Thursday: lecture and lab (white seabass hatchery tour) in Carlsbad.

Directions from SDSU to the hatchery are as follows:

I-8 West
805 north to I-5 north (or go to I-5 from I-8)
I-5 north to Carlsbad, exit at Tamarack Ave. and turn left (west toward ocean)
As you cross over railroad tracks, turn left at stop sign (Garfield St.)
Hatchery is at end of Garfield on the right (9500 Garfield).

There are no signs at end of street and you can't see hatchery. Go down driveway with large black gate and call box. If gate is closed, press button on call box and they will open gate. Drive down and park.

Phone number of hatchery is 760-434-9501

Population Structure

(1) Populations fluctuate in space and time

(2) Fluctuations driven by
-- physical and biological processes that affect production and survival of eggs and larvae
-- growth and mortality during juvenile and adult phases
-- behavioral processes that determine migration or density-dependent habitat use

The Problem: Populations fluctuate unpredictably

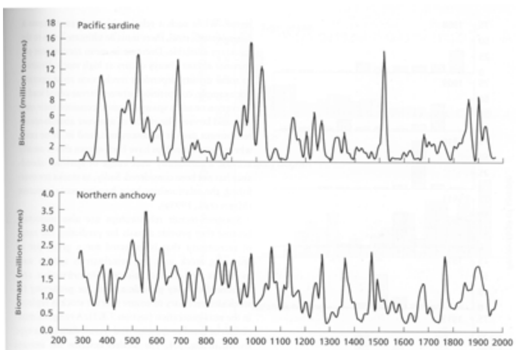


Fig. 4.1 Historical estimates of Pacific sardine and northern anchovy biomass off California. Biomass was estimated from scale deposition rates (density) in two sediment cores from the anoxic Santa Barbara basin. Scale deposition rate was assumed proportional to stock biomass because such relationships can be demonstrated using contemporary data. After Baumgartner *et al.* (1992).

Recruitment

Age structure of populations shows that a few age classes constitute most of the biomass in a population

-- year class success or failure determined during first few months of life
-- recruitment often varies by a factor of 20 or more between years
-- relative effect of each recruitment event on stock size depends on the age structure of existing stock

Recruitment = the number of individuals that reach a specified stage of the life cycle (e.g., metamorphosis, settlement, and entering the fishery)

Age structure of populations shows that a few age classes constitute most of the biomass in a population

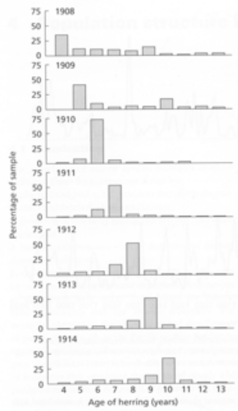


Fig. 4.2 The age composition of Norwegian herring catch samples from 1908 to 1914. Data from Hjort (1914).

<u>Recruitment depends on</u>

-- abundance and distribution of mature population
-- number and viability of eggs produced
-- survival of eggs and larvae

Higher fecundity is associated with greater recruitment variability

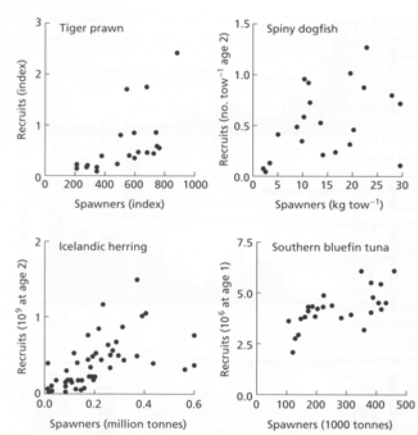
Variable survival of recruits determines population structure, strength of interactions in communities, and the biomass of fishes available to the fishery

Spawner and recruit relationships

<u>Expectation</u>: positive relationship between spawner and recruit relationship (known as stock-recruitment relationships)

If mortality in early life stages was density-independent, then predation, starvation, and oceanographic processes would act independently from number of eggs spawned

If this were true all of the time, what would a graph of spawner to recruit abundance look like?



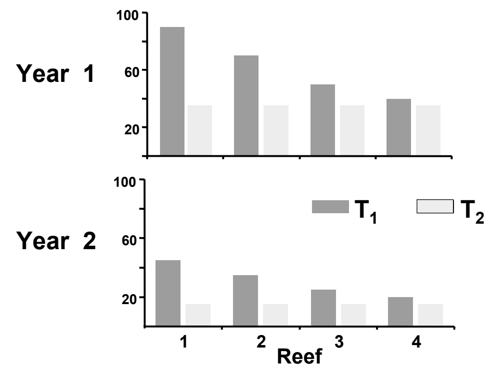
But there must be some ultimate limit to available resources….

-- decrease in mean recruitment per spawner, so density dependence must exist.

Possible explanations:

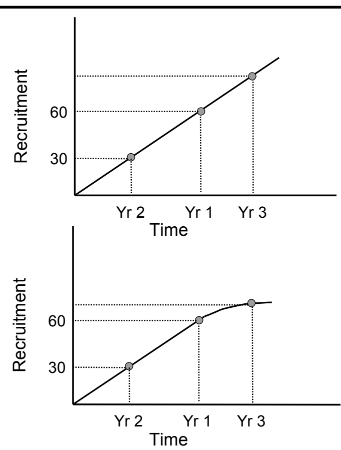
- -- competition between larvae
- -- predation

When spatial ≠ temporal density dependence



Temporal density-independent recruitment

Temporal density-dependent recruitment



Stock-recruitment relationships are important because…

-- they provide a basis for predicting a range in recruitment that is expected for a given size of spawning stock

-- spawner abundance often used an an index of total egg production (egg production per unit stock of biomass may decrease as fishing intensity increases)

…but spawner abundance not directly proportional to egg production (small females produce few eggs per unit body weight)

Theoretical relationships have been used to describe spawner and recruit abundance (stock-recruitment models)

An ideal model should provide
-- a reasonable fit to empirical data
-- pass through the origin
-- not fall to the spawner axis

Assumption: spawner-recruitment relationship constant over time

Problem: Relationships help in understanding how exploitation affects populations but they have been misrepresented. Variance around the mean of the relationship drives short-term stock dynamics

Three density-dependent theoretical models that describe relationships between spawner (*S*) and recruit (*R*) abundance:

a = recruits per unit spawners at low stock sizes
b = the strength of density dependence of the relationship

Beverton-Holt model (1957):

Asymptotic curve with consistently high mean recruitment at high spawner abundance

$R = aS / (1 + bS)$

a increases the height of the asymptote
b increases the rate of approach to the asymptote

Beverton-Holt model (1957):

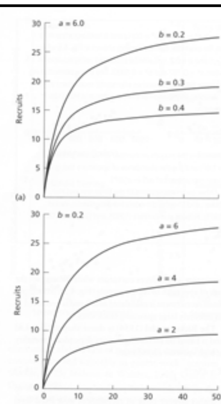


Fig. 4.5 Beverton and Holt (1957) spawner–recruit relationships indicating the effects of (a) changing parameter *b* when *a* = 6, and (b) changing *a* when *b* = 0.2 .

Three density-dependent theoretical models that describe relationships between spawner (*S*) and recruit (*R*) abundance:

a = recruits per unit spawners at low stock sizes
b = the strength of density dependence of the relationship

Ricker model (1954):

Dome-shaped curve based on increasing density-dependent mortality at high spawner abundance

$R = aSe^{-bs}$

a leads to a higher steeper peak in recruitment at a fixed level of spawner abundance
b decreases the height of the peak and reduces level of spawner abundance at which peak occurs

Ricker model (1954)

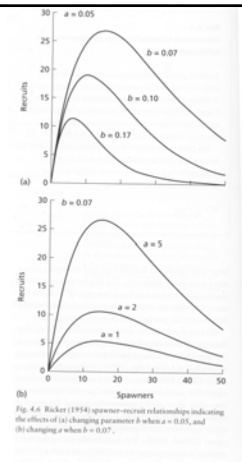


Fig. 4.6 Ricker (1954) spawner–recruit relationships indicating the effects of (a) changing parameter b when a = 0.05, and (b) changing a when b = 0.07.

Three density-dependent theoretical models that describe relationships between spawner (*S*) and recruit (*R*) abundance:

a **= recruits per unit spawners at low stock sizes**
b **= the strength of density dependence of the relationship**

Shepherd model (1982):

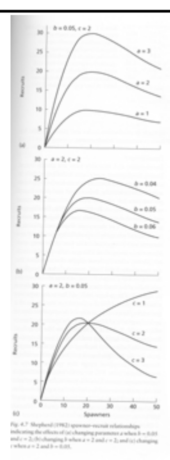
Additional parameter (c) determines the shape of the curve (indication of natural environmental variability?)

$R = aS / (1 + (bS)^c)$

a **= slope of curve at low stock sizes spawner abundance**
b **decreases the height of the peak and reduces level of spawner abundance at which peak occurs**

When c = 0, relationship is density-independent

Shepherd model (1982)



Large variation around stock-recruitment relationship

Often poor fits to empirical data

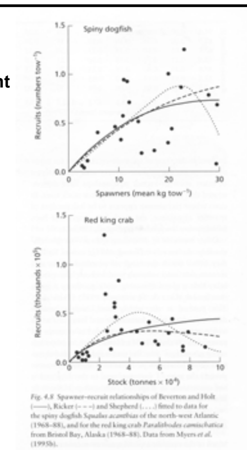


Fig. 4.8 Spawner–recruit relationships of Beverton and Holt (——), Ricker (- - -) and Shepherd (. . . .) fitted to data for the spiny dogfish *Squalus acanthias* of the north-west Atlantic (1968–88), and for the red king crab *Paralithodes camtschatica* from Bristol Bay, Alaska (1968–88). Data from Myers *et al.* (1995b).

Depensation (inverse density dependence)

Lower than expected recruitment success at low population levels

-- could occur if predators ate larvae at a constant rate
-- females fail to find mates when stock size is low
-- fertilization rates of broadcast spawners dependent on sperm concentration

Can also referred to as Allee effect

Depensation may prevent stock recovery from exploitation

What types of species likely would be most affected?

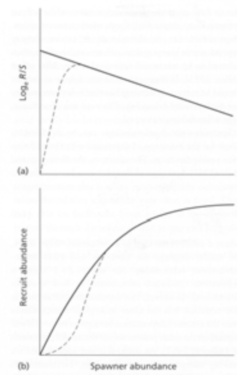


Fig. 4.13 Examples of (a) the relationship between recruits per spawner and spawner abundance when there is compensation (——) or depensation (– – –) and (b) the effects of depensation (– – –) on the mean spawner–recruit relationship.