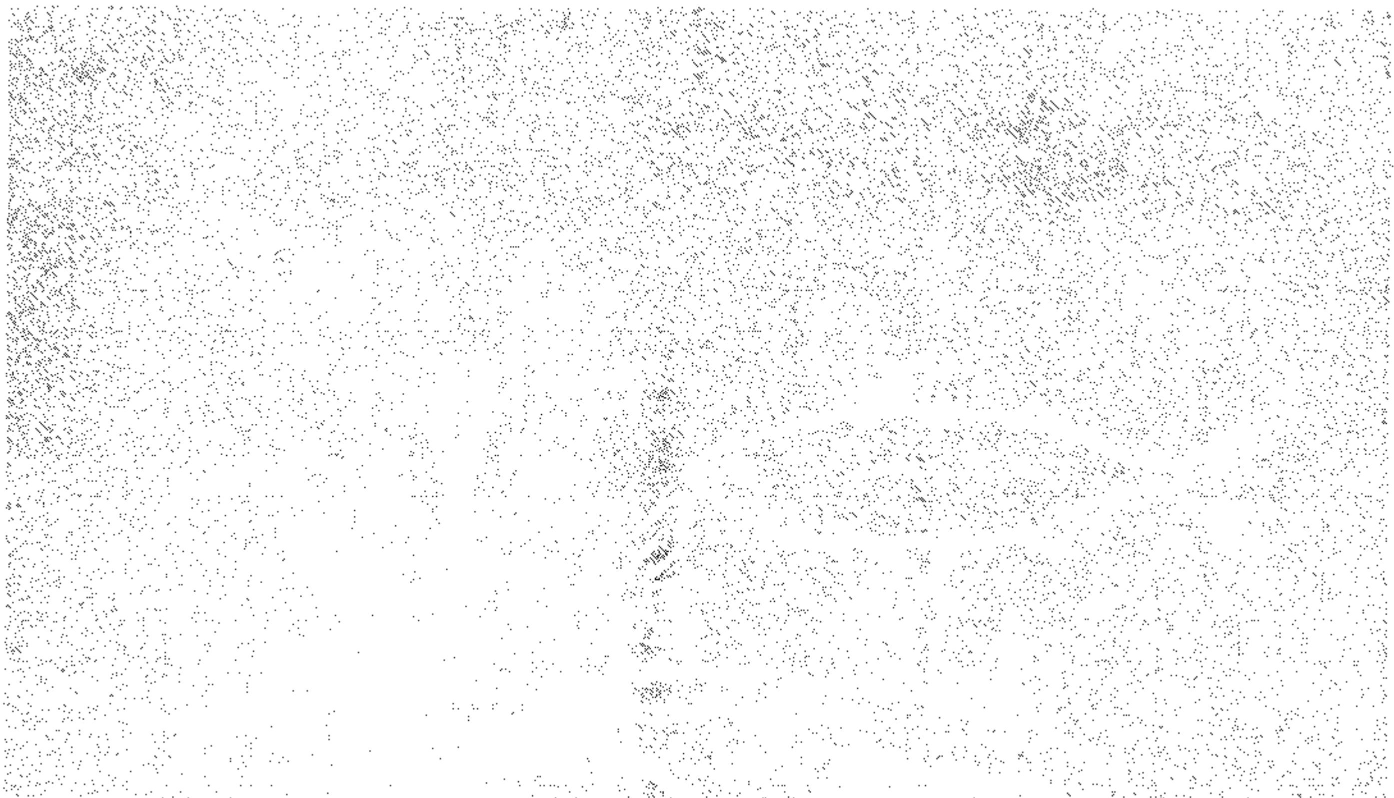
PROCEEDINGS OF THE SYMPOSIUM

ON

LIVING RESOURCES *of* THE SEAS AROUND INDIA

ICAR



PROCEEDINGS OF THE SYMPOSIUM

ON

LIVING RESOURCES OF THE SEAS AROUND INDIA

ICAR

SPECIAL PUBLICATION

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE

COCHIN-11

1973

CONTINUING RESOURCES SURVEY AND DEVELOPMENT OF FISHERY

S. K. BANERJI

Central Marine Fisheries Research Institute, Cochin

ABSTRACT

A fishery resource is a self-renewable living natural resource in a dynamic habitat. Even if the resource was in a static environment and there was no fishing, since it is a living resource it will maintain itself by the adjustments of its inherent biological characteristics like growth, recruitment and mortality which are probably inter-related in some way. When fishing exploits a resource it changes the mortality and therefore the behaviour of the system. The changes in environment may alter all the biological characteristics of a resource and its behaviour pattern. The aim of the fundamental research is to have a full knowledge of all characteristics of a resource and their interaction to changes generated by fishing and dynamic changes in the environment. The purpose of a countinuing resources survey is, however, limited in character but none the less useful. A continuing resources survey is like quality control which keeps a watch on the processing behaviour and warns the industry when the processing is out of control. From the results of the fundamental research whatever be the stage, a certain knowledge of the resource and its behaviour pattern is obtained and the resource is viewed as a system obeying certain laws and having some attributes. The purpose of a continuing resources survey is to collect information on these attributes of the system and maintaining a watch on the system, to see if the estimates of attributes are obeying the laws, any departure from which will at once be a warning that the pattern of the system has changed. The fundamental research and continuing resources survey are complementary to each other and must exist on a continuing basis. The operation characteristics of a continuing resources survey have been illustrated with examples taken from Indian fisheries.

THE natural resources can be broadly classified into two categories, namely, (1) renewable resources and (2) non-renewable resources. Mineral resources are examples of non-renewable resources. A known mineral resource is liable to be completely exhausted after a certain interval of time depending on the rate of exploitation. A fishery resource, on the other hand, is a renewable resource. If a portion of this resource is removed, it can recuperate by growth and new recruitment and come back to its original level. For a given resource there is, however, a maximum which can be removed so that the stock remains unaffected. The ultimate objective of any fishery management programme is to assess this optimum quantity that can be taken from a given fishery resource. Apart from the renewab le characteristics of a fishery resource, it is important to remember that the resource is located in a dynamic environment—dynamic both in the sense of physico-chemical variation as well as in the bio-ecological sense. Theoretical models have been developed to assess the potential yield derivable from a fishery resource considered without references to it habitat—but these only furnish an average assessment from a long-term view. Only by a full understanding of the interaction of a fishery resource in relation to its physico-chemical environment and also its relation to the ecological community whose member it is, a system can be developed for the prediction of the behaviour of the resource on a short-term basis.

The fishing industry of a country is based on the exploitation of such living dynamic fishery resources. For efficient exploitation, it is required to have full information regarding the resources.

The information required with respect to each fishery resource can be broadly grouped into three heads, namely:

(*a*) Distribution, in time and space,

(*b*) Abundance and potential yield,

(*c*) Behaviour of the resource in relation to environmental variations.

Full information on all these aspects may not be available to start with. In the initial stage, some generalized information on the distribution of the resource in the area of fishing may be available. If seasonal changes in the abundance of the resource in the fishing area are noticed, it may suggest that the resource moves out of the area during certain seasons. This would lead to fundamental research for finding out the cause of such migration and also the circuit of migration. Initial research may lead to a general idea of migration pattern and some idea about the cause of such migration. Continuous survey of the migratory routes will reveal if there are any deviations. If any deviations are there, it is necessary to find out if they are correlated with environmental data and/or with some ecological factors. The abundance of the resource may also oscillate or change and they may be due to environmental factors or may be due to fishing. A complete knowledge may only be obtained by fundamental research and collection of data extended over a long period. But the fishing industry and the Government can ill-afford to wait for such a long time. They have to use whatever information is available at any time and formulate their respective strategies.

The resource information is required and used by the industry in connection with their fishing operations and also in extending their operation with a view to achieve maximum operational efficiency.

If only generalized information about the distribution is available, the industry will have to spend quite some time searching for the fish and then catching the same. If, however, detailed life-history of the fish is known and the migratory route is known along with distribution of the fish in space and time then the loss in time due to search for fish will be minimized. If correct information on mortality, growth and recruitment are available, the order of potential catch will be known and the industry can decide if any further investment is worthwhile in the long run in extending and expanding its operations. When complete information on all aspects of the resource is available, the industry will be in a position to know what and how much can be expected at any particular area at a particular time. At this stage, it will be possible to consider the resource as a system in relation to various biological and environmental parameters, so that it will be possible to predict expected results on the basis of the estimates of various parameters involved in the system.

The Government uses the resource information generally for plannnig development, organizing and conducting further work in promoting and assisting development and in guiding the industry within the broad national policy.

The emphasis of Government planning will shift from time to time depending on the national policy and on the total national resources available at hand. However, any planning has to be based on accurate information available at the time. While expansion of fisheries would, no doubt, remain the ultimate Government policy, the decision regarding priorities over a wide range of developmental possibilities has to be taken by it. It may have to decide on the types of fisheries to be developed, the types of boats, fishing gears and equipments to be chosen, and may have to make many other decisions in respect of financial investment in the public and private sector, requirements of competent personnel and their training programme and so on. All these can be effectively made provided there are reliable information available on the various aspects of the resources. In words of Kesteven (1967), this store of information "cannot, however, be a museum—an array of fossilized facts; it must instead be living and growing, its vitality preserved through constant renewal by reconfirmation of its facts; fed by a constant flow of new data, it must grow and develop, transforming its descriptions and models in step with the changes taking place in the natural and industrial systems with which it is concerned". In short, the collection of resource information or resources survey will have to be a continuing one.

All scientific research programmes must start with some hypothesis, which are generally framed on the basis of available information and their understanding by the logical mind of the scientist. Further observations collected in course of time may disprove the hypothesis set up earlier necessitating setting up entirely new or modified hypothesis which will explain all new observations as well as early ones. This is how fundamental scientific research progresses. With regard to a fishery resource, all necessary information may not be available all at once. On the basis of available information, a research scientist must view the resource as a system subjected to certain laws and build up suitable hypothesis or model to describe the resource. The model or hypothesis may have to be modified or changed with accumulation of more and more information. Thus one of the functions of a research scientist is to build up suitable models of a fishery resource based on available information, so that further progress can be made. The model or models built up from time to time will contain some attributes or parameters, estimates of which are to be obtained from information collected about the resoure. Theoretically, it will be possible from the model to predict the changes that will be brought about in the resource if values other than at present are assumed by one or more parameters involved in the model. When in practice, the predicted outcome agrees with the observed outcome, the model stands, otherwise the model has to be revised.

In fisheries science, on the basis of our present knowledge, some models which do not take into consideration changes in the dynamic environment have been built up to predict the yield on a long-term basis from a resource, as fishing intensity is changed. One of them is simple Beverton and Holt model, which may be symbolically written as

$$Y/R = f(t_{\rho}, t_{0}, k, t_{\infty}, w_{\infty}, F, M)$$

where the yield per recruit Y/R is expressed as function of seven parameters. The parameter t_{ρ} is the age of recruit to the fishery; t_0, k, t_{∞_0} and w_∞ are parameters of growth and F and M are fishing and natural mortalities. The model is based on certain implicit assumptions and views the resource as a system, so that by effecting variations in one of the parameters F say, it is possible to predict Y/R. The model has been successfully applied to several fisheries with good results. Another model due to Schaefer relates to the parabolic law of population growth from which it is derived that under equilibrium conditions

$$y/f = a - bf$$

where y/f is the catch per unit effort and represents relative abundance. The above relation implies that while catch per unit effort continually diminishes with increasing effort, the maximum yield is given by $a^2/4b$ corresponding to the effort $a/2b$. In a developing fishery where fishing effort increases continually, it can be easily verified if the above relation holds good. Various other models have been proposed by different scientists. They differ from one another depending upon the assumptions made regarding growth and other characteristics.

Thus model-building or framing hypothesis is one of the main tasks of fundamental research scientist and is dependent on a very deep insight into the many characteristics of a resource. The Government or the Industry are not immediately concerned with the whole lot of information which has guided a research scientist in building up models or hypothesis. Their interest lies mainly in getting certain synoptic information represented by the various attributes and parameters incorporated in the model or based on them and watching their behaviour with change in the magnitude of other attributes. It is the survey of these attributes which has been termed a Continuous Resources Survey or C.R.S.. which interests the Government and the Industry. Kesteven (1967) has defined a C.R.S. as a "special sector of fisheries research distinguished by its strict concern with obtaining currently the information needed by the Government and the Industry in developing and managing the Industry". Thus the purpose of a C.R.S. is limited in character but none the less useful. As fundamental research progresses with more understanding of the resource as a system and its interaction with various biological and hydrological factors, the research scientists will build up newer appropriate models containing probably additional parameters or omitting some superfluous ones. One point that needs emphasizing here is that while in fundamental research it is necessary to know the causative relation between an attribute and the resource, it is not necessary in a C.R.S. Thus a C.R.S. follows and is dependent on the development of fundamental research. The attributes to be surveyed in a

C.R.S. will thus depend very much on the stage of development of the fundamental research. In general, a C.R.S. will have to collect systematic information on the appropriate attributes of (*a*) the natural population of fish, (*b*) the catch and (*c*) the fishing effort. The estimates of catch are generally available by weight. It is necessary to have estimates of catch by numbers also. It is also necessary to have estimates of size and age-composition of the catch. All these can be had by examining a large sample of the catch. The estimates of effort can be obtained initially in terms of hauls of different gear. These efforts could later on be expressed in terms of a standard gear. For standardization of the effort of different gear, special studies may be necessary. After the necessary data have been collected on the above, they have to be processed and analysed to provide information on the current status of the resource. The analysis should also permit to extend the bounds of current knowledge and if necessary be able to forecast unusual events. If the analyses show unusual behaviour of some attributes inconsistent with the model, then either the hypothesis on which the model is built up is no longer valid or something unusual has happened which needs explanation. The C.R.S. is thus like a quality control in industrial production which permits a close watch on the processed things in order to find out if the processing is getting out of control. A list of standard attributes to be kept under observation is presented in Appendix. These are by no means exclusive but are given as illustrations.

Since a C.R.S. is mainly oriented towards meeting the demands for information by the Industry and the Government, the main emphasis will naturally be towards evaluating the effect of fishing on stock and also towards forecasting of fishing success. How these objectives could be attained by keeping close observations on various attributes and synoptics under a C.R.S. are briefly outlined below.

The most fundamental information that a fishing industry would like to know is if the fishing intensity is exerting any appreciable influence on a fish stock. On this information, will depend their strategy of further expansion. It is well known that a fish stock in the sea is influenced by fishing as well as by a multitude of other fishery-independent factors. If the fishing is of such magnitude that it is the predominant factor affecting a stock, it is known from fundamental research that the relative abundance of stock y/f will decrease with increase in effect f. The relationship is usually linear. If, however, the effects of environmental factors are predominant, *i.e.*, the effect of fishing on the stock is negligible, no significant relation will be noticed between y/f and f. Thus a simple plot of y/f against f over some years will be enough to indicate if fishing is exerting any effect on the stock. This is, however, not the only way of recognizing if fishing is exerting influence of the stock. If fishing intensity on a stock increases, as is usually the case in a developing fishery, it will generate additional mortality on the fishable stock, as a result of which the average longevity of the fish in a fishable stock will be reduced. This will mean, in practice, that the average size of the fish in the catch will be reducing with increasing fishing intensity. Thus if we take a fairly large sample from the commercial catch of a year and measure the length of the individual fishes, it will be possible to get a measure of the average size $\bar{l}$ for the year. The behaviour of $\bar{l}$ in relation to fishing effort will indicate if fishing is influencing the stock. If the average minimum size of first capture $\bar{l}_c$, which depends on the mesh-size of the gear used, is not changed, then with increase in fishing intensity, $\bar{l}/\bar{l}_c$ will be decreasing.

Since weight of a fish is closely related to the size of the fish, the behaviour of $\bar{W}$, the average weight of a fish in the commercial catch, in relation to fishing intensity will likewise be a pointer indicating the effect of fishing. The pressure of fishing may also sometime change the size or age composition of catch. With heavy fishing, fewer fish will grow up to higher age groups. Hence a watch on the size/age composition of the commercial catch will also help in indicating if fishing is exerting pressure on the stock. Thus by keeping close observations over several attributes year after year, it will be possible to gain precise knowledge regarding the effect of fishing on the stock.

The fishing industry would like not only to know if fishing is exerting pressure on the stock but also to know how far the fishing intensity can be increased so as to ensure that the total return is not jeopardised. It has alredy been stated that when fishing exerts influence on the stock, the catch per unit effort y/f and the average size and weight of a fish in the catch decrease with increase in effort. But what will happen to the total catch ? In the initial stage of development of a fishery, the total catch will increase with increase in fishing effort though not proportionately, but after some time, additional input of effort will not increase the catch but it may even show downward trend with increase in fishing effort. This is popularly known as the point of overfishing. It is clear that if downward trends in at least 3 attributes, *viz.*, catch, catch per unit effort and mean size of fish in the catch are noticed with increase in fishing effort, conservation measures are called for. This is very simple but significant and fruitful method of watching for any signs of over-fishing. Another fruitful attribute to be observed for this purpose is the rate of exploitation given by $F/(F+M)$ or F/Z where M, F, $Z = F+M$, are the instantaneous natural, fishing and total mortality rates respectively. Z can be easily estimated if we have the relative abundance of various age groups. If it is assumed that Z increases with effort, F can also be estimated. Allen (1953) has given a simple criterion that the yield from a fishery can be increased when

$$E > \bar{W}_c / \bar{W}$$

where $\bar{W}_c$ and $\bar{W}$ are the mean weights at first capture and the mean weight in the commercial catch. This is known as the break-even value of E. When $\bar{W}_c$ and $\bar{W}$ are stipulated, this procedure will supply us with a range of values of E within which an increase in yield can be expected. For example in case of oil sardine fishery, the average weight $\bar{W}_c$ of the new recruit class is 12 gm and the average weight of fish above the recruit size in the commercial catch 32 gms. Thus $\bar{W}_c/\bar{W} = 12/32 = 0{\cdot}4$ approximately. More yield is possible if $E > 0{\cdot}4$. Now this can be achieved if $\bar{W}_c$ is increased, *i.e.* by raising the size of first capture or if $\bar{W}$ is reduced, *i.e.*, by increasing fishing. A suitable combination of the two measures is also possible.

Sometimes, the abundance of a fish stock exhibits tremendous fluctuations from year to year brought about by fluctuations in the recruit numbers entering the fishery. The annual catch is mainly influenced by this fluctuating abundance and not so much by the intensity of fishing. Examples of such fisheries in India are the oil sardine and mackerel fisheries. While everyone would certainly want to know the causes of fluctuation in annual recruitment, the industry would particularly be interested in knowing in advance about the fishing prospects at least for the ensuing season. The catch not only depends on the effort input but also on the abundance (in numbers) of different year classes in the stock that are being exploited. In case of oil sardine, the exploitation is made from 0-year, 1-year, 2-year and 3-year classes respectively. Thus the catch in any year will depend on the strength of the recruit class that year *plus* the strength of recruit classes in previous 3 years. The relative abundances (number) of recruit class in different years can be obtained from the commercial catch data. If catch (by weight) depends mainly on the abundance of recruit classes, then it will be proportional to the sum of the weighted recruitments of the current year *plus* those of previous years the weights being the mean body-weight of the fish of the different year classes. Figure 1 shows the relation between catch in any year and the weighted recruitment. The relationship appears to be good, the slight departure from the regression line being due to difference in the input of fishing effort. For forecasting purpose, the recruitment of the current year will not be available. The catch will have to be predicted on the basis of weighted recruitment of other years. The result is given in Fig. 2. The fitted line predicts the catch very well for some years but for other years, the prediction is not so good mainly because the recruitment for that year not taken into consideraion in this figure was either unusually high or low. Even then for these years, we can give a rough forecast of the order of catch that is to be expected if other things remain normal; and this certainly will be valuable for the industry.

It has been explained above how close watch on some attributes or synoptics envisaged in C.R.S. enables one to obtain the valuable information needed by the industry. It is needless to emphasize again the important role a C.R.S. can play in the development and management of fisheries.

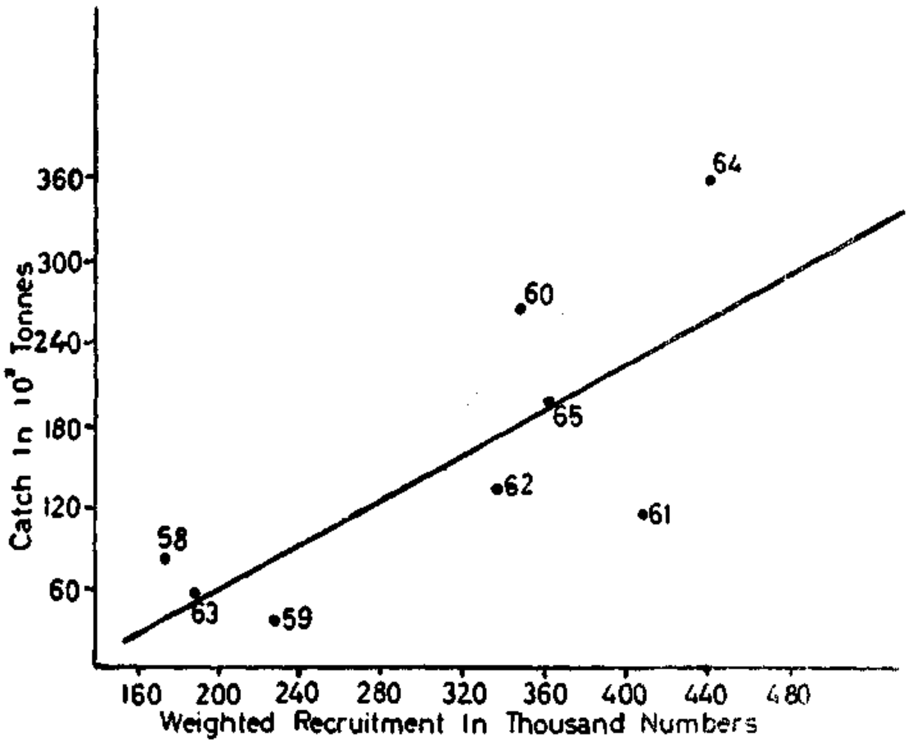


FIG. 1. Relation between weighted recruitment and catch

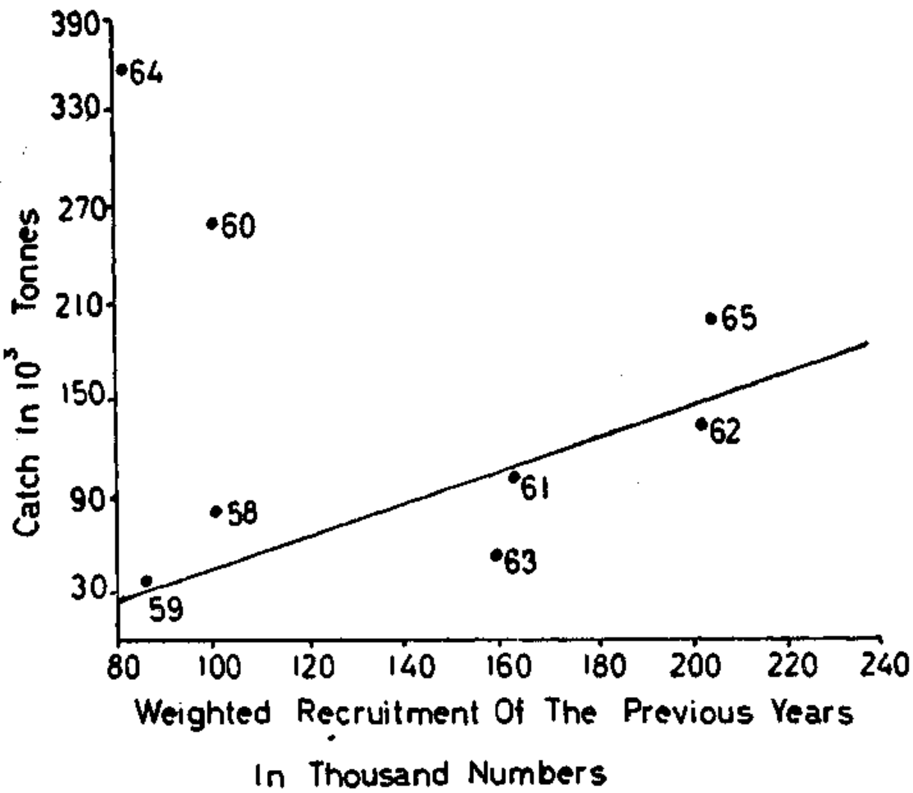


FIG. 2. Relation between weighted recruitment and catch

REFERENCES

ALLEN, K. R. 1953. A method for computing the optimum size limit for a fishery. *Nature*, **172** (4370) : 210.

BEVERTON, R. J. H. AND S. J. HOLT 1957. On the dynamics of exploited fish populations. *Fish. Inv. Series* 11·19, 533 pp., London.

KESTEVEN, G. L. 1967. *Colombo Plan: Fishery Resources Research in India.* Report to the Government of India, C.S.I.R.O., Australia.

SCHAEFER, M. B. 1954. Some aspects of the dynamics of populations important to the management of commercial marine fisheries. *Bull. Inter Amer. Trop. Tuna Commn.*, **1**: 26–56.

———. 1957. A study of the dynamics of the fishery for yellowfin tuna in the Eastern Tropical Pacific Ocean. *Ibid.*, **2**: 245–285.

APPENDIX

List of standard attributes

				Attributes
1.	Catch	Weight	..	y_w
		Numbers	..	y_n
		Size composition	..	n_l
		Age composition	..	n_t
		Sex composition	..	n_m or n_f
		No. of adults	..	n_a
		No. of juveniles	..	n_j
		Mean size of first capture	..	$\bar{l}_c$
		Mean size in the catch	..	$\bar{l}$
		Mean weight of commercial catch	..	$\bar{W}$
2.	Effort	Category-wise	..	f_t
		Standard	..	f
3.	Stock	Structure of stock	Size composition	$N_l \infty n_l/f$
			Age composition ..	$N_t \infty n_t/f$
			Sex composition ..	$N_m \infty n_m/f$
		Size and density	Biomass P ..	$P \infty y_w/f$
			Number N ..	$N \infty y_n/f$
			Density ..	$d \infty y_w/f$
		Mortality	Total z ..	z_t
			Fishing F ..	F_t
			Natural M ..	M_t
		Stock status	Yield curves	$\bar{l}/l_{\infty}, \bar{l}_c/l_{\infty}$
			Rate of Exploitation	$F_t/(F_t + M_t)$
			Break even value	$E > \bar{w}_e/\bar{w}$
4.	Behaviour	Physical factors		
		Ecological factors		