Stock-recruitment Part I

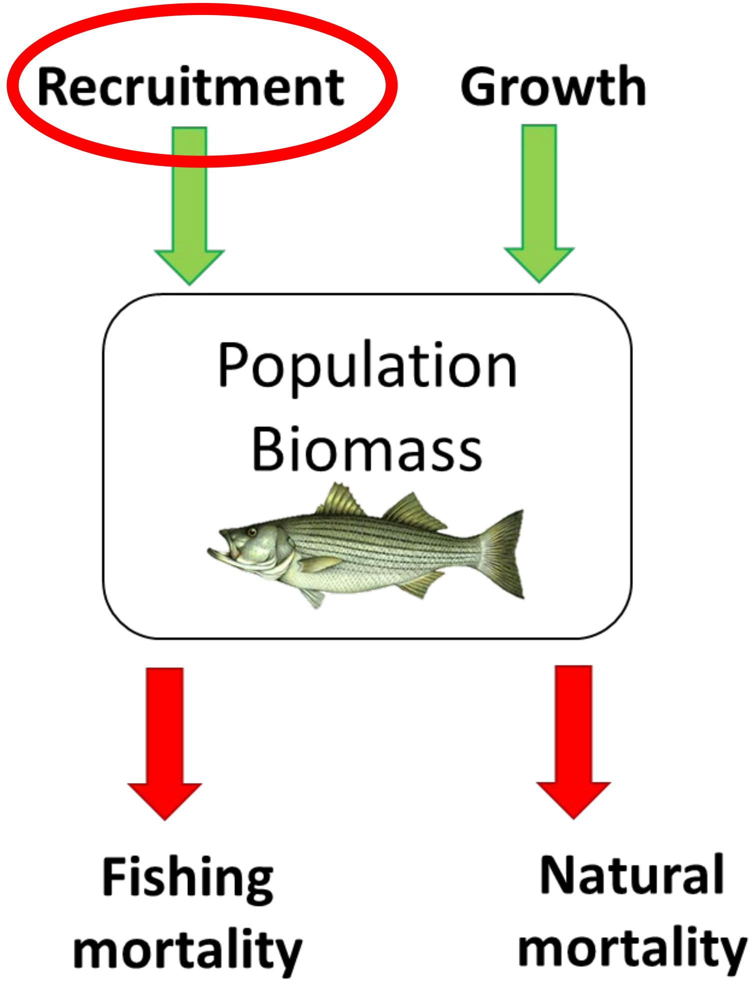
Reading:

Jennings et al. 2001. Marine Fisheries Ecology, Chapter 4 (section 4.2)

Advanced: Quinn and Deriso 1999, Chapter 3

Stock-recruitment

- **Recruitment** = The number of individuals that reach a specified "stage" of their life cycle. Often in reference to a specific age or to a size/age that is vulnerable to fishing



Stock-Recruitment

- Why is this one of the most important topics in fisheries mgmt?
- Answers questions like:
  - How many young are produced by a given amount of adults?
  - How many recruits can we expect in the future for a given stock size?
  - Ability of pop to renew itself is critical for management and conservation
  - How much sustainable harvest can populations generate?

Stock-recruitment

- Interested in finding the relationship between spawners and recruitment

Eggs $\rightarrow$ larvae $\rightarrow$ juveniles $\rightarrow$ spawners

- Side: multiple ways of saying the same thing:
  - Stock-recruitment
  - Stock-recruit
  - Spawner-recruit
  - SR

What is a stock?

“fish management stock funny”

Dead fish handshake

What is a stock?

- **Stocks** are arbitrary groups of fish large enough to be essentially self-reproducing, with members of each group having similar life history characteristics
    - Hilborn and Walters 1992
- More generally: **Stock** defines a semi-discrete group of fish with some definable attributes of interest to managers
    - Begg et al. 1999

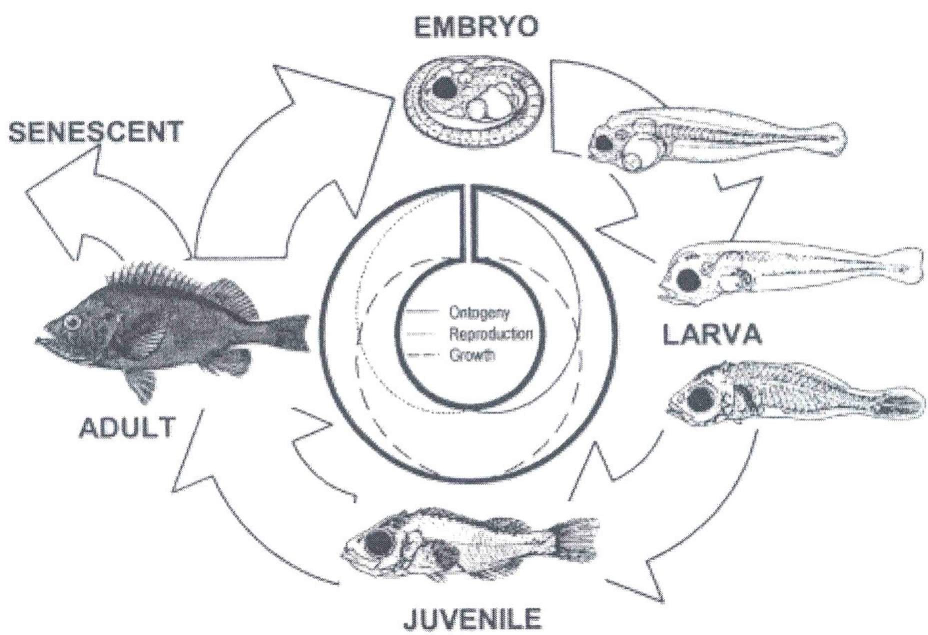
Begg and Waldman 1999

What is a stock?

- ***spawning* stock** - Reproductively active part of the population
- Indices/Proxies include (descending order of quality):
    - Egg (or larval) production in the population
    - Biomass of adult females
    - Biomass of adults
    - Number of adults or adult females
    - CPUE of adults

What is recruitment?

- **Recruitment** = The number of individuals that reach a specified “stage” of their life cycle
  - Typically after egg/larval stage
  - Or referring to fishery
  - Combines reproduction and early life survival
  - Ideally, year class strength set by the selected stage



Where do spawner and recruit data come from?

- Monitoring surveys
  - For eggs/juveniles/adults
- Population models (i.e. stock assessment models)

What does R vs. S look like?

- Draw relationship
- Chat with neighbor
- Why do you think it looks like that?

Shapes of S-R models

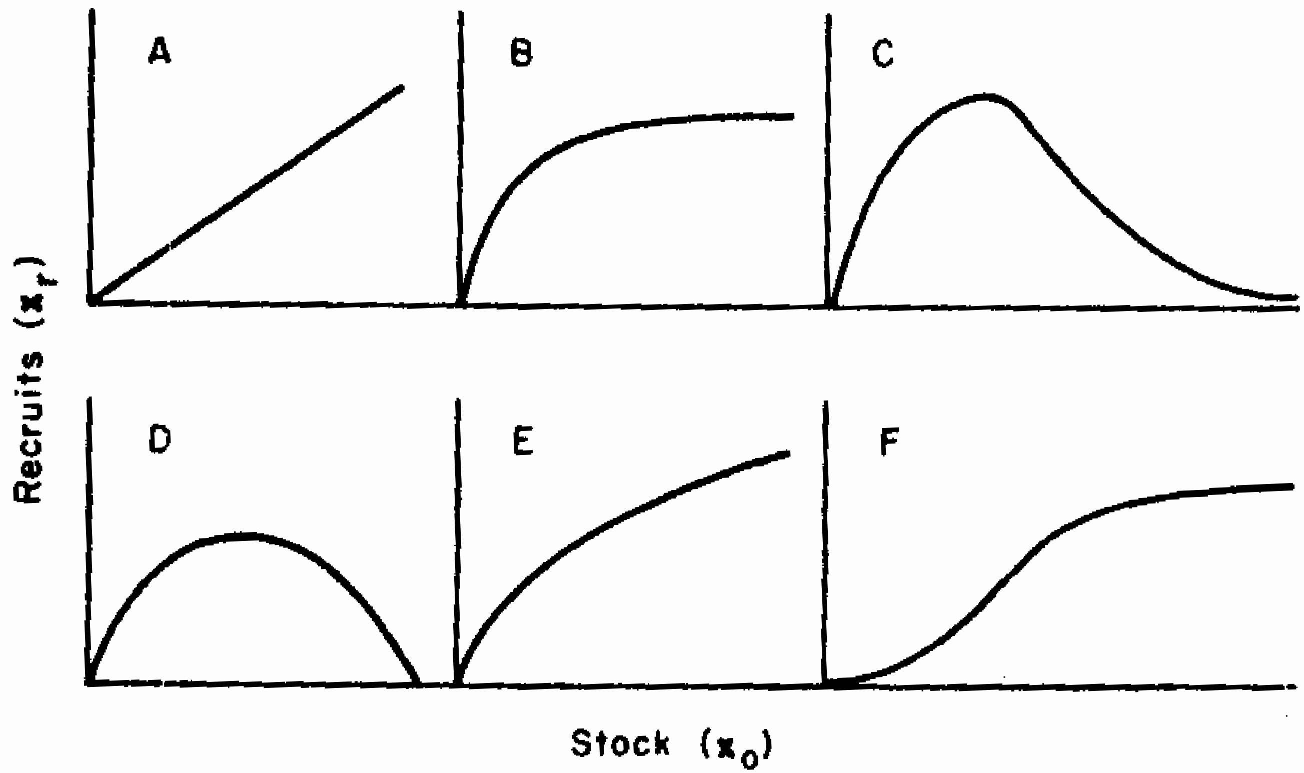
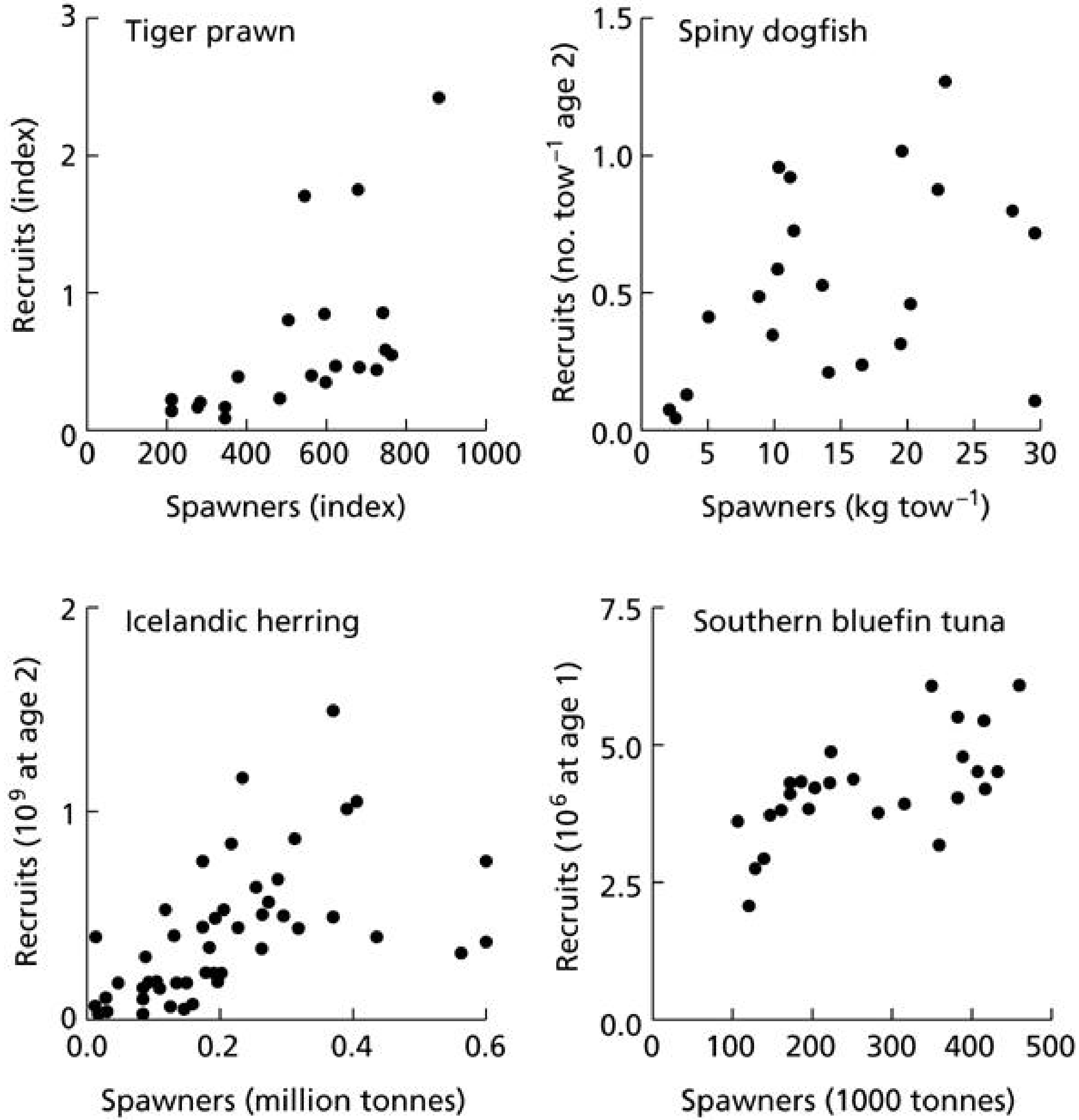


FIGURE 3.1. Nonlinear relationships between newborn individuals (x_0) and survivorship to age r (x_r); see equation (3.8). A, linear; B, Beverton and Holt; C, Ricker; D, Schaefer; E, power function ($0 < \beta < 1$); F, depensation.

Examples (real data)



Jennings, Kaiser, Reynolds
Marine Fisheries Ecology

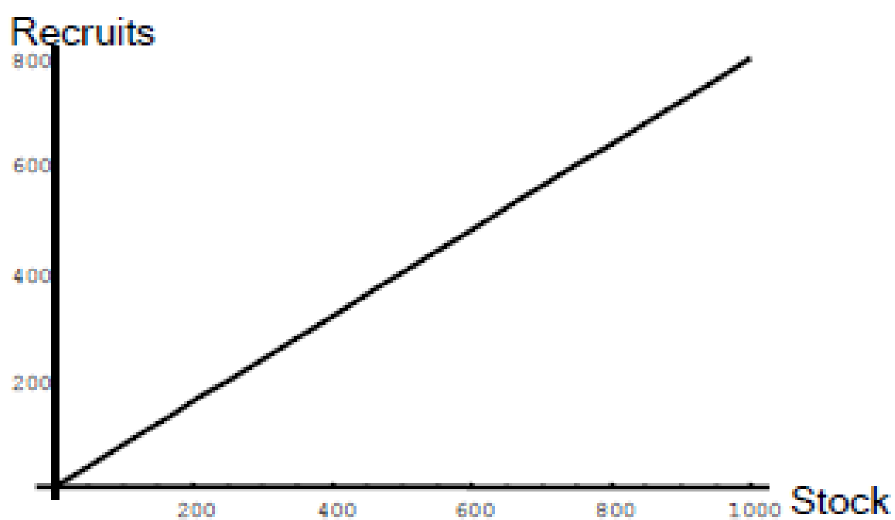
Stock-recruitment models

- 1. Density Independent
- 2. Beverton-Holt
- 3. Ricker
- 4. Shepherd
- 5. Hockey stick
- Others…

Density dependent

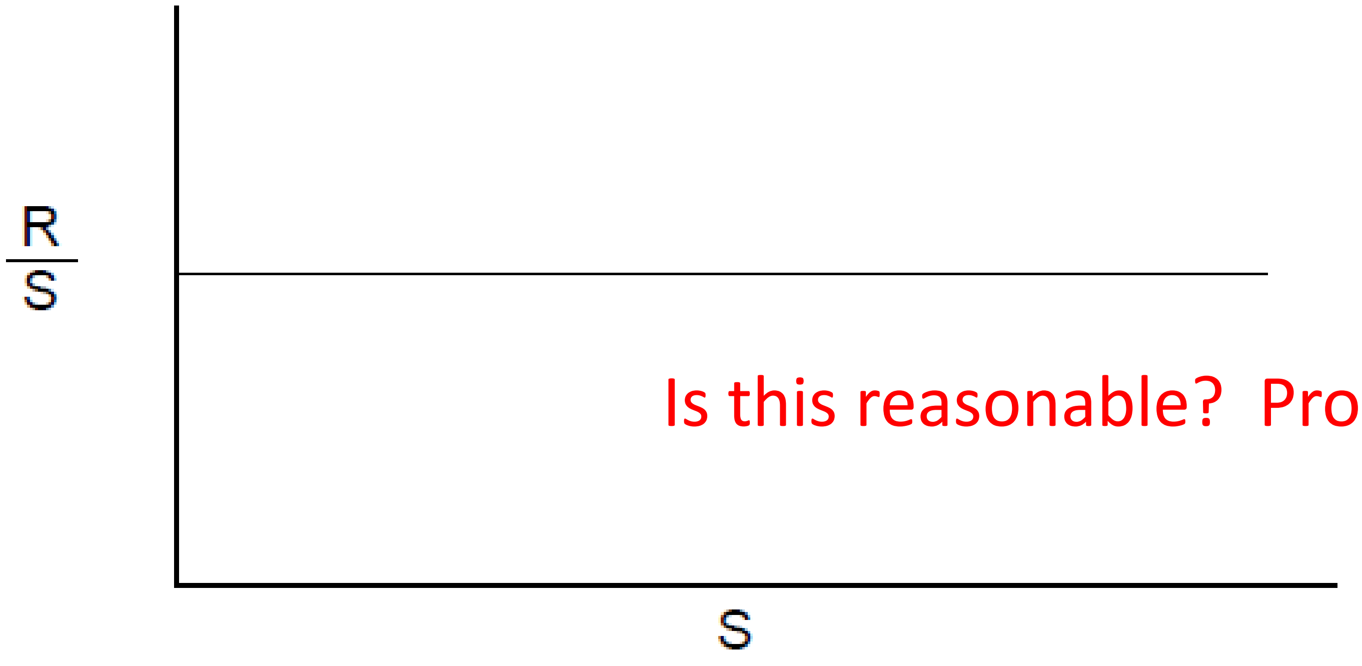
1. Density independent model

- Assumes density independence:
  - Survival (e.g., of eggs, juveniles, adults) does not depend on abundance
  - E.g., no intraspecific competition
- Model: $\boxed{R = a \cdot S}$
  - **a** = productivity or density-independent parameter (combines egg production per spawner and survival to recruit stage)



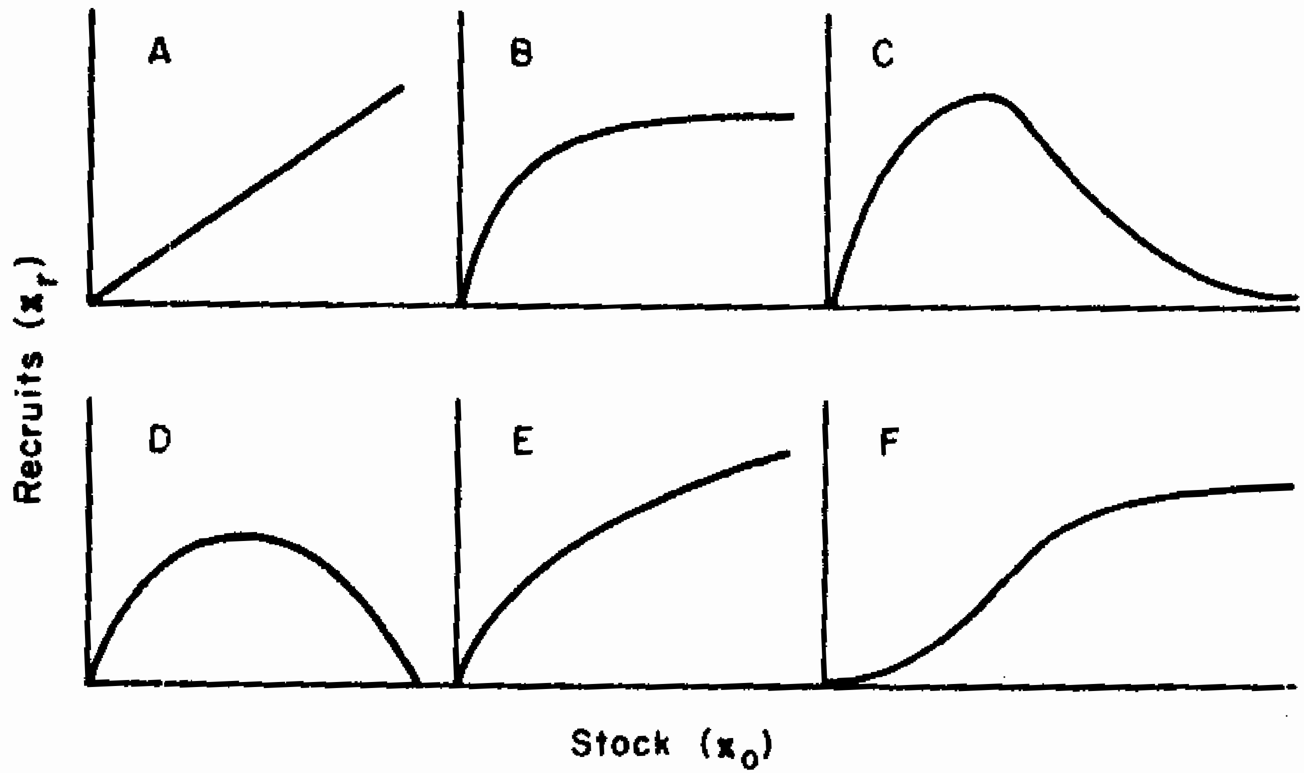
1. Density independent model

- **R/S = a**;
- R/S can be thought of as an index of survival



Is this reasonable? Problems?

Models should be density dependent



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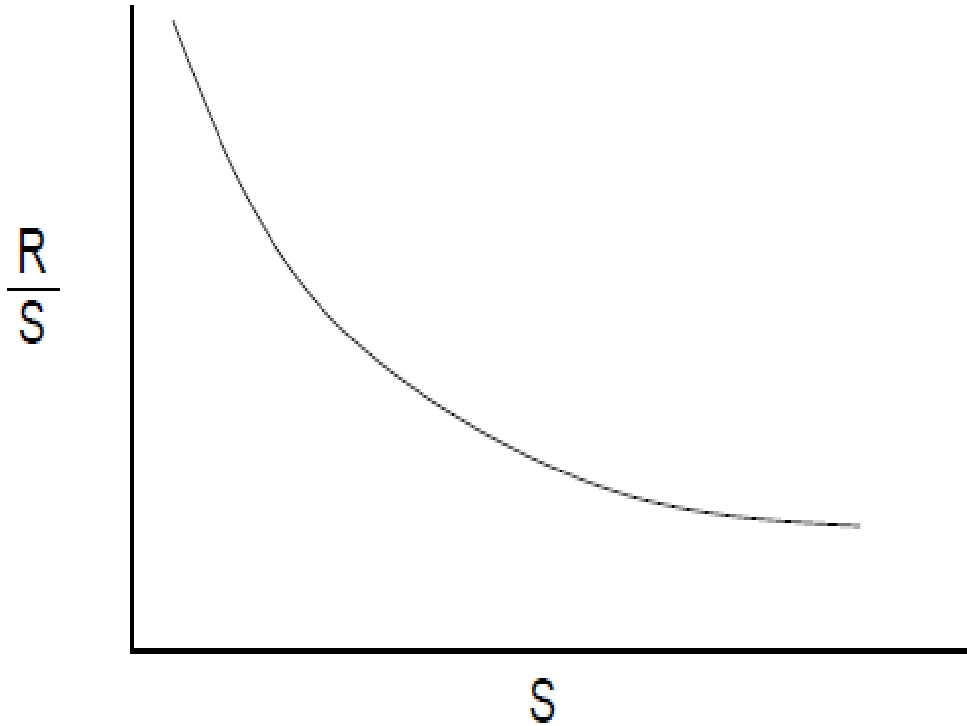
Compensatory stock-recruitment

- **Density dependence** can be built in through compensation (ie changes in survival rate)
- **Compensation =**
  - recruits per spawner (R/S) increases as S decreases, *or*
  - R/S decreases, as S increases

- Why?
  - Density independent model leads to exponential growth
  - Compensation assumes survival declines as S increases (e.g., cannibalism, disease, competition for prey, predation)



Compensatory stock-recruitment

- Density-dependent processes thought to act via two mechanisms:
  - **1. acts via the juveniles** (affected by recruit density)
    - E.g., young compete for food or feed on one another
    - *→ Leads to Beverton Holt model*
  - **2. acts via the adult stock** (affected by spawner density)
    - Aka "stock dependent"
    - E.g., limited numbers of nests, cannibalism of young by adults, disease transmission from adults to juveniles, density-dependent growth combined with size-specific predation
    - *→ leads to Ricker model*

Extra

2. Beverton-Holt Model

- Based on idea of density-dependence acting on the **juveniles**
  - Change in abundance affected by total mortality, Z
  - Assume Z described by linear function of abundance, affected by density independent (a) and density dependent (b) parameters
  - Leads to nonlinear differential equation (see Quinn & Deriso for solution)

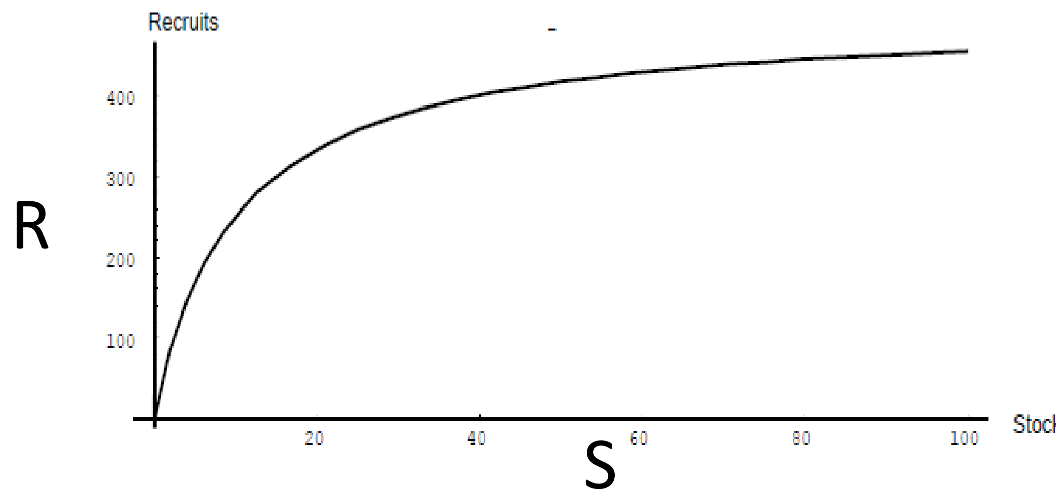
$$\frac{dN}{dt} = -ZN$$

$$Z = a + bN$$

$$\frac{dN}{dt} = -(a + bN)N$$

2. Beverton-Holt Model

$$\boxed{R = \frac{aS}{1+bS}}$$



- R = number (or biomass) of recruiting individuals
- S = number (or biomass) of spawners
- a = productivity parameter (number of R per S at low S); slope of curve at the origin
- b = parameter for degree of density dependence (affects rate of approaching asymptote)

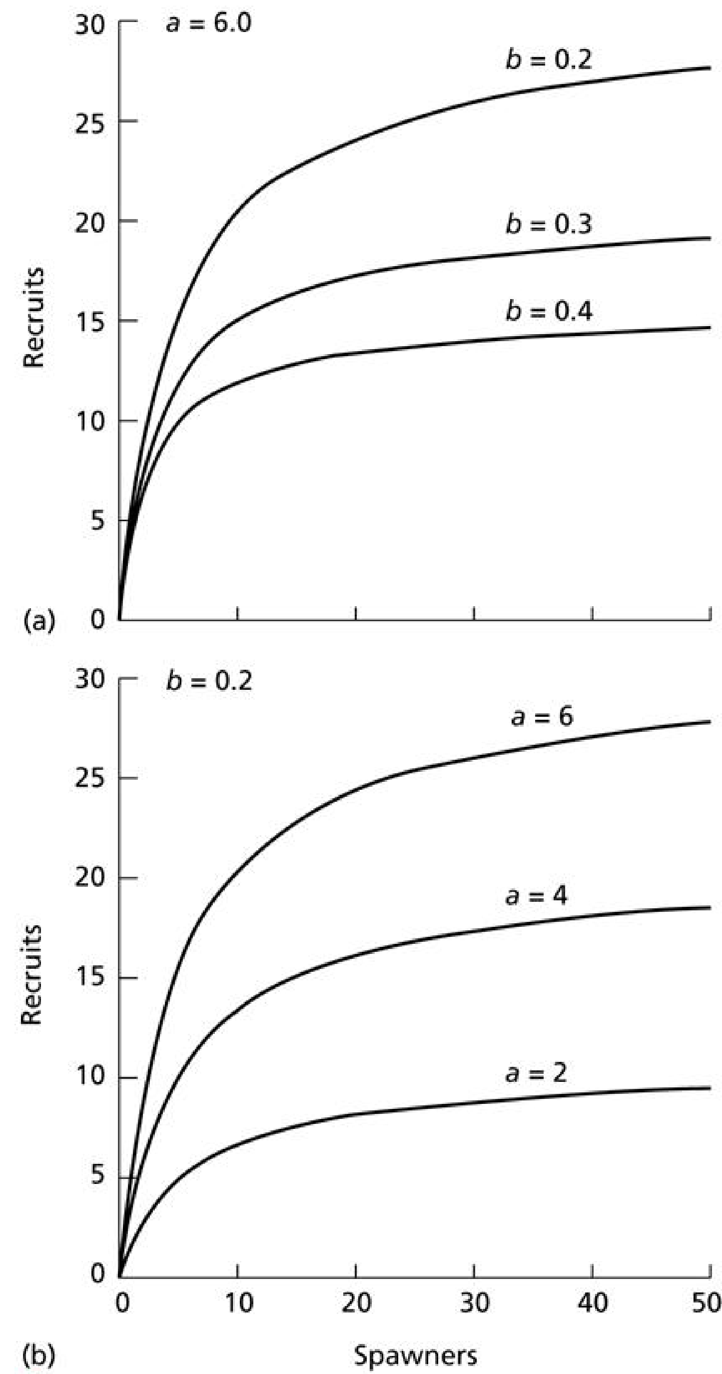
- Basic property: R constantly increases toward an asymptote as S increases

2. Beverton-Holt Model

- Effects of changing parameters

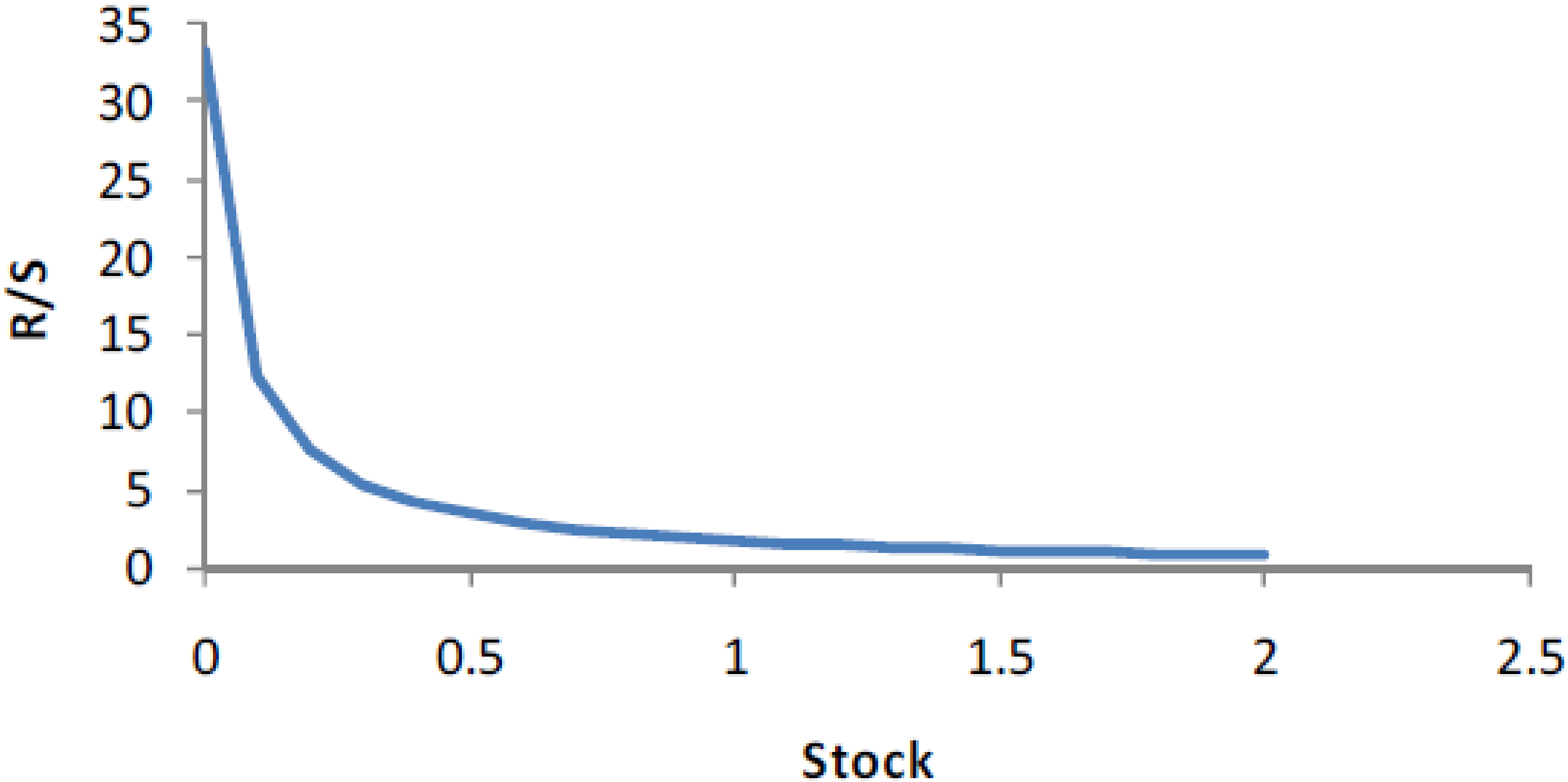
$$\boxed{R = \frac{aS}{1 + bS}}$$

- Max R = a/b



2. Beverton-Holt Model

- What does survival index (R/S) look like?



Extra

Beverton Holt parameterizations

- There are different parameterizations for the same model
- Parameter meanings differ
  - a‘ = 1/a (from before)
  - b‘ = b/a (from before)
  - α = maximum # recruits produced (=1/b’)
  - β = spawners needed to produce R= α/2 (=a’/b’)

$$R = \frac{aS}{1 + bS}$$

$$R = \frac{S}{a' + b'S}$$

$$R = \frac{\alpha S}{\beta + S}$$

Extra

Steepness Parameterization of BH

- Commonly used form of the Beverton-Holt Model

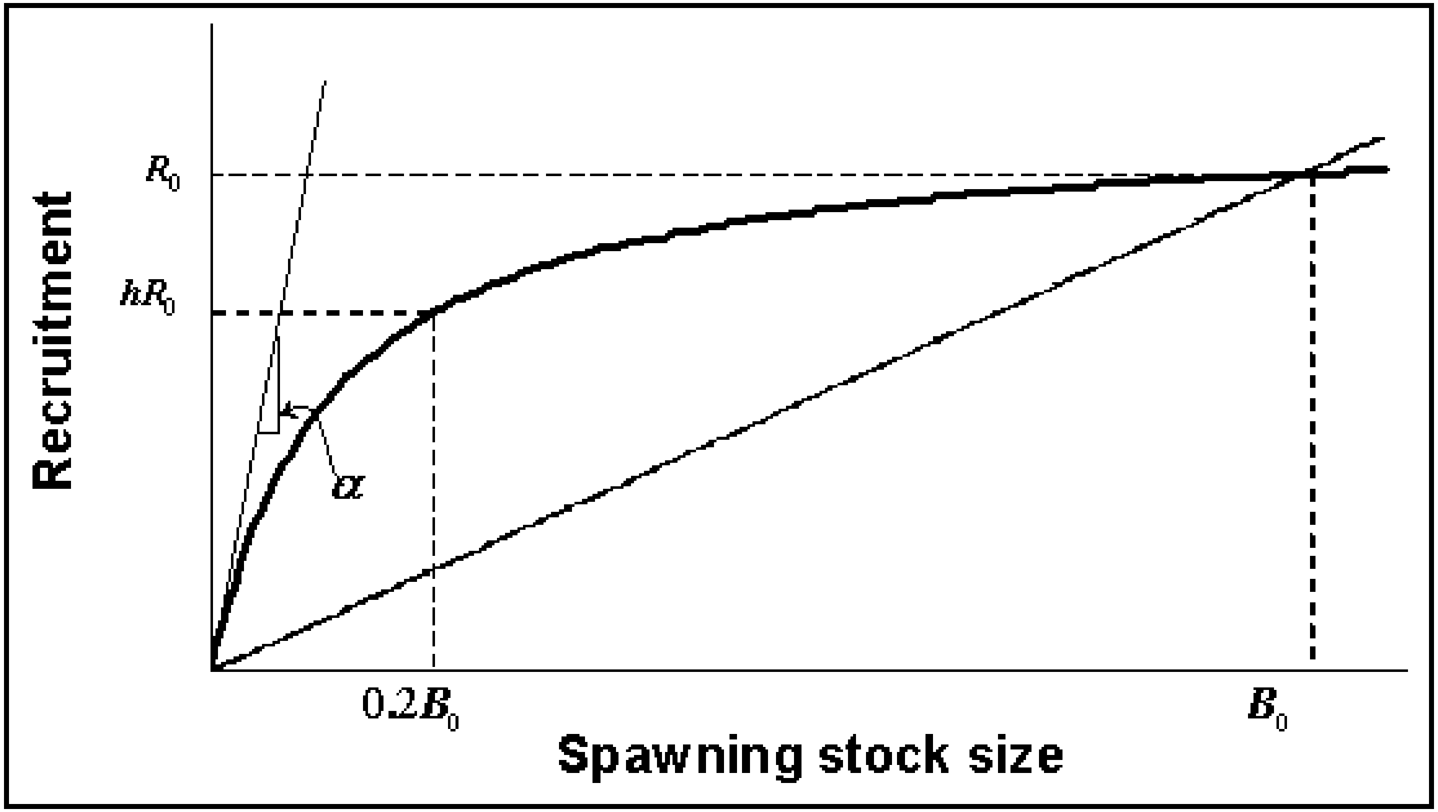
$$\boxed{R = \frac{4hR_{max}S}{S_{max}(1-h)+(5h-1)S}}$$

  - **h=steepness**, measure of how fast asymptote reached
    - Defined as: fraction of max recruitment attained when S is 20% of max (i.e., h = R/Rmax @ 20% Smax)
    - Bounded by: $0.2 < h < 1$
  - R_{max} = Maximum recruitment (ie virgin, unfished R)
  - S_{max} = Maximum observed stock size (virgin, unfished S)

- Why used?
  - Steepness (h) is scale-less, allowing comparison across species
  - Common in marine systems

Extra

Steepness Parameterization of BH



- Note: $R_0 = R_{max}$
- h=steepness; fraction of max recruitment attained when S is 20% of max (i.e., h = R/Rmax @ 20% Smax)