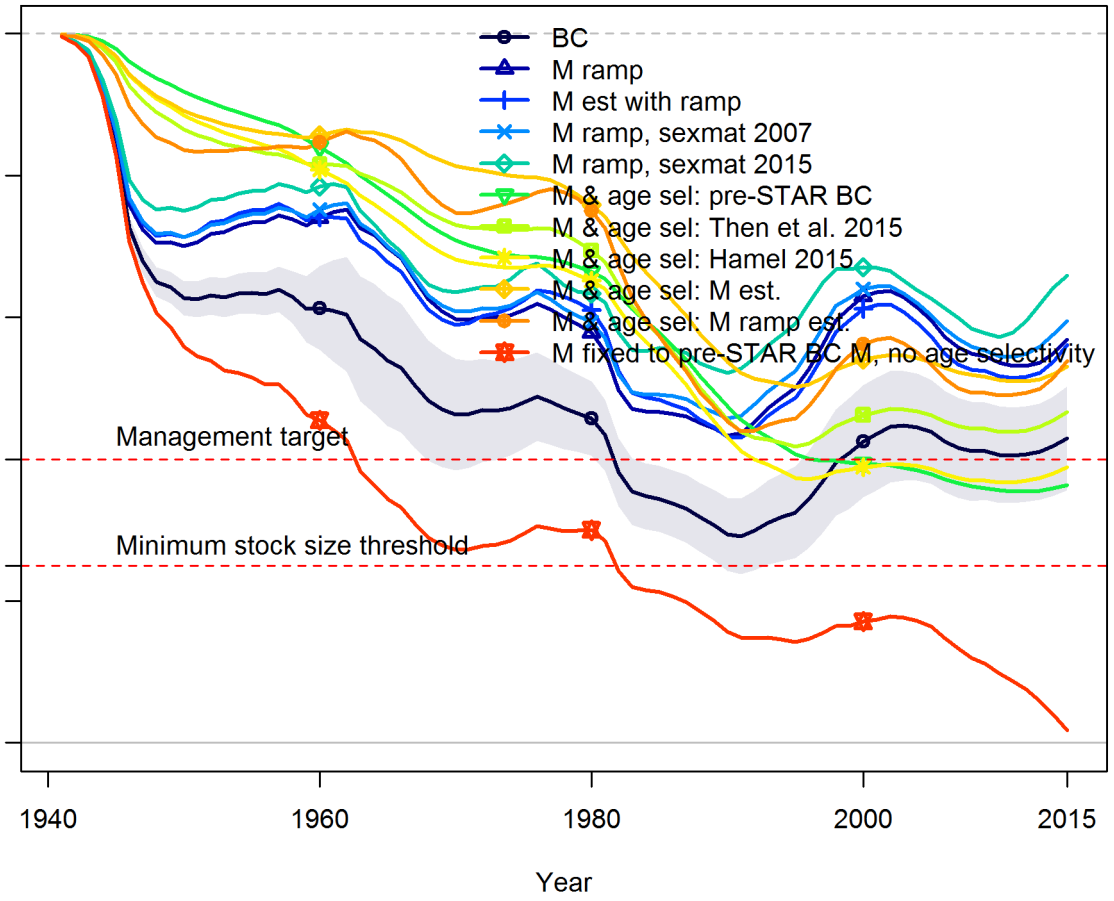
- Identify possible approaches or model inputs (i.e. hypotheses)
- Apply data to chosen hypotheses
- Determine the degree of support for each hypothesis
- Make composite derived quantities (e.g. catch limit)

Model uncertainty

Within model uncertainty



Among model uncertainty

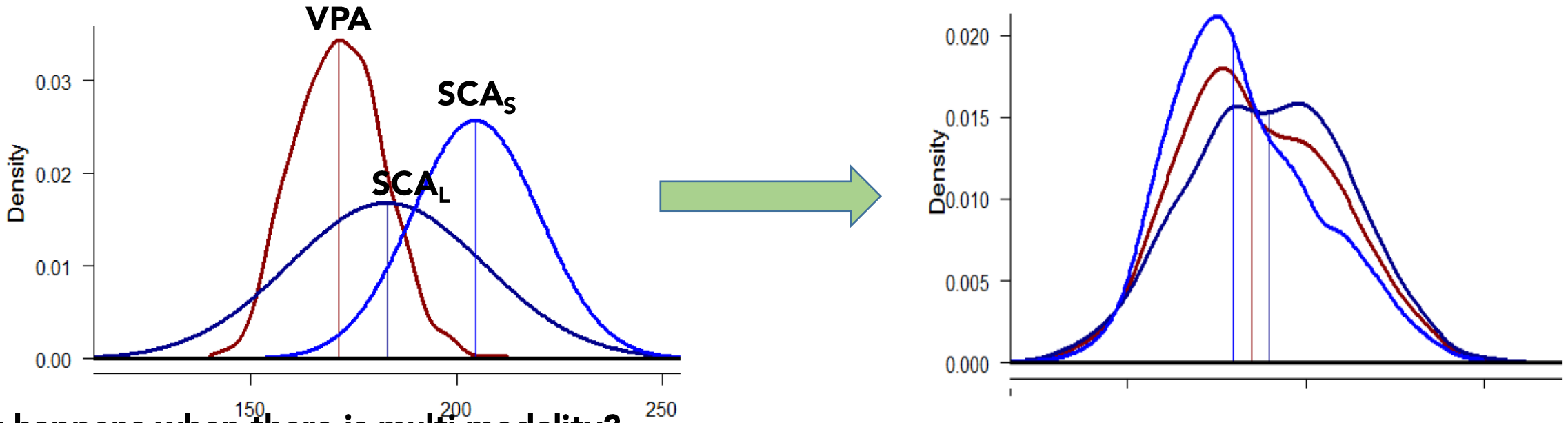


Source: 2015 Black rockfish assessment

Treating multiple hypotheses (inputs and specifications)

As applied to data limited methods

- Identify possible approaches or model specifications (i.e., hypotheses)
- Apply data to chosen hypotheses
- Determine the degree of support for each hypothesis
- **Make composite derived quantities (e.g. catch limit): ensembles**

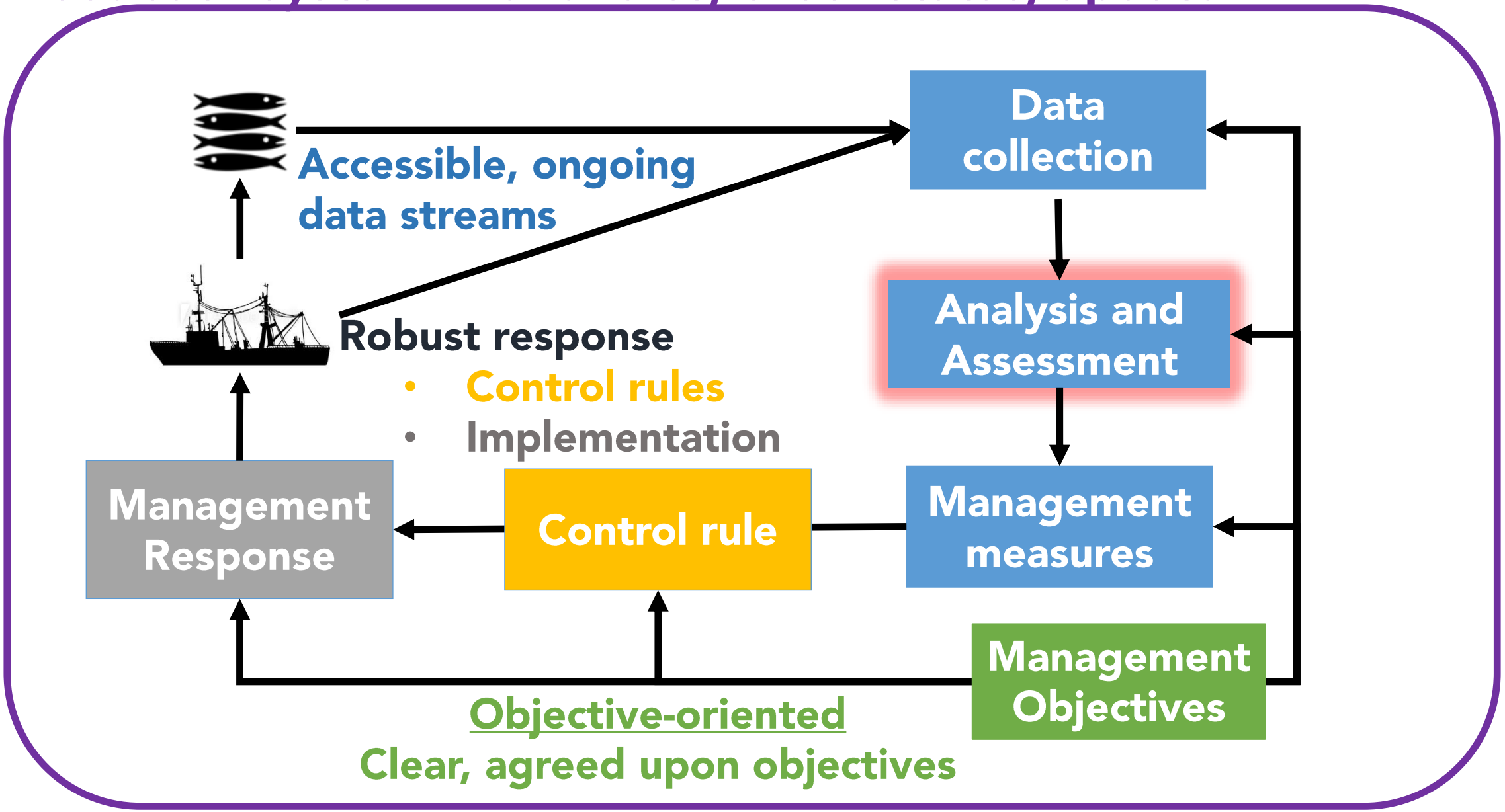


What happens when there is multi-modality?

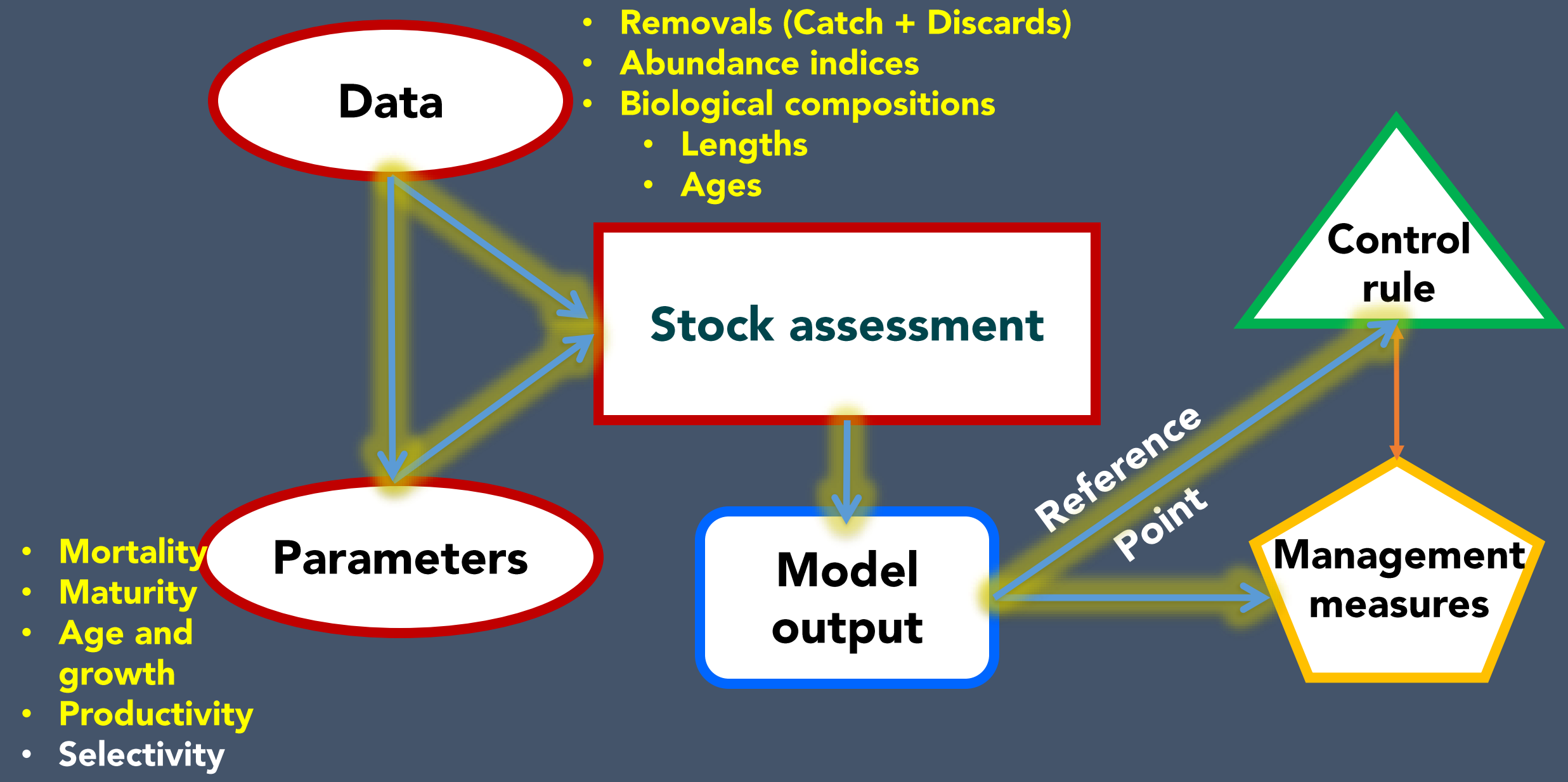
Stewart and Martell 2015

Adaptive Management System

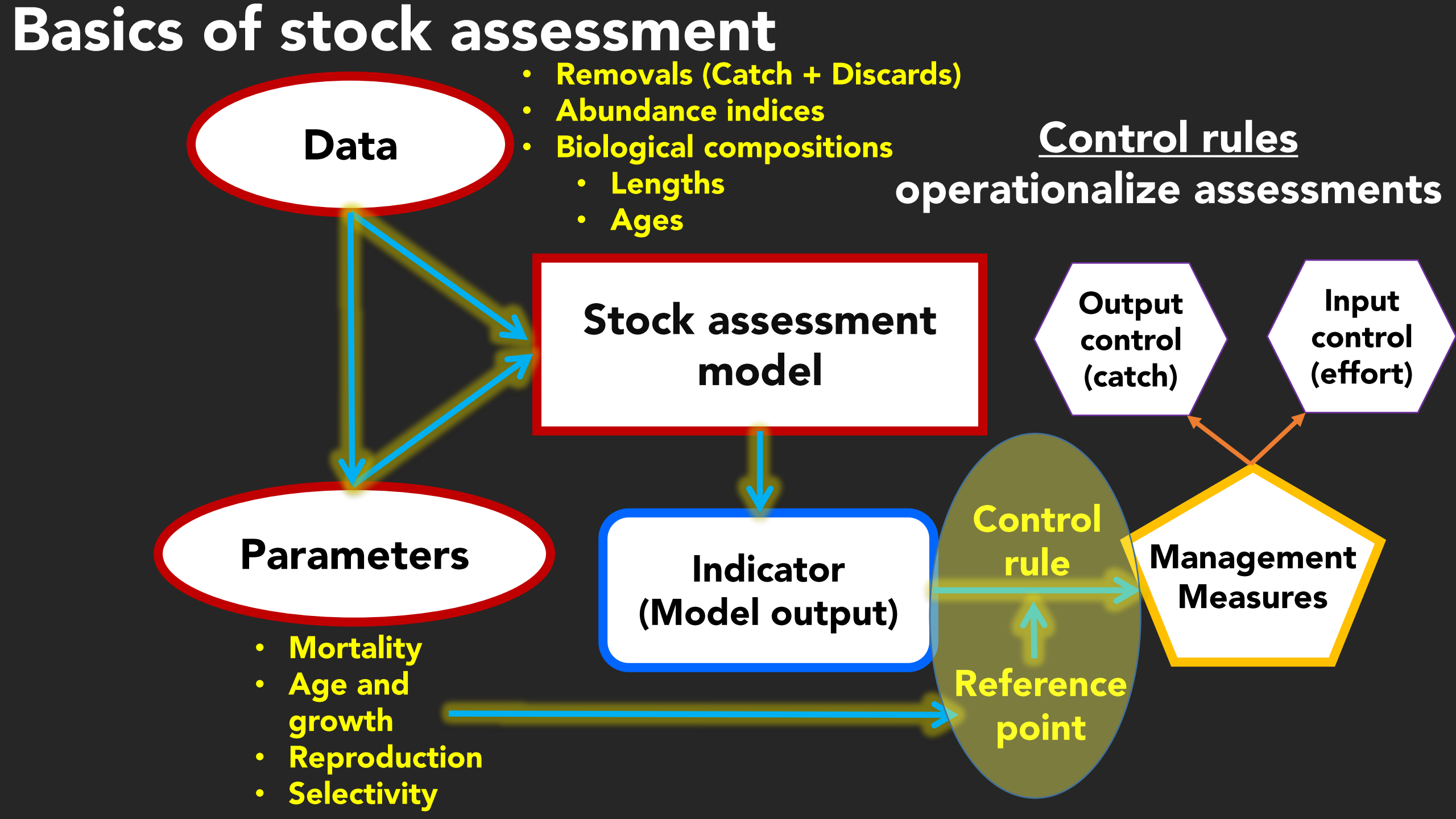
Feedback system: Make rules, check status, update



Basics of stock assessment

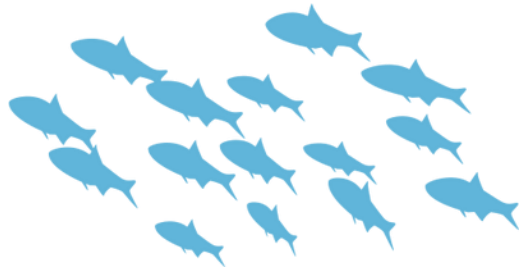


Basics of stock assessment

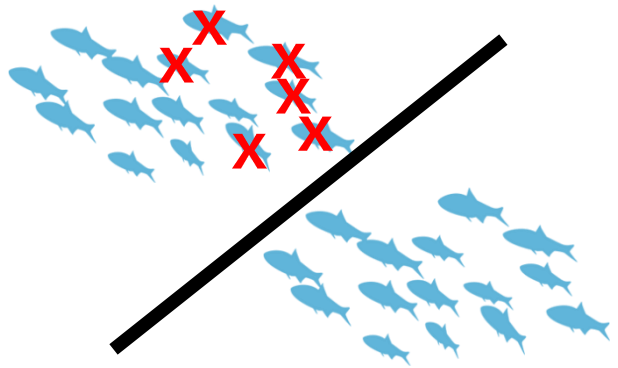


Interpreting Stock Assessments:
Scale, Status, & Productivity

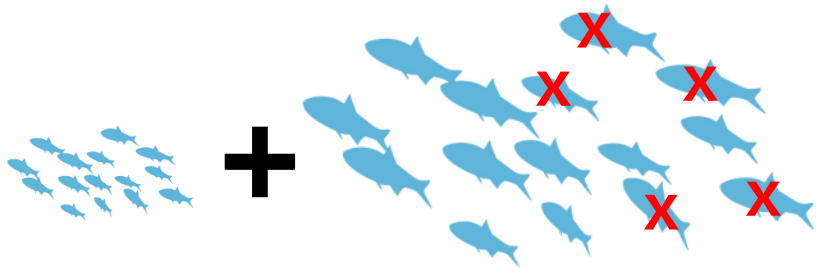
Scale: How many/much (numbers or biomass) are there?



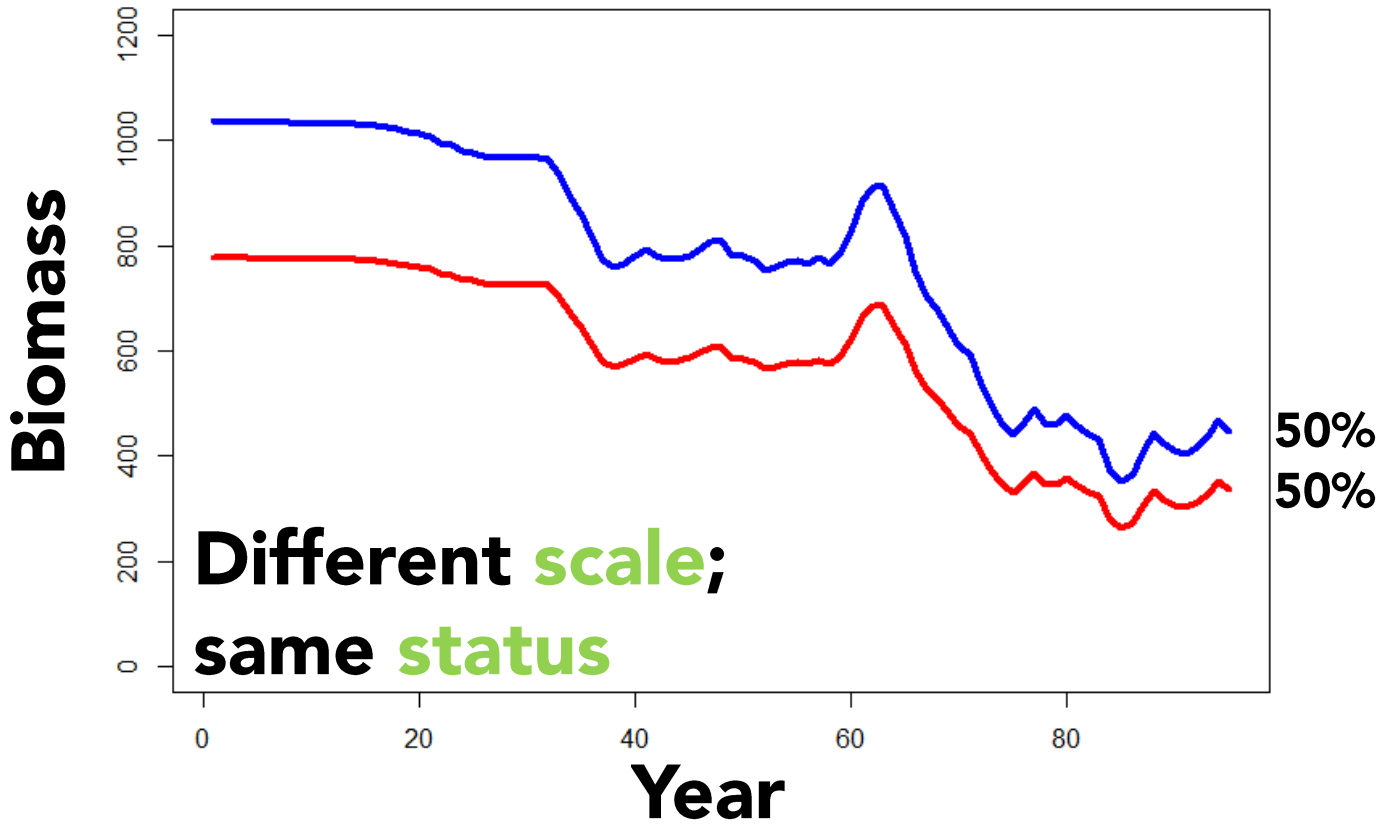
Status: Current scale relative to unfished scale



Productivity: Birth-Death. Rate of new numbers/biomass.

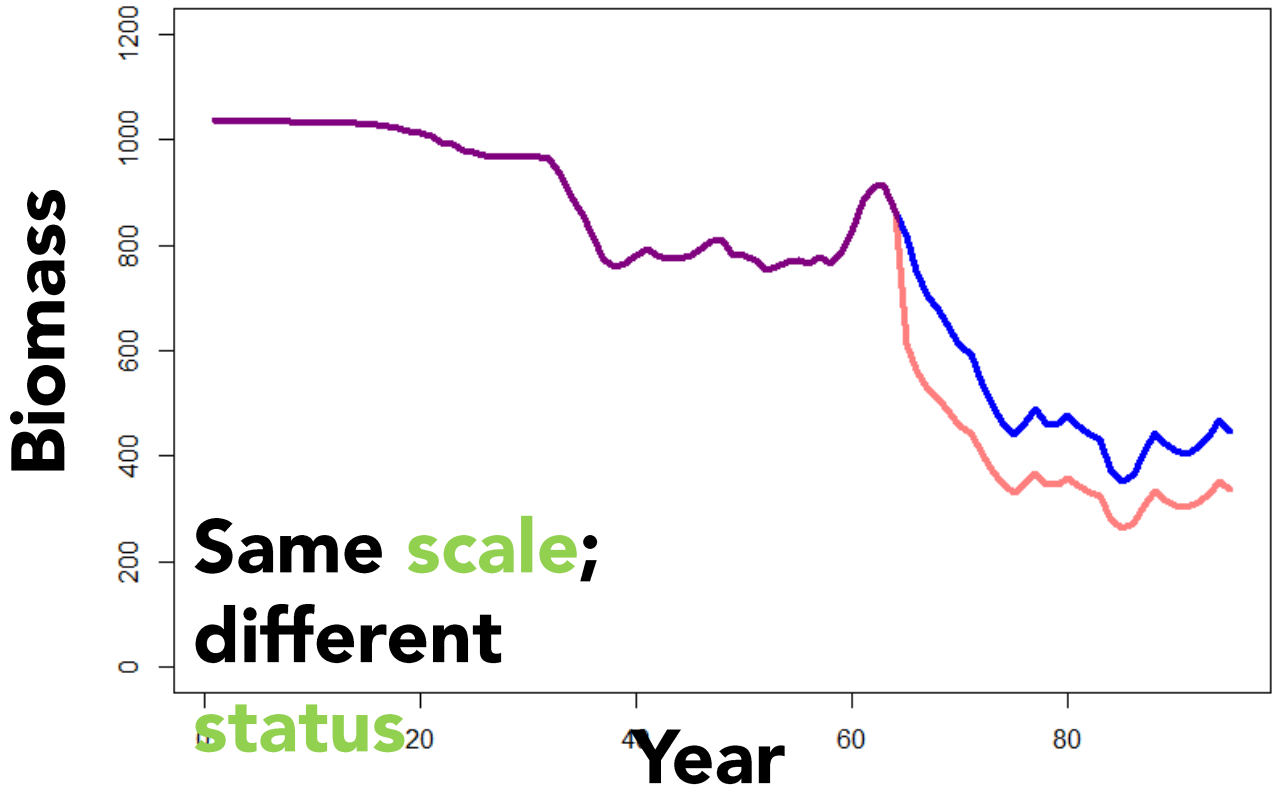


Interpreting Stock Assessments:
Scale, Status, & Productivity



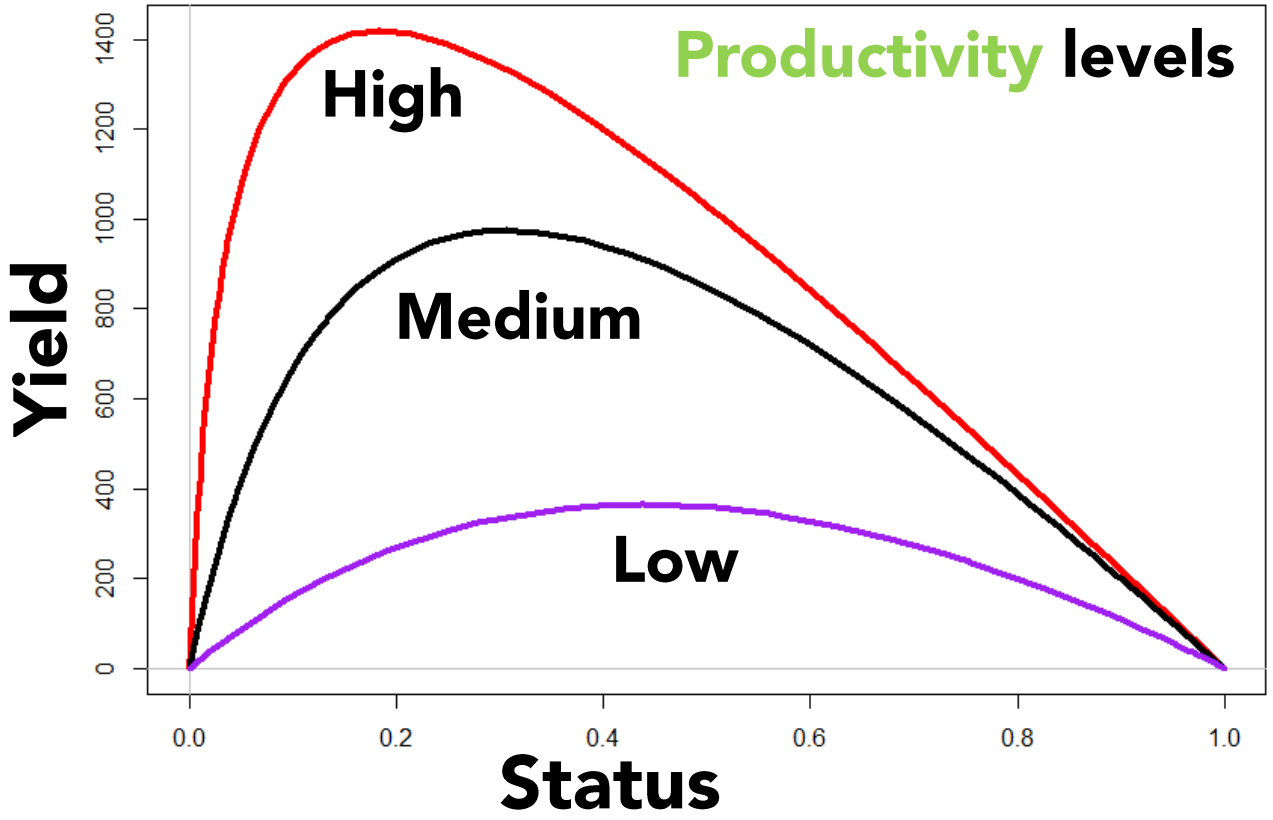
Absolute biomass (Scale):
Catch levels

Interpreting Stock Assessments:
Scale, Status, & Productivity



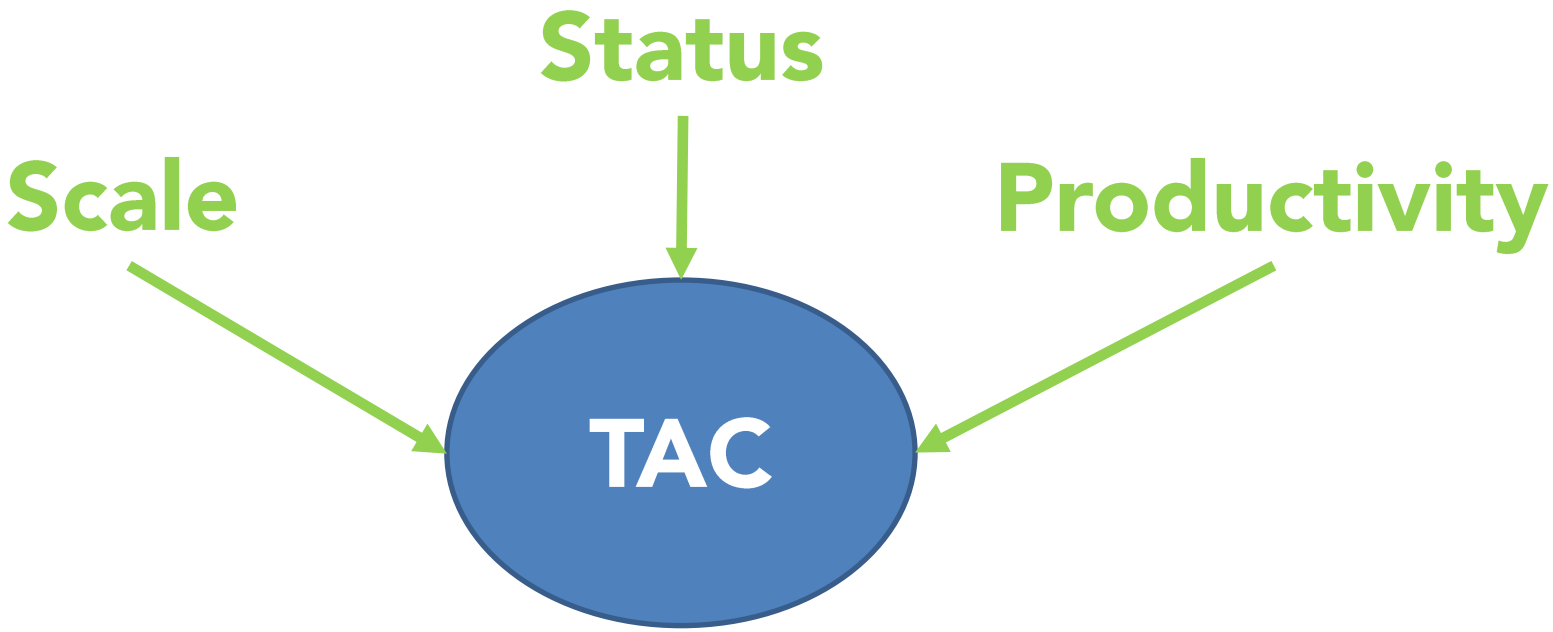
Relative biomass (Status):
Management objectives

Interpreting Stock Assessments:
Scale, Status, & Productivity

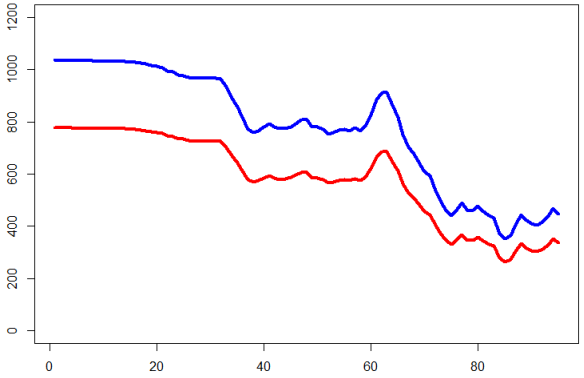


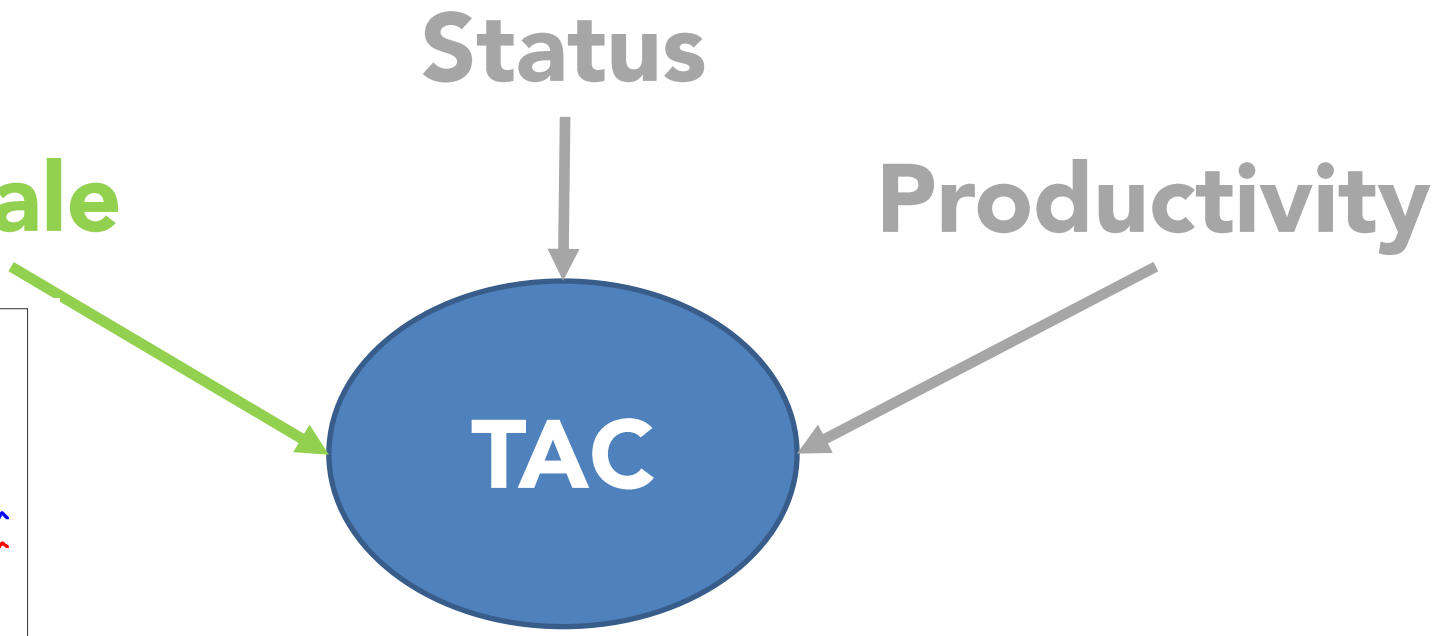
Rate of new biomass (Productivity): Recovery

Interpreting Stock Assessments



Interpreting Stock Assessments

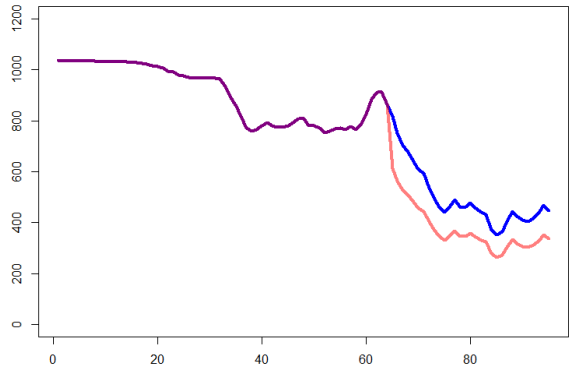


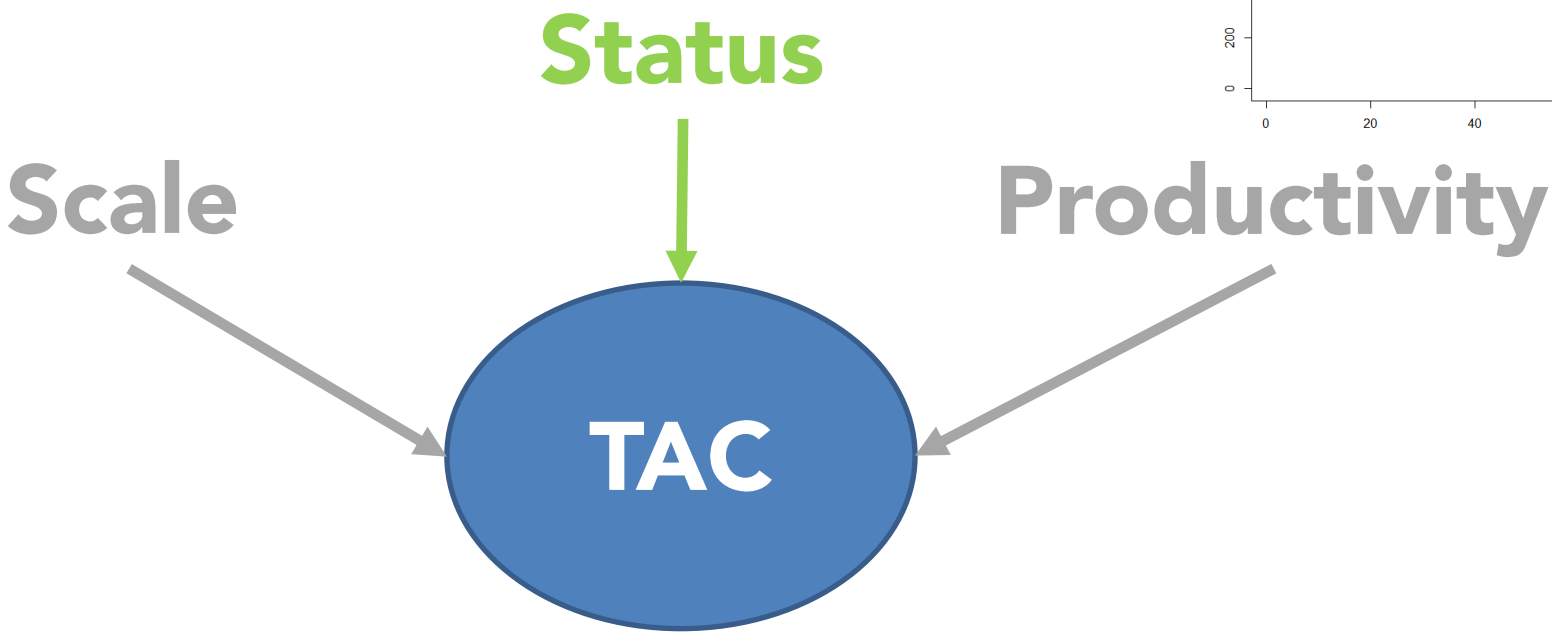


If SCALE goes down, TAC will go down

If SCALE goes up, TAC will go up

Interpreting Stock Assessments

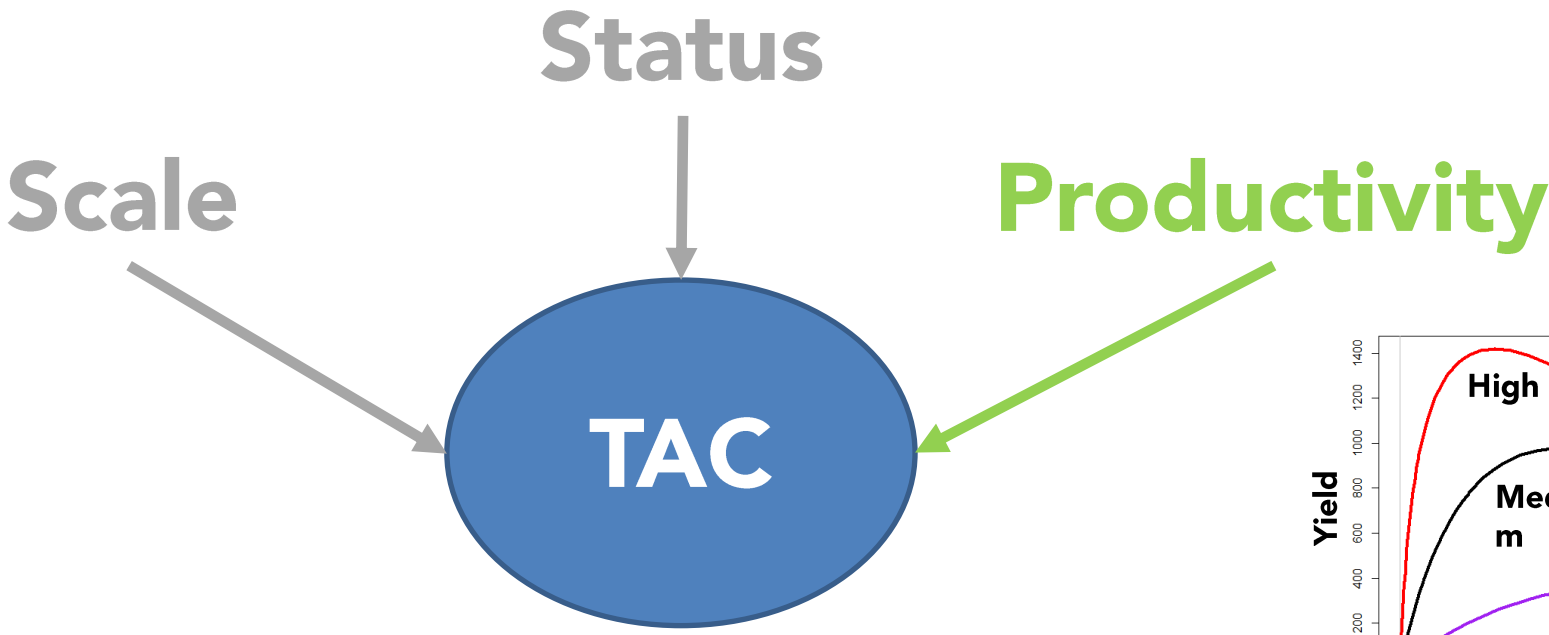


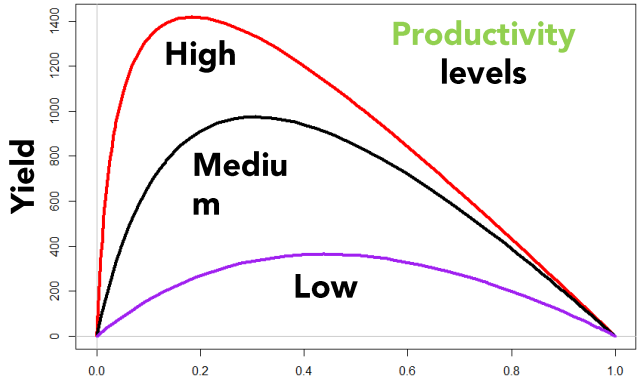


If STATUS goes down, TAC will go down

If STATUS goes up, TAC will go up

Interpreting Stock Assessments

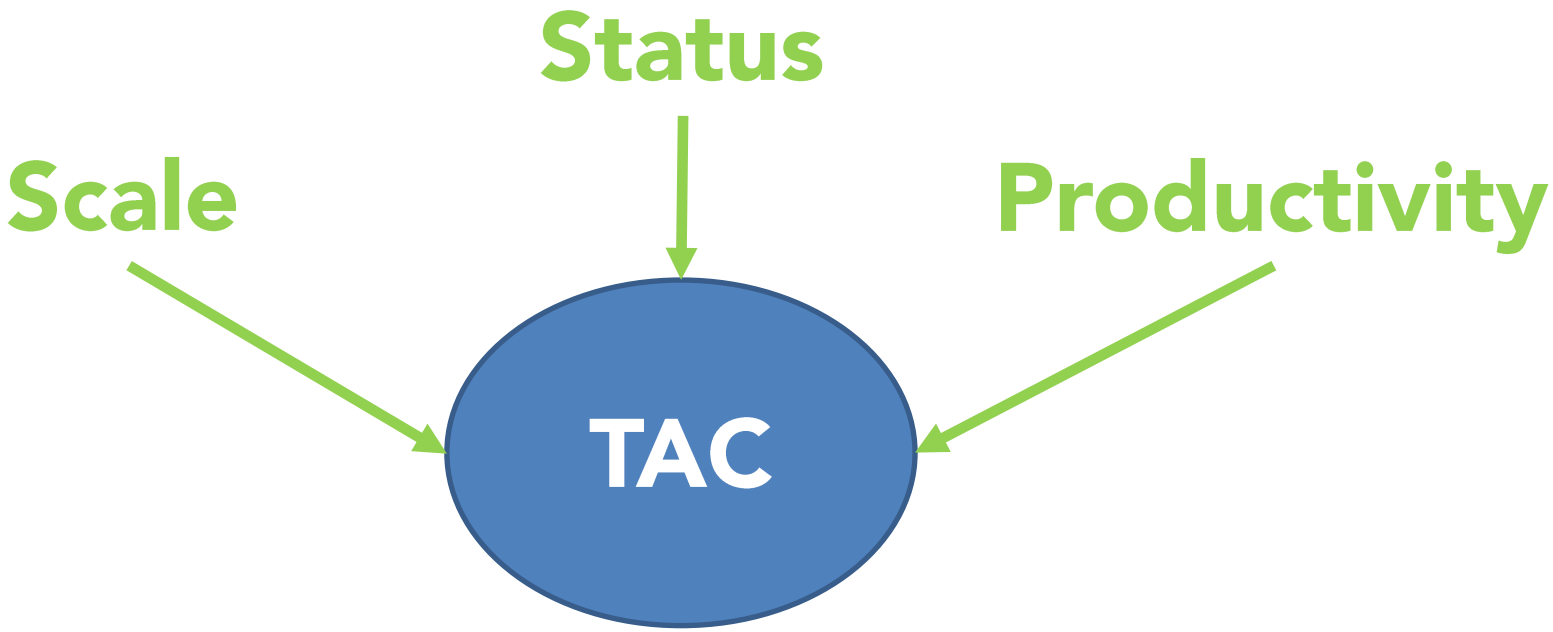




If PRODUCTIVITY goes down, TAC will go down

If PRODUCTIVITY goes up, TAC will go up

Interpreting Stock Assessments



But what happens when more than 1 (or all) change?

LET'S

LET'S

INTERPRET

LET'S INTERPRET STOCK ASSESSMENTS!

HOW TO PLAY:

YOU GET AN ASSESSMENT SCENARIO YOU SAY WHETHER IT IS PLAUSIBLE AND WHY

SCENARIO 1:

A NEW ASSESSMENTS SHOWS THE STOCK STATUS HAS GONE UP FROM 28% TO 41%, BUT THE SUSTAINALBE QUOTA HAS GONE DOWN.

COULD THIS HAPPEN?

HOW?

SCENARIO 2:

A NEW ASSESSMENTS SHOWS A STOCK HAS INCREASED TO SUSTAINABLE LEVELS, BUT ACCORDING TO THE PREVIOUS ASSESSMENT, THE NEW SUSTAINABLE QUOTA WOULD HAVE LED TO OVERFISHING.

COULD THIS HAPPEN?

HOW?

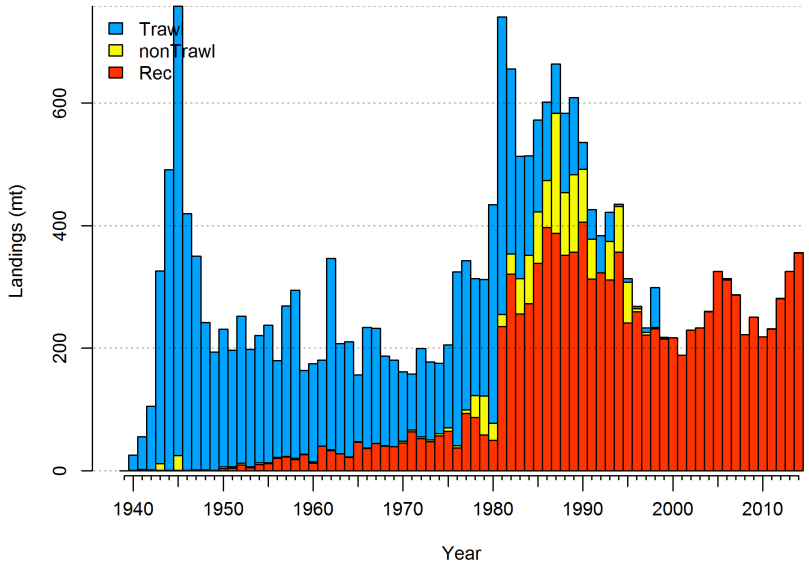
SCENARIO 3:

A NEW ASSESSMENT WITH THE SAME STOCK STATUS AND POPULATION SCALE, BUT LOWER STOCK PRODUCTIVITY, LEADS TO A LARGER SUSTAINABLE QUOTA.

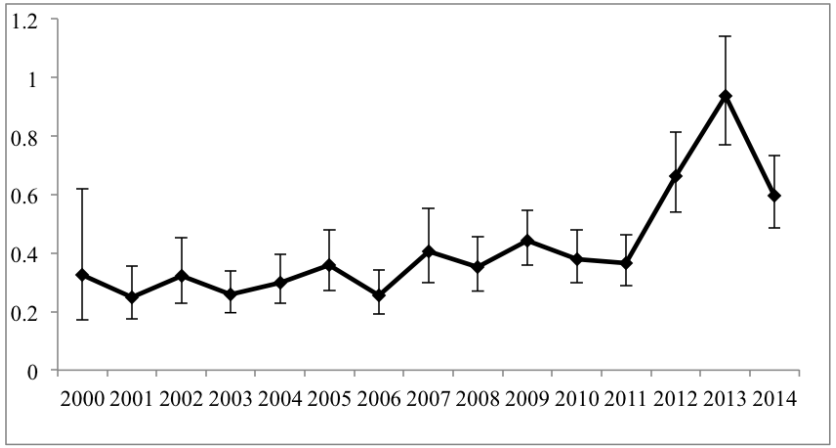
TRUE OR FALSE? WHY?

How data informs assessments

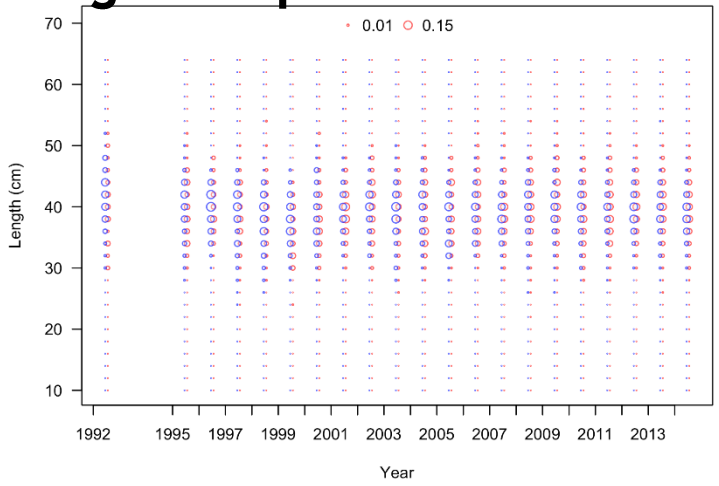
Removals- SCALE



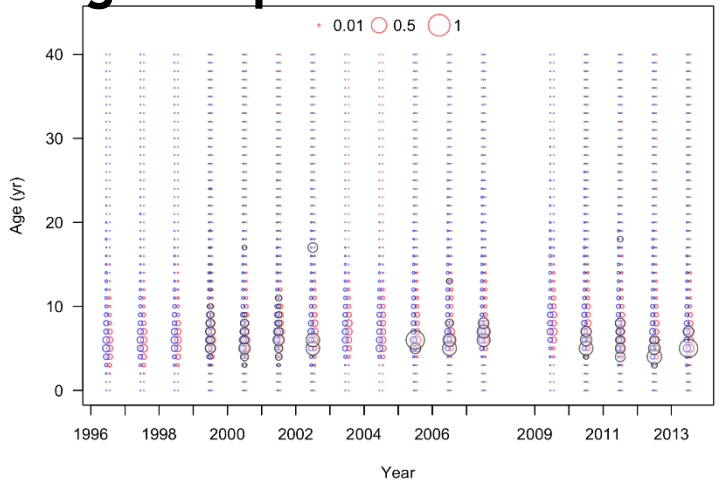
Abundance indices- STATUS



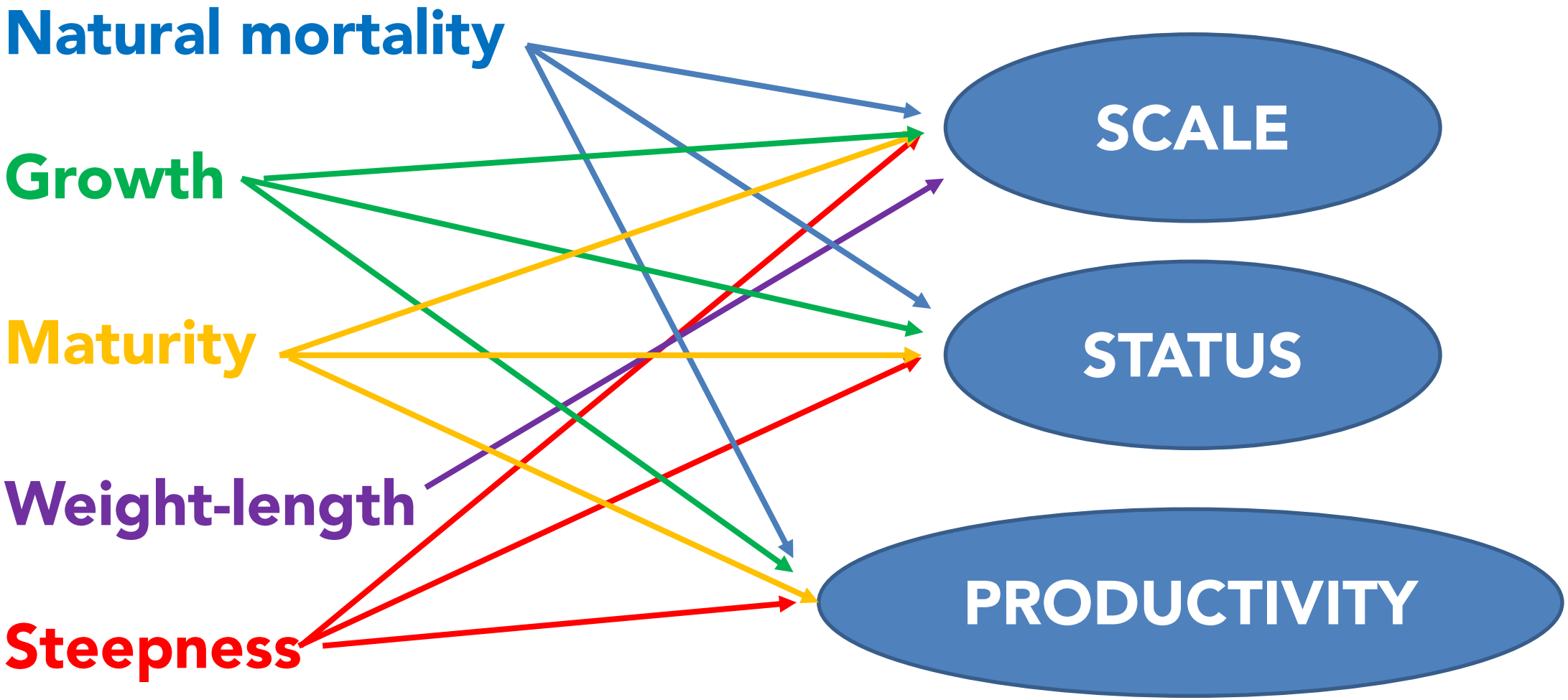
Length compositions-STATUS



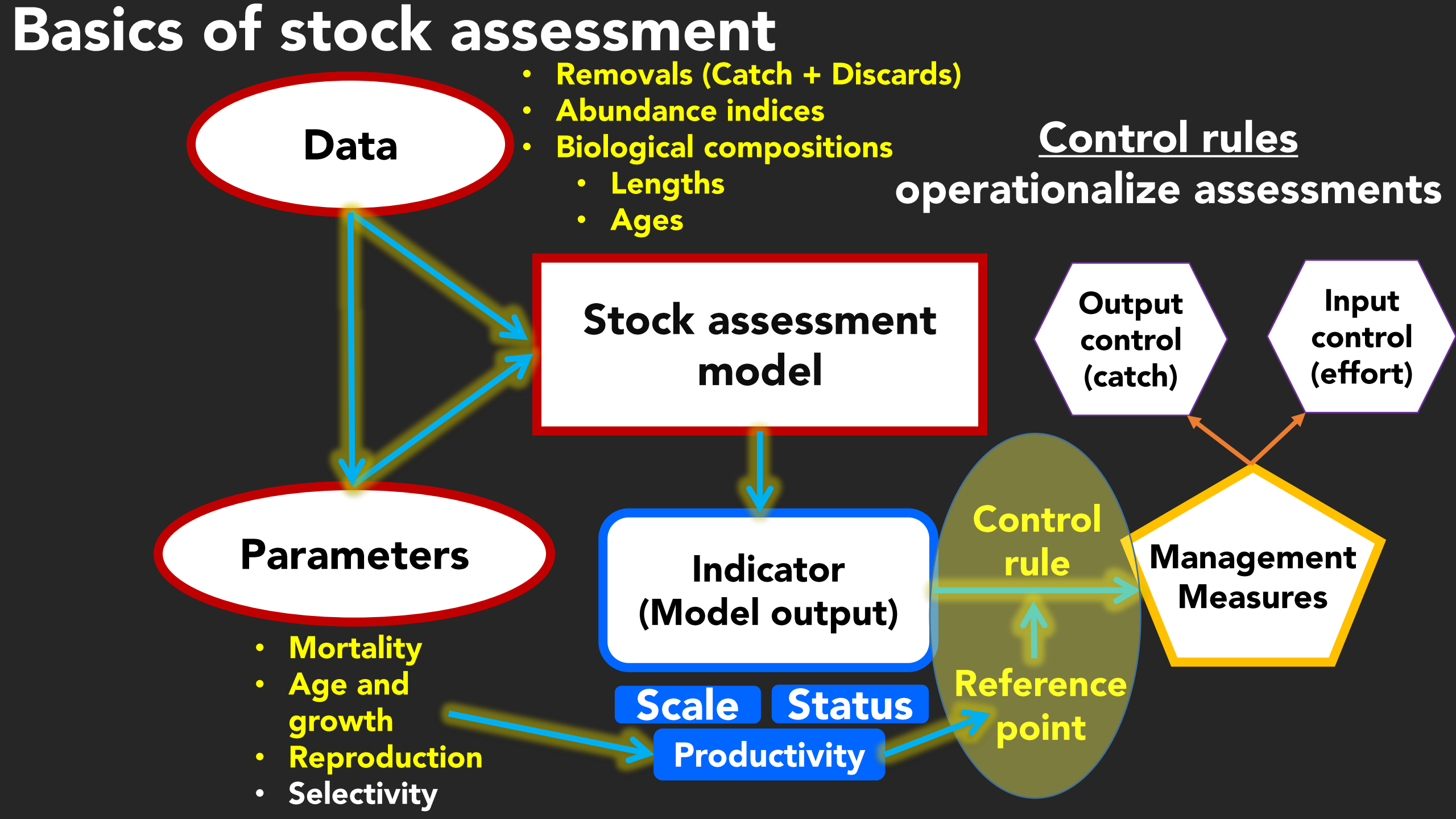
Age compositions- STATUS



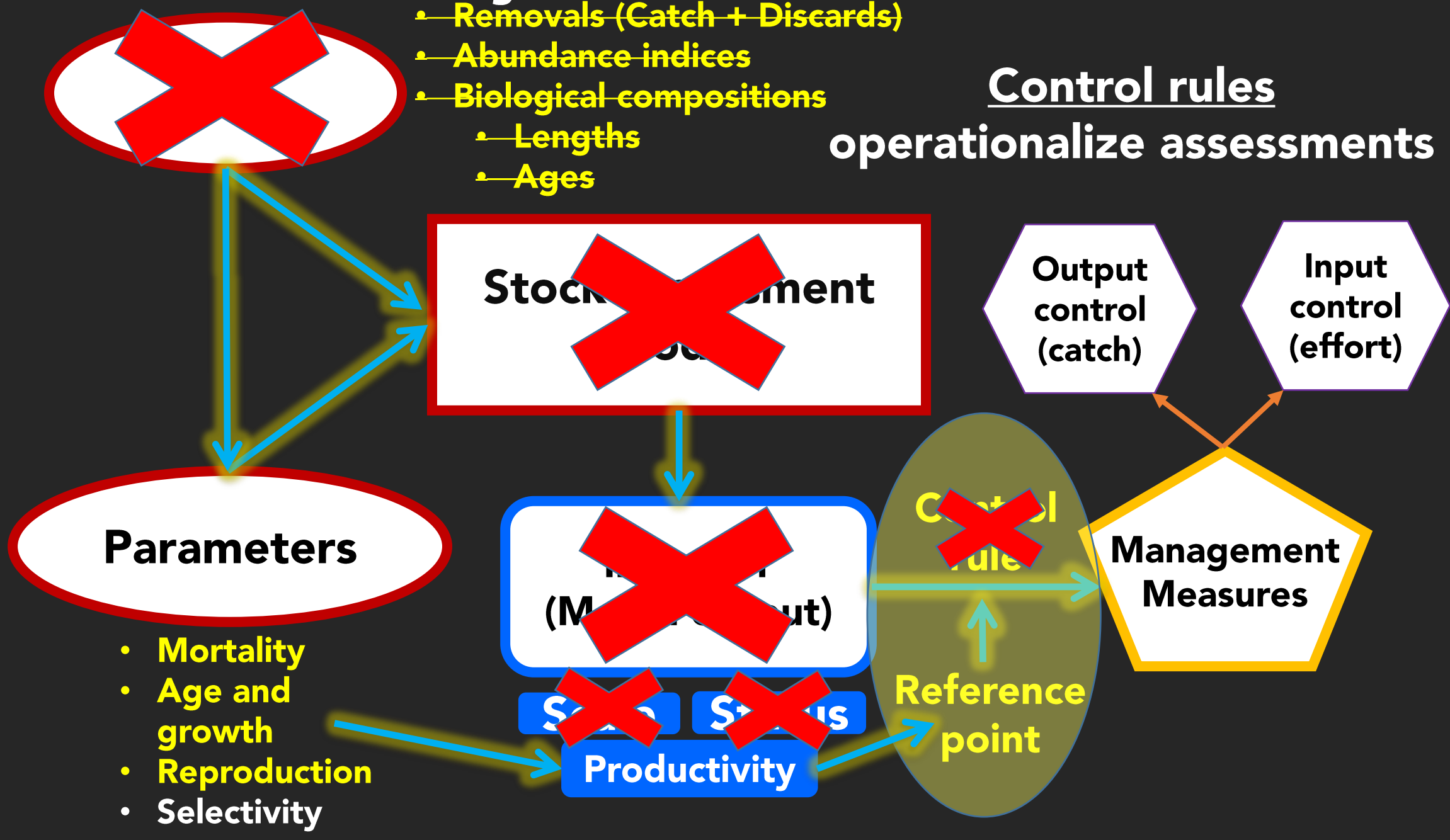
How parameter informs assessments



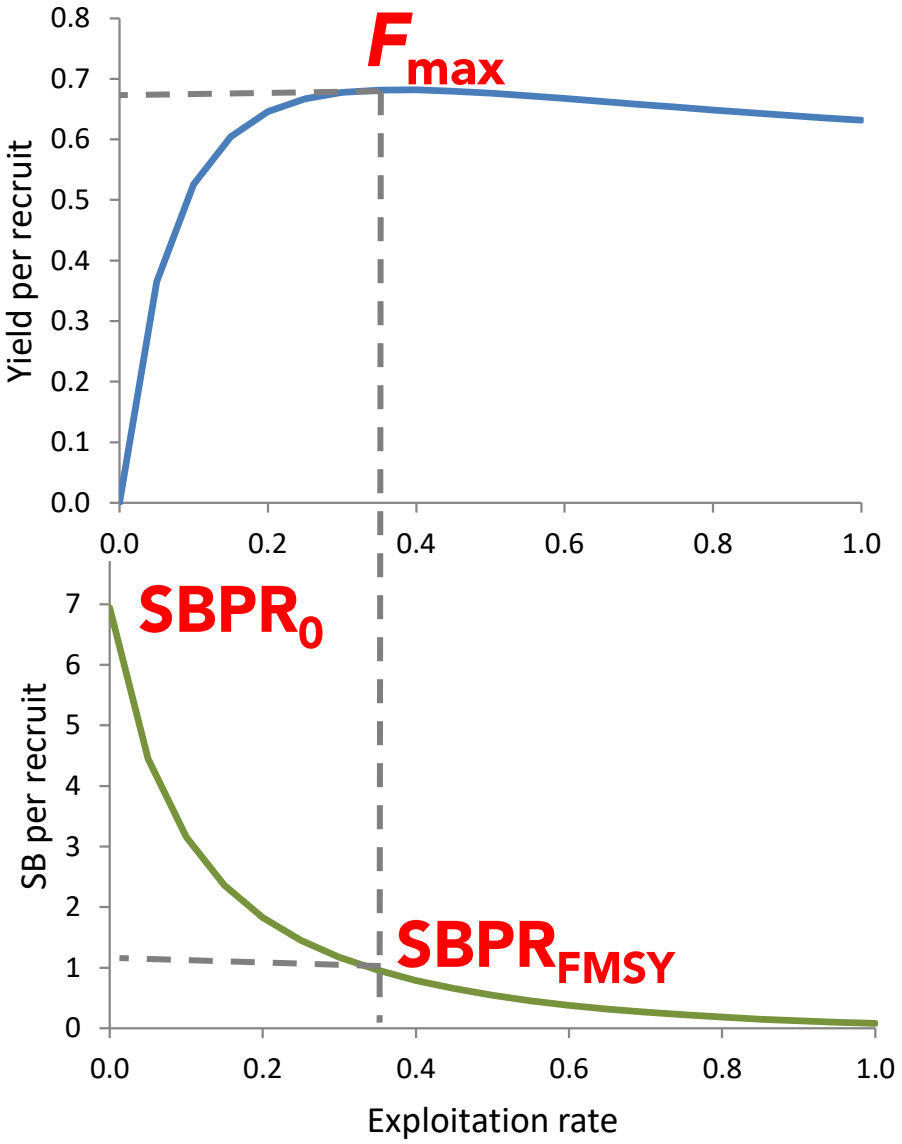
Basics of stock assessment

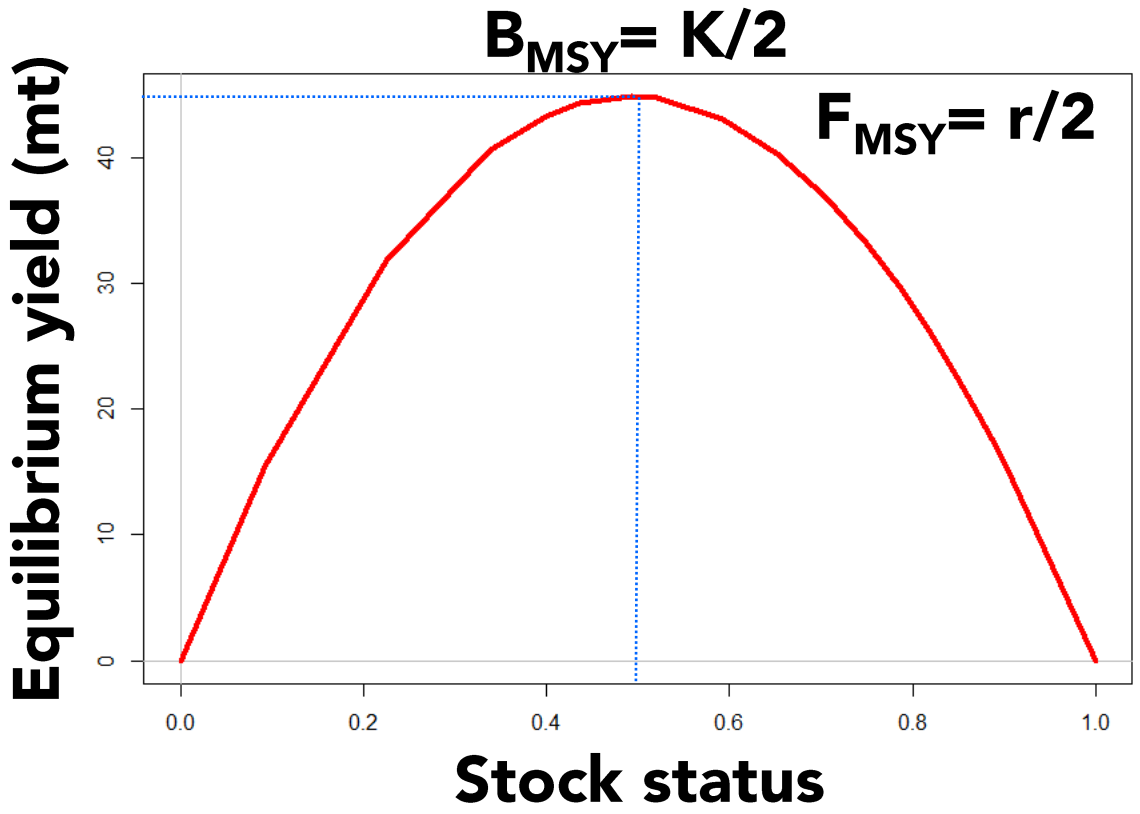


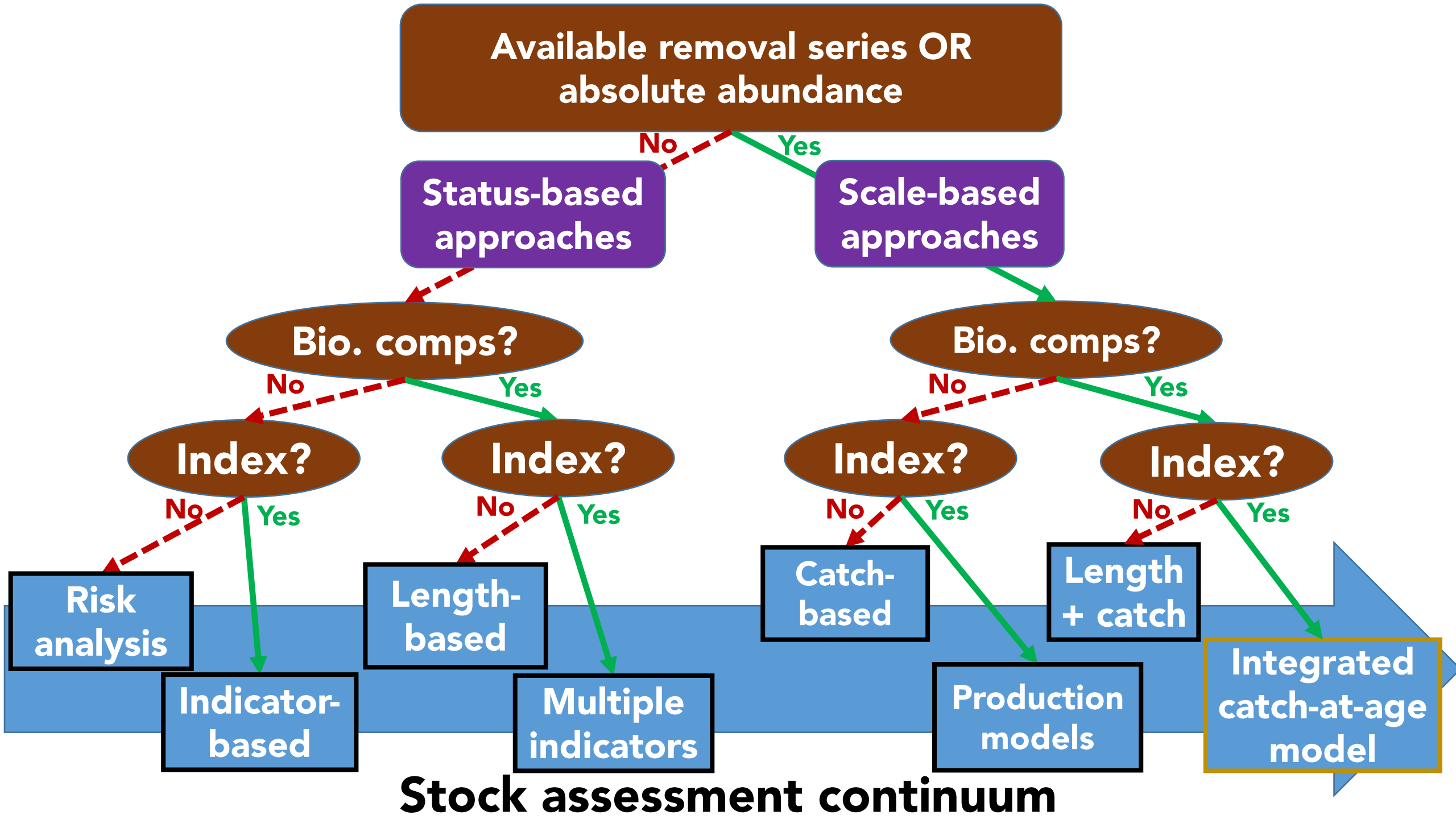
Methods: Life history methods

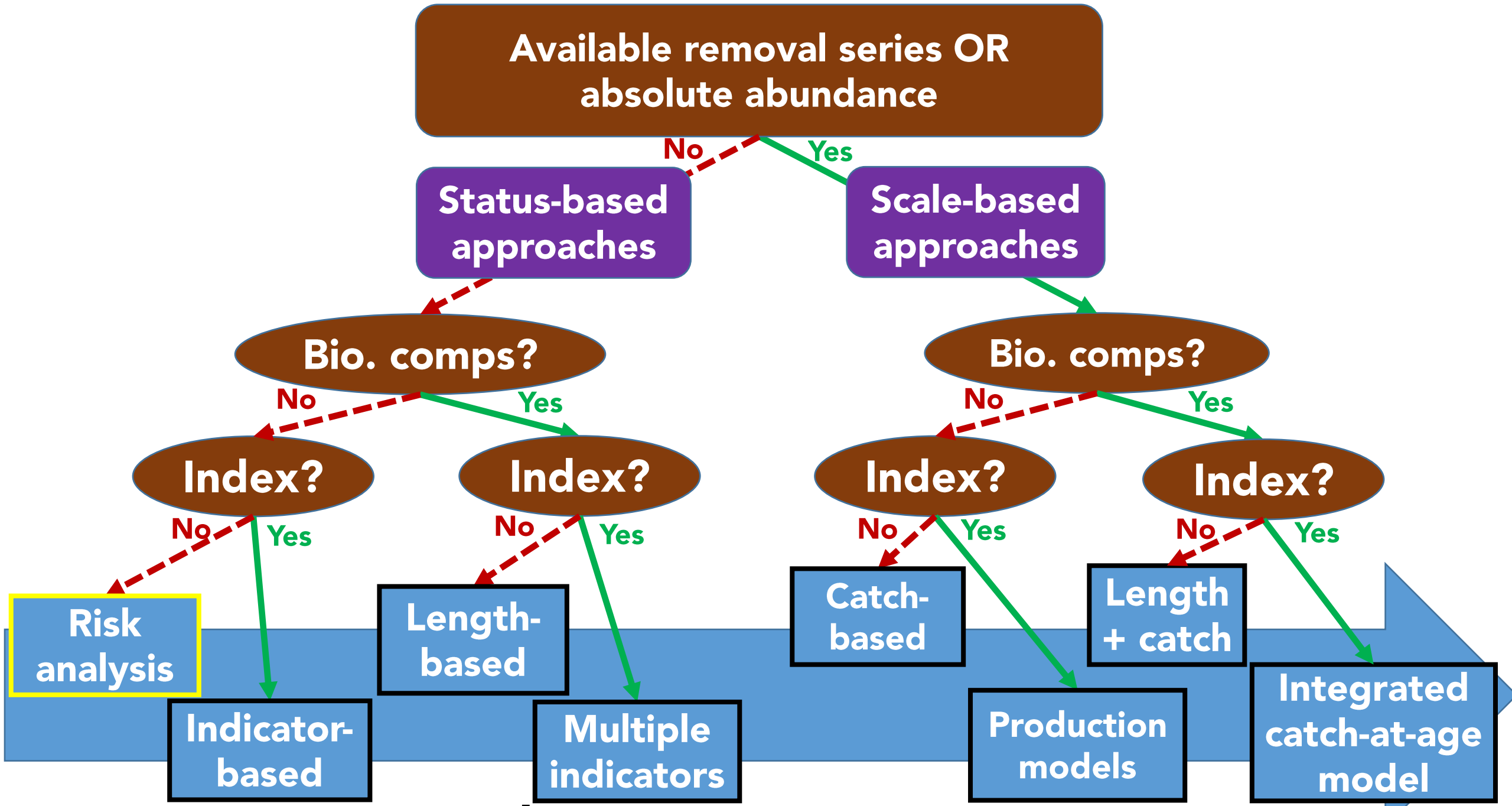


Life history methods: Using *r* to get F_{MSY}



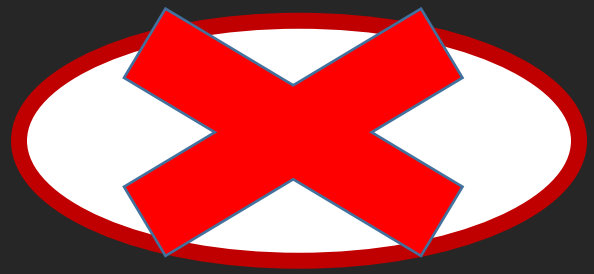



Available removal series OR absolute abundance
No
Yes
Status-based approaches
Scale-based approaches
Bio. comps?
Bio. comps?
No
Yes
No
Yes
Index?
Index?
Index?
Index?
No
Yes
No
Yes
No
Yes
No
Yes
Risk analysis
Indicator-based
Length-based
Multiple indicators
Catch-based
Production models
Length + catch
Integrated catch-at-age model
Stock assessment continuum



Stock assessment continuum

Methods: Risk Assessments



- ~~Removals (Catch + Discards)~~
- ~~Abundance indices~~
- ~~Biological compositions~~
  - ~~Lengths~~
  - ~~Ages~~

Control rules
operationalize assessments

Risk Analysis

Output control (catch)

Input control (effort)

Parameters

- Mortality
- Age and growth
- Reproduction
- Selectivity

Vulnerability, Susceptibility

~~Stock~~ Status

Productivity

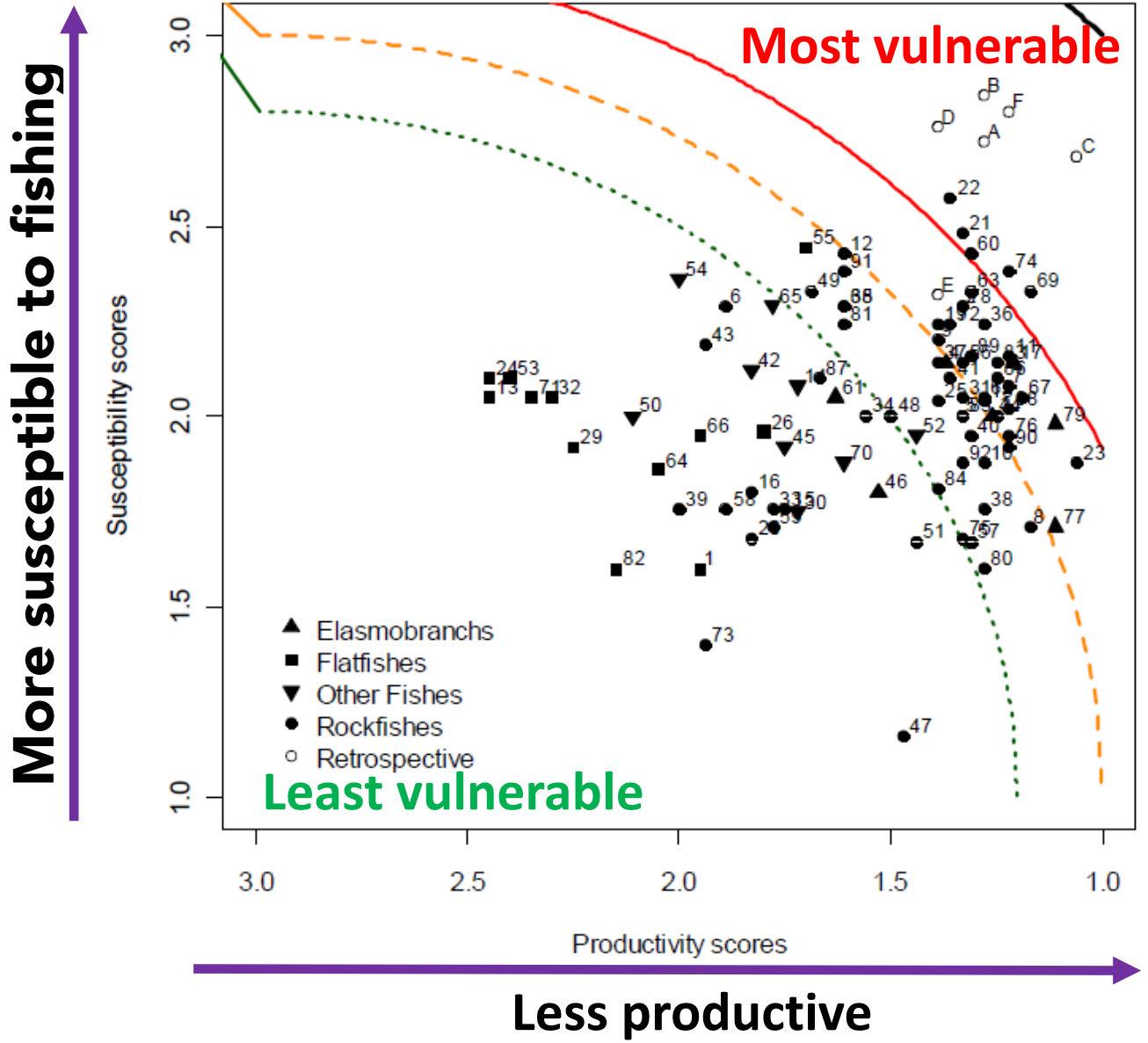
Control rule

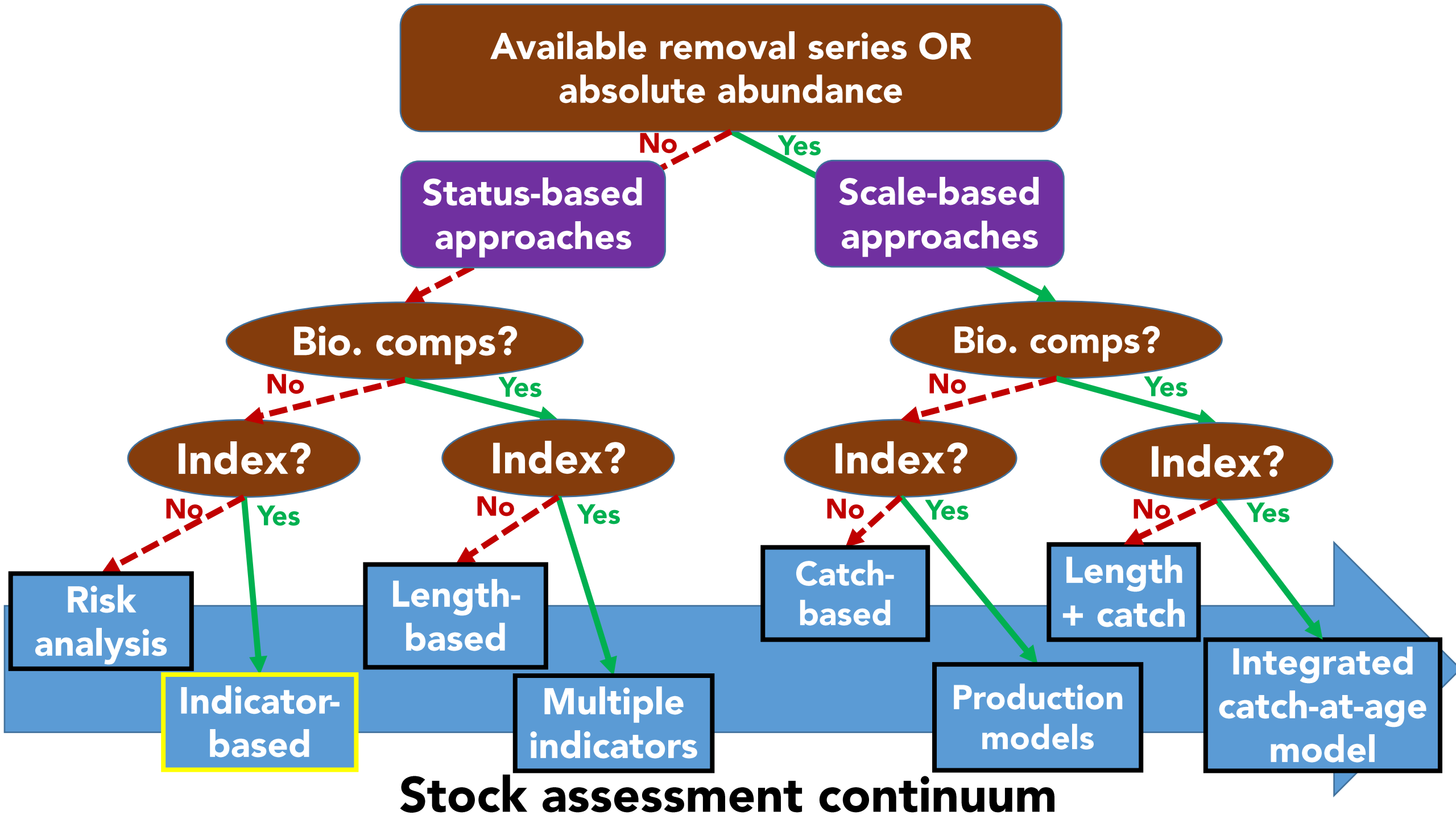
Reference point

Management Measures

Methods: Risk Analysis

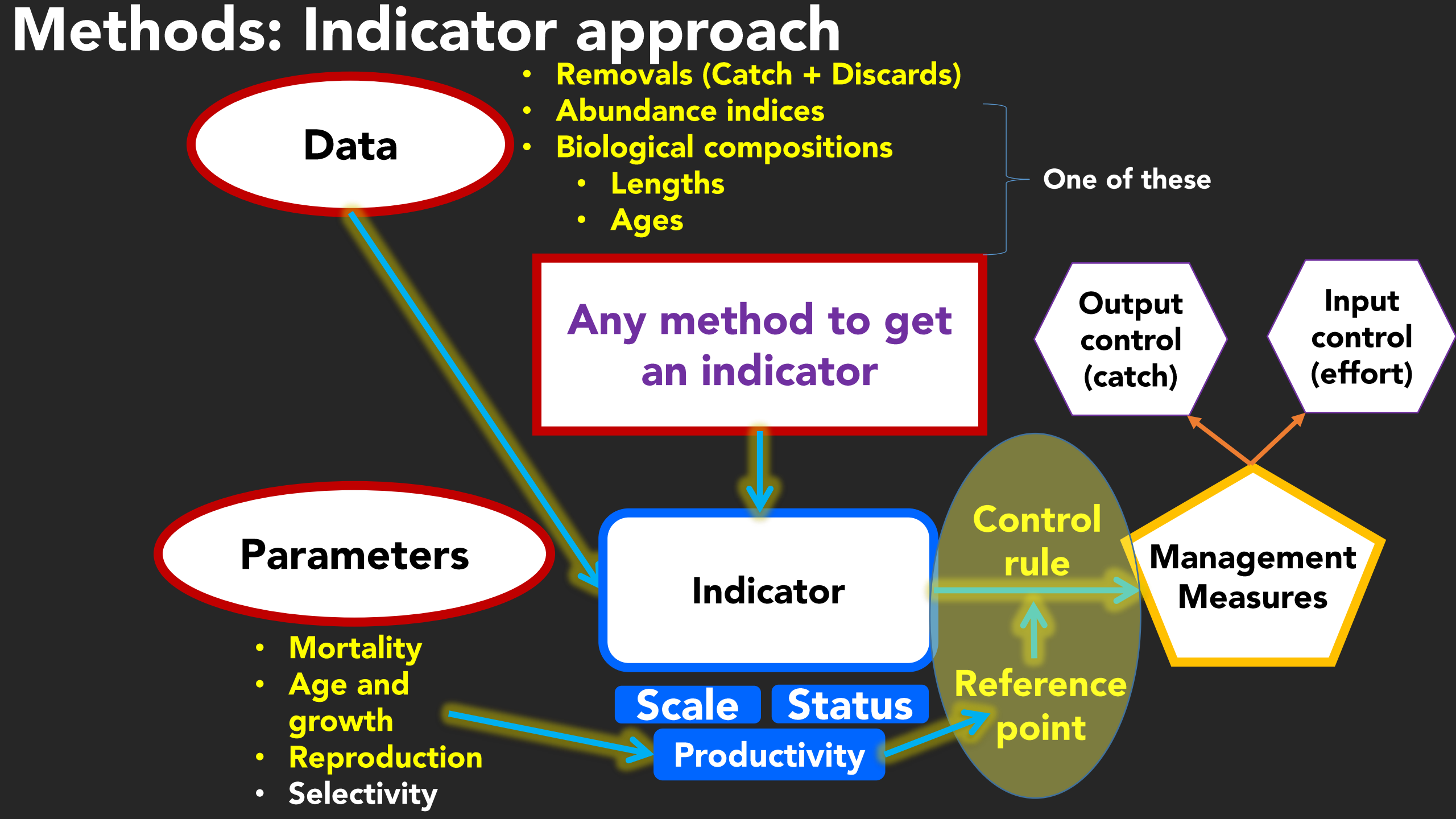
- Uses life history and fishery interactions (e.g. selectivity)
- Often characterizes the risk of overfishing
- Uses expert opinion
- Mostly a strategic tool
  - Used to prioritize stocks with a multi-species with limited data or resources





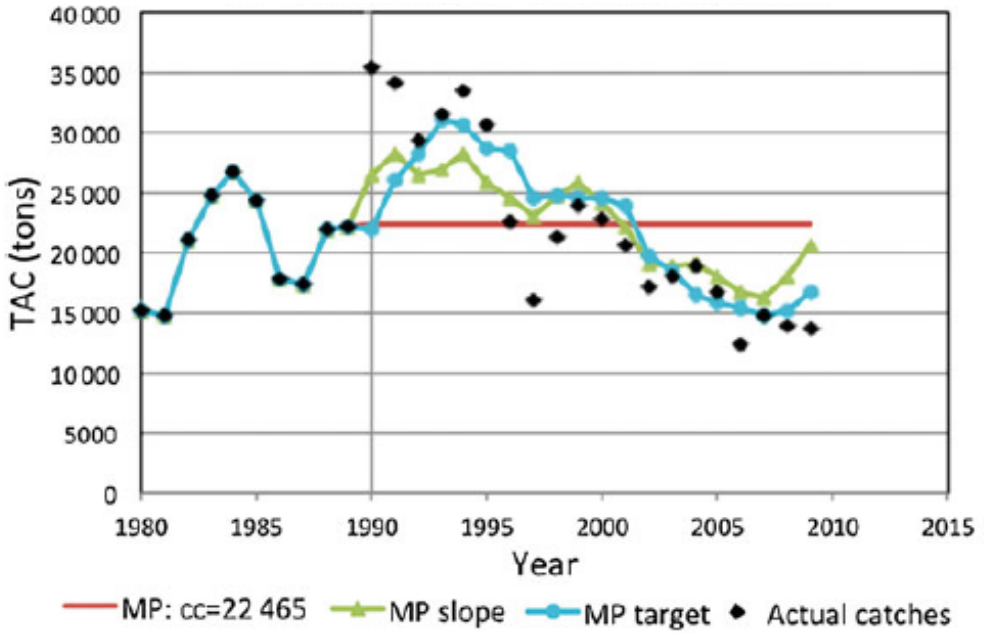
Stock assessment continuum

Methods: Indicator approach



Methods: Indicator approach

Empirical MPs	Control parameters
MP constant catch	$TAC_{y+1} = TAC^{target}$, where TAC^{target} is the annual catch required to reach the target spawning biomass
MP slope: TAC adjusted up or down if the trend in recent survey index values is positive or negative	$TAC_{y+1} = TAC_y\,(1 + \lambda S_y)$, where λ is the smoothing parameter, and S_y the average survey slope over the most recent p years
MP target: TAC adjusted up or down if average of recent survey index values is above or below the target index value.	$TAC_{y+1} = TAC^{target}[w + (1-w)((I_y^{recent} - I^0)/(I^{target} - I^0))]$ *if* $I_y^{recent} \geq I^0$ $TAC_{y+1} = wTAC^{target}(I_y^{recent}/I^0)^2$ if $I_y^{recent} < I^0$, where I^{target} is the target reference point for survey, $I^0 = 0.21^{ave}$ is the limit reference point for survey, I^{ave} the average survey abundance index over past 5 years, I_y^{recent} the average survey of most recent 4 years, TAC^{target} the equilibrium catch, and w a smoothing parameter



$MM_{y+1} = MM_y$ * Modifier

MM = Management Metric (Catch or Effort)

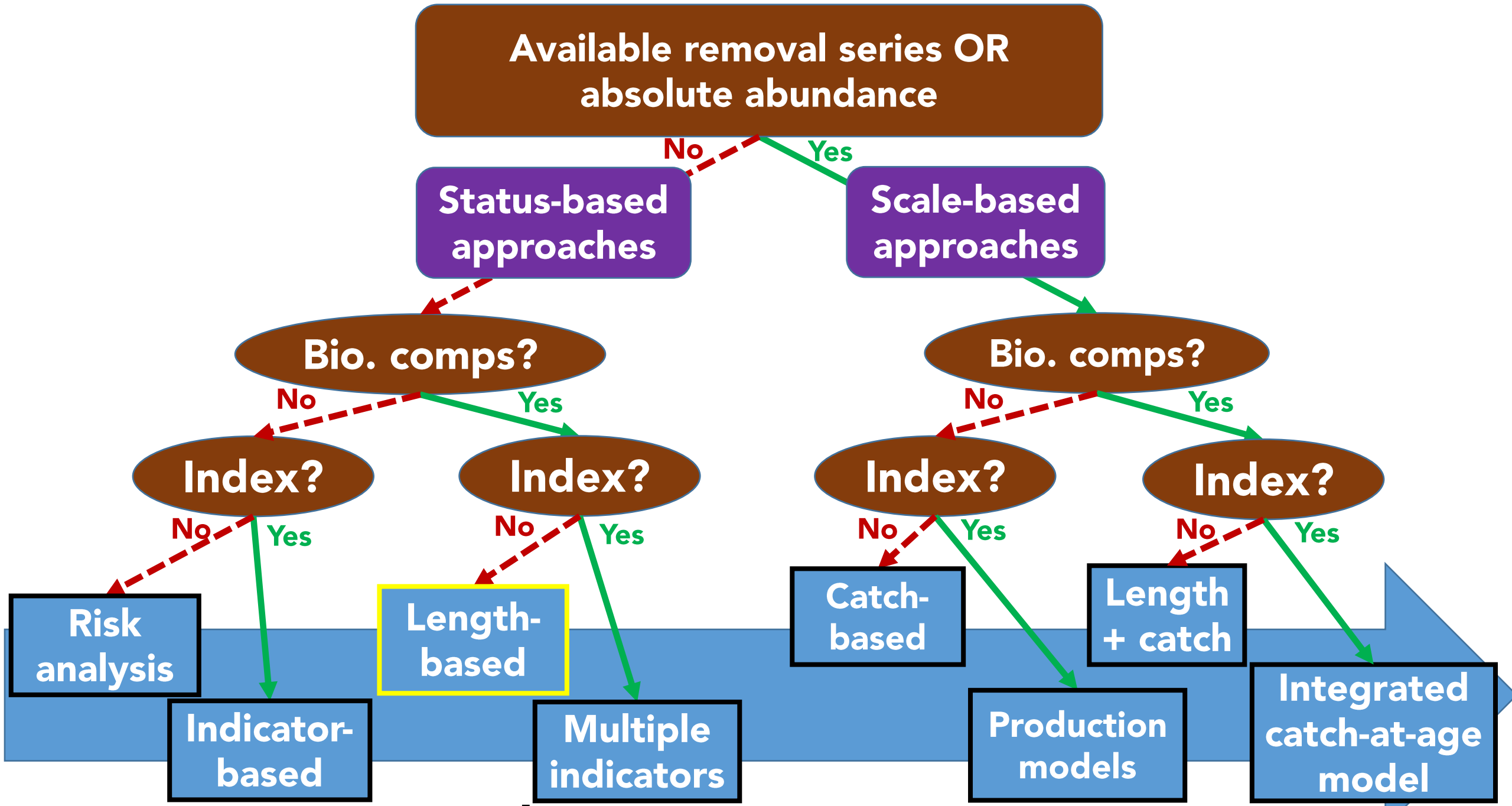
Modifier =

1. **Indicator:Reference Point**
2. **Control rule.**

Source: Geromont and Butterworth 2015

Summary: Indicator approach

- Part of a Management Procedure (Method + Control Rule)
- Often takes form of a multiplier on management metric (catch or effort)
- Incorporates the use of reference points, which dictate when control rule action happens/changes
- Look to identify the indicator and reference point in any method
- Can avoid empirical methods or models
- Reference point is CRITICAL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Length-based
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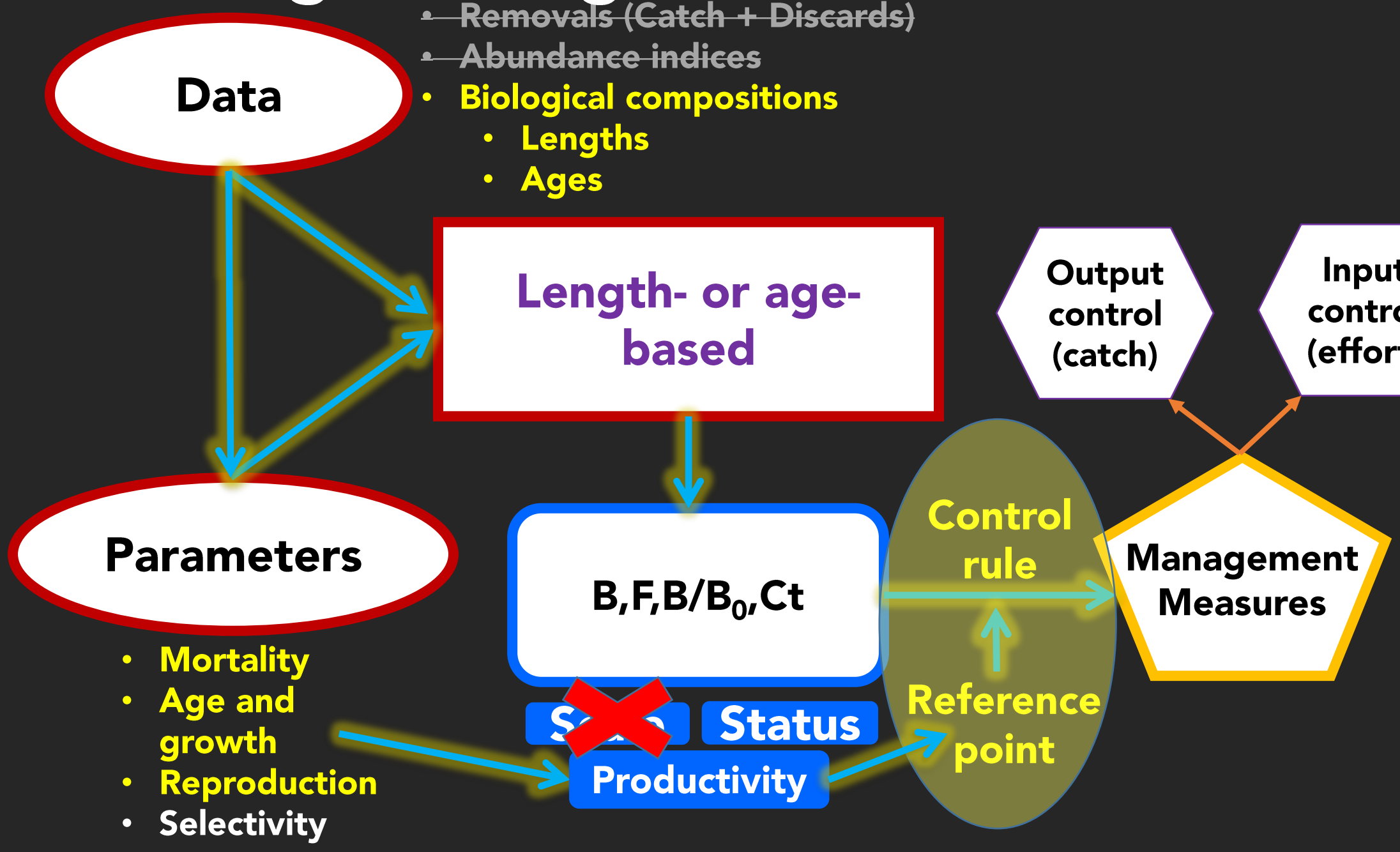
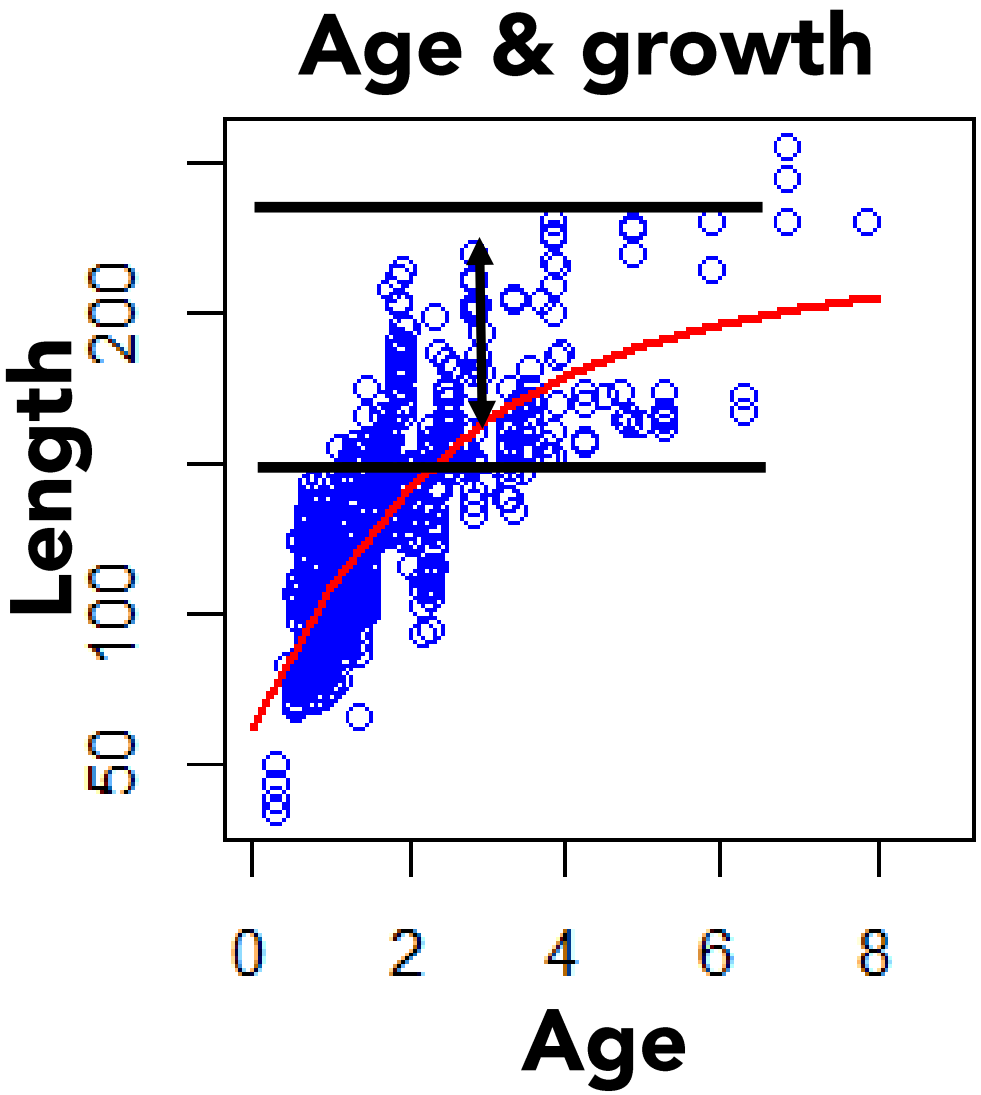
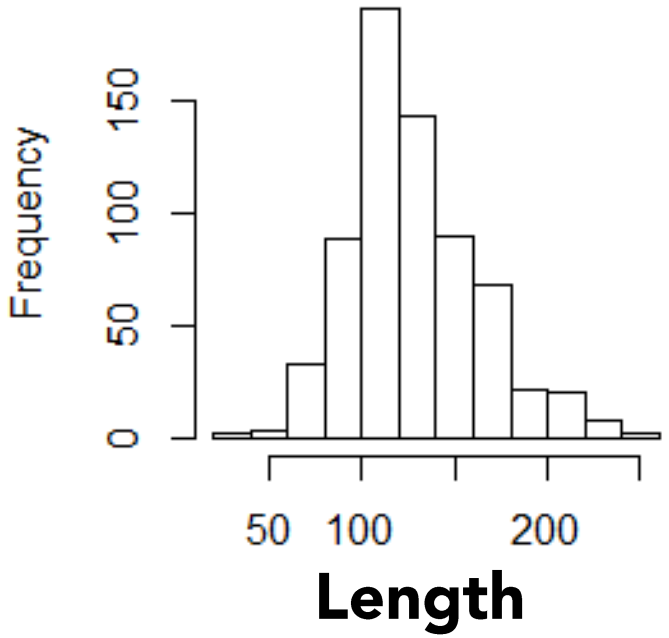
Integrated catch-at-age model
Stock assessment continuum

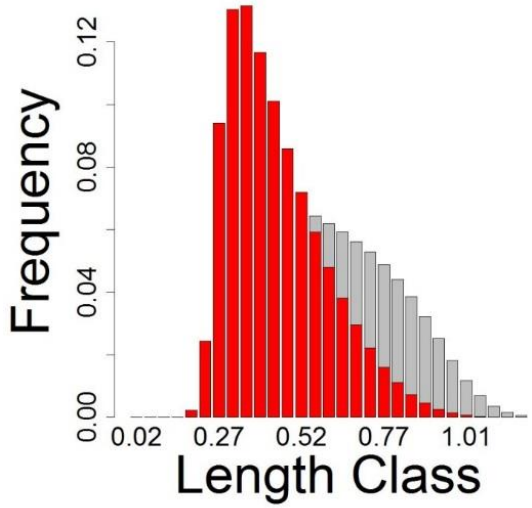
Methods: Length (or Age) based



Length-based methods

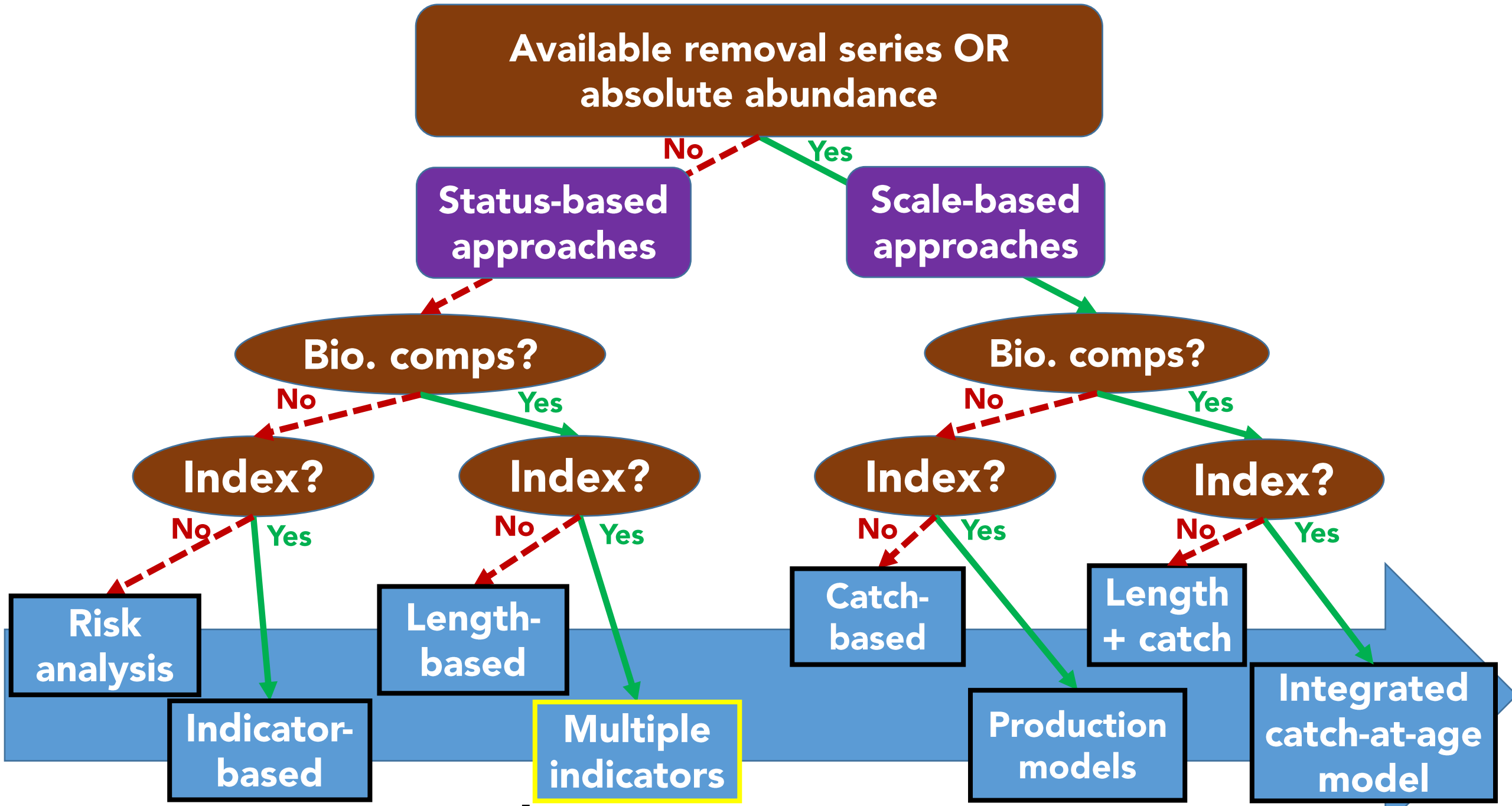






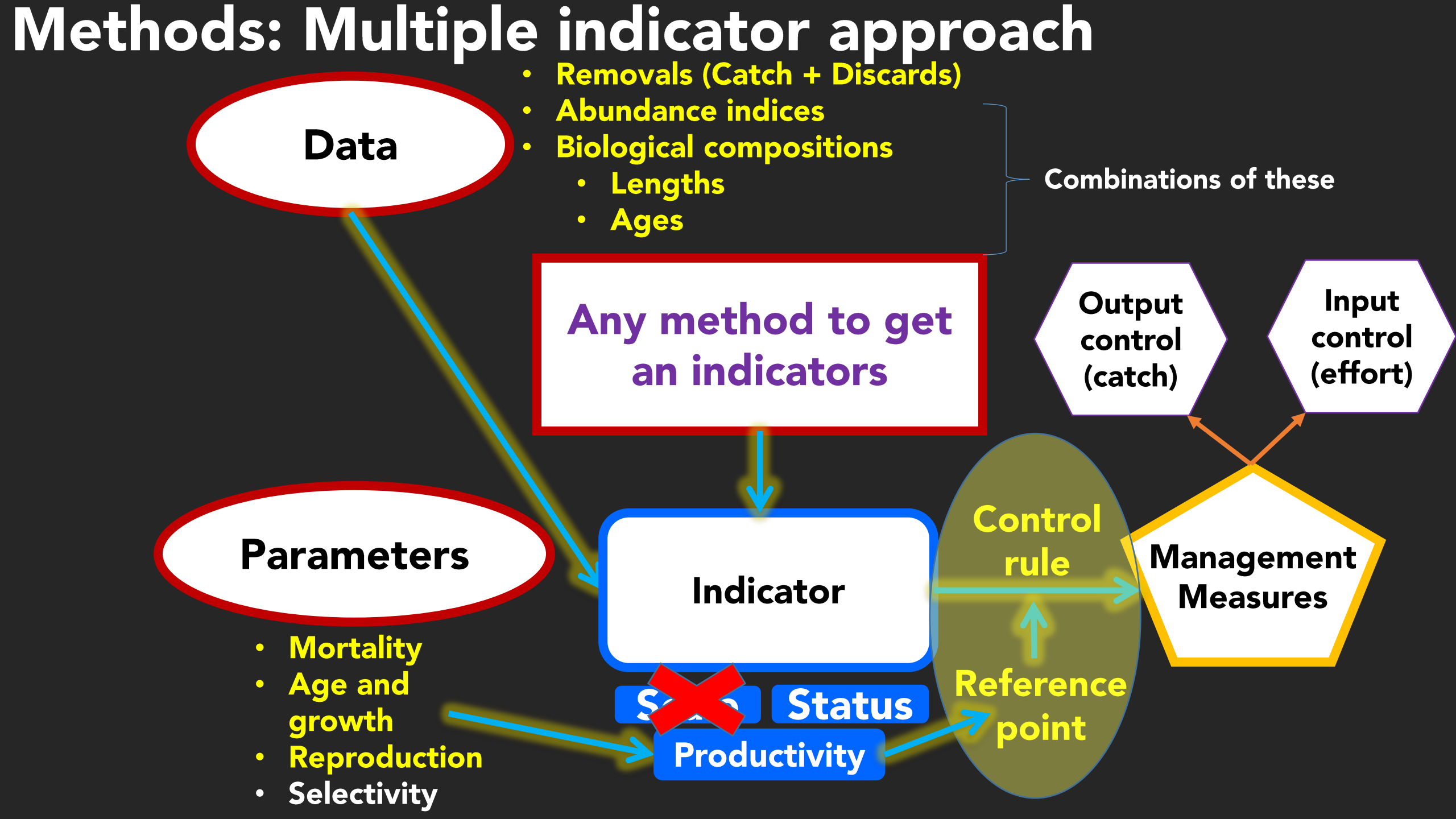
Summary: Length-based methods

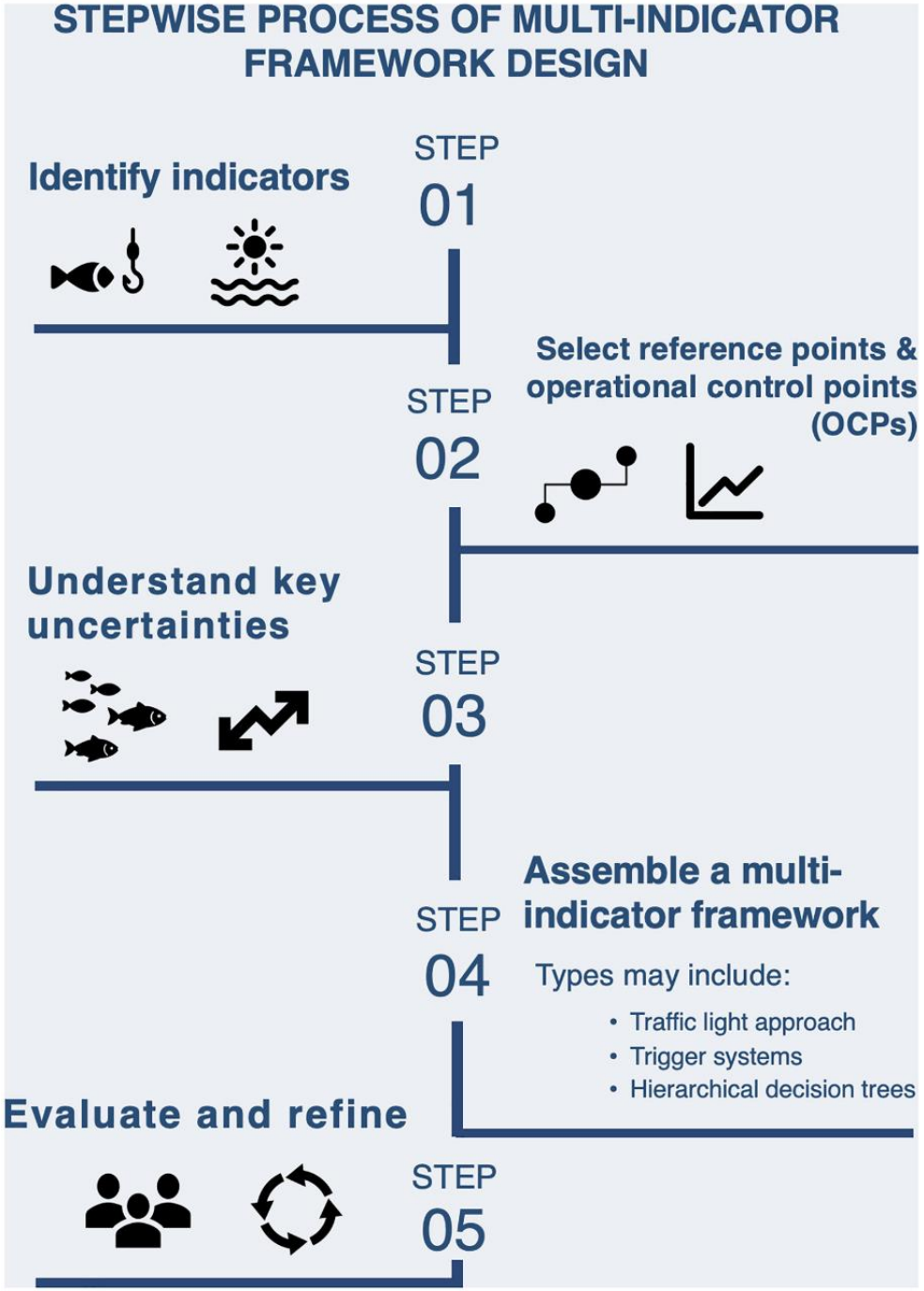
- Lengths (proxy for ages) indicate something about relative stock status
- Resolution of lengths varies given life history
- Specific sensitivities to
  - recruitment variability
  - selectivity
  - life history values



Stock assessment continuum

Methods: Multiple indicator approach

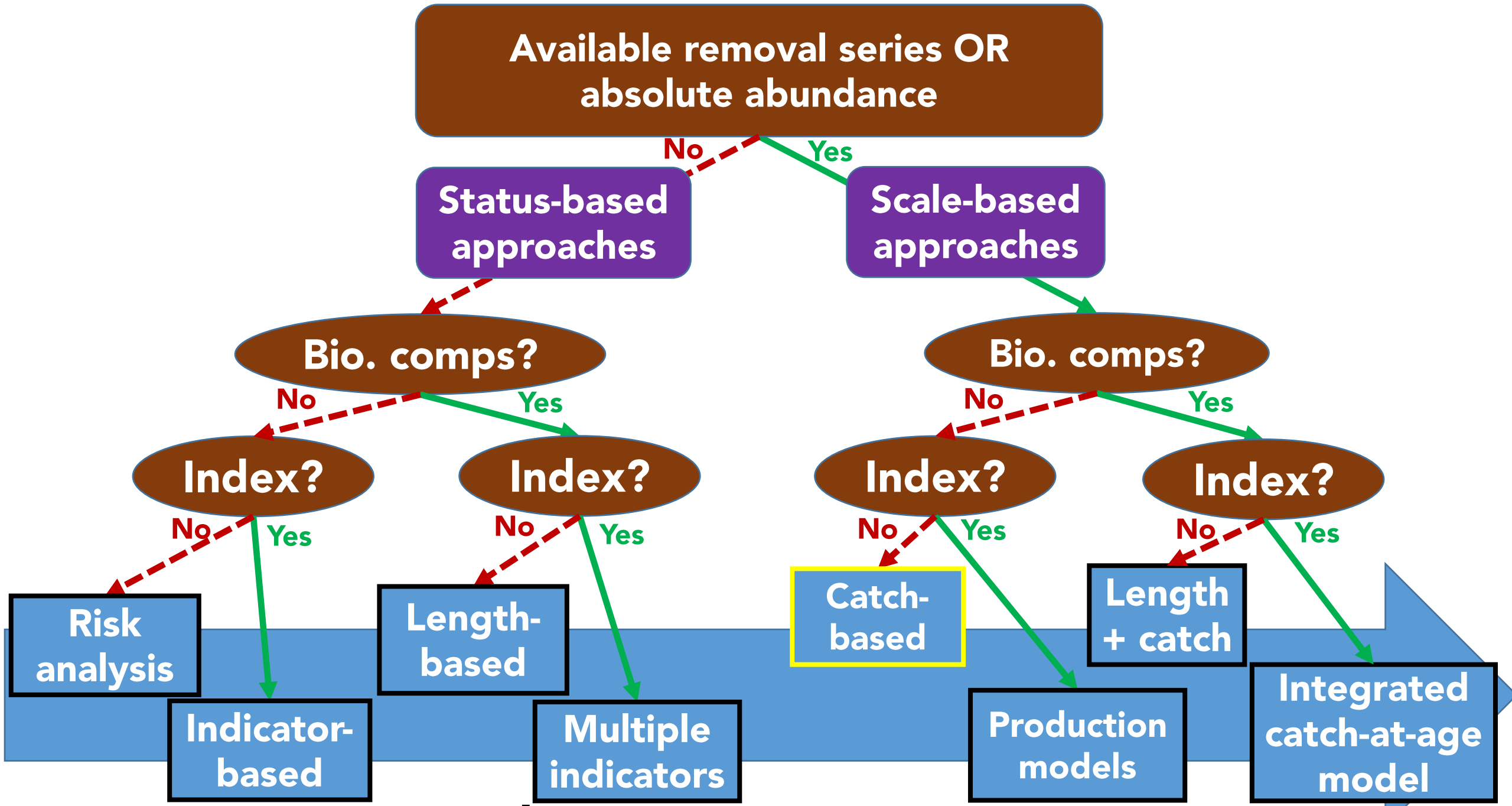




Source: Harford et al. 2023

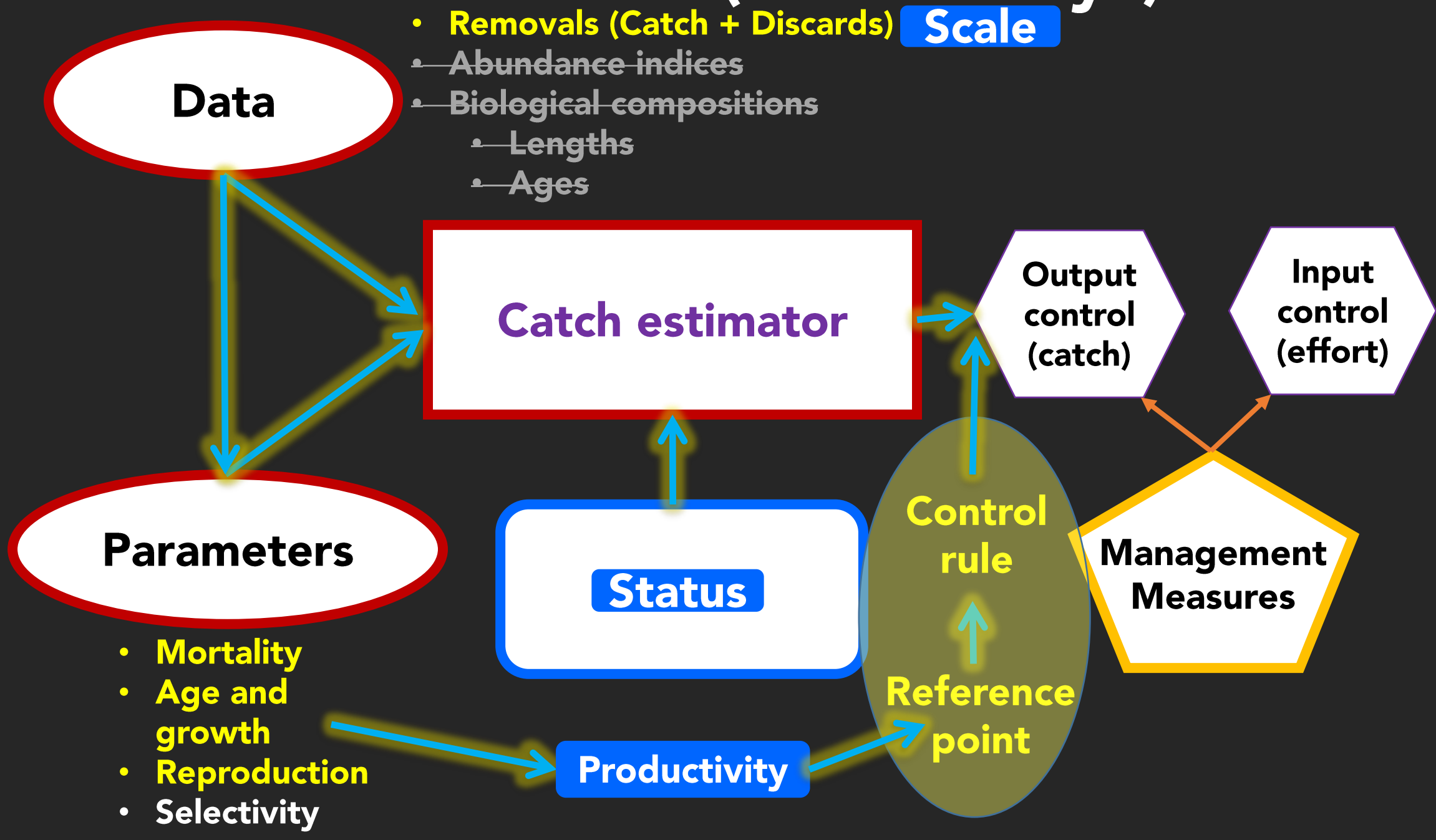
Primary indicators				Secondary indicator		
CPUE	**Mean length**	**Distance traveled**	**Sea temp**	**Recruit pulse**	**Effort change**	**Rationale**
High	High	Near	High	N/A	Watch and wait	Indicators encouraging, but warm water which could result in poor recruitment.
High	High	Near	Low	N/A	Increase	All indicators are encouraging.
High	High	Far	High	N/A	Decrease	Increase in CPUE and size could be from new fishing areas, concern about local depletion.
High	High	Far	Low	N/A	Decrease	Increase in CPUE and size could be from new fishing areas, concern about local depletion.
High	Low	Near	High	Yes	Watch and wait	Maintain status quo because of warmer temperatures.
				No	Decrease	Decrease because of loss of larger fish and warmer temperatures.
High	Low	Near	Low	Yes	Increase	Increase because of encouraging indicator states and recruitment pulse.
				No	Decrease	Decrease because of loss of larger fish.
High	Low	Far	High	Yes	Watch and wait	Temperatures and distance traveled by the fleet concerning, but recruitment pulse.
				No	Decrease	Decrease because of loss of larger fish, warmer water and distance fleet is traveling.
High	Low	Far	Low	Yes	Watch and wait	Maintain status quo because of distance traveled, despite recruitment pulse.
				No	Decrease	Decrease because of loss of larger fish, and distance traveled.
Low	Low	Near	High	N/A	Decrease	Decrease because of low CPUE and warmer waters.
Low	Low	Near	Low	Yes	Watch and wait	Watch and wait, potential for large cohort entering fishery.
				No	Decrease	Decrease because of low CPUE, loss of larger fish.
Low	Low	Far	High	N/A	Decrease	Decrease because of drop in CPUE, mean length, warmer water and distance traveled.
Low	Low	Far	Low	N/A	Decrease	Decrease because of drop in CPUE and mean length, and distance fleet traveled.
Low	High	Near	High	N/A	Watch and wait	Maintain status quo because CPUE is low and warmer waters, while larger fish available.
Low	High	Near	Low	N/A	Watch and wait	Maintain status quo because of increase in fish size even with the decline in CPUE, also fishing on their normal fishing grounds.
Low	High	Far	High	N/A	Decrease	Decrease because CPUE is low, distance traveled, and warmer waters.
Low	High	Far	Low	N/A	Decrease	Reduce fishing because CPUE is down, and fleet is fishing outside of typical fishing grounds.

Source: Harford et al. 2023



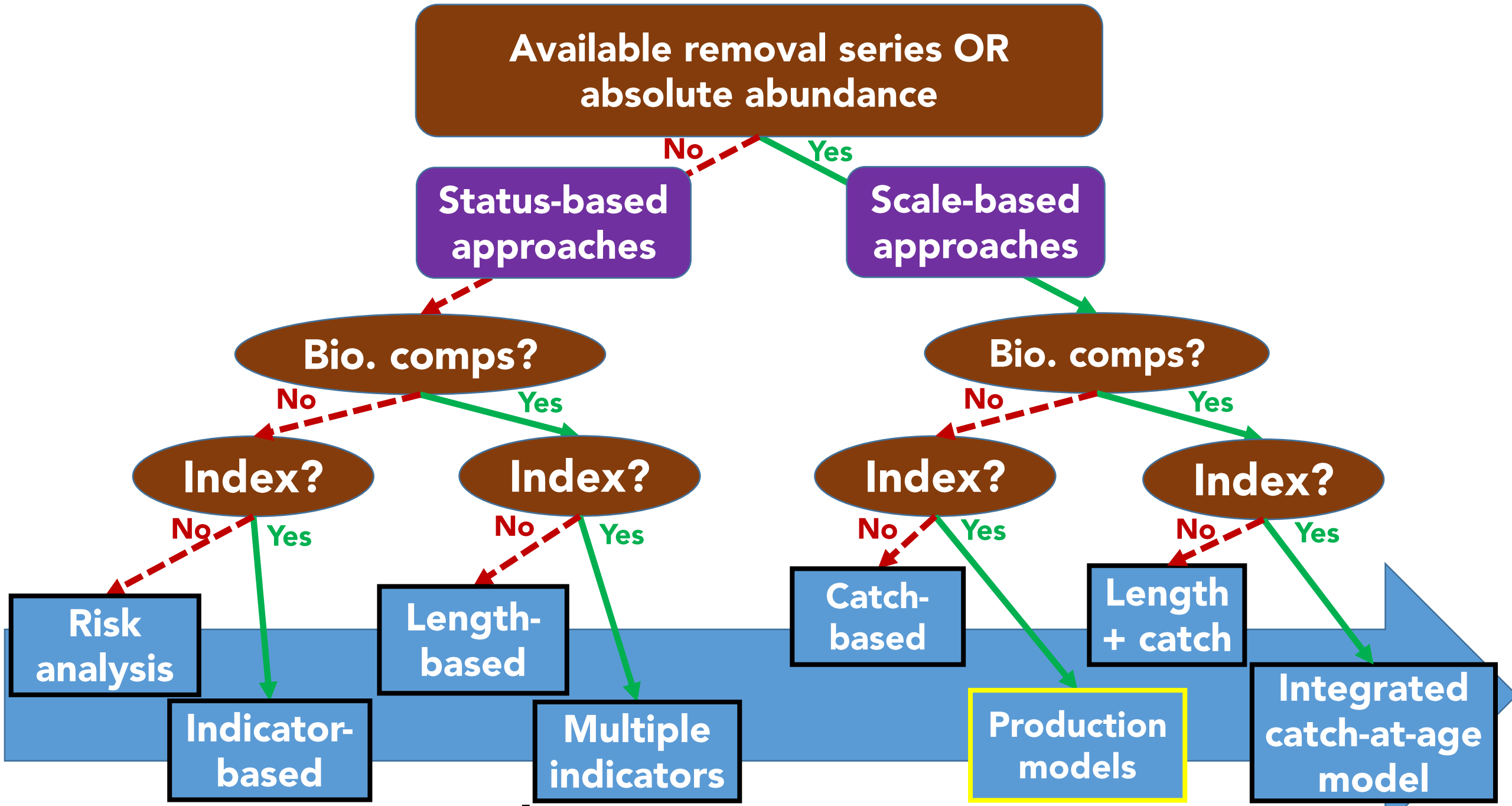
Stock assessment continuum

Methods: Catch estimators ("Catch only")



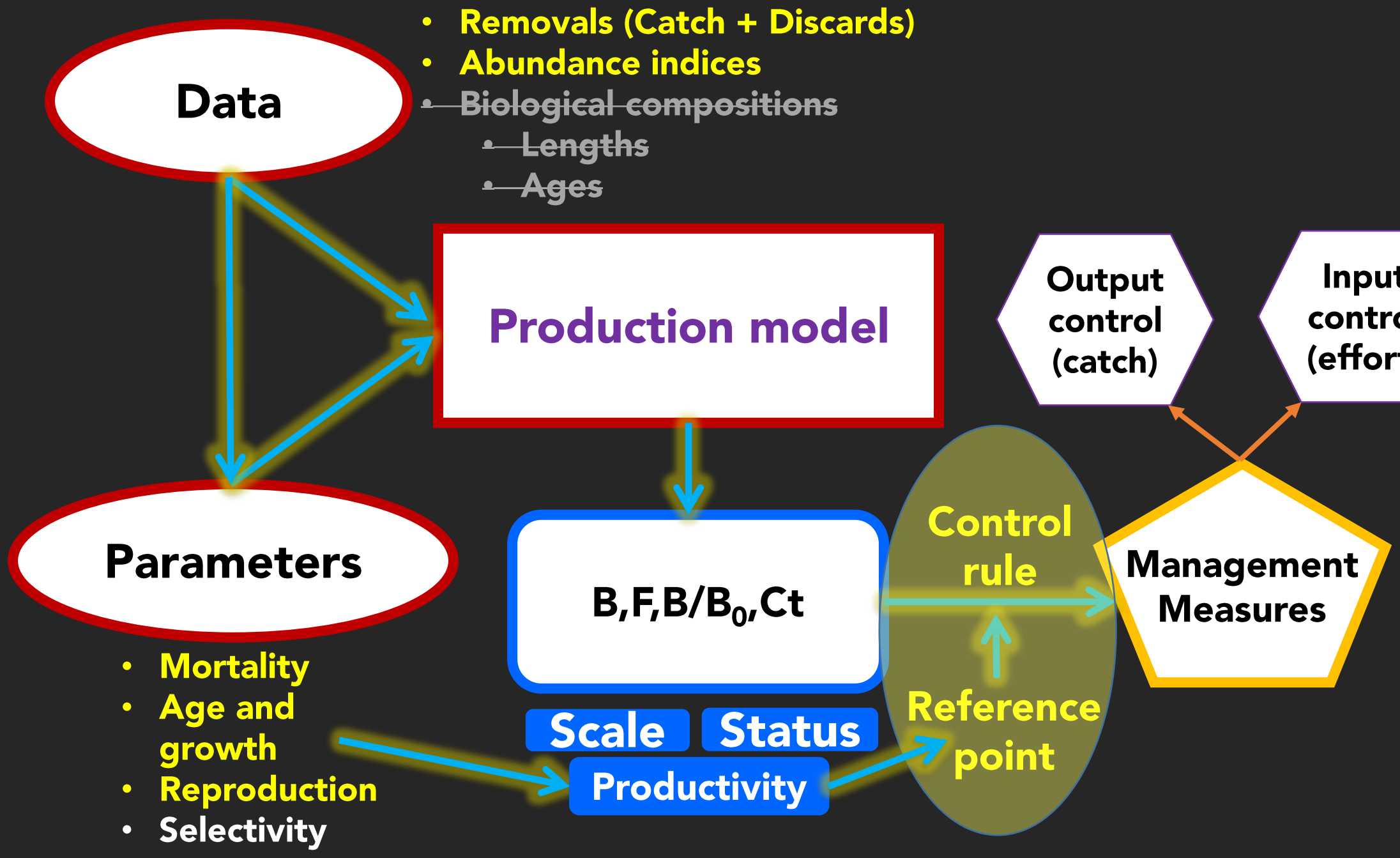
Summary: Catch only methods

- Uses basic life history information with catches
- From simple scalar to analytical solutions to using population dynamics and model fits
- Very sensitive to input parameters and/or model specifications
- Produce catch levels and/or stock status
- Population dynamics should be interpreted with caution



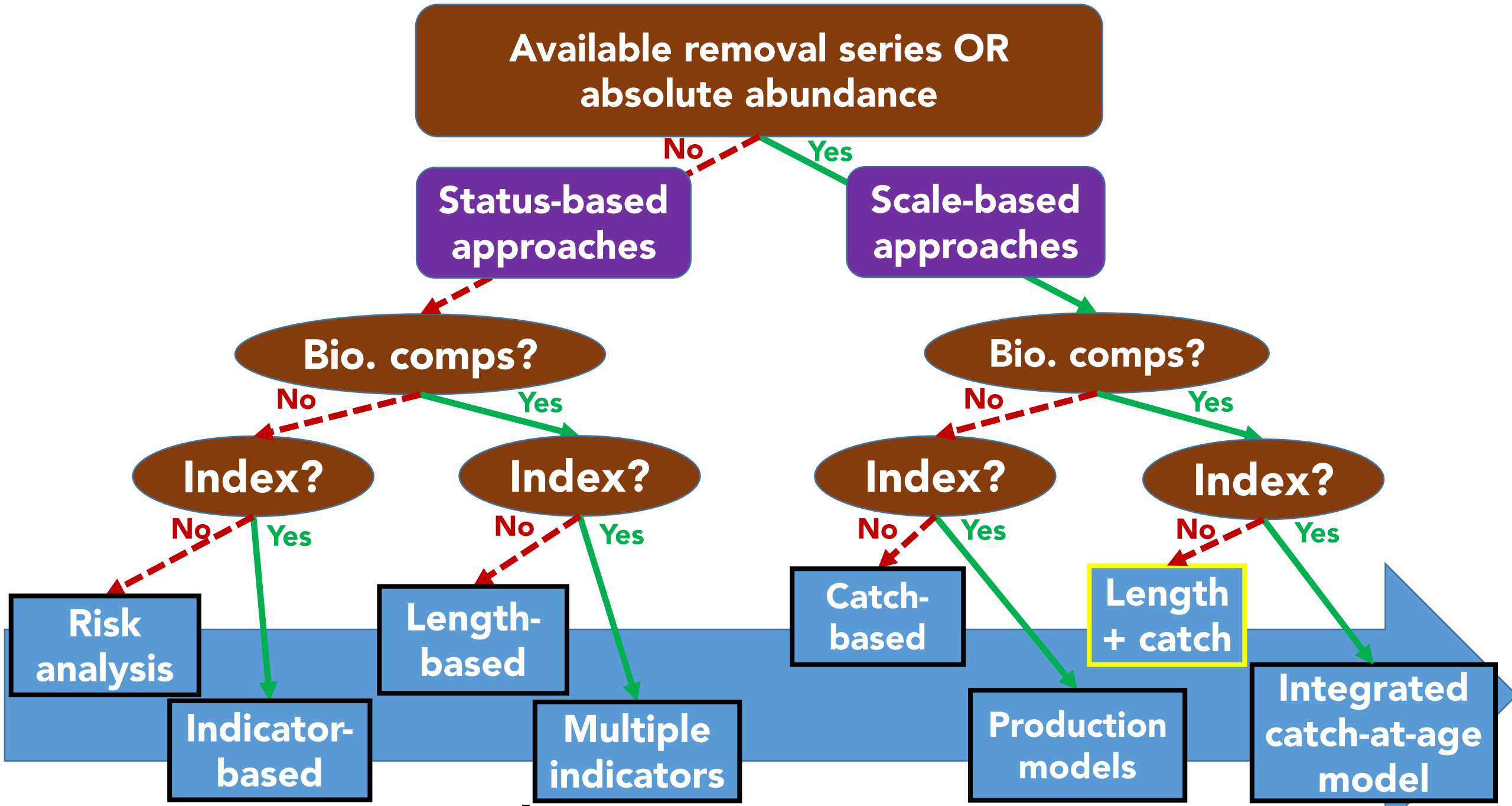
Stock assessment continuum

Methods: Production model



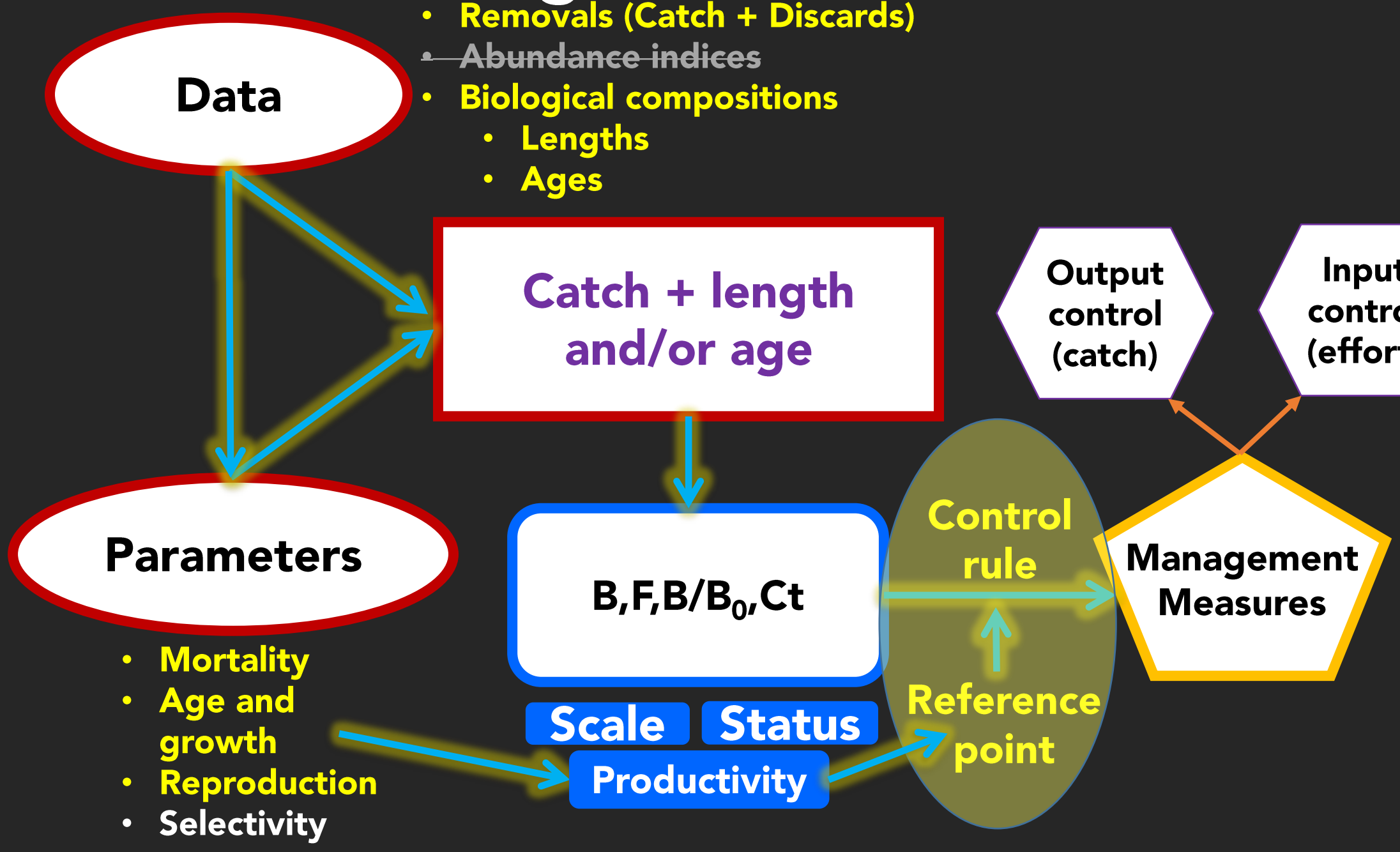
Summary: Production models

- Use catch time series (partial or complete) and at least 1 index of abundance
- May also require an estimate of stock status
- Various forms: biomass, delay-difference, age-structured
- Many outputs: stock status, biomass estimates, F and catch limits
- A "data-moderate" approach: all trust in the indices.



Stock assessment continuum

Methods: Catch + length

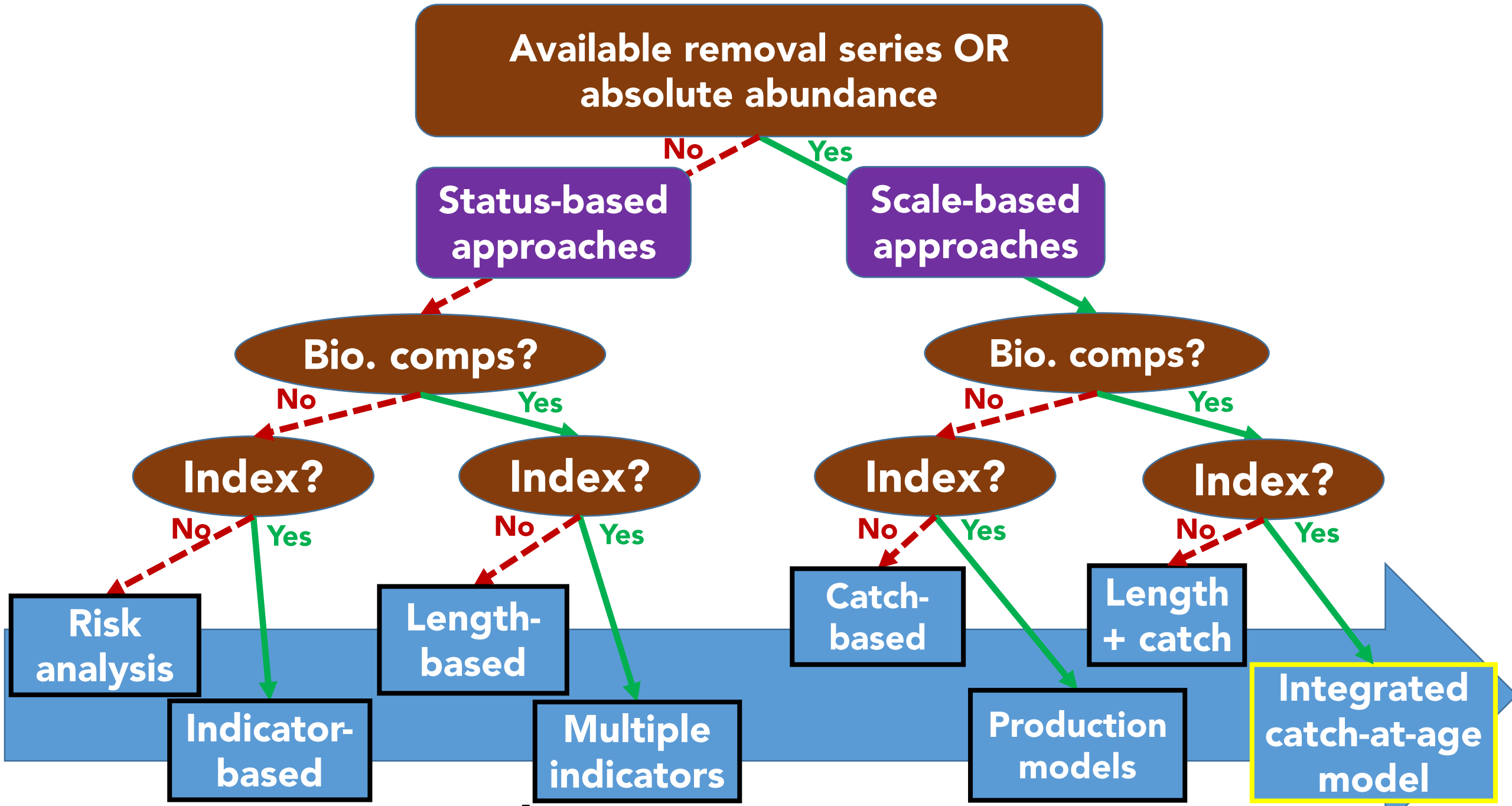


Summary: Catch + length

- Uses catches for scale, lengths for stock status, and life history for productivity to get full compliment of stock assessment outputs.

- Very sensitive to time series of available lengths and age and growth parameters (e.g., L_∞).

- Could also use ages, if available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Yes
Risk analysis
Indicator-based
Length-based
Multiple indicators
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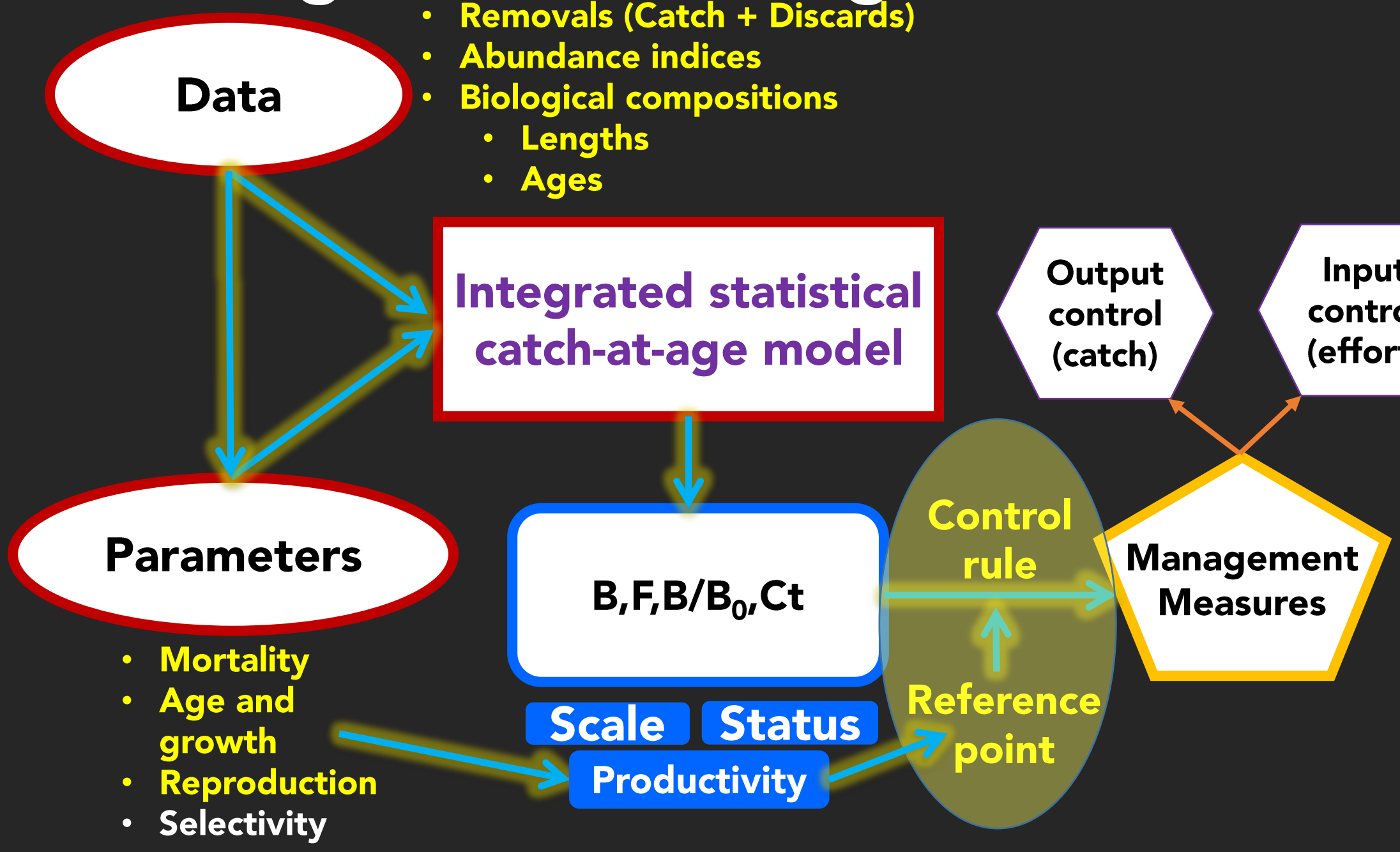
Length + catch
Integrated catch-at-age model
Stock assessment continuum

Methods: Integrated catch-at-age model



Data-weighting

- Integrated model combine different components into a total likelihood

- When you have different data sets, which do you believe? How much weight do they get in the total likelihood?

- Data-weighting consideration variance, sampling or other weightings (lambdas) when putting data signals together

Data-weighting in Stock Synthesis

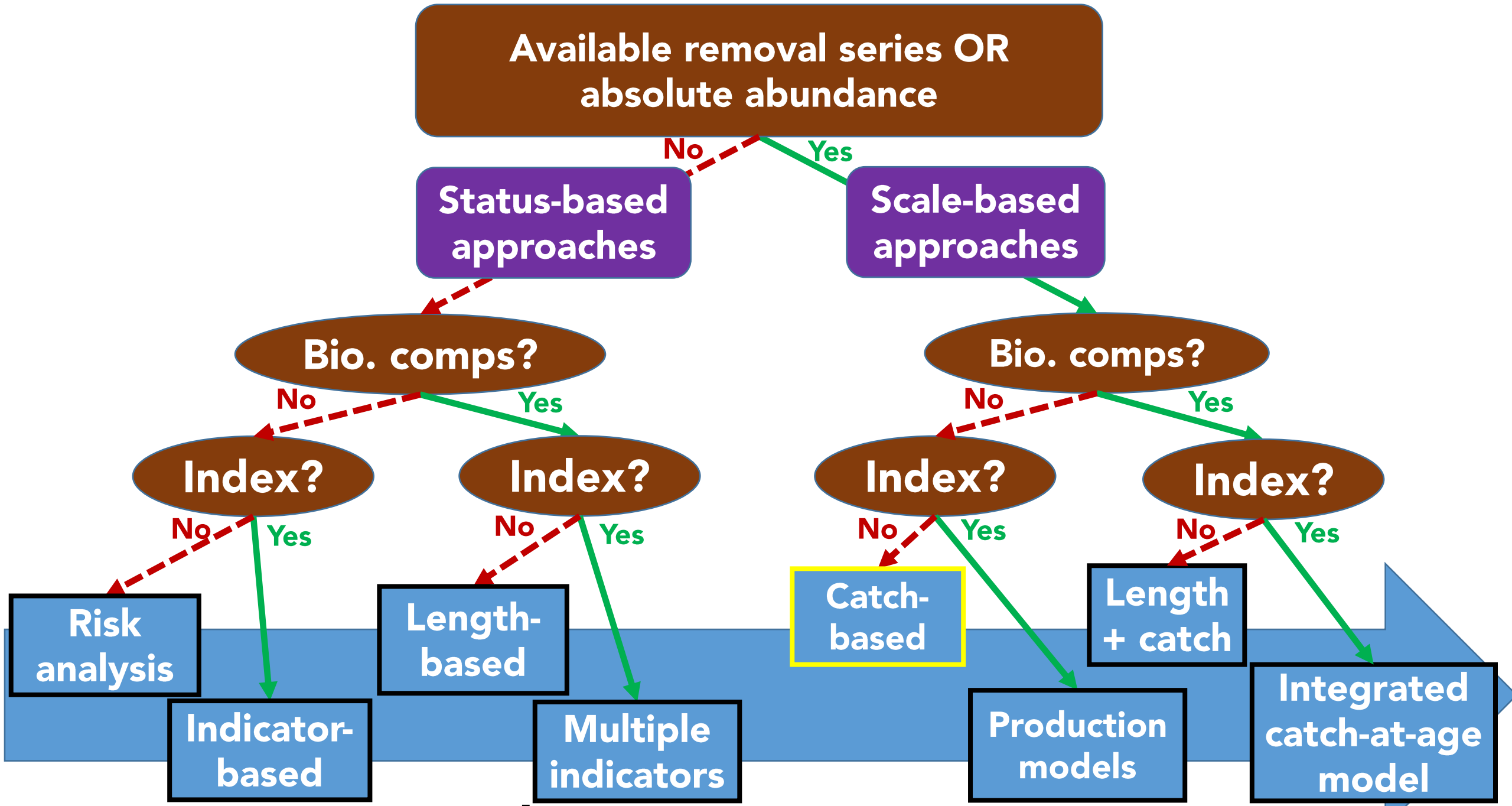
- **Removals** assumed fit perfectly
- **Abundance indices**
  - Input variances
  - Additional variances
  - Estimating catchability
  - Lambdas (multipliers on component)
- **Biological compositions**
  - Input effective sample sizes
  - Data-weighting algorithms
    - Francis Method
    - McAllister & Ianelli
    - Dirichlet
  - Lambdas

Data type/tuning method	Equation	
Length-composition data		
McAllister-Ianelli-1	$\frac{1}{n_y}\sum_y (E_y/N_y)$	(1.A)
McAllister-Ianelli-2	$\left\{\frac{1}{n_y}\sum_y (E_y/N_y)^{-1}\right\}^{-1}$	(1.B)
Francis	$1/var_y\left\{(\bar{L}_y - \hat{\bar{L}}_y)/SE(\hat{\bar{L}}_y)\right\}$	(1.C)
Conditional age-at-length data		
McAllister-Ianelli-1	$\frac{1}{n_{y,L}}\sum_y\sum_L (E_{y,L}/N_{y,L})$	(2.A)
McAllister-Ianelli-2	$\left\{\frac{1}{n_{y,L}}\sum_y (E_{y,L}/N_{y,L})^{-1}\right\}^{-1}$	(2.B)
Francis-B	$1/var_{y,L}\left\{(\bar{a}_{y,L} - \hat{\bar{a}}_{y,L})/SE(\hat{\bar{a}}_{y,L})\right\}$	(2.C)
Francis-A	$1/var_y\left\{(\bar{a}_y - \hat{\bar{a}}_y)/SE(\hat{\bar{a}}_y)\right\}$	(2.D)

SS-DL tool allows for easy implementation of many of these methods

Summary: Statistical catch-at-age

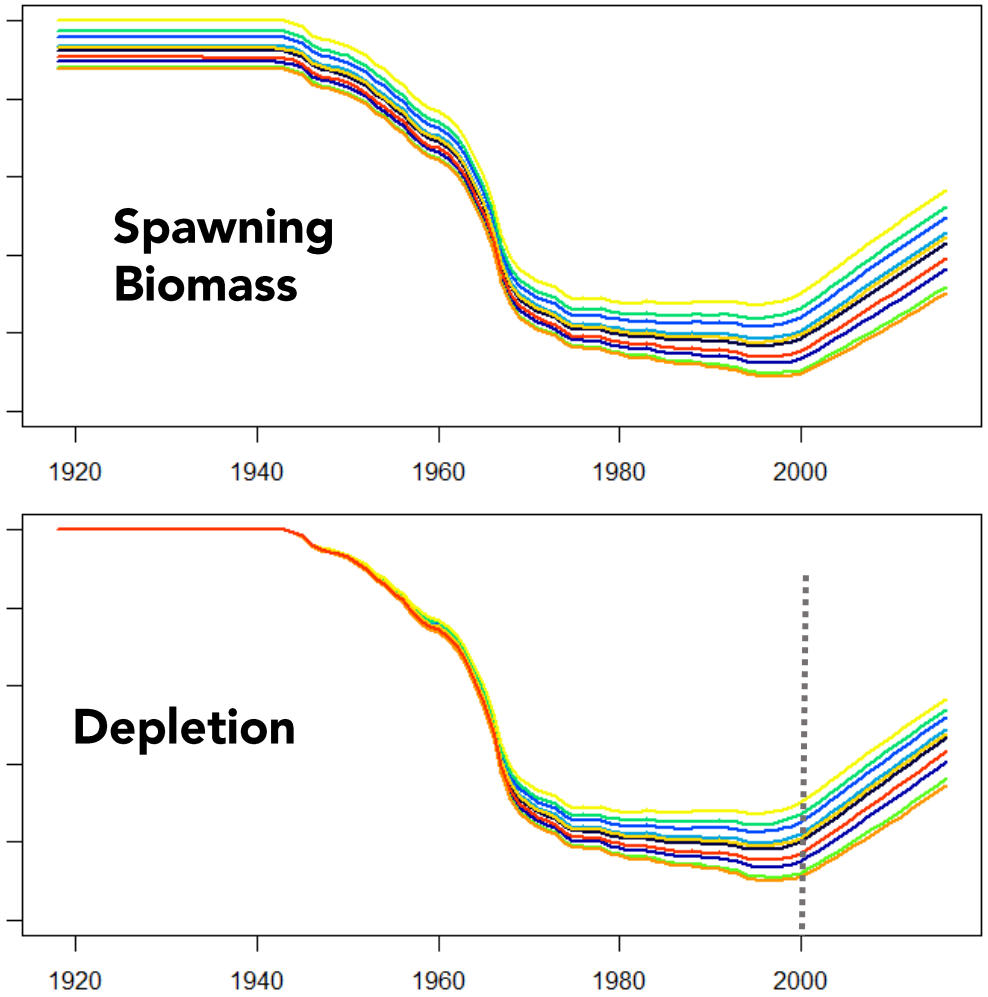
- Uses all available data sets
- **Must consider how to balance each data set (data-weighting)**
- Parameter estimation within model a consideration
- Outputs stock scale, relative stock status and fishing intensity, as well as other metrics (e.g., SPR)
- Uncertainty propagated within model across data and parameters
- High technical capacity required



Stock assessment continuum

Using complex modelling frameworks as simple calculators

- All complex models are a series of parameters that can be fixed.
- In other words, imagine estimating one parameter and fixing the rest.
- Now imagine doing that for several values of an input.
- Example: Current relative stock status (depletion) in fixed over many values, biomass estimated.



Scaling up with data: Stock Synthesis Example

Removals + **Abundance indices** + **Size & Age compositions**

Simple Stock Synthesis (SSS)

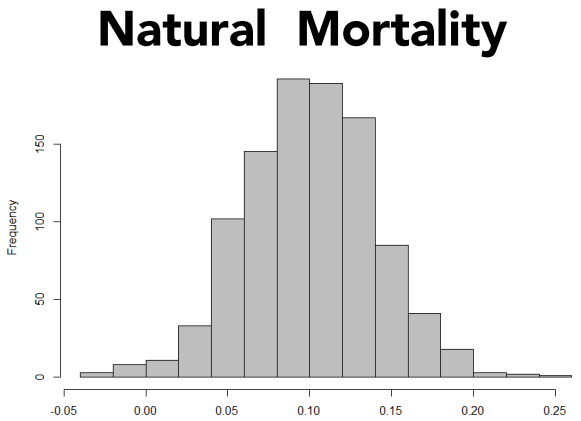
eXtended Simple Stock Synthesis (XSSS);
Age structured production model (ASPM)

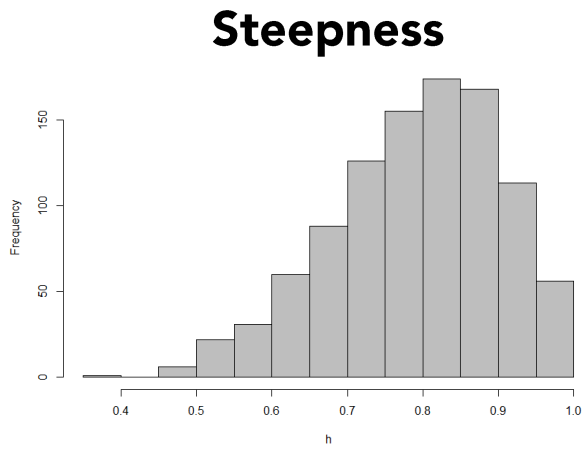
Stock Synthesis (SS)

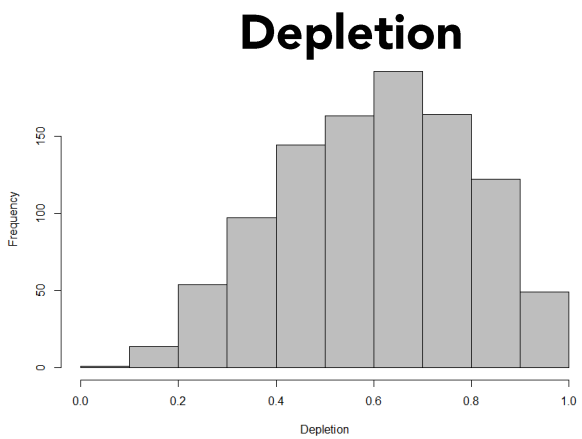
Stock Synthesis nesting doll

Catch only method: Simple Stock Synthesis (SSS)

- Data
  - Catch
- Explore uncertainty about:
  - Natural Mortality
  - Steepness
  - Depletion
- Fixed assumptions:
  - Growth
  - Weight length
  - Fecundity
  - Selectivity
- Solve for $\ln(R_0)$



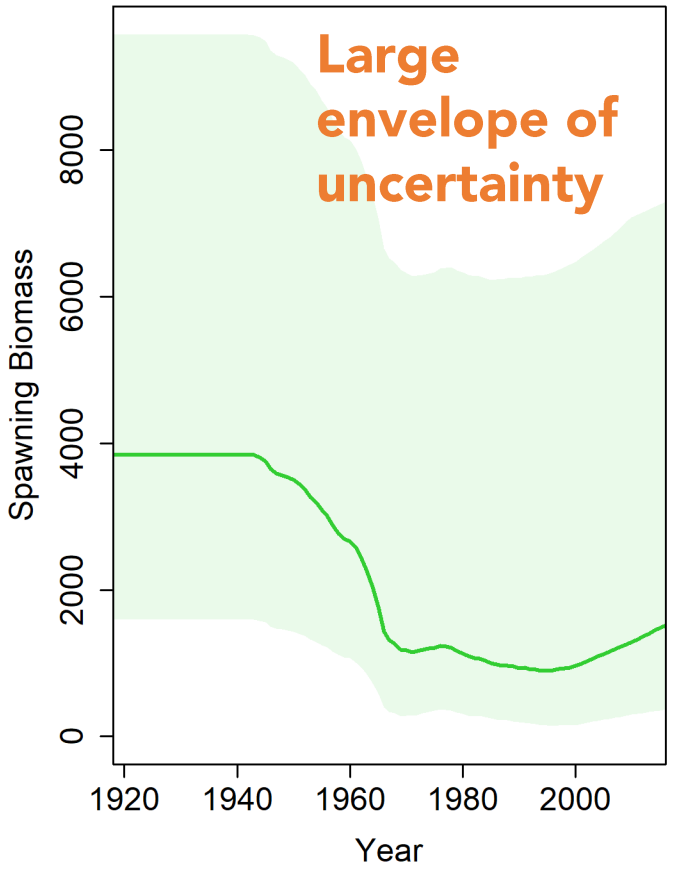


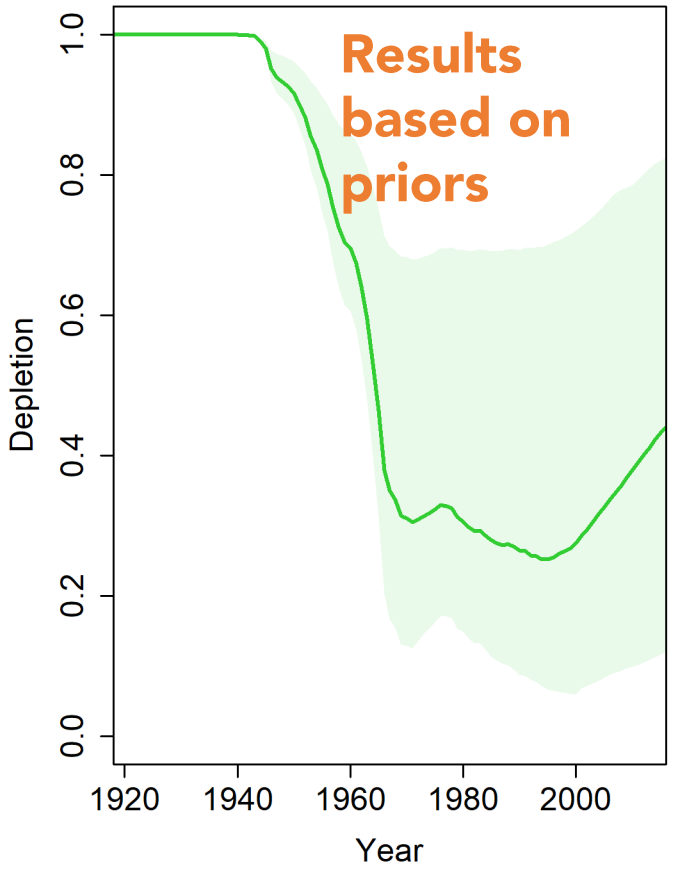


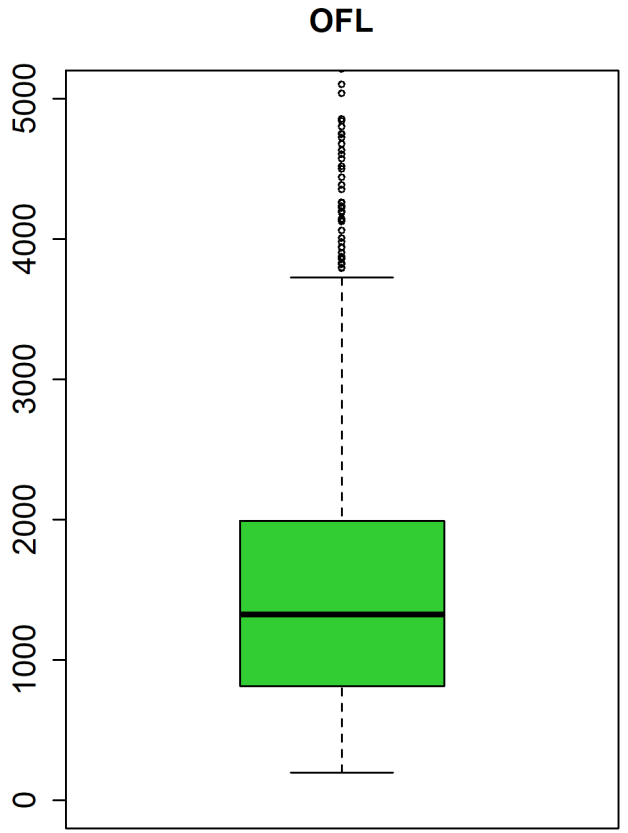
NOAA FISHERIES

Cope, 2013. Fisheries Research 142: 3-14

SSS: stock size, status, and harvest



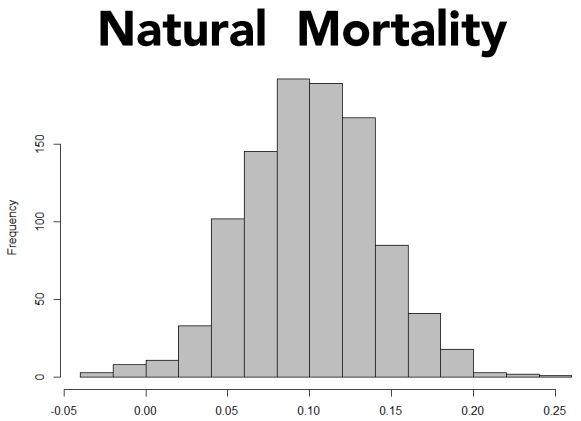


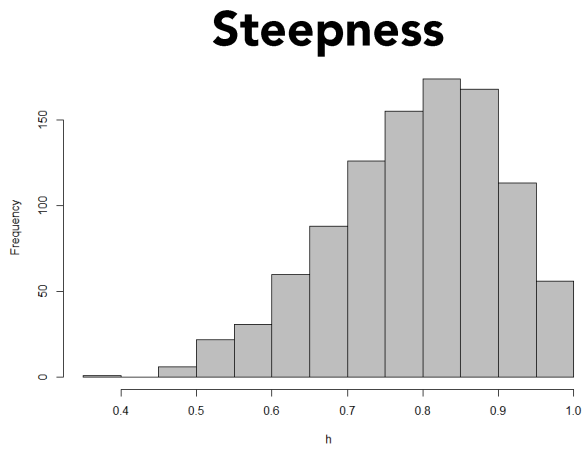


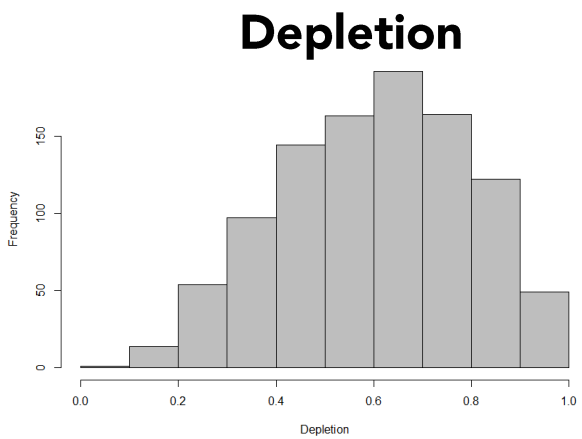
Able to harness harvest control rules and/or precautionary buffers

Catch + Index method: EXtended Simple Stock Synthesis (XSSS)

- Data
  - Catch
  - Indices of Abundance
- Explore uncertainty about:
  - Natural Mortality
  - Steepness
  - Depletion
- Fixed assumptions:
  - Growth
  - Weight length
  - Fecundity
  - Selectivity
- Solve for $\ln(R_0)$







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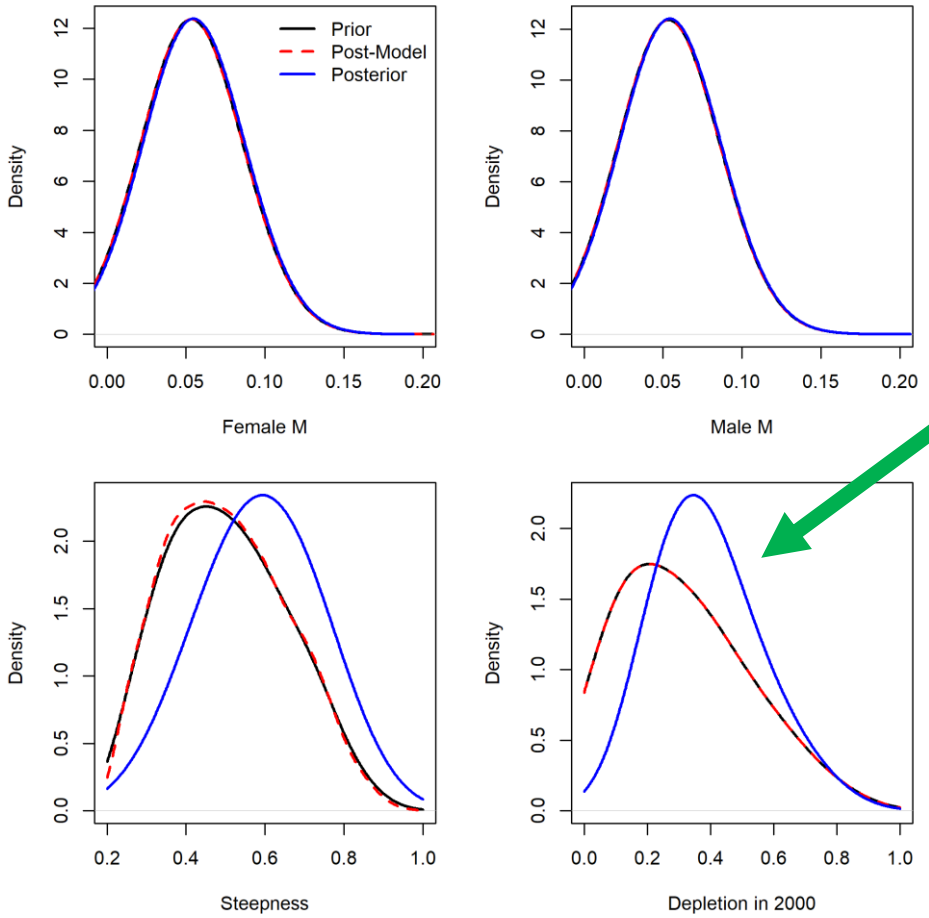
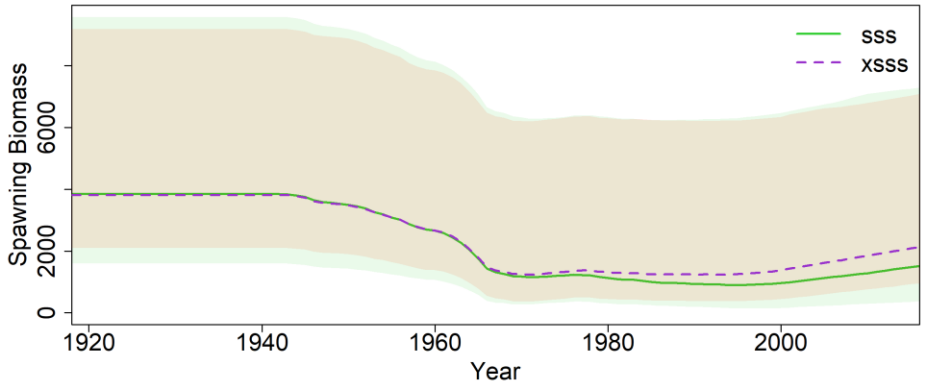
XSSS: outputs

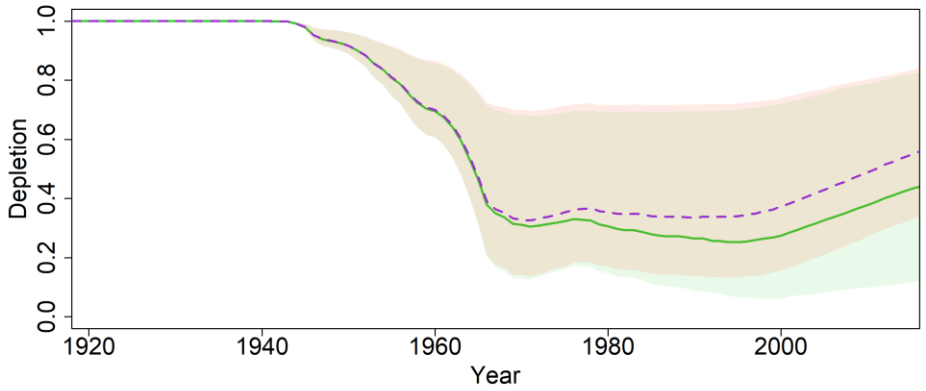
XSSS Posteriors

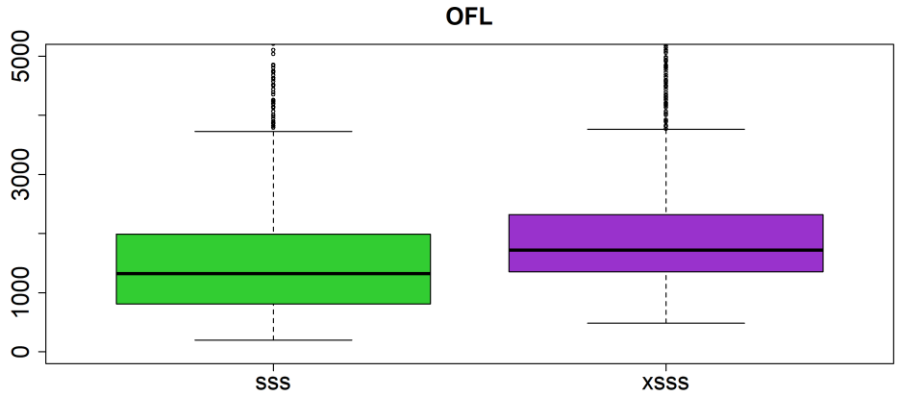


Data reduces the uncertainty

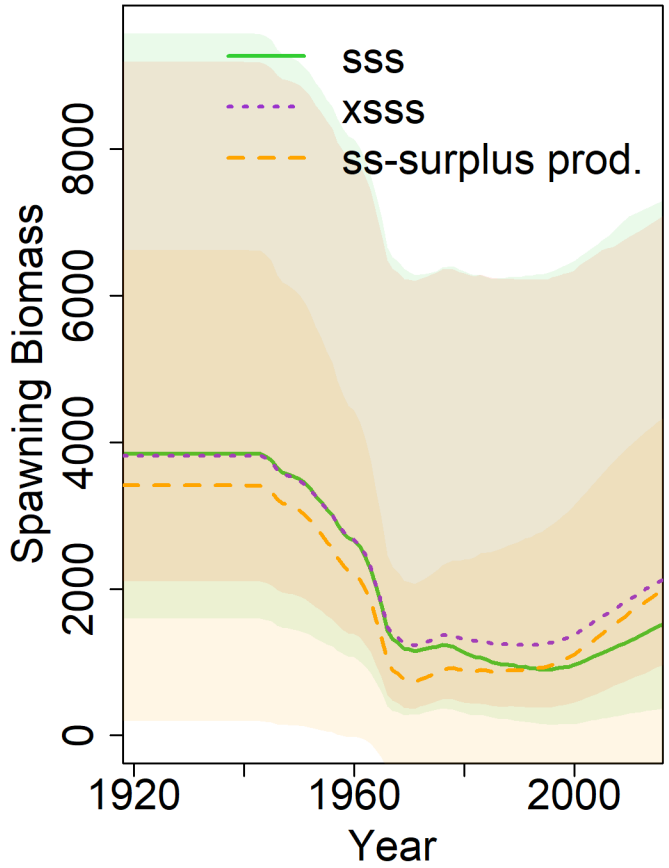
Posteriors updated based on the data

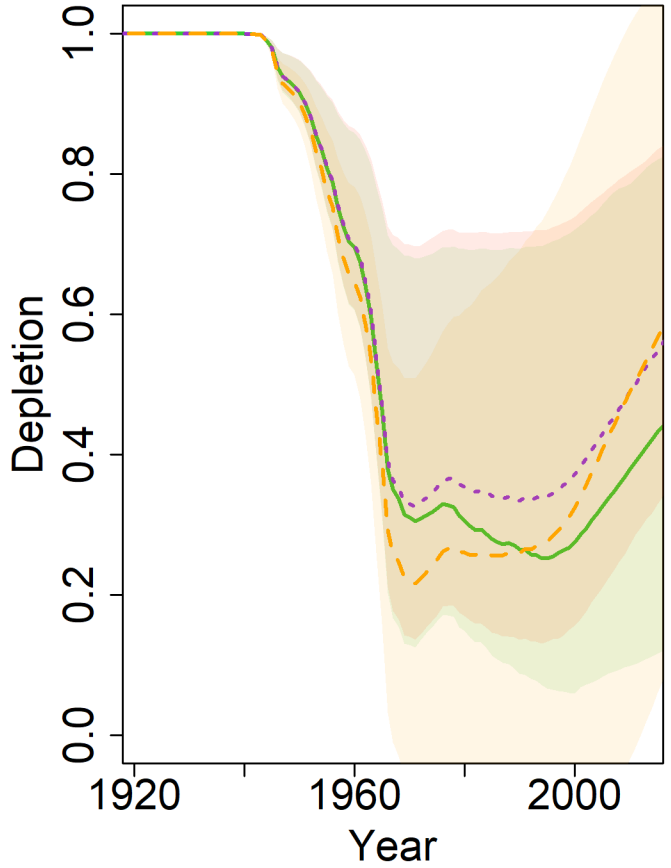


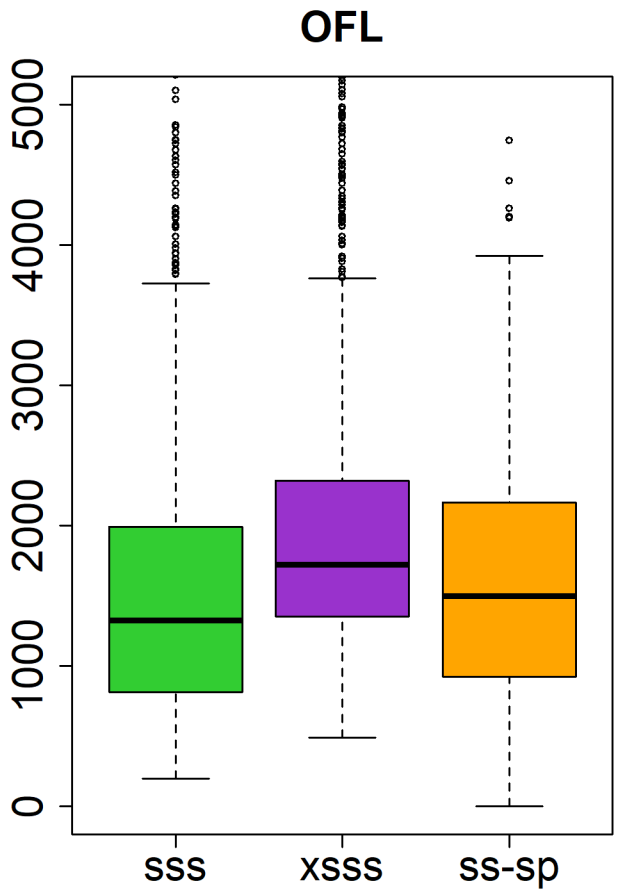




Compare with an ASPM



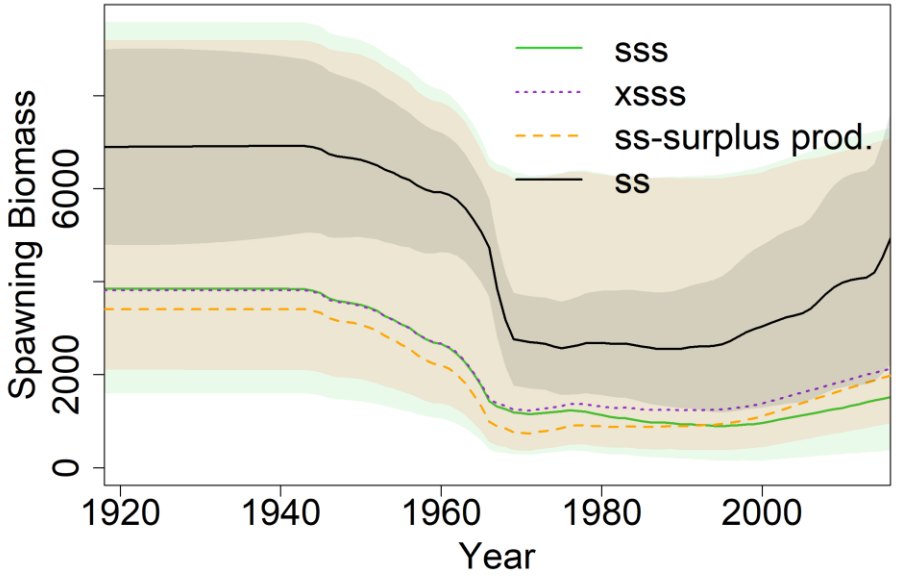


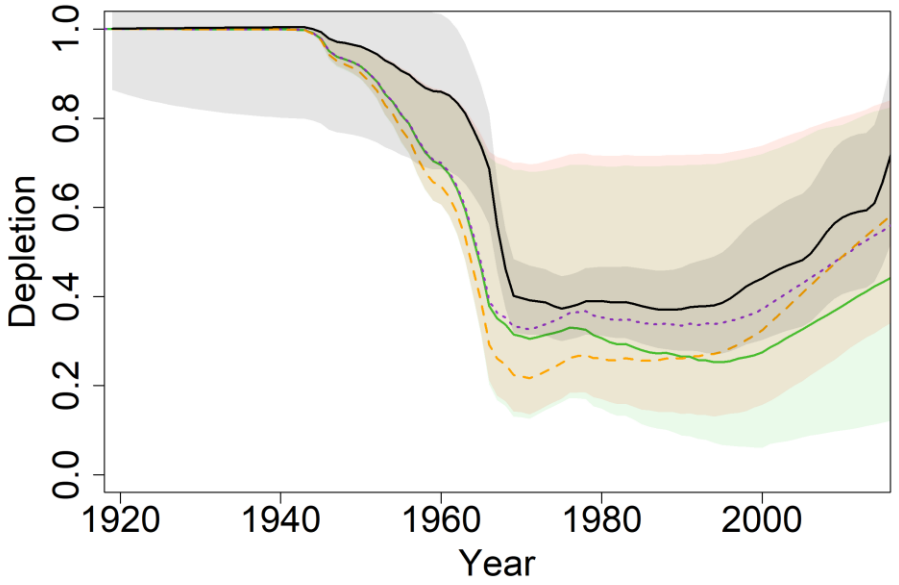


SS ASPM model eliminates the depletion prior, estimates *M*, steepness, lnR_0

Compare across models: data-limited to data-rich

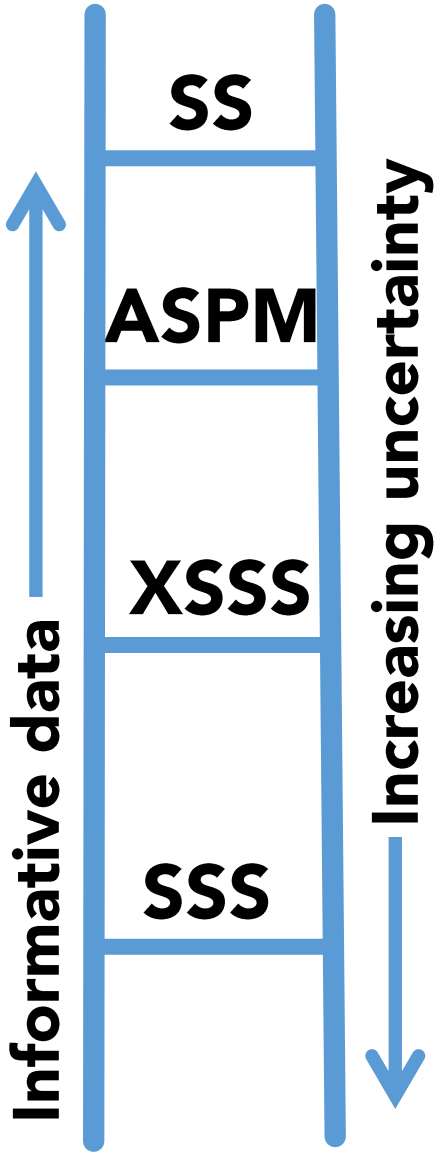
- **Full SS model has a higher spawning biomass**
  - **Log(R0) in the full model informed by recruitment deviations**
  - **Composition data heavily influential in the full model**
- **Relative scale**
  - **The data-limited approaches are in the right ballpark despite the simplifications**

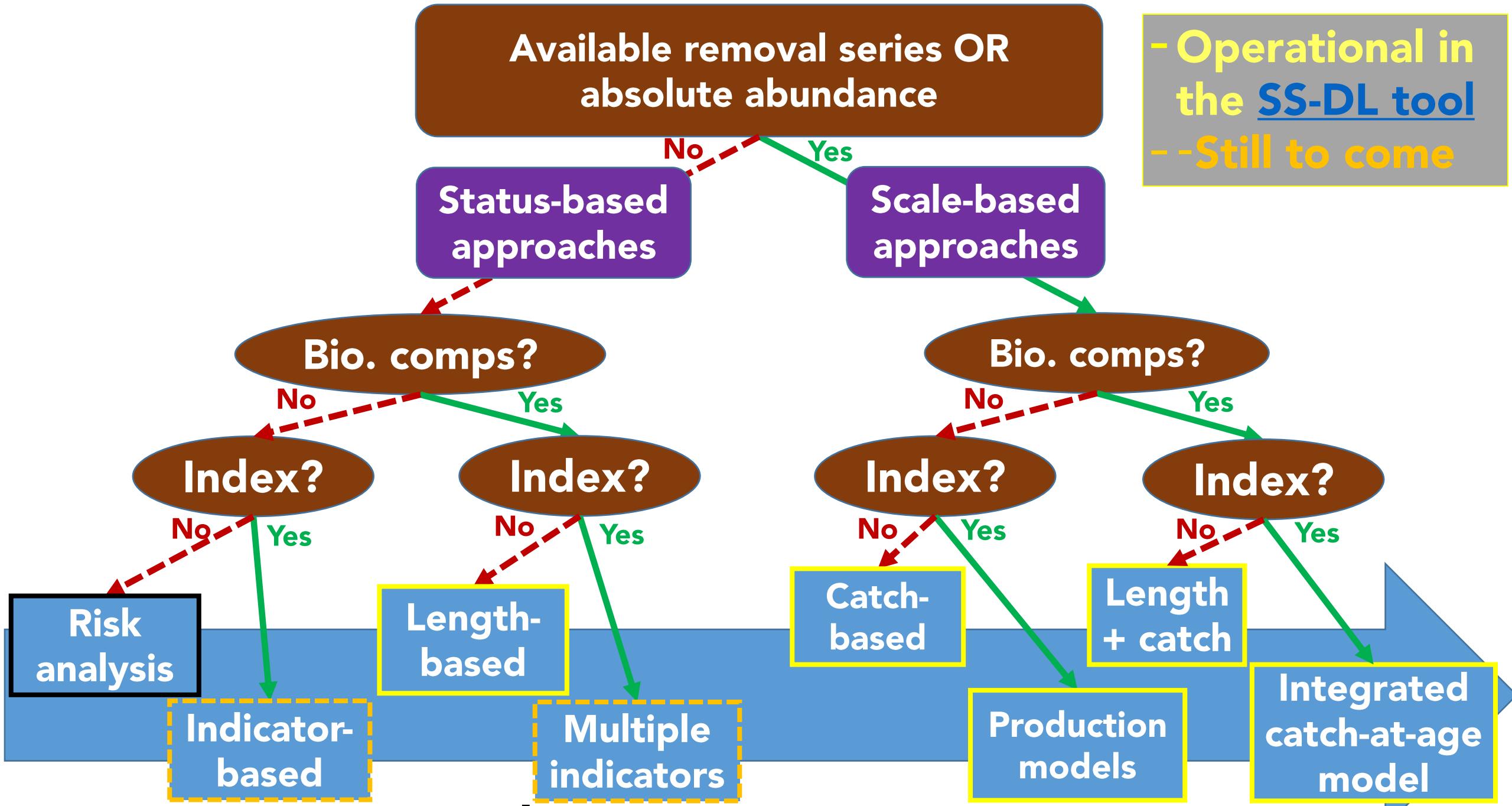




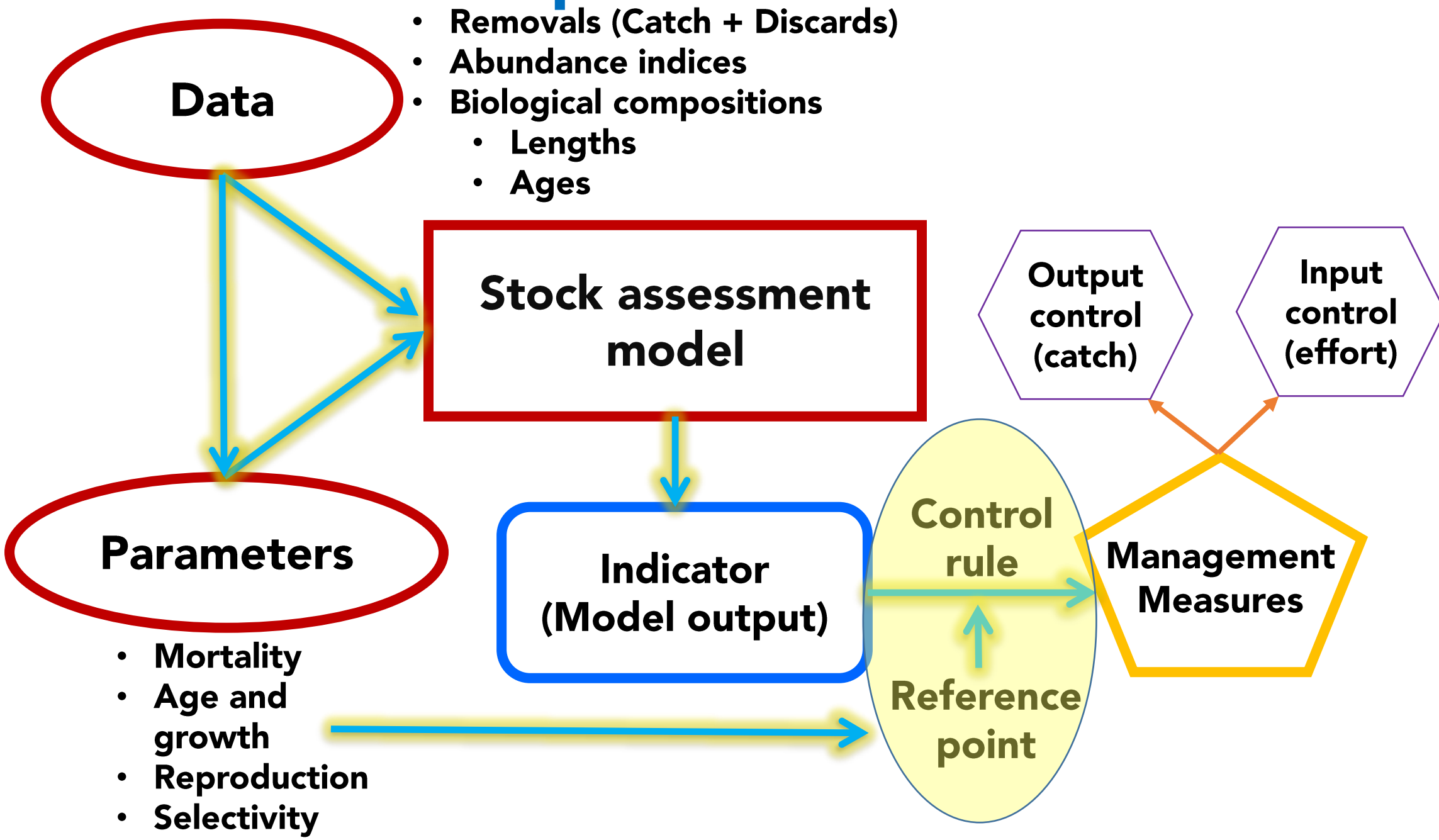
Moving up the assessment "ladder"

- Ability to incorporate new data
- Comparable results
  - Avoids jumping between modelling approaches
- Reduced uncertainty




Available removal series OR absolute abundance
No
Yes
- Operational in the SS-DL tool
- -Still to come
Status-based approaches
Scale-based approaches
Bio. comps?
No
Yes
Bio. comps?
No
Yes
Index?
No
Yes
Index?
No
Yes
Index?
No
Yes
Index?
No
Yes
Risk analysis
Indicator-based
Length-based
Multiple indicators
Catch-based
Production models
Length + catch
Integrated catch-at-age model
Stock assessment continuum

Stock assessment template



Preliminary Anchovy Harvest Strategy

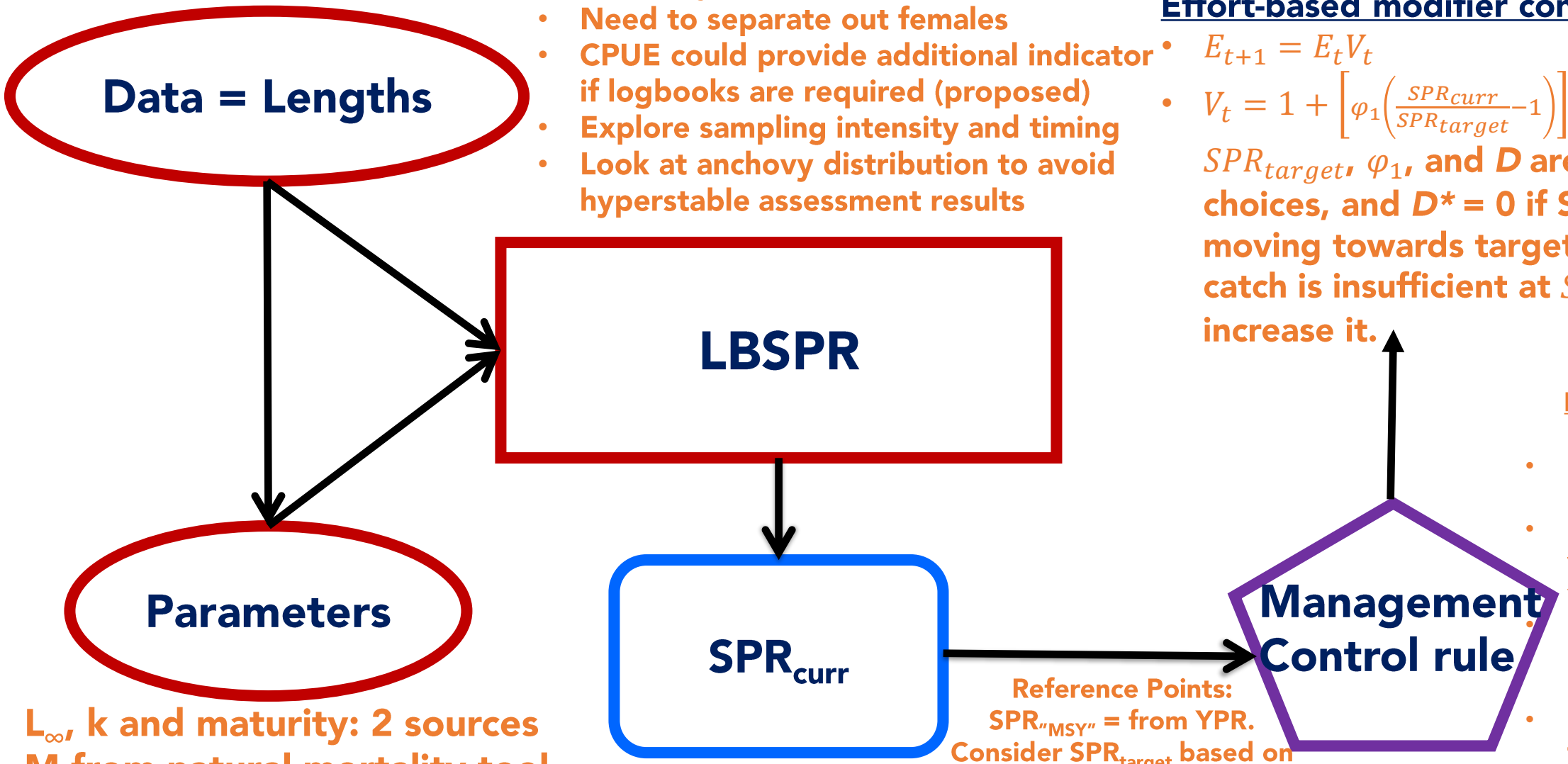
Data improvements

- Currently females + males
- Need to separate out females
- CPUE could provide additional indicator if logbooks are required (proposed)
- Explore sampling intensity and timing
- Look at anchovy distribution to avoid hyperstable assessment results

Effort-based modifier control rule

- $E_{t+1} = E_t V_t$
- $V_t = 1 + \left[\varphi_1\left(\frac{SPR_{curr}}{SPR_{target}} - 1\right)\right][1 + D^*]$

SPR_{target}, φ_1, and ***D*** are all policy choices, and ***D**** = 0 if SPR is moving towards target. If village catch is insufficient at SPR_{target}, increase it.



Management Measures

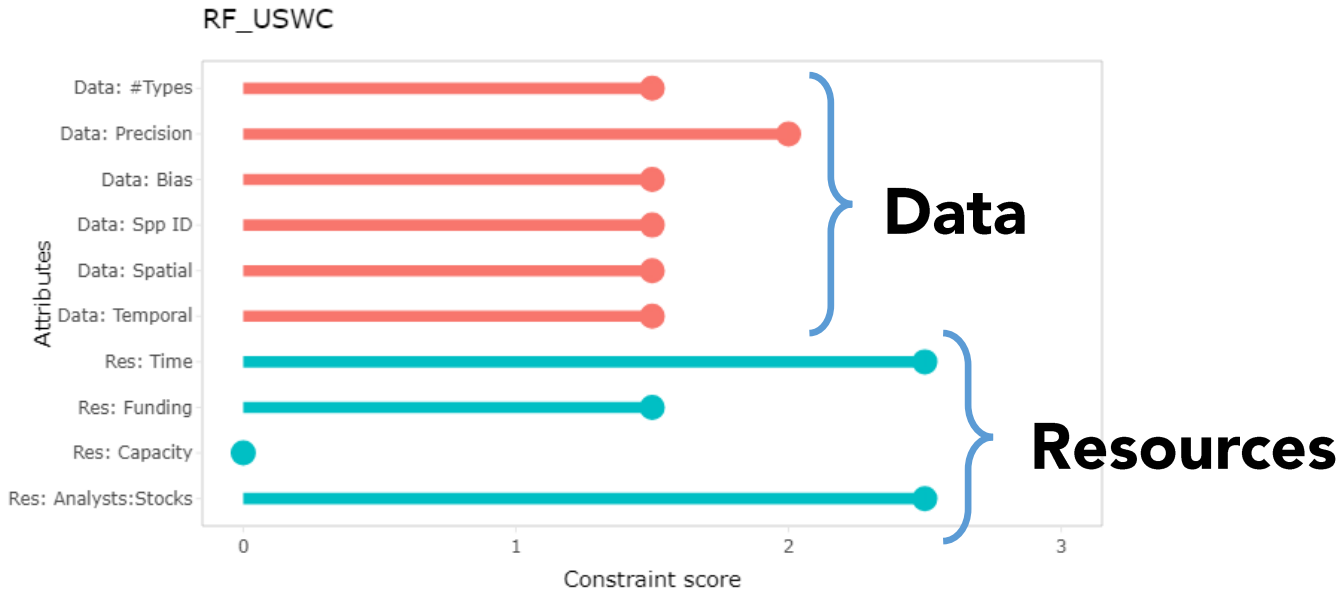
- 5 mm minimum mesh size
- No fishing within 3 km of village
- 1 night closure during black moon
- Enforce no fishing in conservation areas

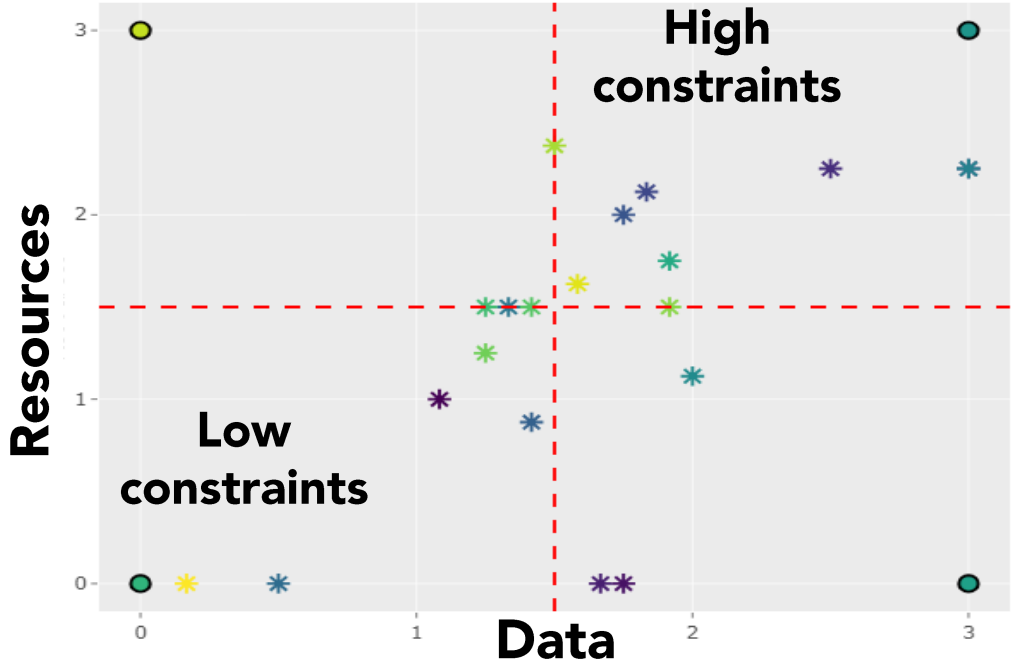
- L_∞, k and maturity: 2 sources
- M from natural mortality tool
- M/k distribution explored

Reference Points: $SPR_{"MSY"}$ = from YPR. Consider SPR_{target} based on other factors (socio-economic, ecological, risk)

What is data-limited? Data-poor? Data-less?

- Limitations = Data and Resource constraints
- A continuum of conditions
- Articulating them specifies condition, identifies ways forward
- Data and resources limited (DRL)





Cope et al. in review

Output from the DLMapper tool:
https://connect.fisheries.noaa.gov/DLMapper/