Spawning per recruit

(Spawning stock biomass per recruit)

Reading:

See Jennings et al. 2001, section 7.7

Haddon et al. 2011, section 2.8

Acknowledgement: M. Wilberg

Announcements

- Still grading take home exams
- Grad students, please review the requirements for your project (see canvas) → will discuss later this week
  - Synopsis Due: March 18

Spawning per recruit

- Developed to address YPR limitations of not accounting for maturation and recruitment
- Goal is to determine the lifetime spawning potential of a recruit and how much it is reduced by fishing
- Spawning: typically SSB or eggs
- Used to calculate reference points for fisheries management.

With Fishing

			Mortality Rate			
Age	Wt (kg)	Maturity at age	Natural (v)	Fishing (u)	Stock Size (#)	SSB (kg)
					1000	
1	0.1	0.00	0.2	0		
2	0.5	0.00	0.2	0.3		
3	1	0.50	0.2	0.3		
4	1.5	1.00	0.2	0.3		
5	2	1.00	0.2	0.3		
					TOTAL SSB	
					SSB/R	

Calculate the following (no calculator should be needed):

- stock sizes based on the mortality rates
- Spawning stock biomass (SSB)
- Total SSB
- SSB per recruit (divide by initial # of recruits)

With Fishing

			Mortality Rate			
Age	Wt (kg)	Maturity at age	Natural (v)	Fishing (u)	Stock Size (#)	SSB (kg)
					1000	
1	0.1	0.00	0.2	0	800	0
2	0.5	0.00	0.2	0.3	400	0
3	1	0.50	0.2	0.3	200	100
4	1.5	1.00	0.2	0.3	100	150
5	2	1.00	0.2	0.3	50	100
					TOTAL SSB	**350**
					SSB/R	**0.35**

Spawning Stock Biomass per Recruit

- Calculation of SSB/R
- Info needed:
  - Maturity at age (Mat_a)
  - Mortality at age (Z_a)
  - Size at age (W_a)

$$SSB/R = \sum_a Mat_a W_a e^{\sum_{j=\min a}^{a-1} -Z_j}$$

- What are the components of this equation?

What is the maximum SSB/R that is possible?

With Fishing

			Mortality Rate			
Age	Wt (kg)	Maturity at age	Natural (v)	Fishing (u)	Stock Size (#)	SSB (kg)
					1000	
1	0.1	0.00	0.2	0	800	0
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3	1	0.50	0.2	0.3	200	100
4	1.5	1.00	0.2	0.3	100	150
5	2	1.00	0.2	0.3	50	100
					TOTAL SSB	**350**
					SSB/R	**0.35**

NO Fishing

			Mortality Rate			
Age	Wt (kg)	Maturity at age	Natural (v)	Fishing (u)	Stock Size (#)	SSB (kg)
					1000	
1	0.1	0.00	0.2	0	800	0
2	0.5	0.00	0.2	0	640	0
3	1	0.50	0.2	0	512	256
4	1.5	1.00	0.2	0	410	614
5	2	1.00	0.2	0	328	655
					TOTAL SSB	**1526**
					SSB/R	**1.53**

Maximum spawning potential (MSP)

Spawning Stock Biomass per Recruit

- **<u>Maximum spawning potential (MSP)</u>**
  - **biomass of reproductively mature fish per recruit *in the absence of fishing***
  - **IE, the max. expected lifetime contribution of a recruit to the spawning stock biomass**
  - **SSB/R with no fishing**

No Fishing (MSP):

$$SSB/R_{F=0} = \sum_a Mat_a W_a e^{\sum_{j=\min a}^{a-1} -M_j}$$

- How much are we reducing the lifetime spawning potential by fishing?
  - Calculate ratio of values → "**spawning potential ratio (SPR)**"

With Fishing

			Mortality Rate			
Age	Wt (kg)	Maturity at age	Natural (v)	Fishing (u)	Stock Size (#)	SSB (kg)
					1000	
1	0.1	0.00	0.2	0	800	0
2	0.5	0.00	0.2	0.3	400	0
3	1	0.50	0.2	0.3	200	100
4	1.5	1.00	0.2	0.3	100	150
5	2	1.00	0.2	0.3	50	100
					TOTAL SSB	**350**
					SSB/R	**0.35**

NO Fishing

			Mortality Rate			
Age	Wt (kg)	Maturity at age	Natural (v)	Fishing (u)	Stock Size (#)	SSB (kg)
					1000	
1	0.1	0.00	0.2	0	800	0
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5	2	1.00	0.2	0	328	655
					TOTAL SSB	**1526**
					SSB/R	**1.53**

Maximum spawning potential (MSP)

$$SPR = \frac{SSB/R_{Fishing}}{SSB/R_{NoFishing}} = \frac{0.35}{1.53} = 0.23\ (or\ 23\%)$$

Spawning Stock Biomass per Recruit

- **Spawning potential ratio (SPR)**
  - **the fraction of MSP that is achieved at different fishing mortality rates**
  - **i.e., Ratio of fished SSB/R to unfished SSB/R**

With Fishing:

$$SSB/R = \sum_a Mat_a W_a e^{\sum_{j=\min a}^{a-1} -Z_j}$$

No Fishing (MSP):

$$SSB/R_{F=0} = \sum_a Mat_a W_a e^{\sum_{j=\min a}^{a-1} -M_j}$$

Spawning potential ratio

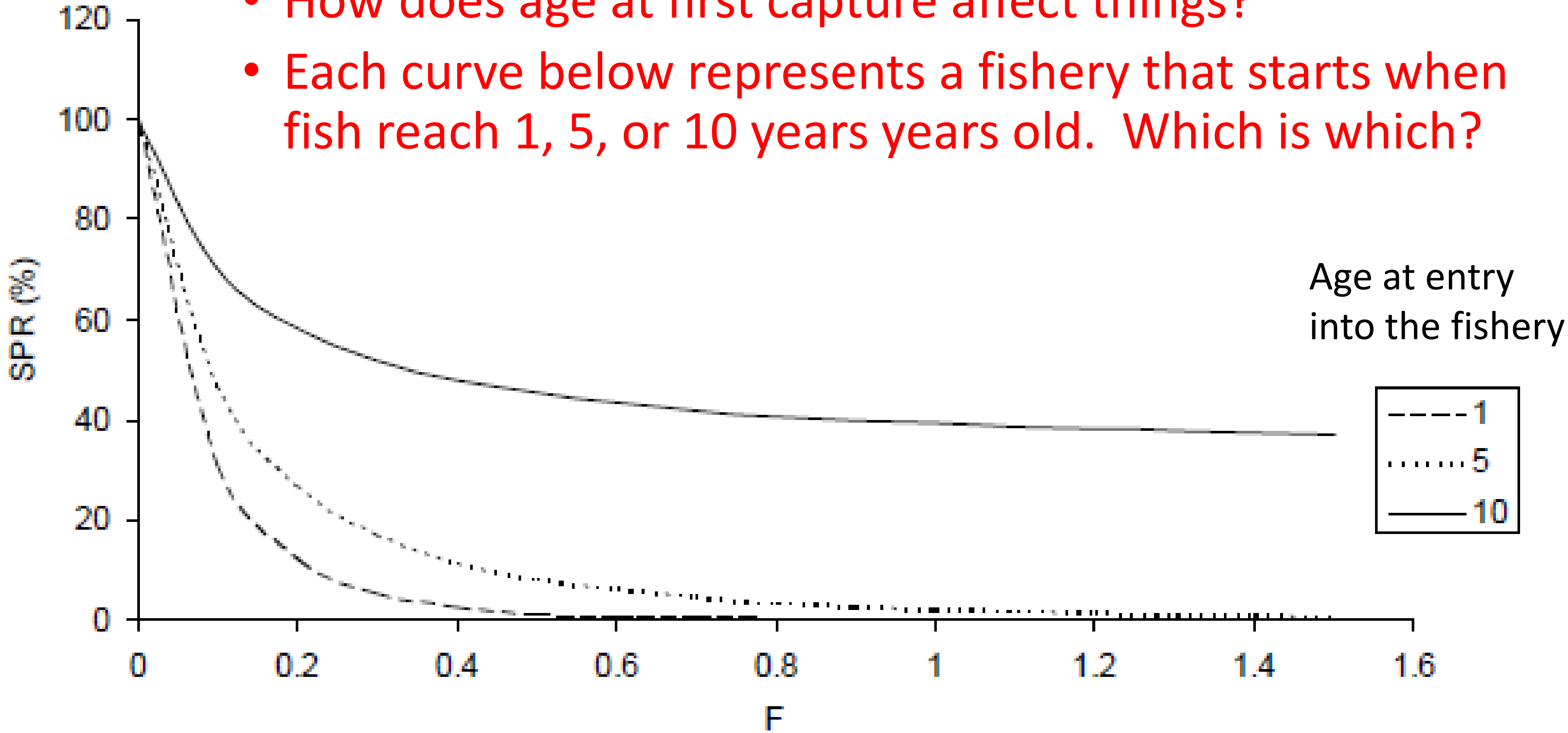
$$\text{SPR} = \frac{SSB/R}{SSB/R_{F=0}} \times 100$$

Terminology/acronyms

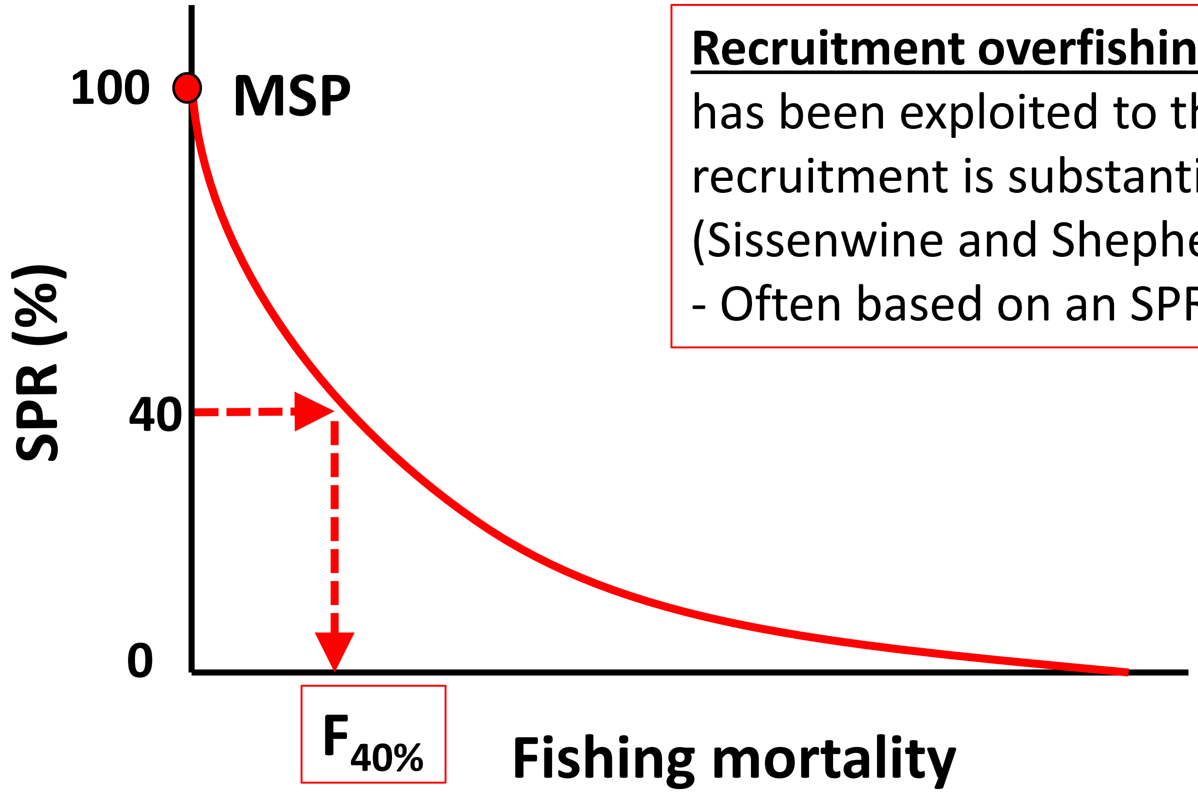
- Spawning stock biomass per recruit
  - Also: spawners per recruit, spawning per recruit
  - Acronyms: SSB/R or S/R or SSBR or SPR (e.g., Gabriel and Mace 1999, Rochet 2000)
  - **Maximum spawning potential (MSP)** – SSB/R with no fishing
- Ratio of SSB/R to unfished SSB/R
  - **Spawning potential ratio** (SPR, or %SPR)
  - %MSP
  - Compensation ratio (CR) (Goodyear 1993)

Spawning potential ratio (SPR)

- Example curves
  - How does age at first capture affect things?
  - Each curve below represents a fishery that starts when fish reach 1, 5, or 10 years years old. Which is which?



Reference points from SSB/R

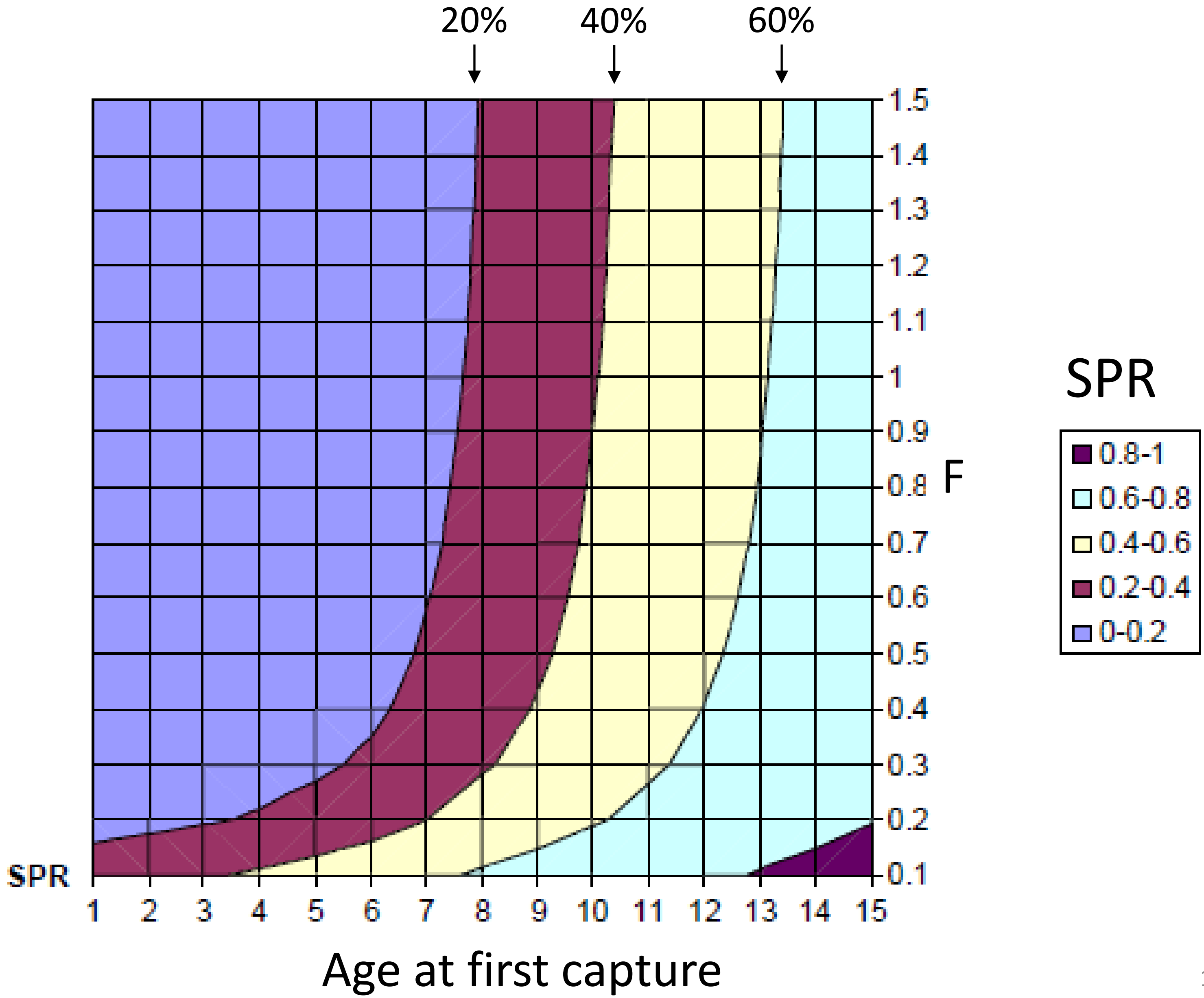


<u>Recruitment overfishing</u> – when a population has been exploited to the point at which recruitment is substantially reduced (Sissenwine and Shepherd 1987)

- Often based on an SPR-type reference point

- **$F_{x\%SPR}$** = fishing mortality rate that keeps spawning potential ratio at X% of the maximum spawning potential
  - E.g., $F_{40\%}$ is relatively common.

Spawning Potential Ratio (SPR)



Spawning per recruit assumptions

- Constant life history schedules
  - Mortality at age
  - Growth (weight at age)
  - Maturity at age
  - Fecundity at age (for Eggs-Per-Recruit [EPR] models)

- Assumes spawning occurs over a short period in time (ie not continuous process)

Uses of spawning per recruit

- Generation of biological reference points ($F_{x\%SPR}$)
  - Used as a proxy of F_{msy}
  - 35% SPR suggested as a general reference point, but may be too aggressive for many life histories
  - 40% SPR now commonly used but higher values (50% to 60%) have been suggested for some species.

- Helpful in avoiding recruitment overfishing

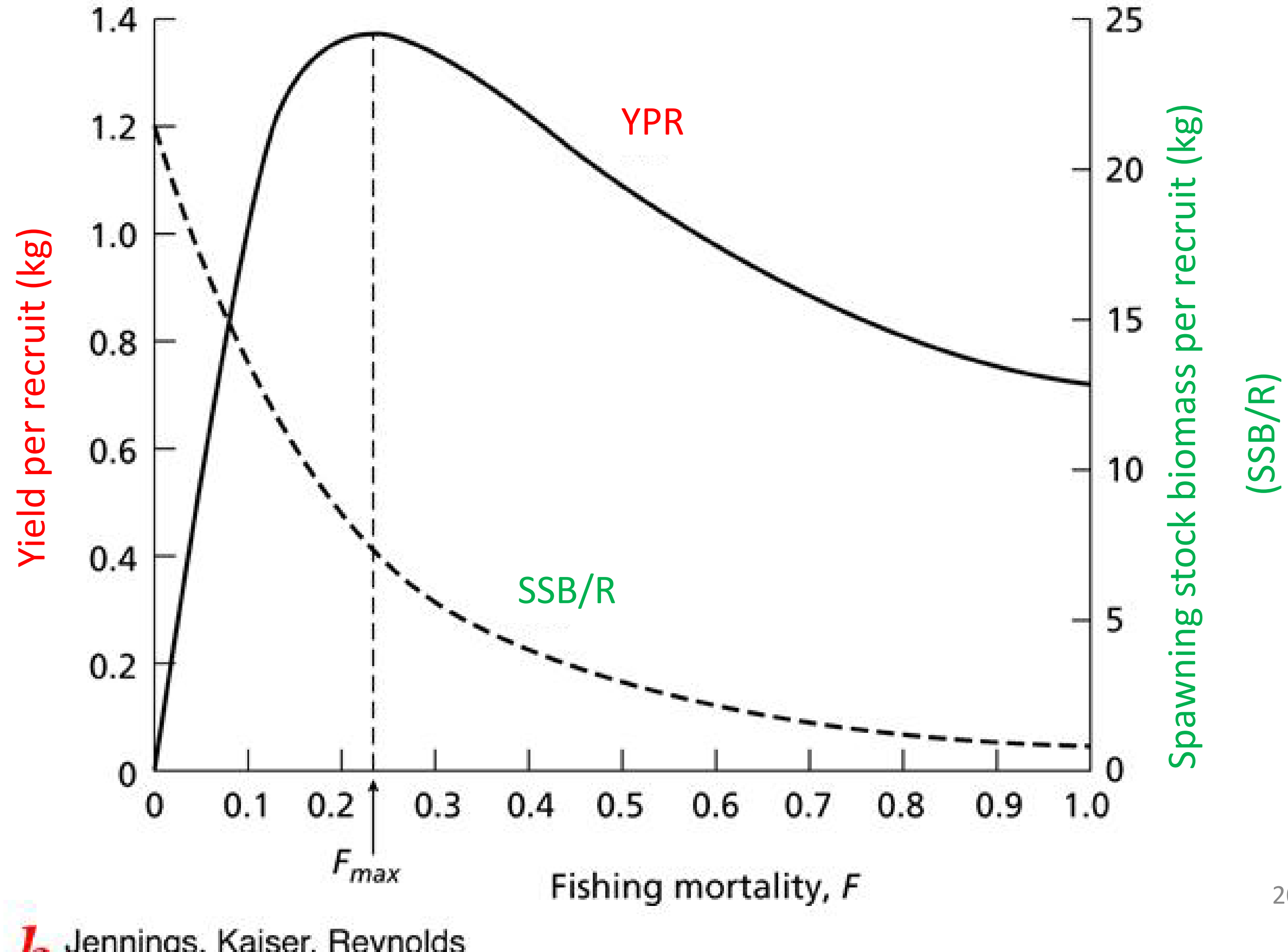
Limitations of SPR Models

- Constant assumptions
- Equilibrium conditions
  - No density dependence
- Does not contain stock-recruitment assumptions
  - But possible to build this in

Examples of challenges/problems

- External drivers of populations
  - Environment, Climate, etc.
- Doesn’t account for density dependence
- Possible changes as density decreases:
  - Growth rate increases (ie increased W at age)
  - Earlier maturity
  - Higher fecundity at age (due to size)
  - Smaller egg sizes (due to younger age at maturity)
  - Decreased natural mortality
- How have life history traits changed over the history of the fishery?
  - Traits/schedules now (which we estimate) may be different than virgin population

Tradeoffs in YPR and SSB/R



Color: SSB/R
Contours: YPR

Example

- Walleye YPR and SSBR in Mille Lacs Lake

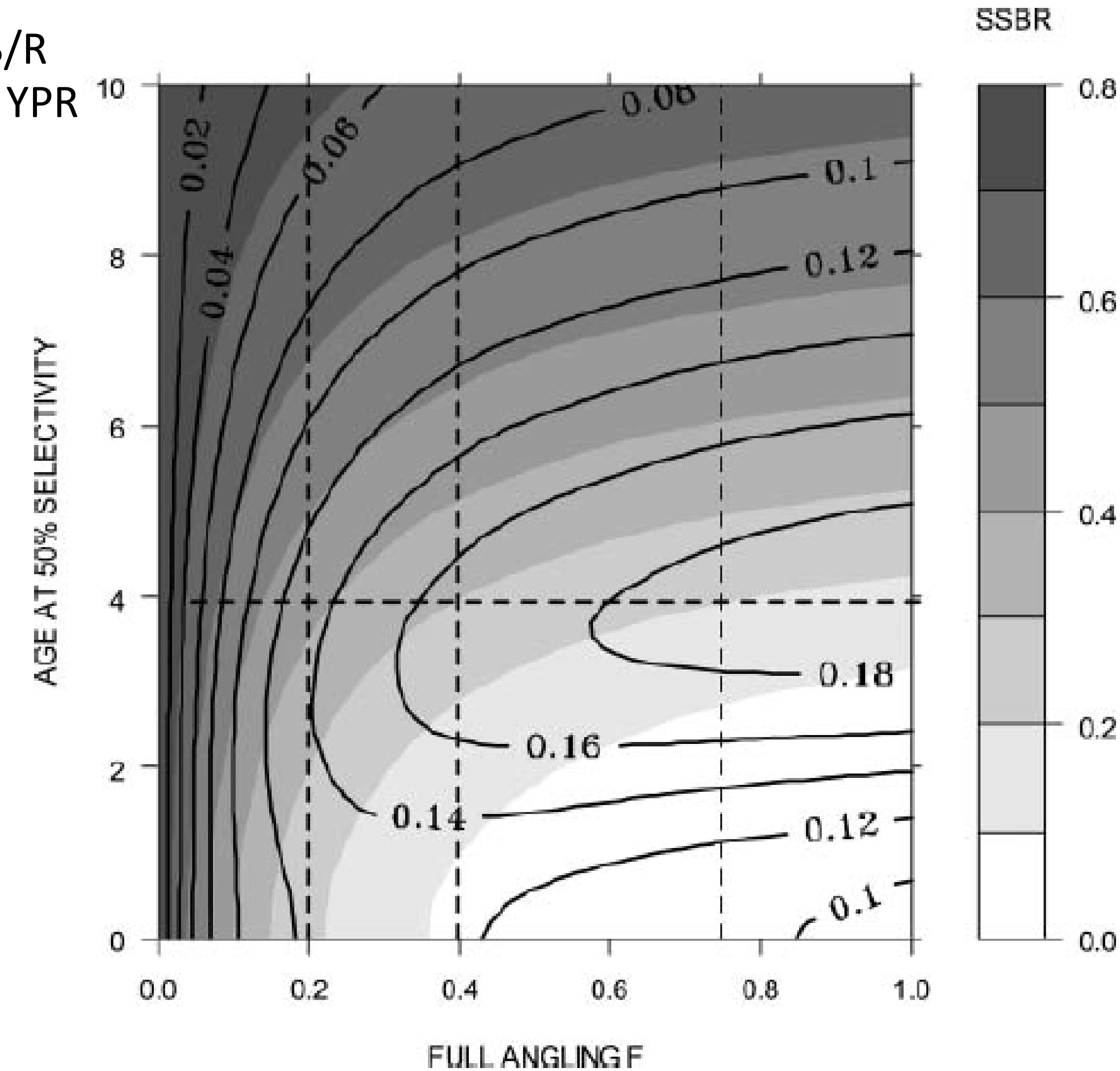
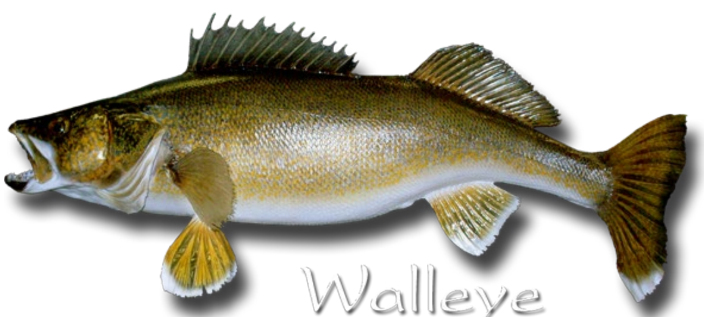


FIGURE 2. Mille Lacs Lake Walleye YPR and SSBR as a function of the age at which 50% selection to the angling fishery occurs, at Full Angling F. The horizontal dashed line represents the age (3.9 years) where 50% selection results in an SSBR = 0.3 at a median F = 0.4, as estimated from the SCAA model. The vertical dashed lines represent low F = 0.2 (10th percentile of SCAA-estimated F) and high F = 0.75 (90th percentile of SCAA-estimated F).



Schmalz et al. 2016

Summary – SSB/R

$$SSB/R = \sum_a Mat_a W_a e^{\sum_{j=\min a}^{a} -Z_j}$$

- SSB/R models
  - Examples of "spawning per recruit" models → but they look at different measures of spawning
  - Typically expressed as ratio of fished to unfished values
  - Definitions/concepts to know: **SSB/R**, **SPR**, **MSP**, **recruitment overfishing**
- SSB/R models account for:
  - age-structure
  - growth, mortality, maturity
- Don't account for:
  - Recruitment, changes in growth/mortality/maturity schedules, or density dependence
- Provide info and reference points for management
  - Deals with **recruitment overfishing**
  - $F_{x\%}$ (e.g., $F_{35\%}$ and $F_{40\%}$)
  - Often used as a proxy for F_{MSY} (b/c don't need S-R relationship)
  - Info on best age at first capture
  - These methods can also be modified to calculate eggs per recruit (EPR)