Chapter 12

Fish Stock Assessment Method: Virtual Population Analysis

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The basic purpose of fish stock assessment is to provide advice on the optimum exploitation of aquatic living resources such as fish and shrimp. In fisheries, optimum exploitation is called Maximum Sustainable yield (MSY). Fishing effort level which gives the Maximum Sustainable yield is indicated by Maximum Sustainable effort. The understanding of concept about stock is very essential in fisheries before applying the fish stock assessment method. Stock can be defined as sub-set of one species having the same growth and mortality parameters, and inhabiting a particular geographical area. Growth parameters are numerical values in an equation by which we can predict the body size of a fish when it reaches a certain age and mortality parameters reflect the rate at which the animals die *i.e.* the number of deaths per time unit.

Models

Fish stock assessment use tools for linking between input and output called "models". Basically, two type of model are applied in fish stock assessment *i. e.* holistic models and analytical models. Holistic models use fewer population parameters than the analytical models. Holistic models consider a fish stock as a homogeneous biomass and also do not take into account the length or age-structure of the stock e. g. Swept area method, Surplus production model. Whereas, analytical models are based on a more detailed description of the stock and more demanding in terms of quality and quantity of the input data. Analytical models give more reliable predictions in comparison to holistic models. Also analytical models are age-structured models. The basic concept in age-structured models is that of a "cohort". A "cohort" of fish is a group of fish all of the same age belonging to the same stock. Basic ideas of the analytical models are, if *there are "too few old fish" the stock is overfished and the fishing pressure on the stock should be reduced* and *if there are "very many old fish" the stock is underfished and more fish should be caught in order to maximize the yield*.

Virtual population analysis

Virtual population analysis (VPA) is a modelling technique commonly used in fisheries science for reconstructing the historical population structure of fish stock using information on the deaths of individuals due to fishing and natural mortality in each time step. VPA calculates the number of fish alive in each cohort for each past year by observing the commercial fisheries and helps fishery scientists to predict the future catches from the stock. It is also called cohort analysis because each cohort is analysed separately. The idea behind the method is to analyse that what can be seen, the catch, in order to calculate the population that must have been in the water to produce this catch. The total landing from a cohort in its lifetime is the first estimate of the numbers of recruits from that cohort.

The basic equation for VPA is

Number alive at beginning of this year	=	Number alive at beginning of next year	+	Catch of this year	+	Natural mortality of this year

VPA is based on three equations;

1. C (y, t, t+1) = N (y, t) * $[\frac{F(y,\ t,\ t+1)}{M+F(y,\ t,\ t+1)}$*{1-exp(-z)}]
2. C (y, t, t+1) = N (y+1, t+1)$*\frac{F(y,t,t+1)}{M+F(y,t,t+1)}$ [exp {F*(y, t, t+1)+M}-1]
3. N (y, t) = N (y+1, t+1) *exp [F (y, t, t+1)+M]

   Where, C (y, t, t+1) = number caught between age't' and age 't+1' in 'y' year

   N (y, t) = No. of survivors in the sea with 't' age in starting of 'y' year

   N (y+1, t+1) = No. of survivors in the sea with 't+1' age in starting of 'y+1' year

   F = Fishing mortality coefficient and M= Natural mortality coefficient

Age-based cohort analysis (Pope's cohort analysis)

Pope's cohort analysis is the version of VPA developed by Pope (1972). It is based on an approximation. The catch is taken continuously during the year, but in cohort analysis the assumption is made that all fish are caught on one single day. Consequently in the first half year the fish suffer only natural mortality so the number of survivors on 1 July becomes:

N (y, t + 0.5) = N (y, t) * exp (-M/2)

Then, instantaneously, the catch is taken and the number of survivors becomes:

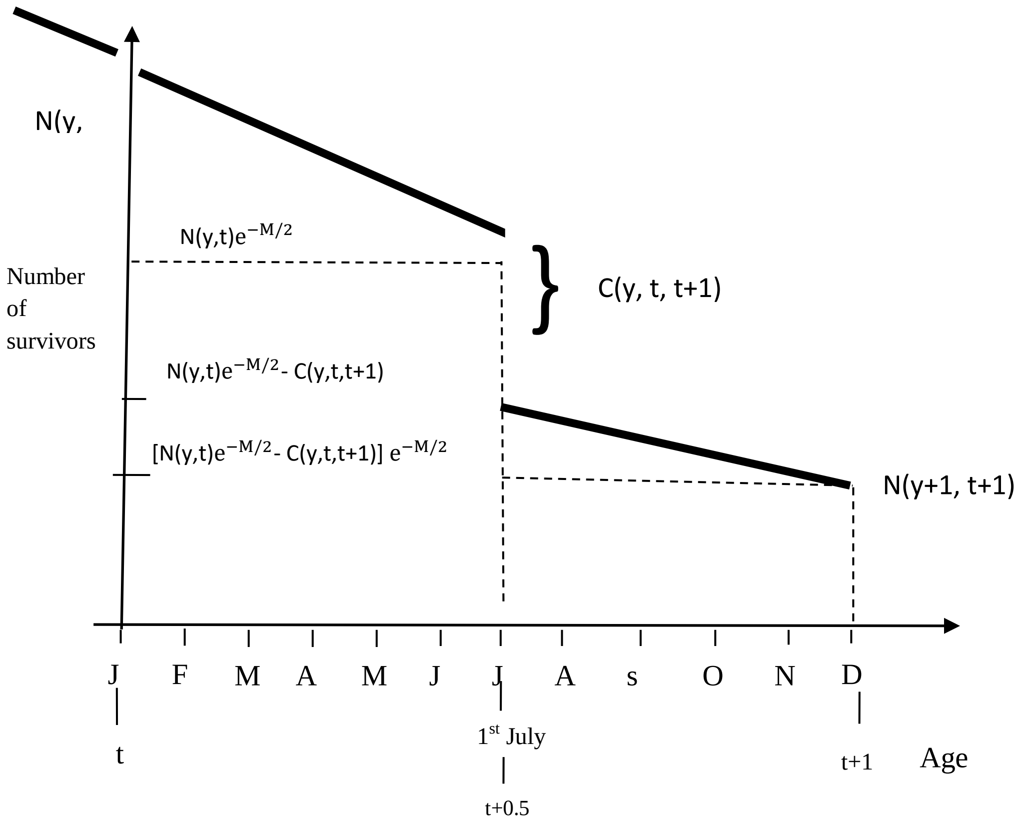
N (y, t) * exp (-M/2) – C (y, t, t + 1)

This number of survivors then suffers further only natural mortality in the second half year and finally the number of survivors at the end of the year is:

N (y+1, t+1) = (N (y, t) * exp (-M/2) – C (y, t, t+1)) * exp (-M/2)

For convenience of calculation this equation is rearranged as:

N (y, t) = (N (y + 1, t + 1) * exp (M/2) + C (y, t, t+1)) * exp (M/2)



Diagrammatic representation of age-based cohort analysis

Jones' Length-based cohort analysis

It *is length based cohort analysis* and based on the assumption of all length (or age) classes caught during one year reflects a single cohort during its entire life span. Example for length-based cohort analysis is length composition of total catch of hake (*Merluccius merluccius*):

Length group (cm) L1-L2	Number caught ('000) C(L1, L2)	Length group (cm) L1-L2	Number caught ('000) C(L1, L2)
6-12	1823	48-54	653
12-18	14463	54-60	322
18-24	25227	60-66	228
24-30	8134	66-72	181
30-36	3889	72-78	96
26-42	2959	78-84	16
42-48	1871	84-∞	46

Here length group is converted into age intervals by the inverse Von Bertalanffy equation:

$t(L1) = t_0 - \frac{1}{K} * \ln[1 - \frac{L1}{L\infty}]$, therefore, $\Delta t = t(L2) - t(L1) = -\frac{1}{K} * \ln[\frac{L\infty - L1}{L\infty - L2}]$

To convert the cohort analysis equation into a length-based version, only the term

exp [(M* Δ t)/2] has to be changed. This is done by substituting Δt with following equation:

$$\exp[(M^* \Delta t)/2] = \exp[\frac{M}{2} * \frac{1}{K} * \ln(\frac{L\infty - L1}{L\infty - L2})] = \exp[\ln\left(\frac{L\infty - L1}{L\infty - L2}\right)^{\frac{M}{2K}}] = (\frac{L\infty - L1}{L\infty - L2})^{\frac{M}{2K}}$$

It is convenient to use a symbol instead of this complicated term, therefore we introduce the symbols:

N (L1) = N [t (L1)] = Number of fish that attain length L1
= Number of fish that attain age t (L1)
(also called the number of survivors)

N (L2) = N (t (L1 + Δ t) = Number of fish that attain length L2
= Number of fish that attain age t (L2)
[= t (L1) + Δ t]

C (L1, L2) = C (t, t + Δ t) = Number of fish caught of lengths between L1 and L2

= the number of fish caught of ages between t (L1) and t (L2)

H (L1, L2) = $\left(\frac{L\infty - L1}{L\infty - L2}\right)^{\frac{M}{2K}}$

Now equation can be rewritten using these length-based symbols, as:

N (L1) = [N (L2) * H (L1, L2) + C (L1,L2)] * H (L1, L2)

C (L1, L2) = N (L1) * $\frac{F}{Z}[\,1 - \exp(-z * \Delta t)]$

Limitation

1. Natural mortality of cohort at age't' (M) is constant.
2. It deals with the population dynamics of single species, whereas natural fish populations almost always interact among themselves and with others.

Further reading

Pope J. G., 1972. An Investigation of the Accuracy of Virtual Population Analysis Using Cohort Analysis. *ICNAF Research Bulletin* 9: 65-74.

Sparre, P and S.C. Venema 1992. Introduction to Tropical Fish Stock Assessment. Part I. Manual. FAO Fisheries Technical paper, No. 306.1. Rev1. Rome. FAO. 376 pp.