SPR Proxies

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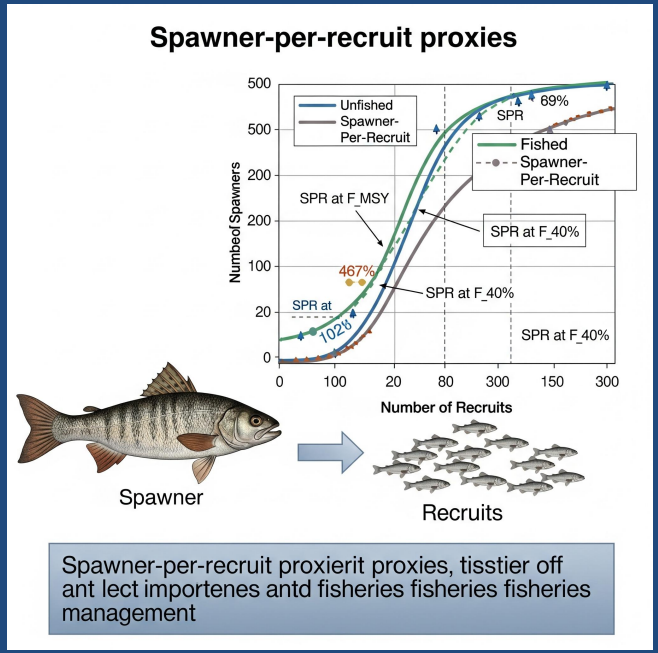
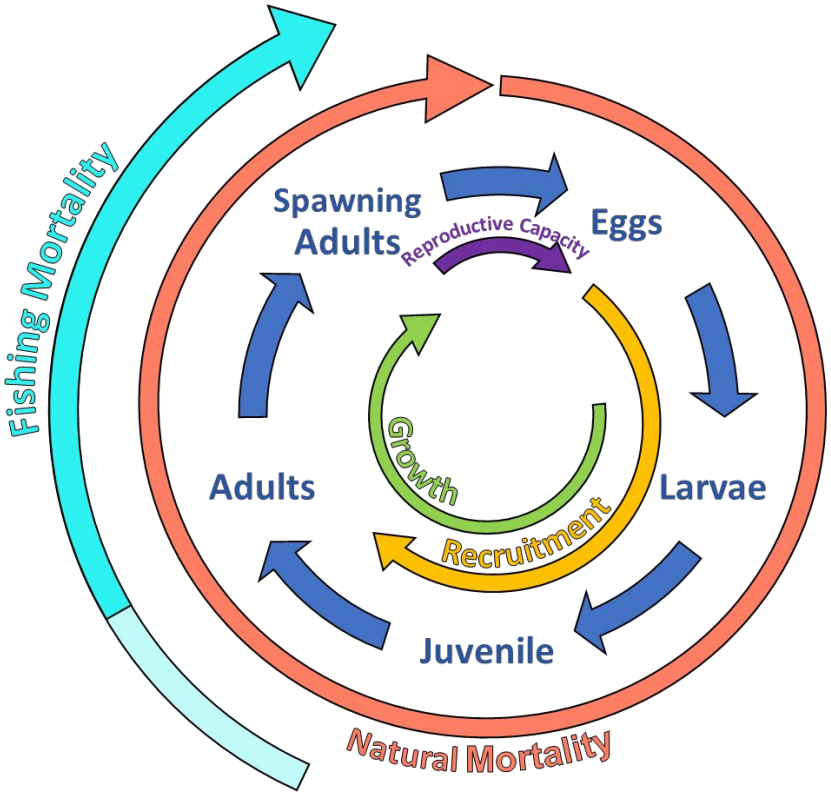


AI generated image of "spawner-per-recruit proxies"

Outline

- Population Dynamics
- Compensation
- Define SPR and relation to MSY
- Factors Affecting SPR
- Literature Review
- NMFS Recommendations

Fish Population Dynamics



External/Ecosystem Factors:

- Immigration/Emigration
- Habitat
- Climate
- Food Web

All of these factors combined determine population size

Surplus Production

- **Density Dependent Compensation**

Surplus Production

- Population grows quicker at sizes below carrying capacity

Density Dependence

- How rates of vital population processes respond to changes in population size

Compensatory Mechanisms

- Specific population processes that respond at lower population sizes and allow for surplus production

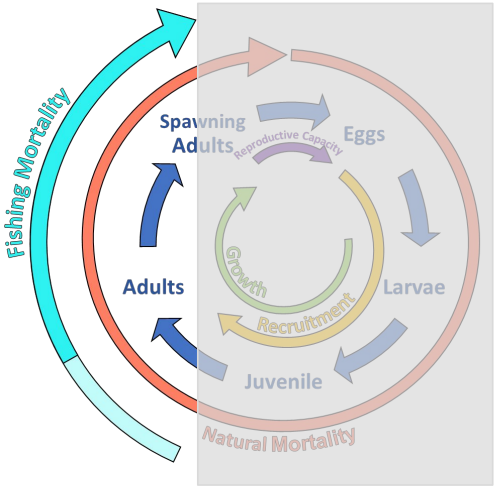
Compensatory Mechanisms

Mechanisms:

- Population Factors
  - Basic population dynamic factors for the stock
- Fishing Factors
  - When, where and how fishing is being prosecuted
- External Factors
  - Physical and biological environmental conditions

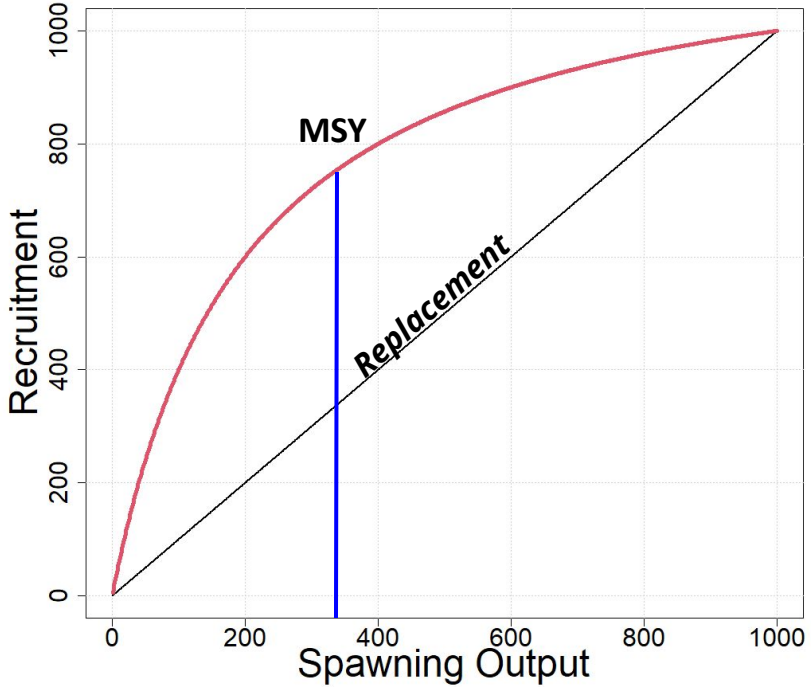
S-R Function

Compensatory Recruitment is the primary density dependent mechanism in our models



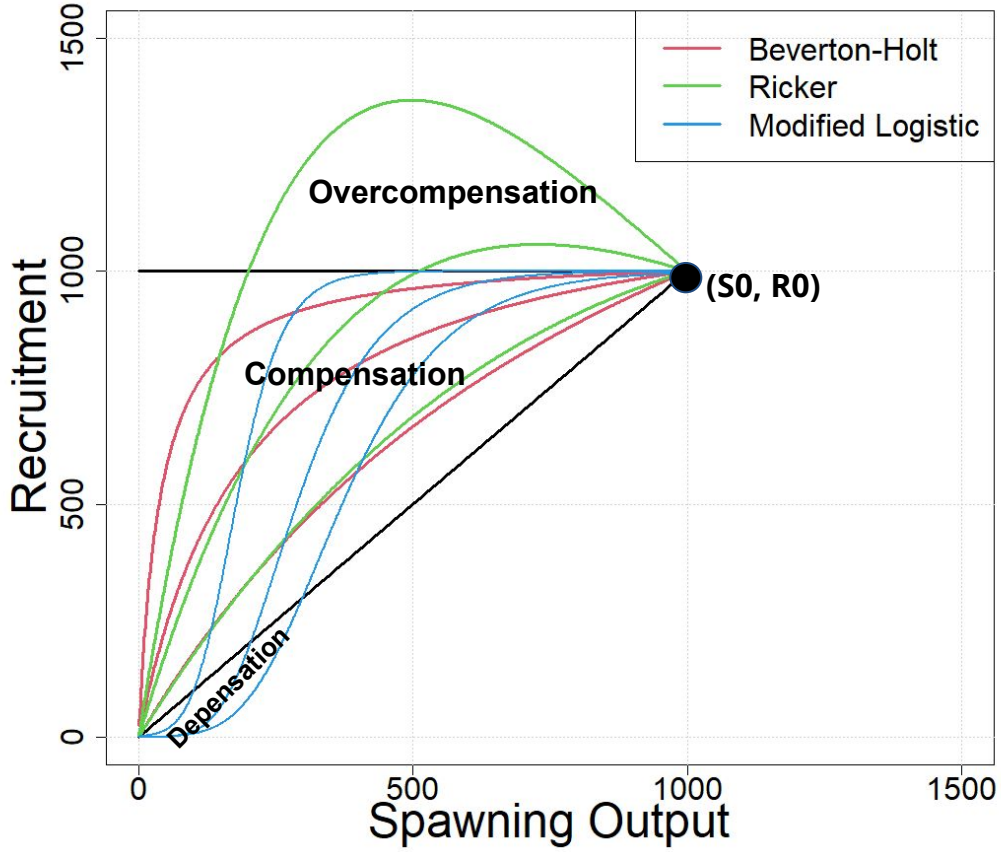
Assessment models go from Spawning Output (S) directly to Recruitment (R)

S → R

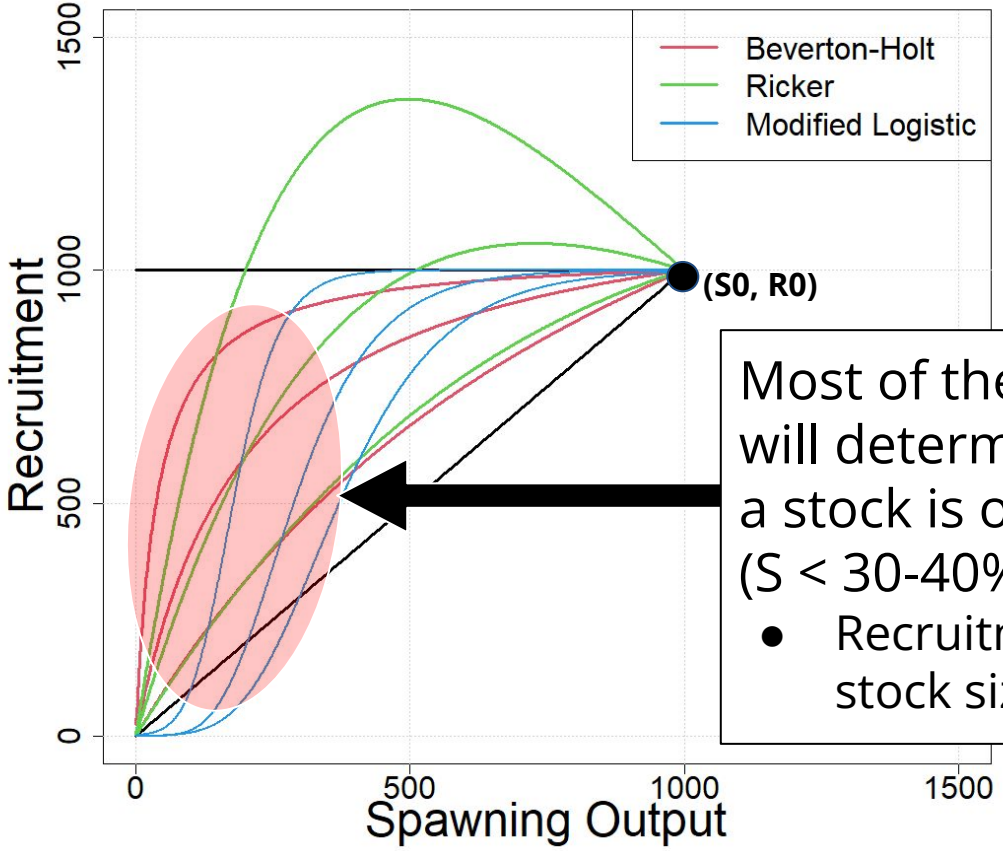


Most of our data comes from fishing and the juvenile-adult life stages. Early life stages remain hidden.

Modeling Compensatory Recruitment



Modeling Compensatory Recruitment



Most of the information that will determine how productive a stock is occurs here (S < 30-40% of S0).

- Recruitment response at low stock sizes

Surplus Production

When we discuss, estimate or apply a model of how a stock achieves Maximum Sustainable Yield (***MSY***) or the stock's productivity, we should be considering the recruitment (***R***) response at low spawning stock sizes (***S***).

Spawners-Per-Recruit (SPR)

$\%SPR = SPR_F / SPR_{F=0}$

- The percent of unfished spawning potential per-recruit
- $F_{X\%}$ is the fishing mortality level that equals %SPR

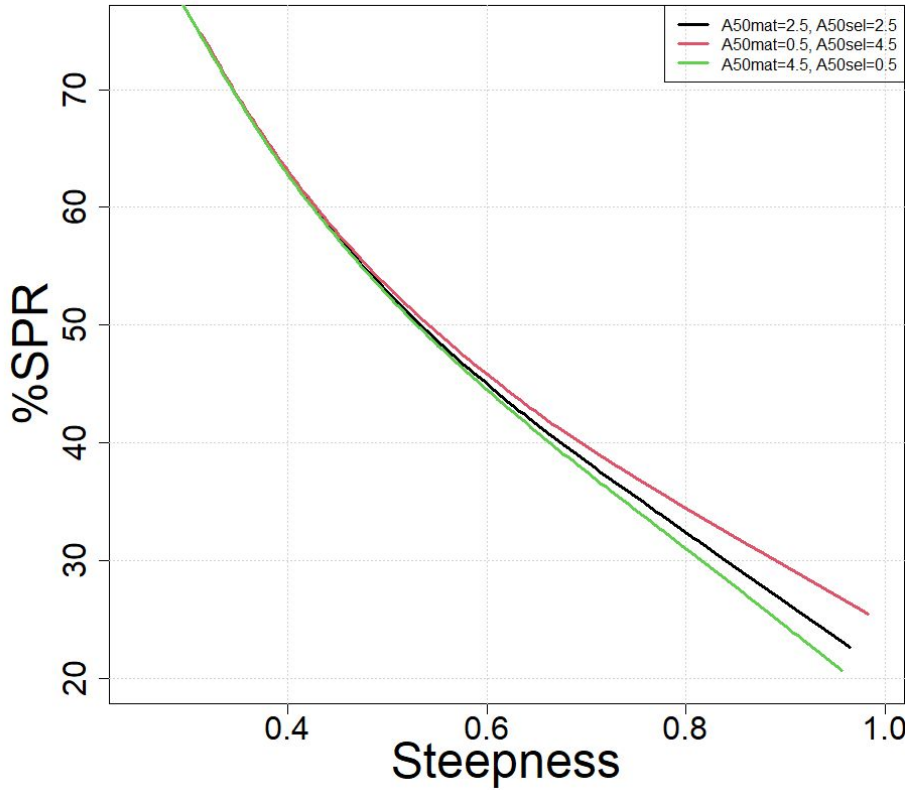
%SPR	$F_{\%SPR} = F_{MSY}$	steepness	MSY	SSB_{MSY}
30%	0.29	0.83	850	230
40%	0.18	0.68	640	290
50%	0.13	0.54	510	370

**Beverton-Holt S-R relationship*

Picking a proxy %SPR value is making an assumption about recruitment compensation and F_{MSY}

%SPR = BH steepness

$F_{SPR} = F_{MSY}$



Brooks et al. (2010) covers the mathematical relationship

Relationship is affected by:

- Fishery Selectivity
- Maturity/Spawning metric
- Natural Mortality
- Growth

Generally does not vary too far from the range shown here

MSY is Our Mandate:

National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) requires preventing overfishing while achieving, on a continuing basis, optimum yield (OY), from managed U.S. fisheries. OY is limited by the biologically feasible maximum sustainable yield (MSY) which in turn serves as the basis for status determination criteria (SDC) by which NOAA determines when a stock is experiencing overfishing or is overfished.

Proxy %SPR = F_{MSY} = MFMT

How Can We Pick A Proxy %SPR For F_{MSY}?

Picking a Proxy %SPR = MSY

1. Simulation studies
2. Estimation models
3. Expert Opinion
4. Cases with F_{MSY} estimates
    i. Predictive Correlation Analysis
    ii. Regional Analysis

Picking a proxy %SPR makes an assumption about recruitment compensation at low stock sizes

Picking a Proxy %SPR = MSY

1. Simulation studies

Clark (1991, 1993): Recommended %SPR = 35-40%

- excluded some SR relationships from consideration on the grounds that they implied either too little or too much density-dependent change in reproductive success, in comparison with the performance of real populations that have been heavily fished or overfished.

Mace (1994): Recommended %SPR= 40%

- used fixed ranges of biological and S-R parameters, focused on avoiding low compensatory S-R curves. .

Clark (2002): Recommended %SPR greater than 40%

- the paramount question in attempting to choose a different target is, as before, what kind of S-R relationships to consider.

Harford et al. (2018): Recommended %SPR (gonochorists) = 40%, %SPR (hermaphrodites) = 50%

- used Snapper-Grouper species for life history data, assumed range of steepness values, focused on achieving MSY under harvest control rule and rebuilding.

Picking a Proxy %SPR = MSY

2. Estimation models

Dorn (2002): Recommended %SPR = 50%

- estimated S-R functions from S-R data in a Bayesian hierarchical framework, focused on West Coast rockfish.

Legault and Brooks (2013): Recommended %SPR = 40%

- used S-R data from groundfish stocks in the NE examining proportion of points above and below replacement.

Picking a Proxy %SPR = MSY

3. Expert opinion

PFMC SSC (2000) - after 12 presentations and deliberations, recommended "risk-neutral" proxies for FMSY

- Sebastes and Sebastolobus = F50%
- Pacific whiting = F40%
- Flatfishes = F40%
- Other groundfish = F45%
- "Remaining Rockfish" = 0.75 M

Methot, Rago, Scott (2009) - Red Snapper recommended %SPR = 40%, but labeled it as conservative

NS1 Technical Guidance (2025) - Recommends default %SPR = 40-45%

Picking a Proxy %SPR = MSY

4. Using F_{MSY} estimates
    i. Predictive Correlation Analysis

Zhou et al. (2020): **Mean %SPR = 47%**

- used RAM legacy database (n=185) of S-R estimates and corresponding %SPR values in a Bayesian model to predict %SPR based on life history parameters only. Ignored maturity and selectivity curves in the analysis. .

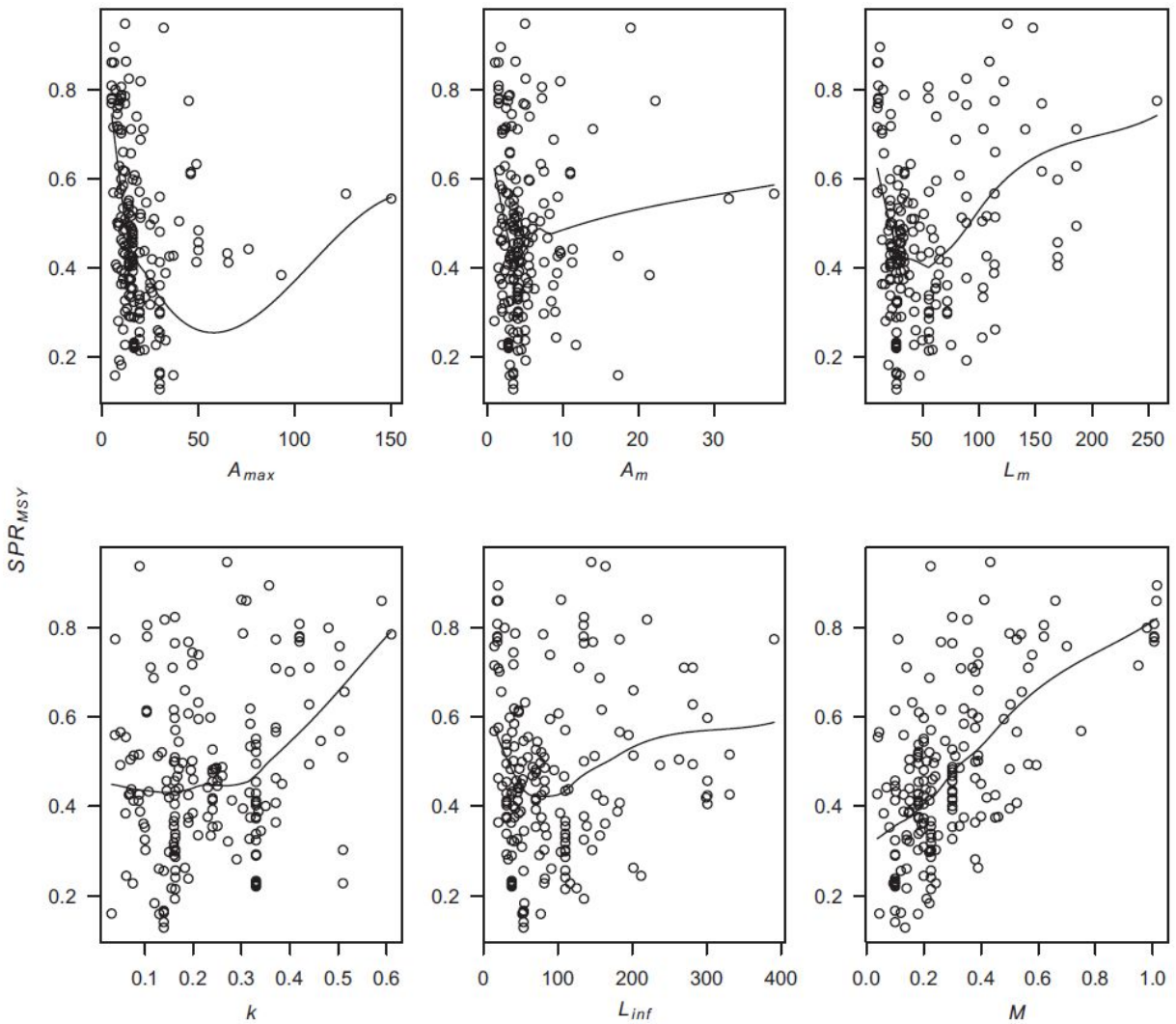
Zhou et al. (2020)

Relationships with %SPR (SPR_{MSY})

<u>Weakest:</u>
Age-at-maturity (A_m)
Asymptotic length (L_{inf})
Growth rate (k)
Length-at-maturity (L_m)

<u>Better:</u>
Natural mortality (M)
Maximum age (A_{max})

Opposite of common perception



Overall Predictive Power??

Picking a Proxy %SPR = MSY

4. Using F_{MSY} estimates
   ii. Regional analysis

South Atlantic - Estimated S-R Curves

	Red Porgy	Gag Grouper	Black Sea Bass	Tilefish
F_{MSY}	0.18	0.37	0.29	0.22
BH Steepness	0.38	0.898	0.39	0.58
%SPR	62%	20%	61%	40%

Average %SPR = 45%

Summary

1. Proxy %SPR choice makes an implicit assumption about compensatory recruitment and F_{MSY}
2. Simplifying compensatory recruitment in one step, S to R, ignores many factors
3. Environmental and ecosystem forces play an important role in compensatory recruitment that is often ignored (or unknown)
4. Fishery characteristics should be an important consideration in selecting an appropriate proxy %SPR
5. Life history characteristics alone seem insufficient to determine %SPR

Summary of Research

1. Simulation studies potentially make too many assumptions about underlying S-R relationships
2. Estimation models are better because they may use actual S-R estimates or S-R data
3. Expert opinion may be useful but may not be “risk-neutral” or could be biased by misperceptions
4. Predictive models seem insufficient by focusing on too few data sources (e.g. exclude fishery or environmental data)
5. Using estimates from other stocks in the region might be useful, but low sample size could be problematic

Summary of Research

Most of the research and empirical data seems to be pointing toward a central tendency of

$$\%SPR = 40\text{-}45\% \sim F_{MSY}$$

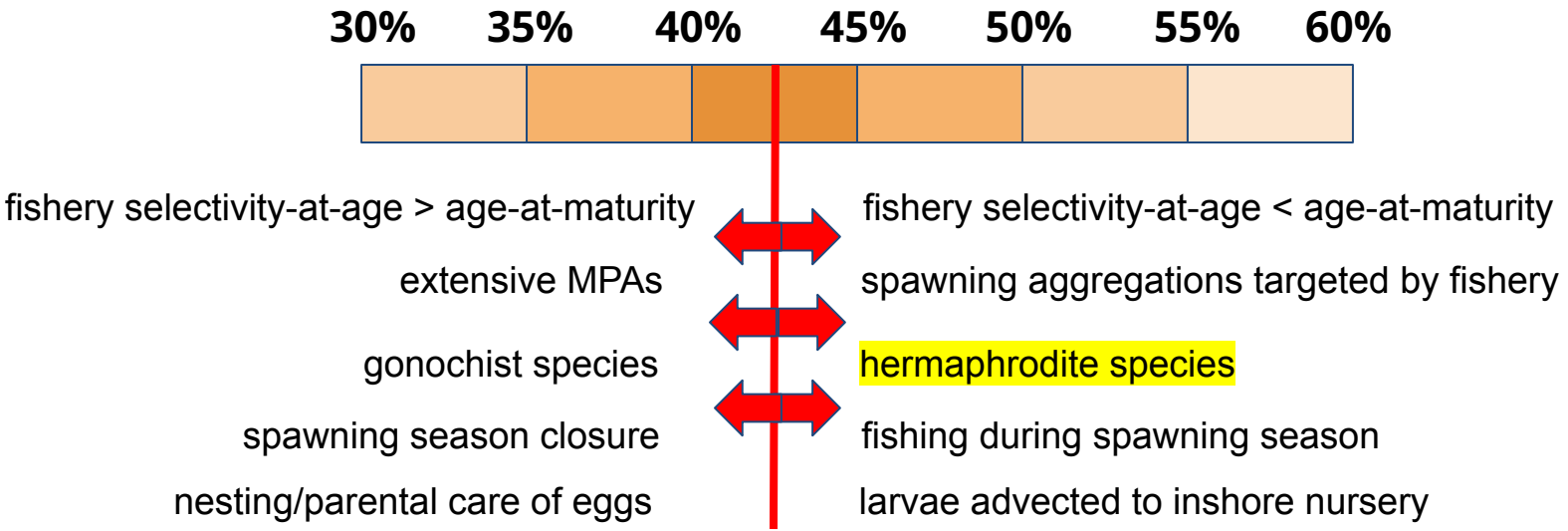
Recommendations

1. Best: direct estimation based on empirical observations (or stock assessment estimated) recruitment at low stock sizes
   a. S-R curves may be “unestimable”, but estimates of recruitment at low stock sizes (S < 30-40%S0) are informative
   b. Update estimation of S-R data and estimation with each new stock assessment

2. Next Best: Use the central tendency of research results and NS1 guidelines to focus on %SPR = 40-45%, with an overall range of 30-60%
   a. Modify this default based on known, correlated population, fishing, and environmental factors

Recommendations

- Start with the NS1 default range, then consider which direction population, fishing, and environmental factors would increase or decrease compensatory recruitment at low stock sizes



Recommendations

- Do not lose sight of what the proxy %SPR represents

$$\textbf{Proxy \%SPR} = F_{MSY} = \textbf{MFMT}$$

- Choice of proxy %SPR must remain risk-neutral

- Recruitment estimates at low stock sizes are the best indicator of potential compensatory recruitment (e.g. S-R function)

Questions?