Replacement Lines

Reading:

Jennings et al. 2001, section 7.8

Supplemental: Mace and Sissenwine 1993

Supplemental: Gabriel et al. 1989

Acknowledgement: M. Wilberg

"Tom, we're letting you go, but we'd like you to stay on and train your replacement so they know what not to do."

Background

- Dynamic pool models (YPR, SSB/R, EPR) did not account for stock-recruit relationships

- Why is this potentially problematic?

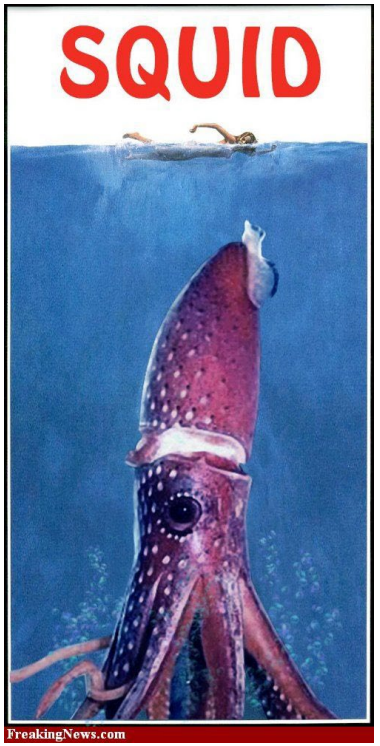
Background

- **Replacement line** = Line on a stock-recruit plot indicating the amount of recruits per spawner needed to replenish the population on average
  - Semelparous species – can use stock recruit models alone
  - Iteroparous species – combine SSB/R models with stock-recruit models

Example of replacement lines

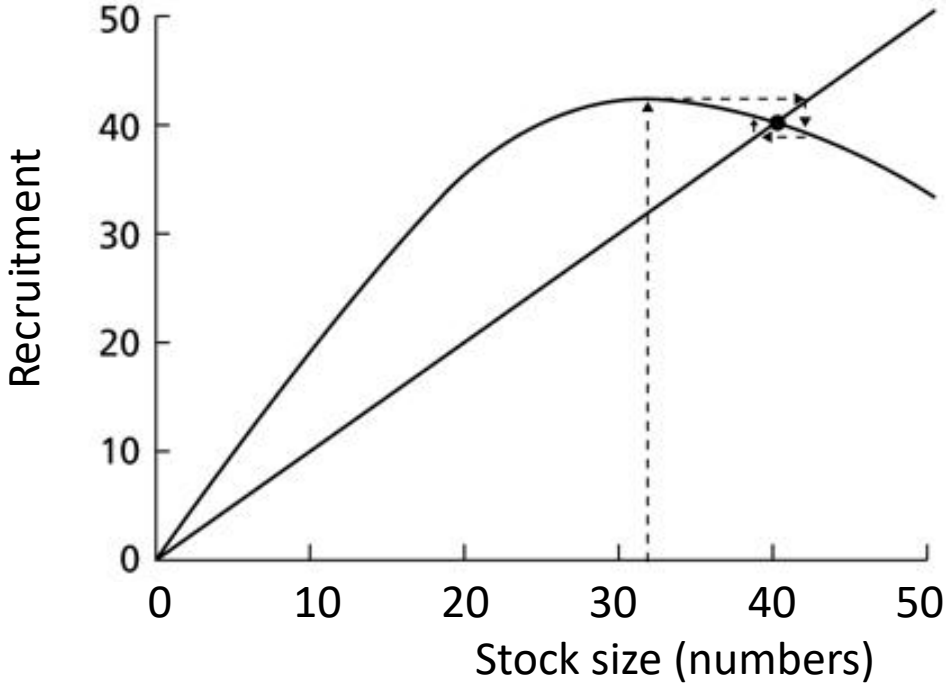
- **Example**: consider a semelparous species with a life span of 1 year (e.g., squid)

- Draw Ricker Curve with replacement line. Discuss:
  - Meaning
  - Equilibrium
  - Effect of fishing on replacement line



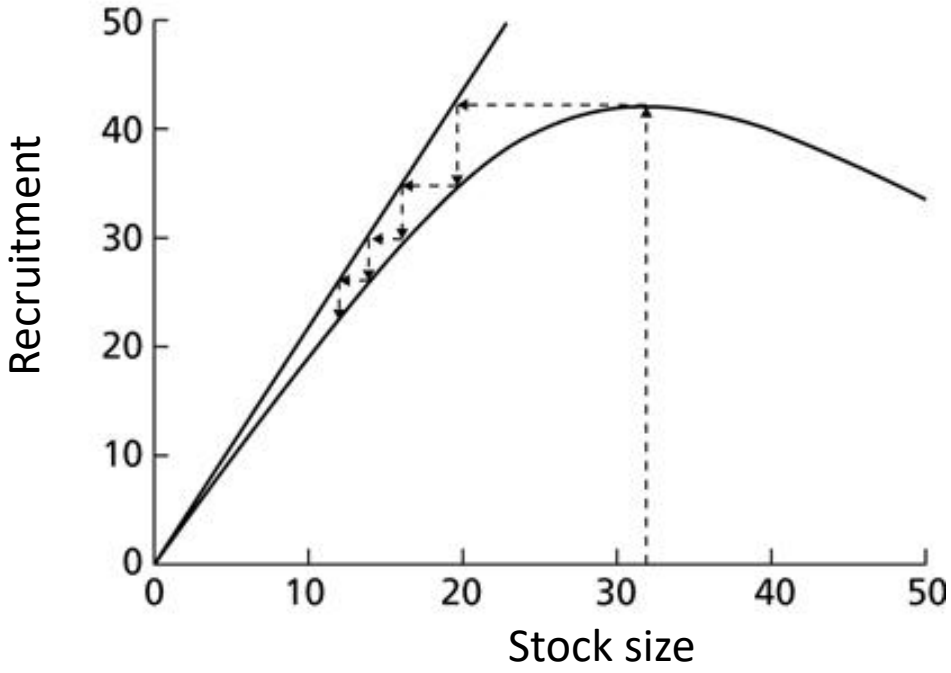
Example

- Ricker SR model
- 1:1 replacement line
  - 1:1 b/c dealing with annual species; assume all mortality occurs prior to recruitment
- If SR curve is above replacement line, we get a stable equilibrium (at intersection)



Example

- Steeper replacement line to accommodate fishing
- If SR curve is below the replacement line, population crashes



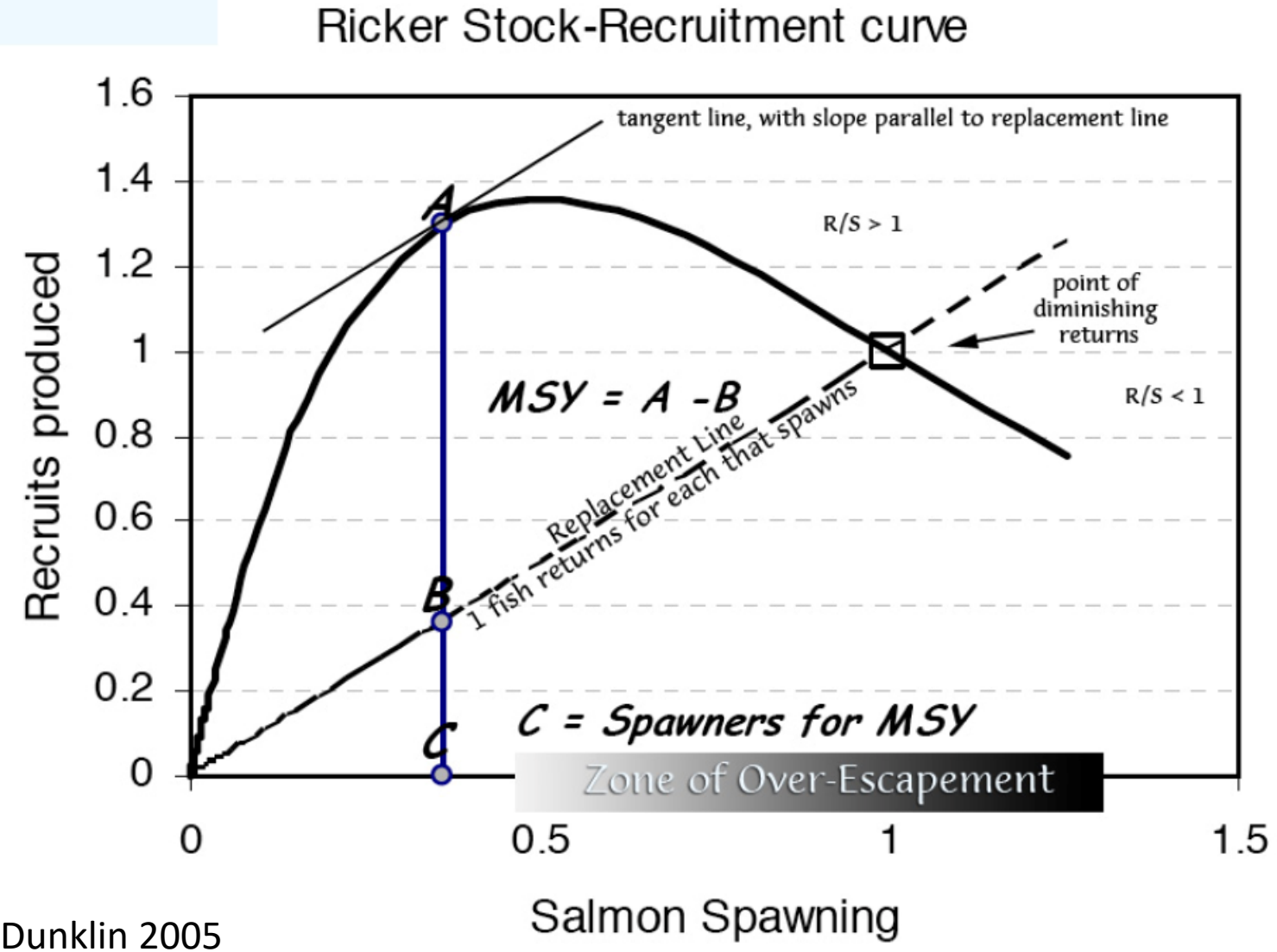
Replacement lines and MSY **for semelparous species**

- Area above the replacement line equates to surplus production
- Use this to calculate MSY from SR models
- Qualifications:
  - Semelparous species only
  - Recruitment is measured after all non-fishing mortality
  - Fixed timing of life cycle (ie non-overlapping generations)
  - Recruitment needs to be adjusted for years at large
- Best example: Pacific salmon

→ Draw a Ricker S-R Model with a replacement line and use that to identify the following values: S_{MSY}, MSY

Hilborn and Walters 1992 - Chapter 7

MSY from replacement lines in Stock-Recruitment Models



Escapement – the number of fish that are not caught in the fishery and allowed to survive and reproduce

Dunklin 2005

Ricker Model – MSY calculations

Extra

- Approximations to estimate MSY reference points from SR parameters
- Side: can use numerical methods to get exact values

$$R = \alpha S e^{-\beta S}$$

$$S_{MSY} \sim \frac{\log_e \alpha}{\beta}(0.5 - 0.07\log\alpha)$$

$$MSY \sim \alpha S_{MSY} e^{-\beta S_{MSY}} - S_{MSY}$$

$$u_{MSY} \sim 0.5\log_e \alpha - 0.07(\log\alpha)^2$$

Hilborn and Walters 1992 (Chapter 7)

Beverton Holt Model – MSY calculations

Extra

- Analytic solutions for BH model: $R = \frac{\alpha S}{\beta + S}$

$$S_{MSY} = \alpha\sqrt{\frac{\beta}{\alpha}} - \beta$$

$$MSY = \frac{\alpha S_{MSY}}{\beta + S_{MSY}} - S_{MSY}$$

$$u_{MSY} = 1 - \sqrt{\frac{\beta}{\alpha}}$$

Replacement lines for iteroparous species

- Challenges determining the replacement line (e.g., iteroparous species):
  - Depends on maturation schedule, longevity, mortality rates
- Need to combine SR model with YPR and SSB/R models
- No easy analytical solution for MSY reference points

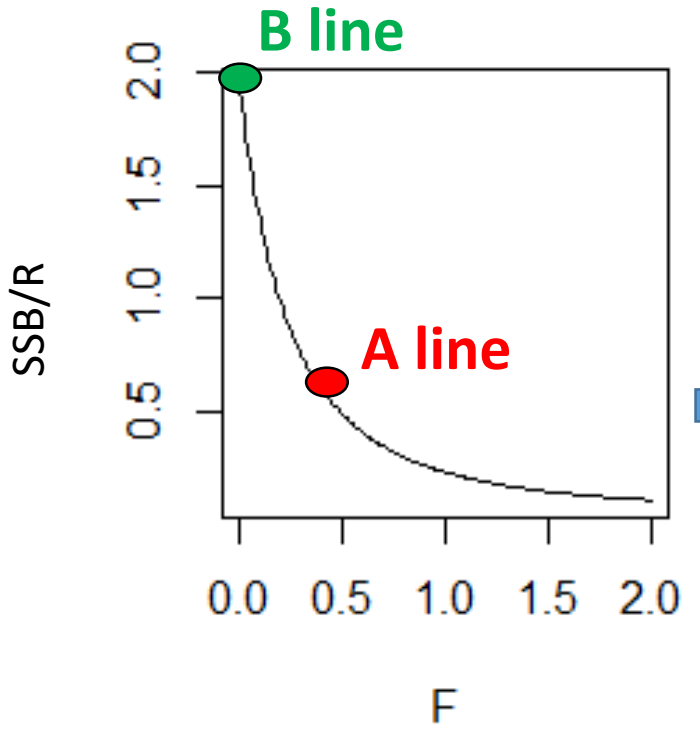
Relating SSB/R and R/SSB

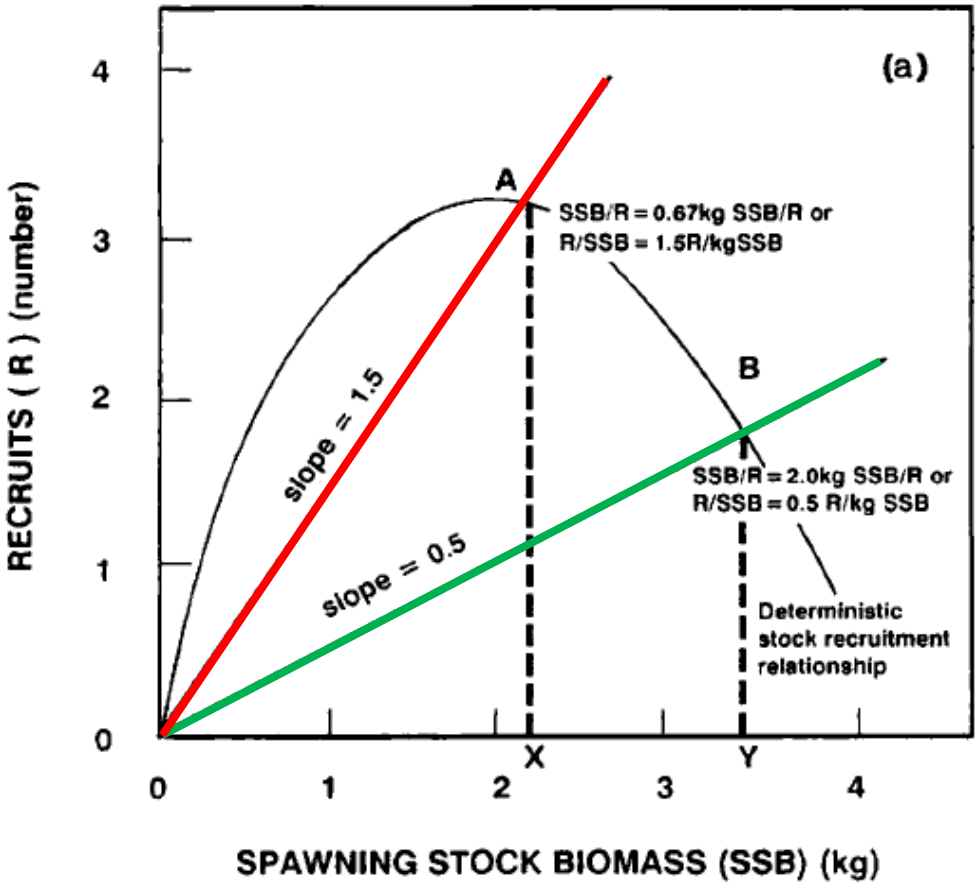
- Select desired **SSB/R** for a given level of fishing
- The inverse (**R/SSB**) is the survival ratio for our stock-recruit model
- **Replacement line** = recruits per spawner needed to replenish the population on average
  - **OR**: line in a stock-recruit plot with a slope equal to the observed average *survival ratio* (R/SSB)

Mace and Sissenwine 1993

Relating SSB/R and R/SSB

- Slope on S-R curve depends on the fishing mortality rate
- Slope on S-R = inverse of SSB/R

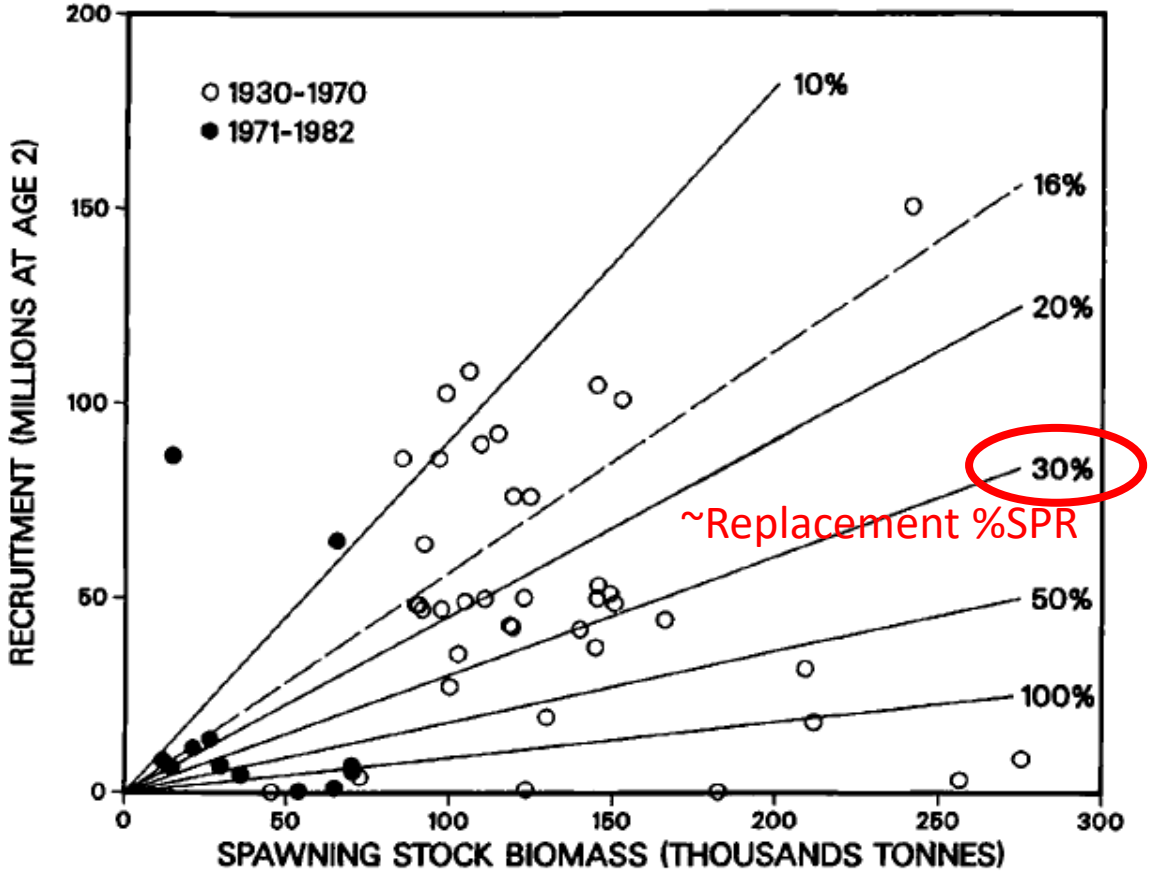




Gabriel et al. 1989

Example with real data: haddock

- Replacement lines labeled as % of maximum spawning potential
- Points above a line = R/SSB sufficient to maintain or increase pop (on average)
- One meta-analysis recommend 30%SPR as guide



Gabriel et al. 1989, Mace and Sissenwine 1993

Benefits of replacement lines

- Explicitly account for the effect of fishing on future recruitment (ie accounts for stock-recruit relationship)
- Addresses recruitment overfishing
- Can be used to determine biological reference points
  - E.g., F_{MSY}, F_{rep}, replacement %SPR
  - (Mace and Sissenwine 1993)
- Estimates of MSY are possible:
  - Easier for semelparous species like Pacific salmon
  - For iteroparous species, see Shepherd 1982

Limitations of replacement lines

- Data limitations
  - S-R models may not fit observed data well
  - narrow range of S
  - imprecise estimates
- Don’t account for changes in survival rates (R/S)
  - environmental effects
  - changes through time
- Only accounts for density dependence in production

Summary – Replacement lines

- **Replacement lines** represent the recruits per spawner needed to replenish a population on average
- Deals with **recruitment overfishing** (know def. from before)
- For semelparous species like Pacific salmon, they can be used with SR model to estimate MSY reference points
  - [know conceptually how to get MSY from stock recruitment model & replacement line]
- For most species, replacement lines can be drawn using SSB/R models in conjunction with Stock-Recruit models
  - Higher fishing → higher slope of replacement line
- Biological reference points for management can be derived from these concepts