Characteristics of Fish Populations

- Unexploited Populations
  - Recruitment - Birth
  - Mortality (natural)
  - Growth

- Exploited Populations
  - Recruitment and Yield
  - Fishing and Natural Mortality
  - Compensatory Growth
BIDE - Birth, Immigration, Death and Emigration

- $N_{t+1} = N_t + B - D + I - E$, where:
- $N_{t+1} =$ abundance at time $t+1$
- $N_t =$ abundance at time $t$
- $B =$ number of births within the population between $N_t$ and $N_{t+1}$
- $D =$ number of deaths within the population between $N_t$ and $N_{t+1}$
- $I =$ number of individuals immigrating into the population between $N_t$ and $N_{t+1}$
- $E =$ number of individuals emigrating from the population between $N_t$ and $N_{t+1}$
Exponential growth versus logistic growth

Exponentional growth:
\[ \frac{dn}{dt} = rt \]

Logistic growth:
\[ \frac{dN}{dt} = r_m N (1 - \frac{N}{K}) \]
\[ N_{t+1} = N_t + r N_t (1 - \frac{N_t}{K}) \]
Mortality

• Essential component to understand in management
• Natural causes
• Fishing mortality

• \( \frac{dN}{dt} = -ZN \), rate of change in cohort over time, where \( Z \) is the rate of change
Parameters generally using 1 year segments and estimation methods

- **Z** total mortality (instantaneous)
- **M** natural mortality (instantaneous)
- **F** fishing mortality (instantaneous)
- **S** annual total survival \( S = \frac{N_{t+1}}{N_t} = e^{-z} \)
- **S_0** Annual natural survival \( e^{-m} \)
- **A** annual total mortality rate \( A = u + v \)
  - u exploitation rate, v natural mortality rate
Discrete fisheries mortality

• $cf = \text{Conditional fishing mortality (annual)}$
• $cm = \text{Conditional natural mortality (annual)}$

• $u \ (\text{exploitation rate}) = cf = 1 - e^{-f}$
• $v \ (\text{natural mortality rate}) = cm = 1 - e^{-m}$
Other parameters for growth models

- $L_\infty$ Asymptotic length (theoretical max)
- $k$ Growth rate
- $T_0$ Age at zero length
Mortality

• $\frac{dN}{dt} = -ZN$, rate of change in cohort over time

• Integrating and rearranging and integrating this we get:

$$N_t = N_0 e^{-Zt}$$

where $N_t$ is number of fish at time t and $N_0$ is number fish at time 0 and $Z$ is the force of total mortality
Survival is the Opposite of Mortality

- \( S = \frac{N_t}{N_0} \) or \( S = \frac{N_{t+1}}{N_t} \), if survival is comparable over times to consider
- Rearranging and integrating this, substituting \( S \) in the equation before
  \( N(t) = N(0)e^{-zt} \), Then \( N_t/N_0 = S = e^{-Zt} \)
  then take the natural log of that equation and you get
  \( Z = -\ln S \) or \( \ln S = -Z \), or substituted back it would be
  \( = -(\ln N_{t+1} - \ln N_t) \)
Calculation of finite and instantaneous rates

- $A =$ annual mortality $= 9\%$
- $S =$ annual survival rate
- $Z =$ instantaneous total mortality

- $S = 1 - A; \quad 1 - 0.09 = 0.91$
- $S = e^{-z}$
- $Z = - \log_e(S)$
- $Z = - 1 \log_e (0.91) = 0.0943$
Graphical Method for the calculation of mortality, Z

\[ \text{Slope} = -Z \]

- \( \text{Ln Number of fish} \)
- \( \text{Age of Fish} \)
Alternative methods

- \( S = \frac{\sum (N - N_0)}{\sum N} \)

If you are estimating survival from an age series

\( S = \frac{N_{t+1} + N_{t+2} \ldots}{N_t + N_{t+1} + N_{t+2}} \)
Using a catch curve to estimate mortality

\[ \text{Ln Frequency of fish at age} \]

\[ \text{Age of Fish} \]
Assumptions

- Mortality is constant across ages
- Recruitment is constant
- Age sample is a random sample of fish abundance with age
When we add fishing to natural mortality

- Terminology is $Z = F + M$, where $F$ is fishing mortality, and $M$ is natural mortality

- $N(t) = N(0) e^{-(F+M)t} = N(0) e^{-Ft} e^{-Mt}$
Determining Fishing Mortality

• Direct Comparison of Catch and Fishing Effort

\[ \frac{C_2/N_2}{C_1/N_1} = \frac{C_2N_1}{C_1N_2} \]

where \( F \) (fishing mortality) is considered proportional to fishing effort \( f \).
• or \( S = \frac{N_{t+1}}{N_t} \)
Growth (length and weight)

- Age and Growth methods
- Hard parts, length at age, condition factor

- Types of growth rates
  - Absolute increase (incremental; $t_2 - t_1$)
  - Relative growth (incremental divided by intital, $t_2 - t_1 / t_1$)
  - Instantaneous growth $\ln t_2 - \ln t_1$
Growth is often measured in length

• Regulations generally use length limits or slots- gear restrictions can be mesh that includes the body characteristics.
Weight-Length Relations

- \( W = al^b \)
- \( \log w = \log a + b(\log l) \)
- Fulton’s index of condition \( w/l^3 \) or
- Allometric condition factor \( w/l^b \)
Length and weight at age

• \( L_t = L_\infty (1 - e^{-\left(\frac{k(t-t_0)}{k}\right)}) \)

• Von Bertalanffy growth
• \( L_t \) is length at age \( t \)
• \( L_\infty \) = maximum length
• \( k \) = growth rate at which fish approach max
Growth Models

• The individual growth model, published by von Bertalanffy in 1934, can be used to model the rate at which fish grow. It exists in a number of versions, but in its simplest form it is expressed as a differential equation of length (L) over time (t):

\[ \frac{dL}{dt} = r_B L^{1-n} \]

• where \( r_B \) is the von Bertalanffy growth rate and \( L_\infty \) the ultimate length of the individual.
Growth Length over time

\[ \frac{dl}{dt} = K (L_\infty - l) \]
\( \frac{dl}{dt} = K (L_\infty - l) \)

- Looks like \( Y = ax + b \) if
- \( \frac{dl}{dt} = -l (K) + KL_\infty \)

- \( a = -K; \ b = KL_\infty \)
Rate of growth plotted against length
– Von Bertalanffy (1938)

\[ \frac{dl}{dt} = K (L_\infty - l) \]

Integration \[ L_t = L_\infty \left[ 1 - e^{-k(t-t_0)} \right] \]

Annual increment

Slope \[ = -(1-e^{-k}) \]

dl/dt

\[ L_t \quad L_\infty \]
Von Bert

• Considered growth in weight was resultant of difference between anabolic and catabolic factors that were related to surface area and weights
Incremental growth plotted against length at time previous – Ford Walford

\[ \frac{dl}{dt} = K (L_{\infty} - l) \]

Slope $e^{-K}$

\( L_{t+1} \)

\( L_t \)

\( L_{\infty} \)
Growth weight over time

\[ W_\infty = aL_\infty^3 \]
Indices of Condition

• Length and weight of fish can be modeled for populations

• Indices of condition can be interpreted and compared
  – Fulton Condition Factor \( W = aL^3 \), where the cubic relationship is implied, and data are in C (Metric) or K, (English) units with a power correction, \((X \times 10^5)\) to make whole units)
$W/L^3$

- Can best be used to compare same age classes, but does not always show relationship like plots of length and weight at various ages.
- Problem is that many species change their shape as they grow, and therefore the relationship changes.
Relative Weight or Relative Condition Factor $W_r = \left(\frac{W}{W_s}\right) \times 100$

- This would be comparison of sample to that value that is normally seen for the population.
- Example, developed regression equation for each population as opposed to pooled data.
- There is generally a minimum length for which this is valid
Von Bert weight model

- \( W_t = W_\infty \left[ 1 - e^{-K(t - t_0)} \right]^3 \)
Assignment

• Provide for the class an assessment of one of the assigned papers for Thursday

  http://www.cnr.uidaho.edu/fish510/Readings.htm

• Squid
• Sharks
• Red drum
• Paddlefish
• http://fishweb.ifas.ufl.edu/allenlab/courses.html