J. mar. biol. Ass. India, 1989, 31 (1 & 2) : 167-171

A BRIEF ACCOUNT ON STOCK ASSESSMENT MODELS AND ESTIMATION OF PARAMETERS SUITED TO TROPICAL FISH STOCKS*

K. Alagaraja

Central Marine Fisheries Research Institute, Cochin-682 031

Abstract

Many stock assessment models are available in the literature for assessing fish stocks under the major groups namely macro and micro analytical models.

Important stock assessment models suited to tropical fish stocks have been considered and their relative merits indicated in this paper. Methods of estimation of parameters for assessing exploited fish stocks, with suitable examples have been presented.

Introduction

Tropical marine fishery resources differ from their temperate counterparts on many aspects. Unlike temperate resources, these in tropics in general are short lived with fast growth and spawning is continuous and that too with fractional spawning. The effort expended also is quite complex in which it is neither species specific nor gear specific. As India is multilingual, multireligious, multiracial and what not, so also Indian fisheries are of multigears operated on multi-species thus making fish stock assessment difficult. However, methods for stock assessment, suitable to specific conditions obtaining in these waters have been considered in this paper. The problems faced while using length frequency data have been indicated. Appropriate methods under micro and macro analytical models for stock assessment have been highlighted.

Relevance of Length Frequency Data

Data requirements for assessing fish stocks are well known. Once age structure of a stock with their relative frequencies is known, estimation of total instantaneous mortality rate 'Z' becomes straight forward. Aging fish is found to be relatively difficult in tropical fish stocks for the very nature of stocks mentioned above. Using hard parts, attempts have been made in temperate waters for finding out the age structure of fish stocks. The variability encountered in this approach is highlighted by Chelton and Beamish (1982). These authors emphasize that such techniques should be validated each time when applied to a different population or stock. They even go a step further stating that a technique valid for younger fish need not be valid for older fish and the process of estimating the age of fish should never be taken for granted. If it is so far temperate stocks one can imagine the problems faced in the case of tropical stocks. In the absence of any reliable periodic marks

* Presented at the 'Symposium on Tropical Marine Living Resources' held by the Marine Biological Association of India at Cochin from January 12-16, 1988.

on the hard parts of tropical stocks attention is drawn to length frequency data to obtain information on growth and mortality.

While dealing with length frequency data, the source of their availability has to be taken into consideration while estimating parameters. In this context the nature of effort expended for exploitation plays a vital role. Nature of effort as indicated earlier is such that no gear is species specific. Multigears operate on multi-species resulting in a catch consisting of species in various size ranges need not necessarily represent the stock structue of each exploited species. Non-selective gears such as trawls have undergone changes particularly in their cod end mesh sizes over the years thus making the data over the years not easily comparable. Apart from this, selective gears such as gill nets are also not uniform in the sense that each net having many pieces has different mesh sizes in each piece leading to differential fishing mortality at different length segments of the stock. Hence one can imagine that in the presence of a large number of gears of different natue, how difficult it would be to estimate the fishing mortality of the exploited fish stocks in tropics. Assuming the knife edge selection in the non-selective gears like trawls and the length frequency of the stocks particularly of the target species to represent the structure of the exploited stocks in the population, stock assessment is attempted using existing methods applied to temperate waters with suitable modifications. Target species for trawls happens to be penaeid prawns, this group has been considered as an example for stock assessment.

The author is grateful to Dr. P. S. B. R. James, Direetor, Central Marine Fisheries Research Institute, Cochin for the encouragement in the preparation of this paper.

Nature of Stocks

Due to their short life, fast growth and continuous spawning nature together with the complexity of effort the modes encountered in the samples raise three important questions namely whether these modes are growth modes, if so are the periods between modes uniform and if so what is the period whether it is monthly, bimonthly, etc. Unless these points are ascertained further work has no meaning at all. To overcome this difficulty one assumption made in length based approach is that the growth follows von Bertanlaffy growth (VBG). In addition if one has an idea about the maximum ideal length l_∞ and the growth rate, t becomes easy to fix up the modes to satisfy these three requirements.

Estimation of Parameters

Estimation of l_∞, k and t_0, the parameters of VBG becomes simple and straight forward once the modes are identified and their periodicity ascertained. Elefan approach of Pauly and David (1981) assumes the available modes as the true modes which is the basic drawback of this method, and tries to locate that combination of l_∞, k and t_0 for which the curve passes through the maximum number of modes. In ideal conditions this may work well leading to a unique solution. Otherwise it does not give a unique solution. In addition this method requires sophisticated calculator. The example given here takes into account the following.

1. The modes available from the data are approximate ones hence precise modes have to be found out using any of the methods for resolving multimodal normal group into unimodal ones. For this purpose different method is used and modes identified in this example.
2. The modes thus available need not be equi-spaced, in other words the period between two modes need not be the same for all modes.
3. Due to fast growth, short life span and continuous spawning, tracing a cohort

may not be possible after a certain period. Thus the number of successive modes traceable becomes very few.

4. Available biological information on maximum life span and $l\infty$.

5. Growth in length follows VBG.

Straight line method (Alagaraja, 1984) tries to estimate $l\infty$ and k and at the same time helps one to find out the period between two modes. In the example (Alagaraja *et al.*, 1986) a set of modes in mm at Sakthikulangara for *Parapenaeopsis stylifera* males is 54.10, 64.58, 74.54 and 80.5. As it is well known that to follow VBG, modes should be neither in arithmetic (AP) nor in geometric progression (GP). In this example the first three modes are in AP. Omitting the first mode, the estimate of $l\infty$ obtained from the rest is 87.39 which is too low to be considered. As such the entire set of modes could not be considered for estimating $l\infty$ and k. In the case of *P. stylifera* females the set of modes is 51.06, 68.89, 90.86 and 105.46. The successive differences between modes are 17.83, 21.97 and 14.60. The second and third differences when compared to the first indicate the period of time between latter modes may not be the same as in the case of first two modes and period may be twice that of the first. With this assumption and having unit of time as a month the time difference between the mode second and third as well as the third and fourth modes is taken as two months and the estimate for $l\infty$ on this basis comes to 134.38 and for e^{-K} it is 0.8152 which appears to be reasonable. Selecting time unit as a month is also justified since the life span of this group is expected to be less than two years. The equation

$$l_{t+1} = l_{\infty}(1 - e^{-k}) + e^{-k}\, l_t \; \ldots\ldots (1)$$

is used to estimate l_{∞} and e^{-k}.

For the estimation of 'Z' from length based data also the assumption that growth in fish follows VBG is used. On that basis age converted approaches of Pauly (1983) and Jones and von Zalinge (1981) have been developed with few more assumptions. In these two approaches regression lines are obtained and estimate of 'Z' from a regression line will give a precise estimate of 'Z' of the stock exploited. But in practice it is noticed that for different size segments, widely varying estimates of Z are encountered. This fact will not be brought out by the two methods mentioned above. Alagaraja (1984) has developed a method for estimation of 'Z' giving estimates for each length interval. From the group of such estimates of 'Z' those estimates which are outliers from the acceptable limits for 'Z' may be kept aside and the rest of the estimates may be considered for their mean and standard deviation. This estimates of 'Z' (mean) is normally found to be conservative when compared to other estimates obtained from those of Pauly (1983), Jones and von Zalinge (1981) and Beverton and Holt (1957). To explain the advantage of the method of Alagaraja (1984) over that of Jones and von Zalinge (1981) an example from Jones and von Zalinge (1981) is considered below.

Following are the estimates in numbers against the carapace length (not the total length as done in India) for the *Penaeus semisulcatus* malss in Kuwait waters by the industrial fishery for the year 76/77 and the estimates of Z/k using the method of Alagaraja (1984).

Carapace length	Nos. ($X\ 10^6$)	Z/k
18.15	0.450	— 11.994
22.15	3.160	5.783
25.17	1.216	1.118
27.58	1.030	0.000
29.06	1.030	— 2.545
30.87	1.490	6.242
33.16	0.380	3.702
36.19	0.089	0.315
40.50	0.062	

$l\infty$ (42.51 mm) and k (2.80 annual) have been estimated for this stock.

For Jones method the end points alone are omitted when they do not lie on a straight line. The data with the values — 2.545 and 0.000 are considered in Jones method. In the case of Pauly's method when descending right limb of the catch curve is to be considered then the last phase length groups alone need be taken. In that case the last three estimates of Z/k are alone under consideration. In practice where wide variations are encountered, it is worth to consider the major portion of the length frequency data from where descending right limb is discernible. Even in such cases, as seen here, wide variations in the estimates of Z/k may be encountered. Omitting such values that are not realistic, in this case the zero and negative values, the rest of the values vary in 0.315—6.242. The corresponding estimates of Z vary in 0.6552—12.98. From the rest, estimate of Z can be calculated. This is the advantage of the method suggested by Alagaraja (1984). The formulae for estimating M (Pauly, 1983) and Z (Wetheral *et al.*, 1987) are not based on critical evaluation of the data base and hence to be used with utmost care.

Once the estimates for growth and mortality rates are obtained, the rest follows using Beverton and Holt (1957) yield-per-recruit model.

Among the macroanalytic models, Schaeffer's model (Schaeffer, 1957) has been widely used to assess exploited fish stocks. In this model the basic assumption is that the exploitation is done on the surplus production. In other words under equilibrium conditions catches are taken out of the resultant yield obtained from P=R+G—Z where P represents surplus production, R the recruitment, G the growth and Z the mortality. In the heavily exploited fish stocks the yield need not necessarily be from the surplus production. This basic assumption may not hold good in many of the fisheries and there is no way of finding out whether the catches are obtained from surplus production. Moreover in any commercial fisheries, effort is adjusted to the availability of the resources. Hence a direct relationship between catch and effort need not be present in such cases. The relative response model (Alagaraja, 1984) takes into consideration these points and the catches of successive periods alone are considered to find out the maximum yield a fishery is capable of giving. Using this method the exploitable shrimp resource in India from the presently exploited region has been estimated at 1.70 million tonnes.

In the light of the above, it may be clear that a person using a method should first understand the basic assumptions involved in the method and decide accordingly about its suitability for the application.

References

Alagaraja, K. 1984. Simple methods for estimation of parameters for assessing exploited fish stocks. *Indian J. Fish.*, 31 (2) : 177-208.

———, M. J. George, K. Narayanakurup and C. Suseelan 1986. Yield-per recruit analysis on *Parapenaeopsis stylifera* and *Metapenaeus dobsoni* from Kerala State, India. *J. Appl. Ichthyol.*, 2 : 1-11.

Beverton, R. J. H. and S. J. Holt. 1957. On the dynamics of exploited fish populations. *Fishery Investigations, H.M.S.O., London*, 19 (11) : 433 pp.

Chilton, D. T. and R. J. Beamish 1982. Age determination methods for fishes studied by the Ground fish program at the Pacific Biological Station. *Can. Spec. Pub. Fish. Aquat. Sci.*, 60 : 102 p.

Jones, R. and von Zalinge 1981. Estimation of mortality rate and population size for shrimps in Kuwait waters. *Marine Science*, 2 : 273-288.

Pauly, D. 1983. Some simple methods for the assessment of tropical fish stocks. *FAO Fish. Tech. Pap.*, (234) : 52 p.

——— AND N. DAVID 1981. ELEFAN 1, a Basic program for the objective extraction of growth parameters from length frequncy data. *Meeresforch.*, **28** (4) : 205-211.

SCHAEFER, M. S. 1957. A study of the dynamics of the fishery for yellow fin tuna in the eastern tropical Pacific Ocean. *Bull.* 1, *AFTC*, **2** (6) : 247-285.

WETHERALL, J. A., J. J. POLOVINA AND S. RALSTON 1987. Estimating growth and mortality in steady state fish stocks from length frequency data. *In* : D. Pauly and G. R. Morgan (Ed.) *Length based methods in fishery research.* ICLARM Conference Proceedings, **13** : 438 p.