Advanced Population Modeling : Reference Points

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(Biological) Reference Points (BRP)

- Generically, a metric of stock status from a biological perspective
- Often reflects combination of components of stock dynamics (growth, recruitment, mortality)
- 3 most common models for BRPs:

1. Spawner-Recruit
2. Production models
3. Dynamic Pool (per-recruit)

Gabriel & Mace (1994)

Table 1. Summary of principal models that underlie biological reference points, and associated specification of age-structured and stock-recruitment data.

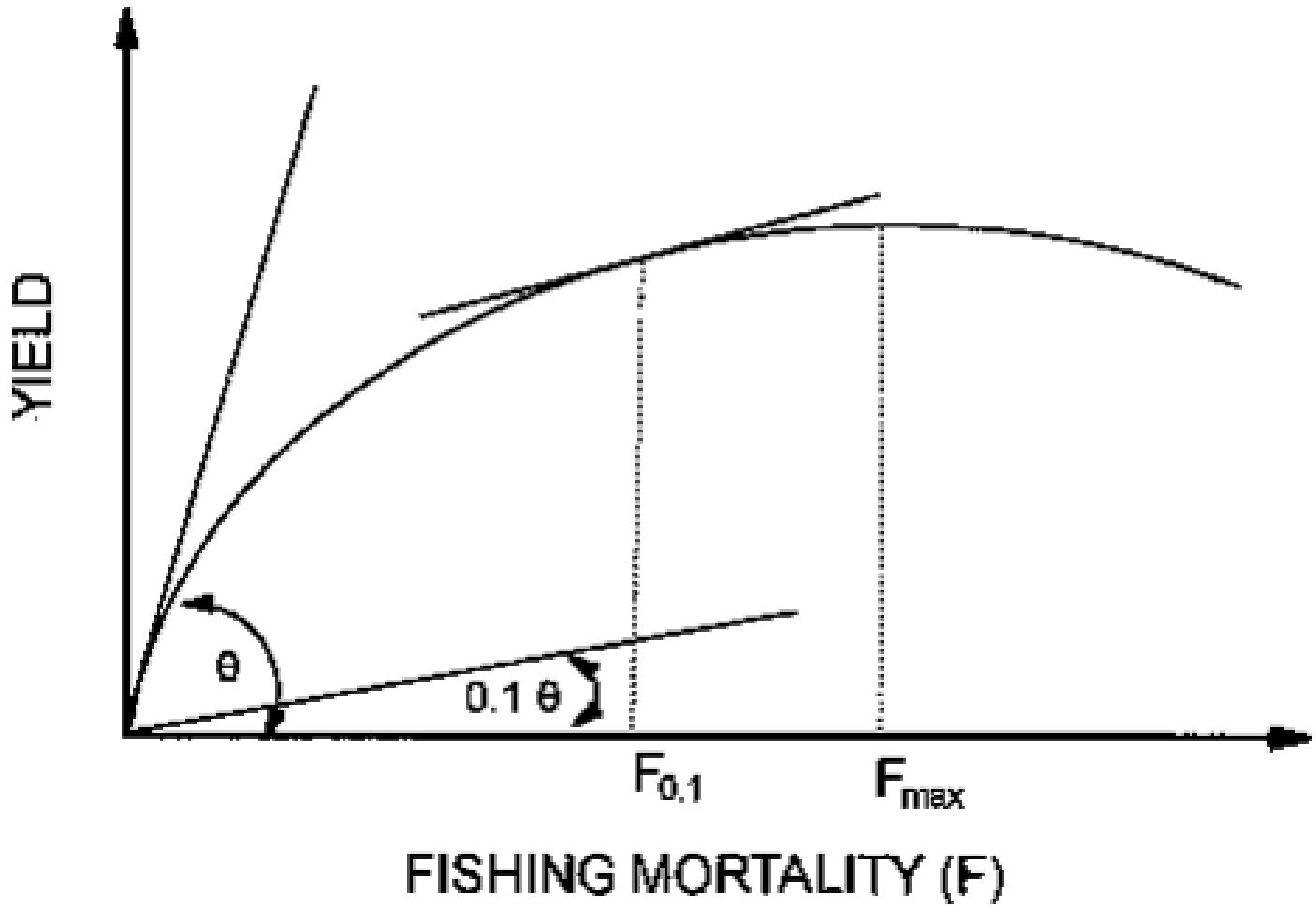
Age structure in population	S-R data required	S-R function required	Model type	Example citation	Reference points	Comments
Unknown	No	No	Surplus production	Schaefer, 1957 Prager, 1993	F_{MSY}, B_{MSY}	Very risk-prone without auxiliary data on recent relative recruitment
No (semelparous)	Yes	Yes	Spawner-recruit	Ricker, 1975	P_s, u_s	
Yes (iteroparous)	No	No	Dynamic pool, Y/R	Thompson and Bell, 1934	F_{max}, $F_{0.1}$	No information about reproductive dynamics
	By analogy	By analogy	Dynamic pool, SSB/R		$F_{20\%SPR}$, $F_{35\%SPR}$	No stock-recruitment relationship, except by analogy
	Yes	No	Dynamic pool, SSB/R	Shepherd, 1982	F_{med}	
	Yes	Yes	Dynamic pool, SSB/R	Mace, 1994	F_{τ}	
	Yes	Yes	Production	Sissenwine and Shepherd, 1987	F_{MSY}, B_{MSY}	

Production models

Reference points from Yield-per-recruit (YPR)

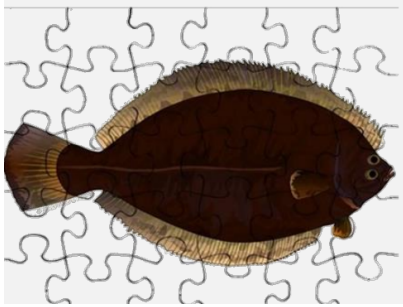
- F_{max}, fully-recruited F that produces maximum YPR.
- $F_{0.1}$, F corresponding to 10% slope of YPR curve at origin.

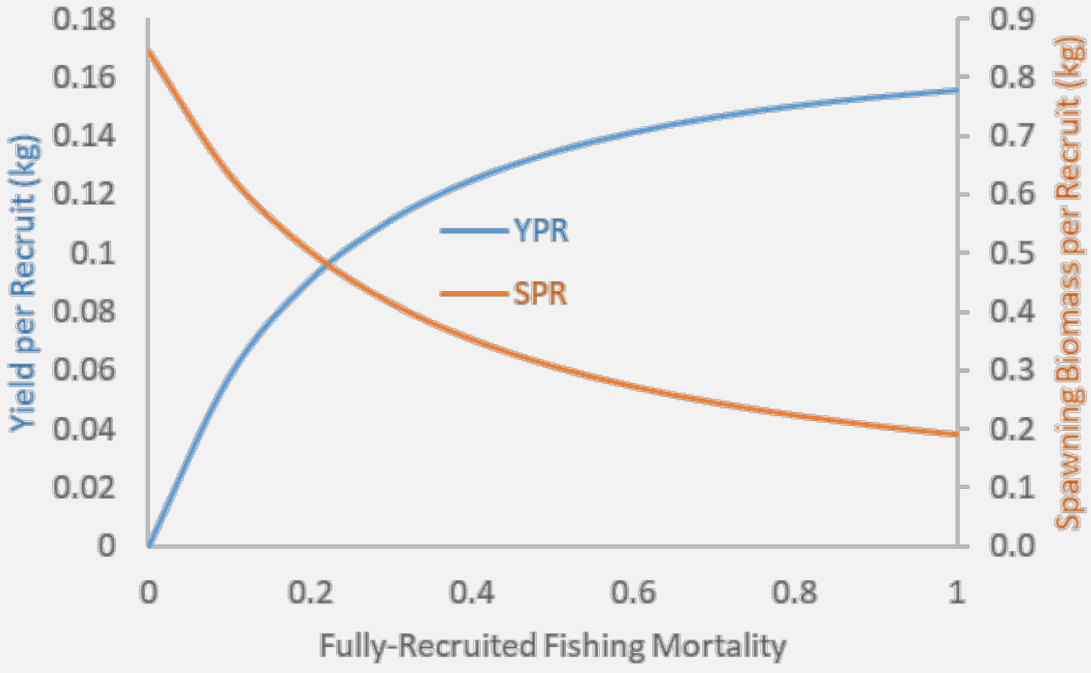
These BRPs are in context of growth overfishing.


YIELD
θ
0.1 θ
$F_{0.1}$
F_{max}
FISHING MORTALITY (F)

Yield and Spawner per Recruit Calculations

- With little selectivity on immature ages, YPR is typically asymptotic, and F_{max} is poorly defined.
- $F_{40\%}$=0.3



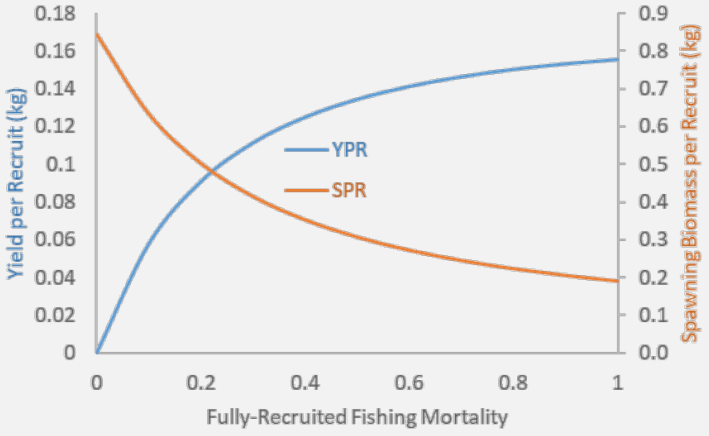


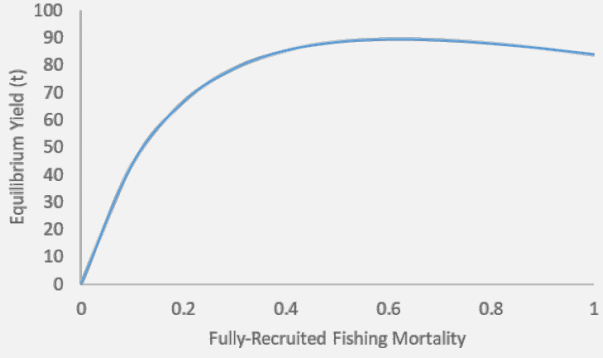
Spawning stock biomass per recruit models

- Spawning potential
- Under no fishing, 100% Spawning potential obtained.
- Quantify spawning stock biomass per recruit relative to unfished (Spawning Potential Ratio)
- e.g. F_{35}, the F that results in a SPR of 35% the unfished level.

Management Reference Points

- Reference points are based on long-term expectations (usually at equilibrium)
  - Yield-per-recruit (F_{max}, $F_{0.1}$) – expected yield from an arbitrary number of recruits, fished at a constant F and selectivity pattern over its lifetime.
  - Spawner-per-recruit ($F_{\%MSP}$) – expected spawning potential (mature biomass, egg production, …) from an arbitrary number of recruits, fished at a constant F and selectivity pattern over its lifetime.
  - Maximum Sustainable Yield (F_{MSY}, SSB_{MSY}) – expected yield (and stock) from fishing at a constant F (and selectivity) over generations



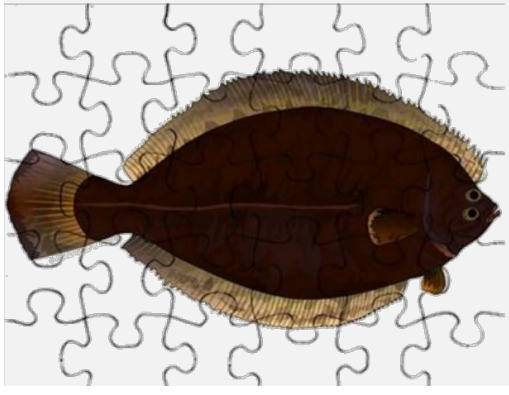


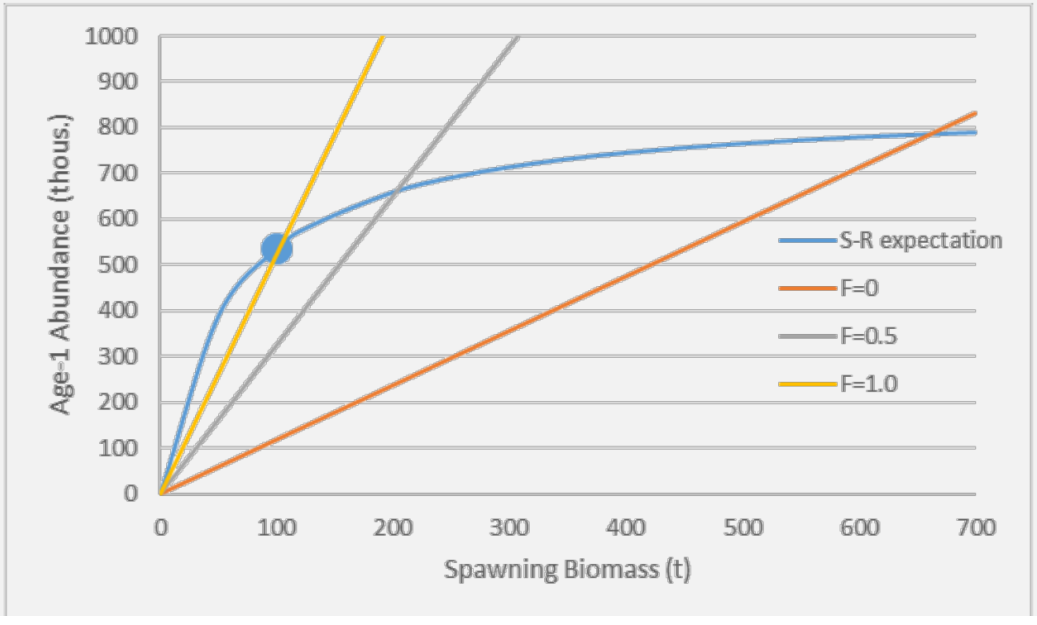
Age-structured FMSY

- Combine SPR with YPR
- Expected number of recruits from $SBPR(F)$ & knowledge of R/SSB
- Multiply by YPR(F) to get the yield
- Growth and recruitment overfishing

‘Self-Regenerating Model’

- Equilibrium expectations (e.g., S_0=662 t) can be derived graphically, by plotting stock-recruit expectations with SPR expectations, R=S/(1/SPR_F).
- Note that assuming h=0.75 (132 k recruits at 588 t SSB) largely determines equilibrium expectations.



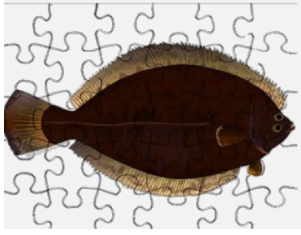


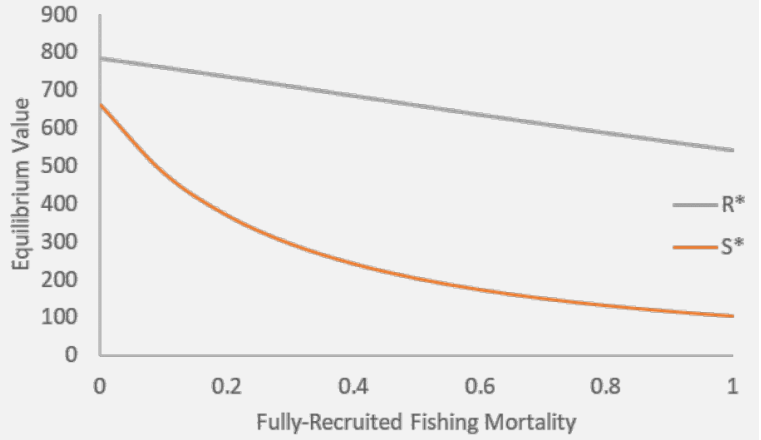
‘Self-Regenerating Model’

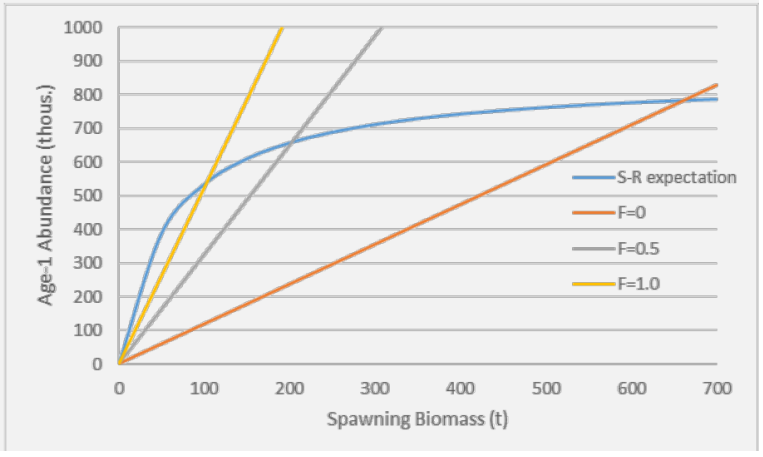
- The same equilibrium expectations can be derived analytically by replacing S_t with R^*SPR_F.

$$R_t = \frac{4hR_0S_t}{S_0(1-h)+S_t(5h-1)}e^{\varepsilon_t}$$

$$R^* = \frac{4hR_0SPR_F - S_0(1-h)}{SPR_F(5h-1)}e^{\varepsilon_t}$$







In practice FMSY is hard to estimate

- principally rely on knowing say h
- More often use proxies for FMSY (e.g. F_{40})

Non-equilibrium

- These approaches are all equilibrium approaches
- Can be analytical, numerical, or projection-based
- Do not reflect process error variance
- Stochastic estimators for FMSY etc. also common
- Rely on projections, given assumptions about future dynamics
- e.g. Future recruitment, weight at age, etc.
- Take some quantile of the distribution over some time-frame