# STOCK ASSESSMENT MODELS AND METHODS

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## Introduction

Fish stocks have an important role in providing cheap protein food, income and employment to millions of people in the world. Judicious management and exploitation of the renewable fish resources is important for sustained production over years. Over fishing leads to disappearance of the renewable fish stocks. Assessment of fish stocks is the first step to determine the level of exploitation necessary for arriving at maximum sustainable yields from the fish resources. Assessment of stocks and study of impact of present level of exploitation on exploited stocks are necessary for maintenance of stocks at maximum sustainable level. Many mathematical and statistical models have been developed and used for fish stock assessment studies. The unique features of fish stocks are, they do not come under visual horizon for direct evaluation of stock sizes, their distribution over space, time and species varies at higher dimension and fish stocks are affected by fishery dependent factors such as effort exerted, size at first capture and fishery independent factors like salinity, temperature, water current etc. The models to study fish stocks should consider the three aspects namely, size of the stock, level of exploitation and effect of fishery independent factors. Multi species and multi gear situation adds to the problem of assessing the fish stock. Stock assessment models satisfying some of these requirements have been developed and successfully used for management of the fishery.

The fish stock assessment models can be categorized as deterministic models and stochastic models. Deterministic models form the major category which is further divided into two class as Macro-analytical models and Micro-analytical models. Stochastic models incorporate random elements into the stock assessment models and deterministic models do not allow chance fluctuations in its construction. Macro-analytical models are used for rough approximation of the existing status of the stocks and these models are simple, require only catch and effort data for different years/time and analysis is straight forward.

## Macro-analytical models

Other names for macro-analytical model are synthetic model and global models. Here the overall net effect of all the factors that control the biomass is considered simultaneously.

In macro-analytical models the change in biomass is expressed as

$B_1 - B_0 = R + G - D$

where $B_0$ and $B_1$ are the initial and final biomass in a year, R is the recruitment, G is the growth and D is the mortality. The relationship of change in biomass ($B_1$-$B_0$) with the biomass B, instantaneous rate of fishing mortality F and the yield Y are considered. Different models under this category are

**Swept Area Method:** In this method the biomass is estimated based on the area swept by experimental trawling and the total area inhibited by the stock taking into consideration the quantity caught and the escapement factor.

**Biomass Approach**: In biomass approach the biomass and MSY are calculated using instantaneous rate of fishing (F), natural mortality rate (M) and intrinsic rate of increase of population (r).

**Surplus Production Model**: This is under the assumption that when a stock is exploited the change in its biomass depends on its intrinsic rates of natural growth and the catch.

1. Schaefer model: When a stock is exploited its biomass decreases and Scheafer used a linear representation for the relationship (biomass function) and obtained the famous logistic growth curve. He thus obtained MSY and corresponding effort by equating the derivative of the equation to zero.
2. Exponential model: Here the functional relationship is taken as non-linear (exponential) relationship.
3. Pella and Tomlinson model: This is a generalization of the surplus production model by proposing a general functional relationship for the biomass function.

**Successive Removal Methods**: These models are under the assumption that the change in stocks is only due to catch removals and during fishing no other change takes place in the stocks.

1. Leslie method: Assuming catch per unit of effort as an index of the stock abundance he took catch per unit effort as proportional to the stock size.
2. De Lury method: This is a slight modification of Leslie method. By assuming that the fraction of stock removed by a unit of effort is very small he obtained an approximation for stock size.
3. Ricker method:

**Capture-Recapture Methods**: In capture-recapture methods the method of estimation of stock is based on probability distribution of the situation especially the hypergeometric probability distribution for single release of marked ones. Also, there are methods covering multiple release and recapture for both closed and open sytems.

1. Hypergeometric model: This is based on the conditional probability distribution of recovery of $m_2$ marked ones in $n_2$ number of fish caught with a total of $n_1$ fish marked and released.
2. Bailey-inverse sampling method: In this method the sampling of animals is continued till a prefixed number of marked fish are recaptured. The probability distribution of the particular situation is then used to estimate the stock size.
3. The generalized hypergeometric method: In this case the joint distribution of a set of random variables are derived and based on the structure of the model the stock size is estimated.
4. Inverse Schnabel census: This is an extension of the inverse sampling procedure combining the generalized hypergeometric method.

**Relative Response Model:** This model depends on successive cathes to predict the maximum catch that the fishery can sustain under the assumptions that, stocks existing in a particular area are exploited by various types of gears that are not species specific, the fishing is increased over a period of time till the optimum level is achieved and when the effort is increased the catch also increase till a maximum level is reached.

**Quick Estimates:** In the absence of earlier history, when the fishery is in progress, it is desirable to have quick estimates based on known statistics.

1. Comparison method: On the basis of yield gradients based on catch or primary productivity of known areas, production in other areas having similar characteristics can be estimated.
2. Indicator method: If an indicator or potential yield that is easily and quickly measurable is available then that indicator can be profitably used for assessing yield.
3. Productivity approach: Knowledge on production at successive trphic levels is required in this approach. Due to the complexity of the trophic relationships the results vary widely.

## Micro-Analytical Models

Micro-analytical models otherwise known as dynamic pool models take into account recruitment, mortality, age, growth and all other factors affecting stock. These models are based on the assumptions that the stock under study is in a steady state (recruitment, growth and mortality are constant) and the yield is directly related to the recruitment. Under this assumptions yield-per-recruitment (Y/R) will be and index of stock. Different models under this category are

1. Beverton and Holt model
2. Jones method
3. Ricker model: He proposed a simple method with no assumptions on the form of growth. The average biomass is obtained first from the successive biomass estimates and substituted it in the yield equation to obtain the final equation for the yield.
4. Cohort analysis: In cohort analysis estimates of stock sizes for different age/size classes are made recursively starting from the terminal class back words to finally end at the initial size assuming a constant fraction for the terminal class exploitation rate. Also, the instantaneous rates of fishing and natural mortalities are assume to be known for this exercise.
5. Thompson and Bell model