DLM Methods:
The DLM toolbox

Data-Limited Methods Toolkit (DLMTool)

- R library designed for testing, comparing, & applying data-limited approaches
- Developed by Dr. Tom Carruthers (UBC), in collaboration with Natural Resources Defense Council (NRDC)

Features

- 65+ existing methods: Output & input controls
- Extensible: Users can add own methods
- Flexible MSE Model
- Built-In operating model examples
- Open access and free
- New user interface!

Data-Limited Methods Toolkit (DLMTool)

Single framework for:

1. Applying Data-Limited Methods to Fishery Data
    - Load all data into single table format
    - Toolkit determines which methods can be used
    - Simple application of method and output of management recommendation

2. Conducting Management Strategy Evaluation (MSE)
    - Evaluate relative performance of different management strategies
    - Examine sensitivities of methods
    - Investigate value of information for improving data sources

DLM Methods:
Life history approaches

Interpreting yield-per-recruit (YPR)

One recruit
(one individual)

Vulnerability

Exploitation rate (Fmax)

$$N_1 = 1$$

Natural survival rate

$$N_{a+1} = (1 - v_a u) s_a N_a \quad \text{for } 1 < a < n$$

$$N_n = \frac{(1 - v_n u) s_n}{\left[1 - (1 - v_n u) s_n\right]} N_{n-1} \quad \text{for } a = n$$

Plus group age

Fecundity

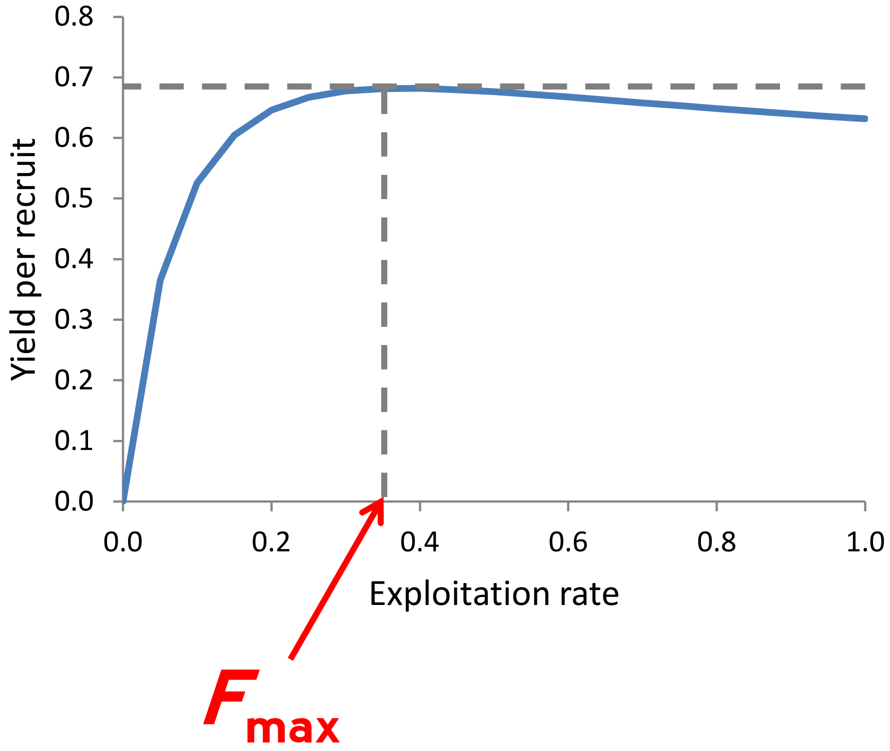
$$E = \sum_{a=1}^{n} f_a N_a \quad \text{spawning-biomass-per-recruit (SBPR)}$$

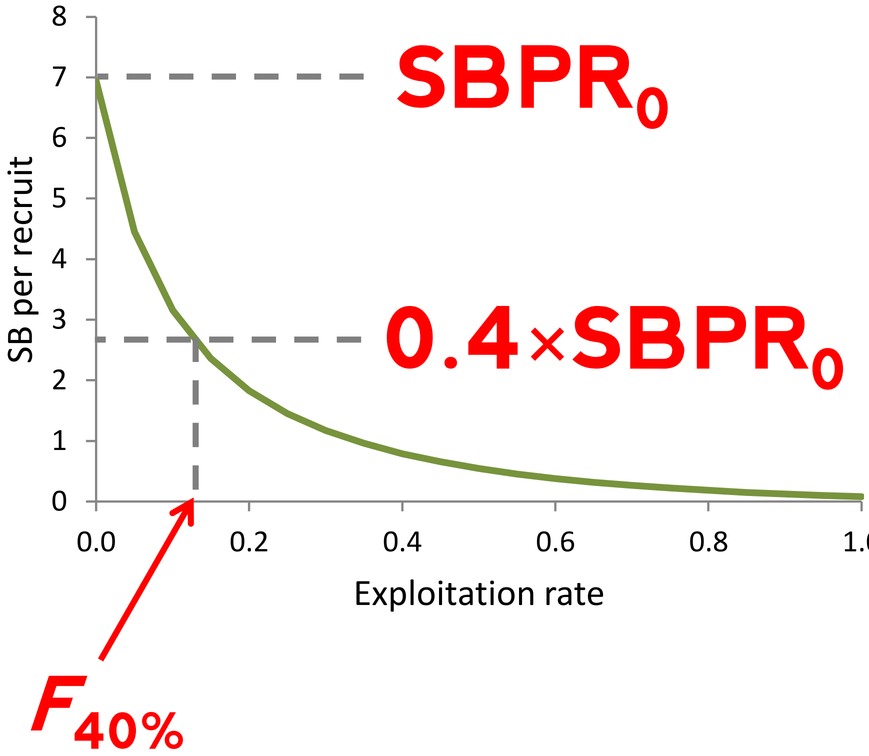
$$C = \sum_{a=1}^{n} v_a u N_a w_a \quad \text{yield-per-recruit (YPR)}$$

Weight-at-age

Source: T. Branch, UW FISH 428 lecture

Interpreting yield-per-recruit

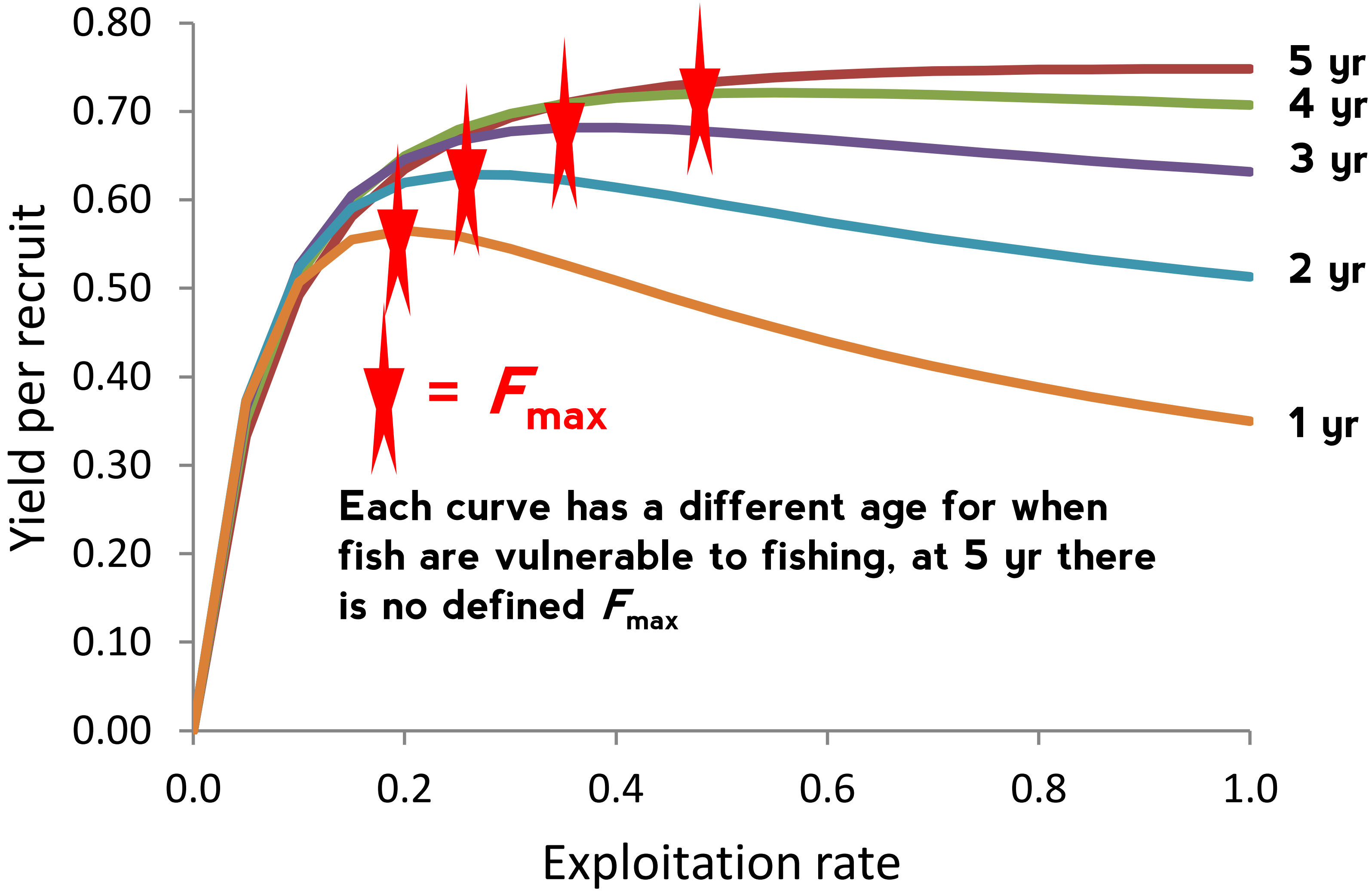




Source: T. Branch, UW FISH 428 lecture

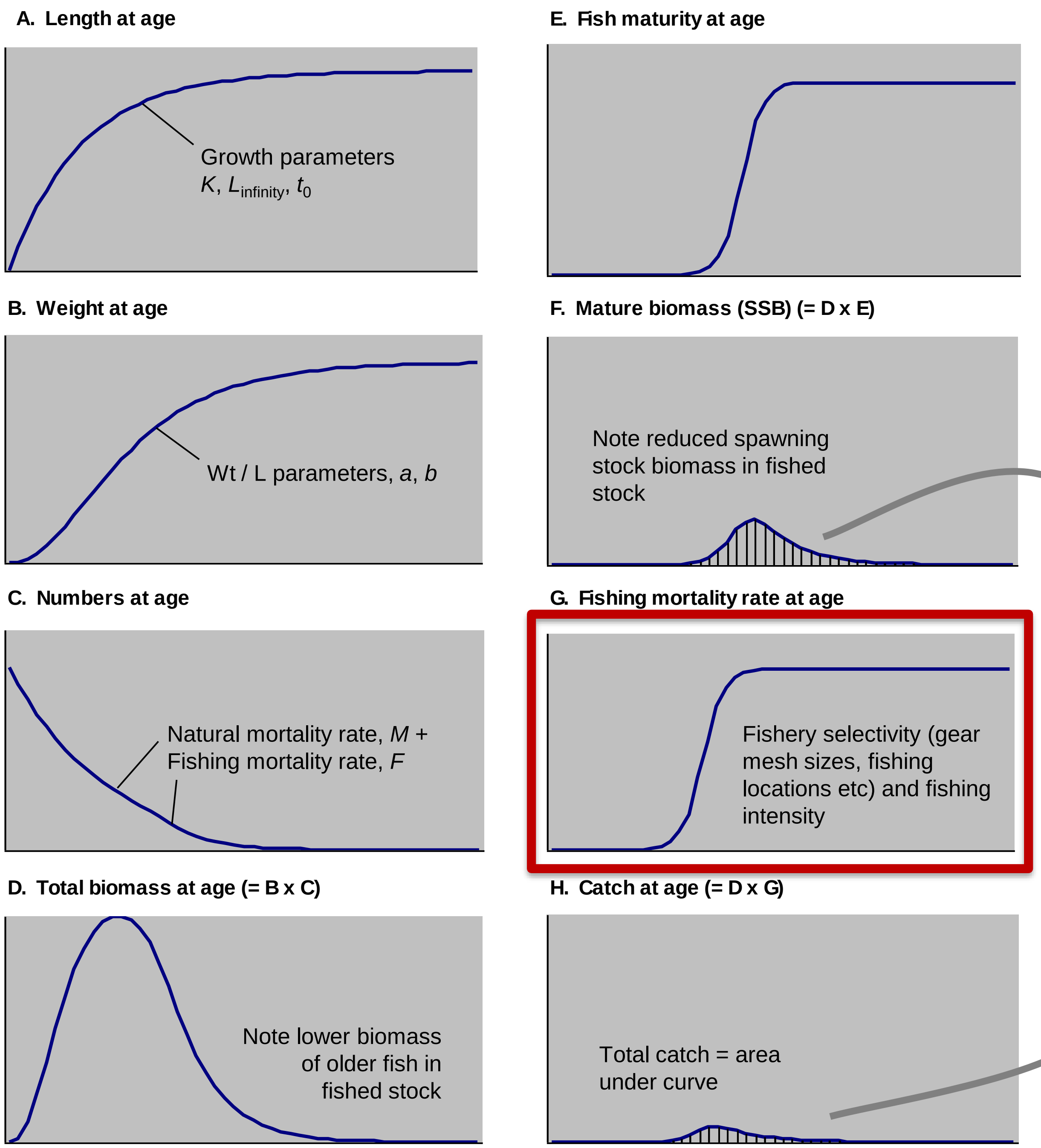
Interpreting yield-per-recruit

F_{max} can be undefined

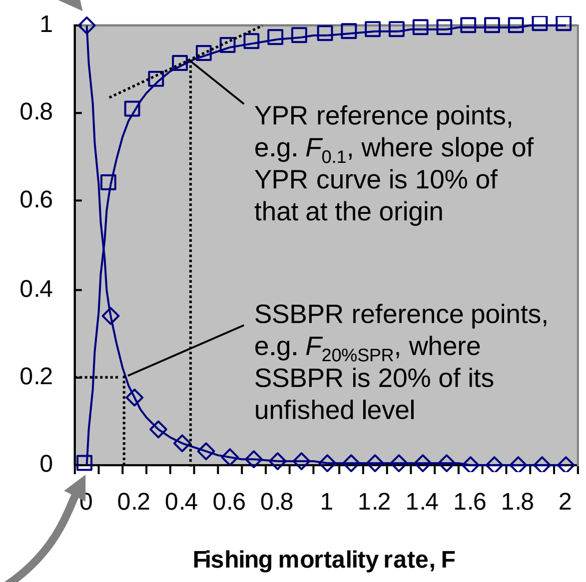


Source: T. Branch, UW FISH 428 lecture

Steps in estimating reference points for an exploited fish stock



'Yield' estimates relative indicators - spawning stock biomass (area under line in graph F) and catch (area under line in graph H) - at different levels of the fishing mortality rate, F, and thereby finds the values of different F-based reference points, e.g. $F_{0.1}$, $F_{\%SPR}$



Interpreting yield-per-recruit

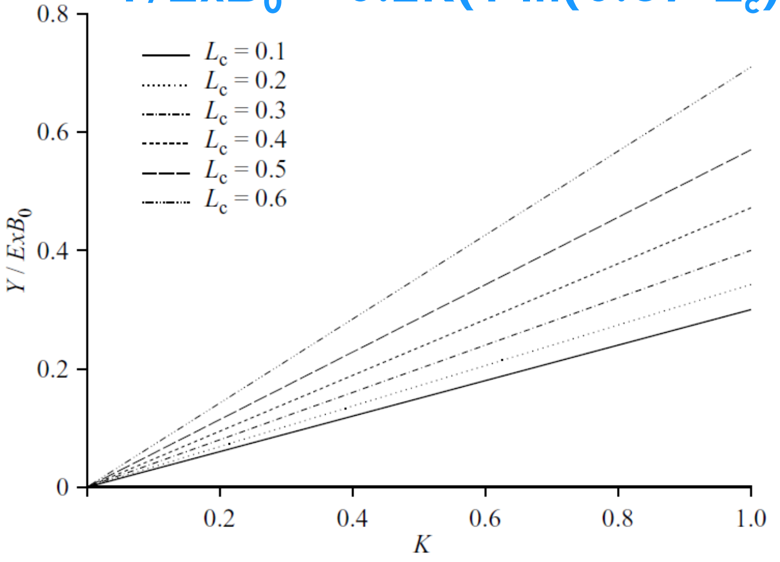
Issues to confront with YPR

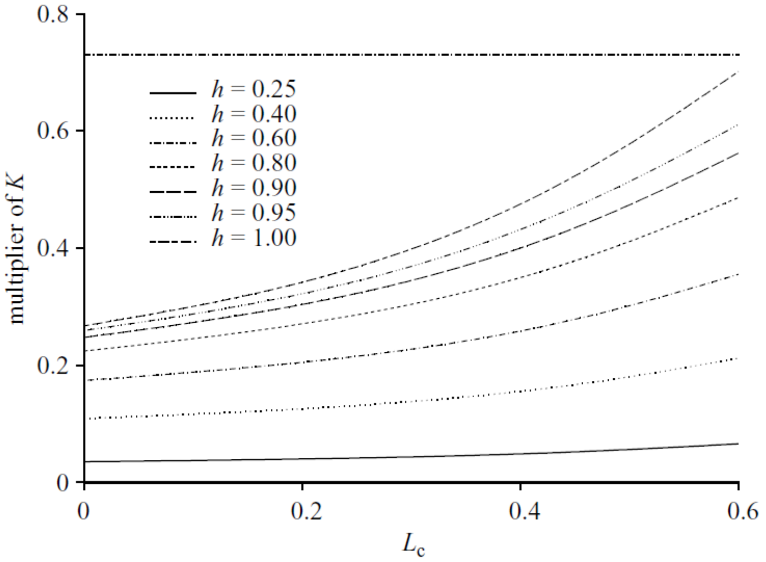
- Interpreting the correct “F” as a reference point
- Defining the correct selectivity for the analysis

YPR demo

Life history methods: Beddington & Kirkwood (2005)

$Y/ExB_0 = 0.2K(1-\ln(0.67-L_c))$





<u>Premise: Can estimate TAC with growth and abundance estimates</u>

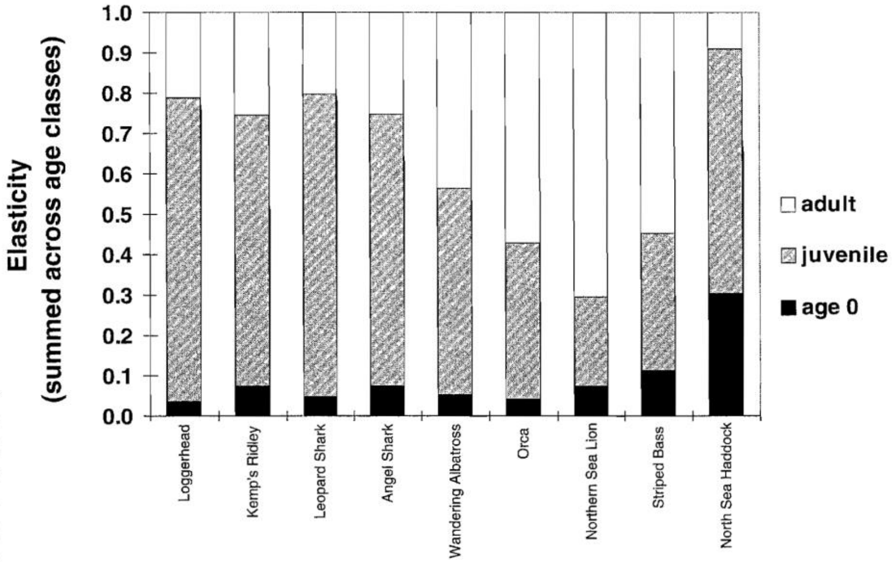
- Needed inputs: M, VB K and Linf, & selectivity relate to exploitation rate ∴
- Life history invariants can be used to estimate exploitation rate
- An estimate of ExB_0 will then give TAC
- Can also incorporate S-R relationship

<u>Caveats:</u>

- Asymptotic selectivity
- Deterministic
- Life history invariants are true
- Ignores density dependence outside of S-R

Life history methods: Matrix models

$$A = \begin{bmatrix} 0 & 0 & 0.08 & 0.36 & 0.96 & 3.2 \\ 0.6 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.7 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.8 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.8 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.9 & 0.9 \end{bmatrix}$$



Premise: Estimate population growth rate (*r*) at different F values

- Needed inputs: Mortality, maturity, fecundity
- Estimates population growth rate (*r*)
- Compare proportional effects of inputs on *r* (elasticity analysis)

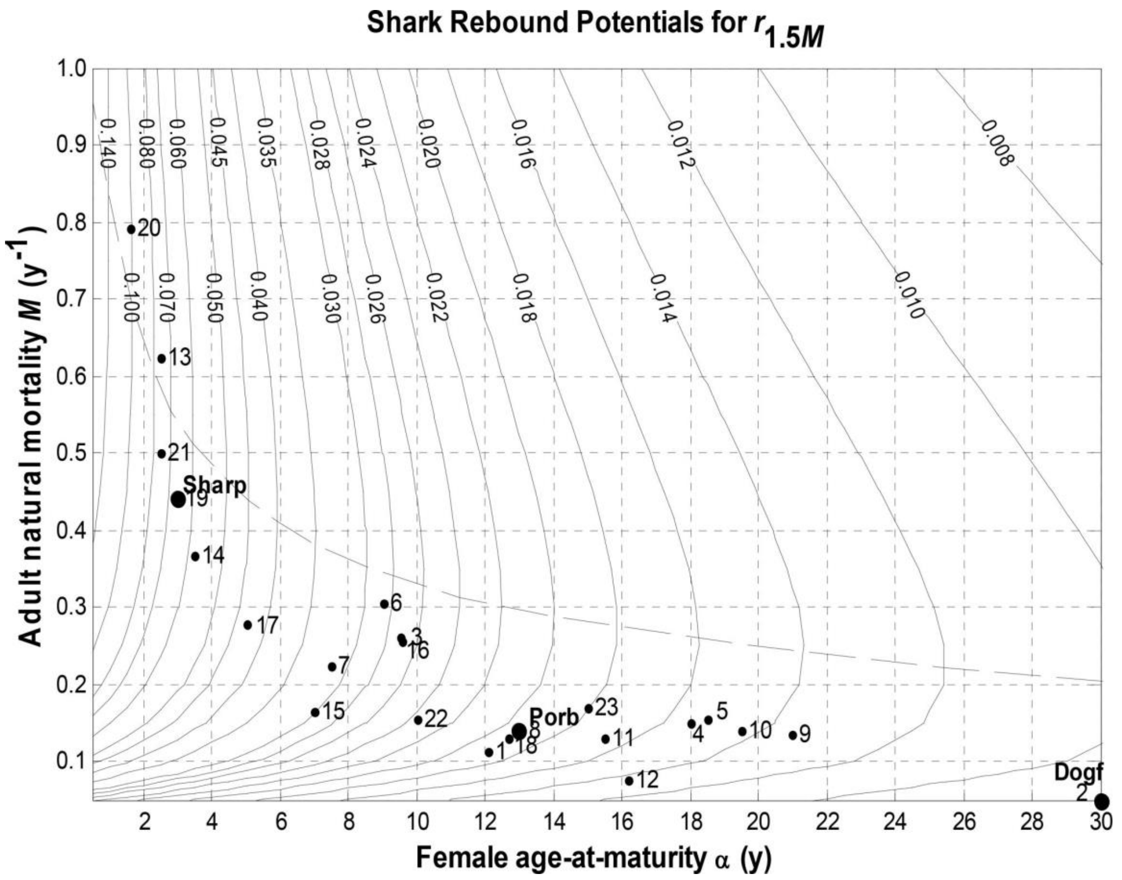
Caveats:

- Equilibrium assumptions diff. than short-term effects.
- Parameter sensitivity
- Time-invariance
- Density independence
- Need scale estimate (e.g., biomass) to get TAC
- Limit recommendations to qualitative (*Cortés 2007*)

Sources: Heppell et al. 1999

Other sources: Caswell 2001; Cortés 1998; Cortés 2007

Life history methods: Intrinsic rebound potential (r_{xM})



$$e^{-(M+r)} + l_\alpha b e^{-r\alpha} = 1$$

$$e^{-Z} + l_\alpha b = 1$$

$$l_\alpha = (1 - e^{-Z})/b$$

Source: Au et al. 2015

Premise: Can calculate *r* with compensation for a given F (*xM*); measures resilience

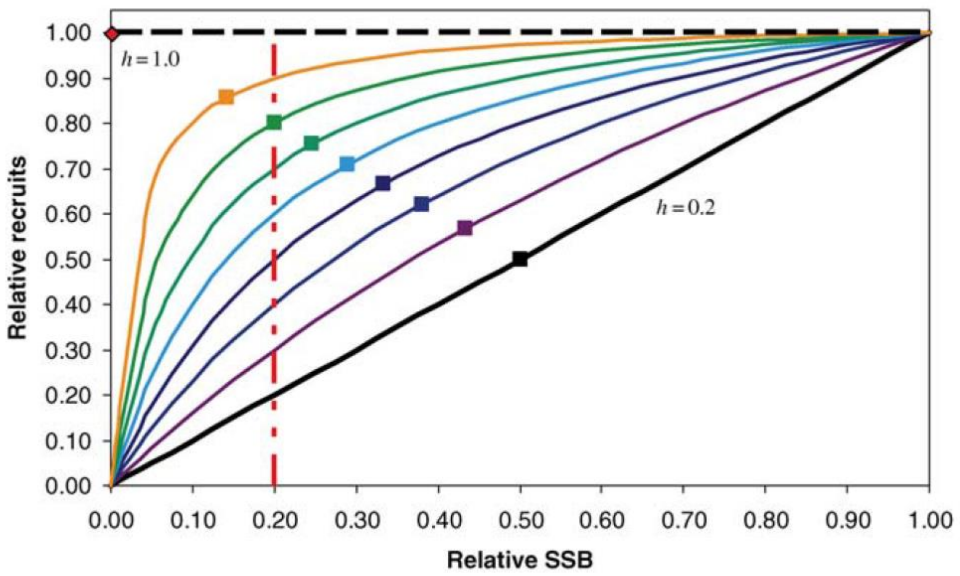
- **Needed inputs: *M*, age at maturity, & fecundity**
- **Need to specify sustainable F (suggested in 1.5*M*)**
- **Solve for *r* using recruitment compensation under sustainable F (i.e., Goodyear's CR).**

Caveats:

- **Many simplifying assumptions, including equilibrium behavior**
- **Parameter sensitivity**
- **Time-invariance**
- **Only provides measure of resilience; HCR?**

Other sources: Au and Smith 1997; Smith et al. 1998

Life history methods: SPR_{MER} (Brooks et al. 2009)



Scientific name	Overfished? (assessment results)	SPR_{MER}	S_{MER}/S_0	D_t	Ratio	Overfished? (analytical prediction)	Reference
Carcharhinus obscurus	Yes	0.86	0.46	0.09	0.19	Yes	Cortés *et al.* (2006)
Carcharhinus plumbeus	Yes	0.64	0.39	0.22	0.56	Yes	NMFS (2006)
Carcharhinus limbatus	No	0.61	0.38	1.55	4.12	No	NMFS (2006)
Carcharhinus limbatus	NC	0.57	0.36	4.93	13.56	No	NMFS (2006)
Prionace glauca	No	0.26	0.21	0.80	3.86	No	ICCAT (2008)
Isurus oxyrinchus	NC	0.89	0.47	0.67	1.43	No	ICCAT (2008)
Sphyrna tiburo	No	0.59	0.37	2.24	6.06	No	NMFS (2007)
Rhizoprionodon terraenovae	No[b]	0.71	0.42	0.72	1.72	No	NMFS (2007)
Rhizoprionodon terraenovae	No	0.73	0.42	8.29	19.63	No	NMFS (2007)
Carcharhinus acronotus	Yes	0.54	0.35	0.08	0.23	Yes	NMFS (2007)
Carcharhinus isodon	No	0.78	0.44	0.42	0.96	No	NMFS (2007)

Premise:

- Needed inputs: *M*, maturity, fecundity & selectivity
- Overfishing: Using S-R relationship, solve for SPR_{MER} (maximum excess recruitment): $$\mathrm{SPR_{MER}} = \frac{\sqrt{1-h}}{2\sqrt{h}}$$
- Overfished: Using current index, compare to relative SPR_{MER} :

$$\frac{D(t=\text{current})}{S_{\text{MER}}/S_0} = \frac{I(t=\text{current})/I(\text{unfished})}{S_{\text{MER}}/S_0} < p$$

Caveats:

- MER is #s, not biomass
- Input sensitivity (e.g., selectivity)
- S-R treated as known
- Need index of abundance
- MER biased low compared to SPR

Demo DLM tool:
life history methods

Summary: Life history methods

- Uses basic life history information or relationships
- Often very simple with large assumptions
  - Fishery selectivity (beware interpretation of F)
  - Large parameter sensitivities
  - Equilibrium assumptions
- Typically provides reference points (status indicators)
- Can be modified to produce output control and have control rules