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PROF. N. BALAKRISHNAN NAIR
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Department of Aquatic Biology and Fisheries
University of Kerala
Trivandrum 695 007, India

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Fishery Resources Assessment–A Challenge

K. ALAGARAJA

1. Introduction

Among the living resources, fishery resource in India plays a very dominant role in all facets of national development. Being a renewable and a very valuable resource it demands attention from all quarters for its rational exploitation and judicious management for reaping sustainable yields. The marine product exports in 1997 have almost reached the level of Rs. 4000 crores, a tremendous progress indeed! Thus having been established as an important foreign exchange earner, marine fish landings, however, fluctuates around 2.6 million tonnes per annum. Hence there is a need to know whether there is any scope to increase marine fish landing from our EEZ of about 2.0 million km^2. It has been pointed out that the presently exploited near shore regions extending to 50m depth, have no more scope for providing more catches. The offshore and deeper areas are the promising ones to further the landings from marine sector.

In the case of inland sector, there is no systematic procedure of arriving at estimates. From the capture fisheries side it is roughly estimated that about 2.1 million tonnes could be the annual landings. These landings are contributed by the rivers, estuaries, lakes, backwaters, reservoirs and impounded water bodies such as ponds. The very nature of these resources–so diverse in their magnitude and distribution and irregular and untimely landings from these resources make assessment of the landings a very difficult task. From the culture fisheries sector which is emerging as a potential resource to augment fish production, the present annual estimate is about 1.0 million tonnes in addition to 100 thousand tonnes from brackishwater aquaculture.

We shall see the involvement of fish with man and general characteristics of the resource comparing with other known living resources.

From time immemorial fish plays a vital role in all aspects of human development. In the religious point of view, Matsya Avatara is the foremost incarnation of Lord Vishnu in Hindu mythology invoking reverence and devotion to fish. It is the fisherman, who was caught in the divine mesh of Lord Jesus as the first disciple. During the sermon on the mount by Him, distribution of fish to all clearly brings out the limitations of the fishery resources even at that time and at the same time indicating their inexhaustiveness due to judicious distribution. The composer of Vedas, Shri. Vyasa, is a son of fisherwomen. Lord Siva assumes a form of a fisherman to win the hand of a fishergirl, his beloved Uma. Aesthetically also beautiful eyes mean they are fish shaped. The divine consort of Siva is fish eyed otherwise called Meenakshi. In Philosophy also fish has its role. Live in the world unattached as the fish in the water, is the adage. Many political wars were fought in the name of fish. Lord Krishna and Arjuna winning their respective brides is by shooting fish. Pandyas of South India had fish as their state emblem. Recently Iceland and England were about to fight a war on their fishing rights. In the social side Bengalis consider fish as an important item in all their social functions. Nutritionally fish stands foremost among the nonvegetarian items. Economically this item gives much needed employment to millions of people in the globe and nations bestowed with fish wealth earn substantially through marketing fish products. Scientifically, study of fish remains a puzzle and hence interesting even now.

Fishery resources differ from other living resources on two major accounts. Variations in the availability over space and time and size variations within species and in their sex compositions and in number of species encountered during a season are so wide so that it remains a challenge for obtaining a representative sample, properly reflecting their distribution in the environment. Secondly what is below a sheet of water is anybody's guess. Since fishery resources remain beyond the visual horizon, many of their behavioural aspects and the impact of fishery independent factors such as salinity, temperature, and currents on them are not easily observable for quantification. Factors that affect the exploited fishery resources are grouped under fishery independent factors indicated above and fishery dependent factors such as the nature of effort, its intensity and magnitude of each unit of effort. The impact of fishery independent factors on the resources are not visible in contrast to those of dependent factors. Fishery independent factors are not controllable whereas fishery dependent factors are controllable. The changes in the fishery independent factors over a long period may be expected to remain more or less at same levels hence remaining stable over a period of time. Stock assessment models take advantage of this last assumption and are built under stable or equilibrium conditions of the fishery independent factors. Models that depend on factors at macro level such as catch and effort are called analytic models. Models that require information at micro level such as growth and mortality come under micro analytic models. Most of these models still remain deterministic due to the complexity and wide range of factors affecting stocks. Addition of stochastic element poses a challenge in building stock assessment models and in obtaining relevant data with required precision.

2. Estimation of Exploited Fish Stocks

Marine sector: Capture fisheries in this sector is at present confined mostly to 50m depth yielding about 2.6 million tonnes annually. From the rest of the EEZ covering almost two thirds of the total area, the contribution at present is less than one percent. Most of the landing from the intensively exploited inshore regions are brought to fixed landing centres numbering about 1400 distributed all over the coastline of the main land. These landings are covered by a well designed sampling scheme developed and improved over the last four decades by the Central Marine fisheries Research Institute on the basis of its vast experience in this field and the researches made in the initial stages by the ICAR Scientists.

In the stratified multistage random sampling design of the CMERI the stratification is over space and time, a two dimensional one. The stratification over space is made by dividing each maritime state into suitable, non overlapping zones on the basis of fishing intensity and geographical considerations. The stratification over time is a calendar month. One zone and a calendar month is a space time stratum and primary stage sampling units are landing centre days. In a month of 30 days and a zone of 20 landing centres the total number of sampling units is 600. In the selection of PSU a combination of cluster and systematic sampling is used. For this purpose 30 days are grouped in three ten day groups. From the first ten days three consecutive clusters of two days each totalling to six days, are selected. For the first cluster a day from the first five days is selected randomly and the consecutive five days are taken to form 3 clusters of two days each. For example if the first day selected is third day then (3, 4), (5, 6) and (7, 8) are the 3 clusters with the respective dates mentioned in the brackets. With the sampling interval of 10 days the other two sets of three clusters each are taken from the rest of the two ten day groups. *viz*: (13, 14), (15, 16), (1? 18), and (23, 24), (25, 26), (27, 28). From the list of landing centres (1. c) in a zone, nine 1.c.ds are selected SRSWR and one 1.c are associated with one of the above selected clusters. In a cluster of two days, data are collected at the selected 1.c. from 12.00-18.00 hrs. of the first day and 0.6.00-12.00 hrs. of the second day and data on the night landings if any, covering 18.00 hrs. of the first day to 06.00 hrs. of the second day are obtained by enquiry. Thus a 24 hr. coverage is made from a 1.c during the two days of the cluster amounting to a single landing centre day (1.cd) coverage. In practice this approach is found to be cost saving and the sampling is well spread over the entire month. In this approach out of 600 1.c.ds nine 1c. are selected for sampling. Combination of sampling procedure in finally arriving at nine 1.c.ds requires more detailed study to find out the validity of the assumption that this selection of nine out of 600 is very near to a SRSWAR and at primary stage level the sampling error is almost negligible.

During each observation period no. of units landing to be selected is as follows:

No. of units landed	Selection of units
≤-15	All
16-19	All the first ten and 1 in 2 from the next
20-29	1 in 2
30-39	1 in 3
40-49	1 in 4
	and so on

Thus in this systems total No. of units selected for detailed observation is at least 10 whenever the total No. of units landed exceeds 10. Here also a constrain is imposed on the No., of units to be selected and the selection is systematic. These units form the second stage units. In this case also the efficiency of such sampling may be studied.

In the third stage from the selected second stage units fish baskets are selected at random for assessing species wise contribution. In the fourth stage from the selected baskets biological samples are taken for detailed studies on length distribution, sex ratio, maturity stages etc.

Inland sector: As indicated earlier there is no regularity either in the landing pattern over time or space and the disposal of catches are too diversified to keep track of the catches. Alagaraja (1988) has suggested a scheme of coverage of the capture fishery sector for arriving at a reasonable estimate. At present a few pockets of vast regions of inland water resources have been covered under sampling scheme such as the estuarine systems of the Hooghly-Matlah, the Godavari and the Mahanadi, a few stretches of rivers like the Ganda, the Narmada and the Godavari and lakes such as the Chilka, the Pulicat and the Vembanad.

Attempts have also been made to formulate a suitable sampling scheme for the estimation of fish catch from tanks and ponds such as the pilot surveys by ICAR during 1955-'59, by the National Sample Surveys in 1958 and subsequently during 1962-'63 and 1973'75 and by the Indian statistical Institute during 1960-'61. All these surveys have more or less the same sampling programme in that, information on extent of water resources and fish catches from them is sought combining enquiry cum direct observation. This approach no doubt poses problems in arriving at valid estimates of error. Hence this area still remains a challenge.

In this connection Alagaraja (1988) suggested suitable sampling programme taking into consideration the pattern of disposal of fish catches from Inland water system. Disposal of fish may be considered under three major heads viz. 1. markets 2. subsistence fishery and 3. disposal at the landing site. At present no reliable statistics exist on the quantities disposed under these heading for any region. Bulk catches from organised capture or culture operations are normally brought to the markets. Identifying fish markets and covering them under a suitable sampling design do not pose a problem. Regarding small scale fishing taking place along river stretches, catches are normally utlised for subsistence or taken by hawkers. A separate sampling scheme for this purpose may be considered. The catches from reservoirs, lakes etc. are mainly brought to fixed landing centres. These landings may also be covered under a suitable sampling programme. Regarding the disposal of bulk quantities of fish for wedding parties in West Bengal enquiry cum observation method can be used. In addition catches from rivers can easily be identified and separated from the fish obtained from ponds etc. Hence for a given region the difference in the estimates of river catch from direct sampling and market sampling may indicate the quantity taken for subsistence and thus an estimate on catch taken for subsistence may be made available from such sampling scheme. In this type of approach at least for the major part of the catch, estimates may be obtained along with their valid estimates of error. As such this area also remains a challenge to sample survey specialists.

3. Assessment of Fish Stocks

Deterministic models compared to stochastic ones are no doubt wider approximations of the status of stocks. Increase in the dimensions of the parametric space demands strong data base. Riffenburg (1969) used nonstationery Markov chains to model the passage of energy through an ecological system involving three fisheries of sardines, anchories and hake. He indicated the problems encountered in obtaining solutions due to weakness of data base. Much work is yet to be done in this area of modelling.

3.1. Deterministic models

Since macro-analytic models do not demand large parametric space, collection of data becomes relatively simple. Analysis is also straight forward. Swept area method involving sample area fished and catch obtained; Biomass approach involving catch and mortality rates; surplus production models and successive removal methods involving catch and effort alone, are some of the models under this category (Alagaraja, 1983). Since the above models to a very large extent are for species specific gears, they are not useful where multispecies and multi gear fishery is in operation. In this context evaluation of effort of different gear and their standardisation is not possible. Hence relative response model (Alagaraja, 1984) has been suggested where successive catches over time alone are needed. This model

$$C_{t+1} = C(1-e^{-k}) + C_t e^{-k} \qquad (1)$$

indicates the maximum catch $C\infty$ expected from the area of exploitation and the assumptions involved under this model is satisfied in Indian conditions. Using the data for the years 1980-'84 the estimated potential yield of marine fish for the 0-50 m depth is 2.20 million (Alagaraja, 1989) tonnes. Specie wise estimates of exploited marine fishery resources in India have not shown any interactive effect among them. In the absence of interaction Maximum contribution approach could be used to obtain the potential yield. Under this approach during 1971-'84 the maximum landing of each group was taken and the total of such maximum was 2.00 million tonnes (Alagaraja, 1989). This estimate is closer to the one obtained by Relative response model. It is interesting to note that the estimated 2.26 million tonnes obtained by George *et al.* (1977) for this region is very close to the above estimates.

Under micro-analytic models, Beaverton & Holt model (Beaverton & Holt, 1957), Ricker model (Ricker, 1975) and Virtual population analysis (Pope, 1972) are the important ones. Availability of age frequency distribution makes these models very useful to arrive at the levels of effort needed for reeping maximum sustainable yields. In tropics aging a fish is a problem. To overcome this difficulty length frequency data are used widely. This length based approach assumes von Bertalanffy's growth and derives the estimates for growth and mortality rates. The methods suggested by Pauly (1983) and Jones & von Zalinge (1981) use age converted length frequency data. Here it is assumed that all modes are distinct and they do belong to the same cohort reflecting age structure of the population sampled.

In tropics the above assumptions are hardly found to be true due to the resources characteristics. Tropical resource in general has fast growth, short life span, continuous and that too fractional spawning and high fecundity. Hence tracing a cohort throughout its life span is well nigh impossible. The modes available in the length frequency need not be of the same cohort and the time intervals between successive modes need not be the same. Under these conditions the above methods are not able to give precise estimates of the required parameters. Taking this into account, Alagaraja (1984) and Alagaraja *et al.*, (1986) have indicated methods to estimate the growth and mortality parameters.

To explain the advantages of the method of Alagaraja (1964) over that of Jones an von Zalinge (1981) an example from Jones an von Zalinge (1981) is considered. Following are the estimates in numbers against the carapace length of *Penaeus samisulcatus* males in Kuwait waters by the industrial fishery for the year '76/'77 and the estimates of Z/K using the method of Alagaraja (1984).

Omitting the end points, all these points have been taken by Jones and von Zalinge (1981) including those which gave negative and zero Z/K values. Omitting these values and such other values which are outliers, Alagaraja (1984) takes other values and obtains the estimate and its standard error. In the length based approach its robustness over the class interval

Carapace length (m.m)	Nos. ($\times 10^6$)	2/K
18.15	0.450	-11.994
22.15	3.160	5.783
25.17	1.216	1.118
17.58	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	–

size is yet to be ascertained and the size of class interval is to be fixed according to the growth and $l\infty$ of the species. This is an area where much work is yet to be done.

There is a global awareness on pisciculture to augment fish production. Hence assessment of the carrying capacity of water bodies assumes significance. In this area different models are available. Ricker & Allen (Ricker, 1971) and Gulin & Rudenko (1973) have developed models with different assumptions on growth and mortality. Error estimate for Ricker & Allen (Ricker 1971) model was given by Chapman (1971). Improving this error estimate, some more models are given by Alagaraja (1986). Among different types of models one based on linear relationship on numbers over times and growth over times is suggested for its simplicity, theoretical soundness and practical applicability. In this area also there is a vast scope to find out methods for estimating number of fish available in the water body. The above account is only an indication on the challenges available in fishery research. On fishery forecast much more challenges are awaiting an interested worker in this field of research.

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