# Biomass estimation and dynamics

## Direct methods (N x mean w) (8.5 A&IFFD P357)

## Approaches to estimate biomass.

### Overview

Biomass is quantified for a fish stock or population for the standing stock (i.e., how much biomass is in the system) or catch (i.e., how much biomass is removed from the system). Standing biomass is quantified as an absolute biomass or as a relative index of the absolute biomass—catch per unit effort. In general, absolute or relative biomass of the fish stock is quantified during fishery independent monitoring where an agency samples a fish stock without removing the catch. Fishery catch is commonly quantified as biomass because payments for harvested fish related to bulk weight (i.e., total weight of catch) of the catch. Catch data depends on reporting from the fishery and is therefore referred to as fishery dependent. The biomass of fish harvested from a stock can be quantified easily from payment records and is commonly a required condition of inland commercial fisheries licenses issued by management agencies. The approaches to estimate absolute or relative biomass of the standing stock is and catch varies and both are needed to quantify biomass dynamics.

#### Biomass of catch

The biomass of fish harvested can be measured directly as bulk weights or estimated by subsampling the catch.

* Bulks good, no uncertainty in measurement, but no abundance, good for fishery dependent
* Subsampling and estimates of catch fishery independent or if observing fishery operations.

##### Simple Random Sample

* 1. Common
  2. Examples from literature?
  3. Equation to estimate mean
  4. Equation to estimate biomass
  5. Equation to estimate variance
  6. Equation to estimate variance for biomass estimate

##### Stratified random sample

* 1. Why stratify? Sex, season, spawning,
  2. Examples from literature
  3. Equation to estimate mean 
  4. Equation to estimate biomass 
  5. Equation to estimate variance
  6. Equation to estimate variance for biomass estimate

##### Exploiting the length-weight relationship

1. In some instances fish catch is measured for length and weight for a subset of the catch and then length is measured for the remaining catch is measured for length.
   1. Fish catch is commonly subsampled and length and weight take for a subset of the catch and length taken for the remainder of the catch to save time processing fish.
   2. Weight is commonly estimated for fish of a given length from a fitted allometric relationship of weight with length.
   3. Lognormal and bias correction for mean?
   4. Biomass can be estimated as the sum of the predicted weights but the associate uncertainties are more complicated to estimate.
   5. Tree paper
   6. Equation to estimate mean
   7. Equation to estimate biomass
   8. Equation to estimate variance
   9. Equation to estimate variance for biomass estimate

#### Biomass of a stock

1. Estimates from fishery catch (8.5 A&IFFD P353)
   1. Estimation of catch is done through models
   2. Differ in production curve and per capita change in biomass over time
   3. Can be done by catch and an independent estimate of q, biomass and catch
      1. Continuous
      2. Catch only
      3. Needs catch only but cannot be a one-way trip
      4. Needs contrast or perturbation to fit the model
         1. ASPIC
         2. Yield data
         3. Biomass independent
         4. Many different types
         5. Log normal multiplicative error each data stream weighted
      5. SDBDM
         1. Likelihood, sum of ll
      6. Discrete
2. There are 3 classes of biomass dynamic models, the models are the same they differ in how
   1. When done over very small timesteps (i.e., $dt$ 🡪0) then the dynamics are continuous
   2. When done with a timestep of 1 (i.e., $dt$ = 1) then discrete
   3. Some are done where losses to the fishery are done discretely while biomass dynamics continue in a continuously
3. The model structure for the 3 approaches are the same, for example the ODE used to project stock changes in biomass does not change, just the application of $dt$ and in the case of SDBDM the application of removals.
4. Differ in assumptions, continuous assumes biomass removed continuously throughout the year and biomass is gained continuously
5. D-BDM assume that dynamics are occurring instantly between one year and the next if using a year time step
6. SD-BDM assuming biomass is changing continuously but removals can occur over a short period, relaxing the assumption of continuous harvest in the C-BDM.
7. Modeling approaches-mass balance of Ecopath equations
8. Biomass dynamics models: surplus production
   1. What is surplus production
      1. Relate the change in biomass to some process
      2. Change in biomass ($dB/dt$) is then used with current biomass to project future biomass governed by gains and losses of biomass to the stock
   2. Compensation- more biomass is produced (i.e., $dB$) at intermediate biomass levels and fishery yield ($Y$) is maximized at intermediate biomass levels
   3. Depensation
   4. Biomass dynamics models
      1. Exponential
         * Base for most biomass dynamics models
         * Density independent (double check)
         * Colvin carp paper used it, good for invasive species early on before density dependence kicks in

 (1)

 (2)

* + 1. Graham-Schaefer

###### 1954

###### Builds on exponential by adding density dependence.

###### Yield is a function of compensation, where biomass is produced at a higher rate at intermediate biomass levels.

###### Per capita biomass change decreases linearly with increasing biomass

 (3)

 (4)

* + 1. Fox
* Year
* Production curve asymmetric
* Per capita biomass change is concave up

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* + 1. Pella Tomlinson
* 1969 (Pella and Tomlinson 1969)
* Asymmetric
* Per capita

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* + 1. Theta logistic
       1. Theta-logistic (1973)

 ()

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### Biological reference points from biomass dynamics models

* ,
* ,
* 

### Estimating parameters for a C-BDM, SD-BM, or D-BDM

* Fishery dependent
  + Catch and catchability
  + One way trip and contrast
* Fishery dependent and independent
  + Least squares-ASPIC models (Prager)
  + Maximum likelihood (Colvin)

### Model assumptions-differential versus difference

1. There are many assumptions used when biomass dynamics are modeled continuously.
   1. First, rates like the intrinsic growth rate are constant over time.
   2. Second, parameters in the model like carrying capacity remain constant over time.
   3. The decrease in per capita rate of change () depends on the model (Figure XX) and may be linear for the possible levels of biomass, whereas models like XX, xx, and xx relax of a linear decrease.
   4. Lastly, the biomass dynamics model specified by equations 1,2,3,4, and 5 assumes that biomass harvested occurs continuously at rate  throughout the year.
2. Model assumptions used to simulate continuous biomass dynamics models can be relaxed to more accurately reflect dynamics.
   1. For example, rates like the intrinsic growth rate can vary among years which may be a function of temperature?
   2. Similarly, parameters like carrying capacity may vary among years randomly due to some unexplained factor (i.e., random noise) or with environmental conditions.
   3. Example using variable rates and parameters???
   4. Adding environmental noise lead to more conservative estimates of reference points for the PT and Fox (Bordet and Rivest 2014)
   5. It is common in inland fisheries for biomass to be removed in pulses over short time intervals like days to weeks instead of being applied continuously over a year.
   6. Semi discrete biomass dynamics models were developed by Colvin et al. XXXX where harvested biomass was treated as a pulsed removal from a continuous biomass dynamics.
   7. Like Bord and Rvest, Colvin et al found that pulsed removals of biomass from a continuous biomass dynamics model resulted in more conservative estimates of reference points.
   8. The results of studies evaluating reference points like  and  using continuous biomass dynamics models indicate that reference points are likely overestimated when model assumptions are violated.
3. Biomass dynamics can be projected given a starting biomass and values for the model parameters but the approach depends on whether biomass is treated as a continuous or a discrete process.
   1. Continuous biomass dynamics are projected using differential equations and discrete biomass dynamics are projected using difference equations (Hilborn and walters).
   2. The difference between the 2 approaches to project biomass dynamics is the type of rates used.
   3. Instantaneous rates are used to in when differential equations are used to project biomass dynamics continuously.
   4. Interval or finite rates are used for difference equations.
   5. As a general pattern instantaneous rates can are always larger than the corresponding interval rate, however discrepancy between the 2 decreases as the rates approach 0.
   6. Instantaneous rates are applied over very small time increments (i.e., dt 🡪0).
   7. The differences between instantaneous and finite rates is further complicated by the fact that as both types of rates approach 0 they become more and more similar in value.
   8. Reference points (, , )for surplus production models can be found by analytical solution and if an analytical solution does not exist or is not easily derived then simulation can be used to identify reference points.
4. Simulation solutions
   1. In some cases analytical reference points may not exist or be difficult to derive for more complicated biomass dynamic models.
   2. Simulation provides a framework to determine biomass reference

* ?? (Pedersen and Berg 2017)
* Multi species model (Dedah et al. 1999)
* Fox model (Fox 1970)
* (Hakanson and Boulion 2004)
* (Hakanson and Boulion 2003; Hakanson and Gyllenhammar 2005)
* (Laloe 1995)
* (Polacheck et al. 1993)
* (Prager 1994; Prager 2002; Williams and Prager 2002)
* (Randall 2002; Randall and Minns 2000)
* (Ricker 1946)
* (Waters and Huntsman 1986; Waters 1969; Waters 1992)
* (Zhang and Megrey 2010)

## Production estimation (8.7 A&IFFD P360)[tom]

### Concepts and terminology: a vital rate (8.7.1 A&IFFD P360)

### Production estimation methods (8.7.2 A&IFFD P361)

#### Summation methods (A&IFFD P362)

#### Instantaneous Growth Rate and Allen Curve methods (A&IFFD P363)

#### Size-Frequency Method (A&IFFD p366)

### Production to mean biomass (P/B) ratio (A&IFFD P367)

#### Direct estimates

#### Estimates based on life history and allometry

5.4.4 Production estimates in practice (A&IFFD P367)

5.5 Summary and practical considerations []

Variable rates and constants…

Multiple species

Management strategy evaluation (MSE)

Figure X. plot of rate of change (left) plots of per captia rates of change versus biomass (right) for each model presented in chapter

Boxes and descriptions

Box 1. Estimating biomass using direct methods, simple random sample and stratified

Box 2. Estimating biomass using a length weight regression

Solving an ordinary differential equation

Box 3. Projecting biomass dynamics Differential versus difference

Box 4. Sustained yield and F0.1

Box 5. Pulsed removals in continuous biomass dynamics

Box 1 Application of surplus production modeling (Box 8.7 A&IFFD P 358)[Code done; needs narrative]

Box 2. Production estimation based on the instantaneous growth rate method (Box 8.8 p364)[pending]

Box 3. Production estimation based on the Size-Frequency method (P368)[pending]

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