Basics of Fisheries Science

GMRI Marine Resources Education Program

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Our objective is for you to better understand how the science behind the management decisions is really done.
Definitions:

Population: all the individuals of a species living in a given area. Populations can grow but are limited by space, food, etc. A stock is a sub-group within the larger population.

Rates: Similar to a proportion but can also refer to the change of value between two points in time (e.g. Rate of increase). Examples: Tax rate, interest rate, exchange rate, etc.

Cohort: members of the population all born in the same year (all the same age). Also referred to as a year class.
Definitions:

**Biomass:** combined weight of all the individuals in a population

**Models:** the mathematical representation of some system or process

e.g. $Y = a + bX$ is a model of a straight line

**Population Dynamics:** the processes and factors involved in the maintenance, decline, or expansion of populations
Concepts in Population Biology
Biological populations (humans, fish, trees, bacteria...) are regulated by four primary factors:

- rate of death \( (d) \),
- rate of immigration \( (i, \text{ coming from some other place}) \),
- rate of emigration \( (e, \text{ going to some other place}) \),
- rate of birth \( (b) \).
In order for population to be stable then:

\[ B_t + I_t = D_t - E_t \]
Populations can be stable at different abundances.. as long as the numbers entering equal the number leaving.

If start with a stable population and
Births ↓ and removals ↑ then abundance ↓

likewise

Births ↑ and removals ↓ then abundance ↑
Populations do not have unlimited growth but are regulated by available resources such as food, habitat, etc.

Described mathematically as Logistic growth

(Malthus 1798)

(Verhulst 1838)
Logistic growth

Amount of growth in time period is the growth rate
Logistic growth

Early phase
Logistic growth

Maximum growth

growth rate

growth

maximum growth phase
Logistic growth

Maximum growth

growth rate

growth

late growth phase
Logistic growth

Maximum growth

Maximum abundance
(Carrying capacity)

Abundance

Time

Change in Abundance

growth

growth rate
Carrying capacity will vary among populations or with changes within populations
Population growth
Populations abundance increases by increasing the number of individuals in the population but total biomass of the population also grows by increase in the size of the individuals.
Weight is roughly a cubic function of length: \( wt = aL^3 \)

We can convert length to weight easily.

Yellowtail length-weight

\[
Wt = 0.0000035 \times len^{3.3}
\]
Dividing the information into age categories provides further insight into a population's dynamics.
Striped bass age structure

- 2003: Heavy exploitation
- 2001: Low exploitation
- 1996
- 1993
Growth curve

Atlantic Cod on Georges Bank

Age (Years)
0 3 6 9 12 15 18

Fish Length (cm)
20
40
60
80
100
120
Sagittal otolith

X-ray photo courtesy Dave Conner, Red Lake Department of Natural Resources
How do we age fish?
How long do marine species live?

- Most in our region live 10-15 years
- Striped bass live 25-30 years
- Sand eels live 3-5 years
- Squids live about 18 months
- Ocean quahogs estimated at 200+!
Reproductive Biology
Egg production in fishes is directly related to body weight. Therefore total biomass of mature females is equivalent to total egg production.
So we need female biomass and maturity information to calculate spawning stock biomass (SSB)

Maturity information collected annually on surveys
Female
Gadus morhua
Atlantic cod

- Immature
- Resting
- Developing
- Spent
- Ripe
- Spawning
Georges Bank Cod Maturity Schedule

Maturation varies by species and region

American Dab Maturity Schedule

Maturation is also sensitive to density, temperature, food resources.
MORTALITY
What is it?

- The loss of fish from the population by natural and fishing related causes.

- Estimating the rate of decline or the number of fish that die during some time period, usually 1 year.
Mortality in a population describes a decay process.

Mortality of 1000 fish over 15 Years

Number Surviving vs. Years

Graph showing the decline in the number of surviving fish over 15 years.
Mortality of a fish population is a combination of natural mortality \((M)\) and fishing mortality \((F)\).

Total mortality \((Z)\) is the combination of both.

It is a rate not a percentage. So can exceed 1.0 (not the same as 100%)
**Mortality Rates Relating the two Types**

Total Instantaneous Mortality (Z) vs Total Annual Mortality (A)

- **Important Points**
  - Annual Rates are Percentage Rates
  - Instantaneous Rates are Exponential Rates
  - A Z of 1 = an A of 63%
  - Instantaneous rates are handy because they can be added, subtracted, multiplied, etc.
  - \[ Z = F + M \]
  - Annual rates cannot be manipulated this way
Effects of Different Fishing Rates

Mortality of 1000 fish over 15 years

- F=0.0, M=0.2
- F=0.2, M=0.2
- F=1.0, M=0.2
Why are mortality rates so important?

With them we can:

• Determine the historical size of a stock.
• Estimate current biomass.
• Estimate next years biomass.
• Determine maximum sustainable yields.
Recruitment
What is Recruitment?

New fish entering the population from a previous annual spawning event.
Why is Recruitment Important?

- It is the engine that drives a fishery
- Provides the new fish that sustains the catch in the future!
- If we can estimate it, we can predict future stock status.
- It changes annually based on spawner biomass and environmental factors.
New recruits

Different each year, related to spawning stock size and environmental factors.
Stock - Recruitment
The relationship between the number of mature adult spawners and the number of juvenile fish entering the population
Stock Recruitment Data

Striped Bass Stock-Recruitment

Not a one to one relationship!
A maximum of average recruitment regardless of SSB
Why is the Study of Stock-Recruitment So Important

• Used to forecast potential recruitment

• Understand level of spawning biomass necessary to produce large sustainable catches

• Calculate key values (reference points) for the stock
Often highly variable but still useful. Low SSB results in reduced chance of average recruitment.
Population Dynamics
Population Dynamics: Study of the Vital Rates of Populations

- **Growth** – change in size of the individuals in the population

- **Mortality** – change in the number of individuals in the population from death

- **Recruitment** – change in the number of individuals in the population from births
The Basic Fish Population Model

change in population biomass = \( (G + R) - (M + C) \)

- **additions**
- **subtractions**

\( G = \) growth

\( R = \) births (recruitment)

\( M = \) natural mortality (deaths)

\( C = \) catch (deaths)
Which of these can management control?

Productivity = \((\text{Growth} + \text{Recruitment}) - (\text{natural Mortality} + \text{Catch})\)

Can only **control** catch directly. In theory, can **influence** recruitment growth, and natural mortality.
Density dependence
Key concept in population dynamic models

Density Dependence - the basis for fishery management

What happens with too many fish?

Growth (yield per fish) declines.
Habitat saturated. Run out of room.
Food can become limiting.
What happens if not enough fish?

- Can have too few for mating success.
- May increase predation risk.
- May reduce feeding efficiency.
- Yield to fisheries is very low.
Density processes important in yield models

- Maximum Population is carrying capacity (K). Productivity low.
- Production is greatest if stock size at half its carrying capacity.
- Associated catch is maximum sustainable yield ($MSY$).
- If removals can be replaced by production each year, on average, the fishery is sustainable at that level.