CONCEPT AND OBJECTIVES OF STOCK ASSESSMENT

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10

Introduction

Among all the exploited natural animal resources, fisheries resources are the largest. The magnitude, dynamics and resilience of fish stock pose great challenge to their assessment as well as management. The fishery resources are unique at least on three factors (Vivekanandan, 2005). (i) Many species have wide spatial distribution. (ii) Several species show wide temporal variations in abundance. (iii) Since the resources cannot be seen visually, gaining an insight into the structure and function of the resources is a challenge. It is reported that 667 marine species are fished (Sathianandan et al., 2013) by 194,490 boats (DAHDF and CMFRI, 2012) along the Indian coast, showing the dynamism of fisheries. To exploit these resources, to manage and develop the fisheries, and to conserve the fish stocks, it is essential to have accurate information on these stocks such as how much or how many are present in the sea, what is their reproductive capacity, their growth potential, etc.

The success of fisheries depends critically on the state of the fish stocks. The fish stocks are controlled by several natural factors such as weather, physical, chemical and biological oceanographic conditions and predator-prey relationships. They are also affected by man's activities, and primarily, to an increasing extent, by fishing. The assessment of a fish stock must consider all the relevant factors, especially the direct impact of a fishery on a single species. Those concerned with making policy decisions about fisheries must take into account, the state of fish stocks and the effect of the proposed decisions on these stocks. The science of stock assessment provides scope for extending advice on these aspects.

Stock assessment is the process of collecting, analyzing and reporting fish population information to determine changes in the abundance of fishery stocks in response to

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fishing and, to the extent possible, predict future trends of stock abundance (Sparre and Venema, 1992). For instance, if the stock assessment studies indicate decline in fish stocks, fishing regulatory measures such as closed fishing seasons, no fishing zones, restrictions on the expansion of fishing fleet or total amount of catch that could be taken, may be contemplated. The stock assessment work would also calculate the amount of increase in the catch, the time required to increase the catch, and the possibility of sustaining the catch if any of the measures mentioned above is implemented. Likewise, if the stock suffers from growth overfishing (exploitation of large quantities of juveniles), mesh size regulation can be suggested. The study can determine that if the juveniles are not caught (by increasing the mesh size), and allowed to grow in the sea, the juveniles would grow to a better size, which may result in, say, 20% increase in total catch.

Objectives of Stock Assessment

Maximum Sustainable Yield (MSY) and Maximum Economic Yield (MEY)

Fisheries resources, although renewable, are exhaustible. The objective of fish stock assessment is to predict changes in the size of stock and the size of yields as functions of both fishery dependant (fishing effort etc) as well as fishery independent factors, so that optimum levels of effort and yield could be determined. Figure 1 illustrates the increase in yield with increase in fishing effort up to a certain level, after which, the renewal of stock (reproduction + growth) does not compensate the loss of biomass due to fishing, and hence, further increase in fishing effort leads to decline in yield.

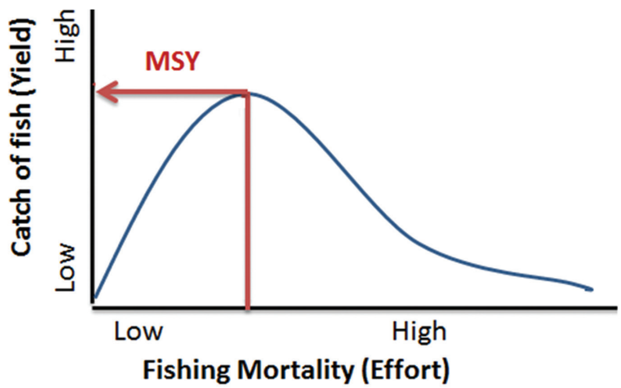

Fig. 1. Concept of Maximum Sustainable Yield

Stock assessment pursues short-term as well as long-term objectives. Assessments for the short-term objectives depend to a large extent on the current state of the stock and suggest what is likely to happen to it in the near future, say, next year or the year after. Those pursuing long–term objectives (such as estimating the Maximum Sustainable Yield, the MSY), on the other hand, depend little on the present state of the stock, but much on recruitment and growth. While long-term objectives seek to formulate strategies for long-term management of fisheries, the short–term objectives relate to the tactics required for the implementation of the strategies of which they are concerned, for example, with the effort required in the immediate future.

The MSY is a useful tool for describing the fish stocks in relation to exploitation. It explains the fact that more fishing does not necessarily mean more fish and that fishing beyond a certain point, overfishing can mean less fish. The fishing effort, which in the long term gives the highest yield, is indicated as F_{MSY}.

The *MSY is defined as the largest average catch, which can continuously be taken from a stock*. The MSY estimate has the important objectives of (i) maximizing the catch, (ii) ensuring that the maximized catch can be sustained, and (iii) interpreting the catch as an approximate measure of the well being of a fishery. The role of MSY for advocating management measures is as follows: In simple cases, if the abundance of a stock is above the MSY, the stock is considered as underexploited and fishing can be increased; if below, the stock is overexploited and fishing should be restricted; and if the stock abundance is equal to the MSY, the fishing is considered as well maintained.

One criticism of the MSY concept is that the actual yield in a particular year can be subject to considerable variations due to non-fishery causes such as environmental factors. It is often felt that in the complex modern fisheries situation, MSY is not an adequate tool either to understand the resource or as an index of management success. In recent years, economic and social considerations are receiving increasing attention. The economic considerations can be seen by converting the curve of Fig. 1 in to relationship between the cost of fishing and the value of the catch (Fig. 2). If economic return is considered as the measure of success, fishing at the point of Maximum Economic Yield (MEY) would be the appropriate objective. However, the MEY also ignores several factors such as the environmental parameters, fishermen empowerment etc. A consensus is now emerging that a single objective of management (MSY or MEY) should not be applied in all situations regardless of changes in the status of the natural resources and in the society's needs.

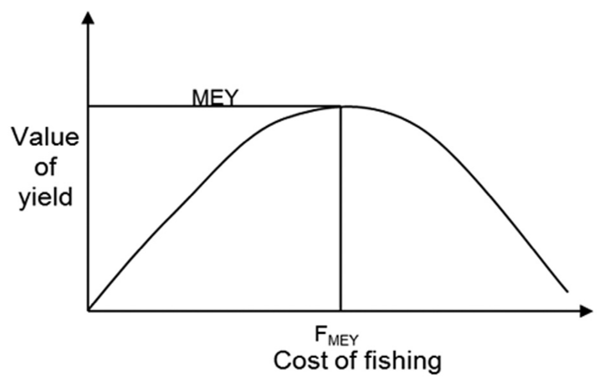

Fig. 2. Concept of Maximum Sustainable Yield

The Unit Stock

For gaining proper understanding of the dynamics of the exploited fisheries resources, information on the fundamental units of such resources, called the unit stocks, is essential. The stock is a term applied in a special way in fisheries management. It is a subset of a species characterized by the same growth and mortality parameters, and inhabiting a particular geographical area. The members of a stock share a common gene pool, and hence, belong to a particular race within a species. A biological fish stock is a group of fish of the same species that live in the same geographic area and mix enough to breed with each other when mature. A management stock may refer to a biological stock, or a multispecies complex that is managed as a single unit.

There are distinctions between the fisheries concept of a stock and the biological concepts of a population (Table 1). Capture fisheries research is usually concerned with the stock of fish exploited by a particular fishery, rather than with an individual fish or with the total population of a species. For instance, the Indian mackerel, *Rastrelliger kanagurta* is exploited along the east and west coasts of India; but the biological characteristics like growth, reproduction, mortalities etc of the different stocks of these species differ greatly from one area to another. The stocks, therefore, should be treated and investigated separately for fisheries management purposes.

Table 1. Differences in the concept between a population and a stock (FAO, 1978)

	Population		**Stock**
i.	Basically a biological concept	i.	Basically a fisheries concept for management purpose
ii.	Breeding unit of a species	ii.	Basic fish sampling unit
iii.	Each member shares a common spawning ground	iii.	Basic fish sampling unit (stock) has production characteristics (like K,Z,F,M etc) as any other individual of the stock
iv.	In a species' geographic range, these individuals have rapid gene flow among all members of the group	iv.	If geographic clusters of a species differ in the above characteristics, more than one stock is set up for management purpose
v.	Larvae develop in the same geographic area	v.	Stock may be a portion of a population or include more than one population
vi.	Mixing between populations very rare		

Ideally, a unit stock is a self-contained and self-perpetuating group, with no mixing from outside. There are well-defined geographical limits of spawning and gene exchange within stocks of the non-migratory or short distance migratory species unlike the highly migratory species. Therefore, it is much easier to identify the stocks of such non-migratory species than those of the species undertaking long distance feeding and spawning migrations like the tunas.

Russell was one of the first to express the factors in the year 1931, which affect the size of a fish stock by the following formula:

$S_2 = S_1 + (R + G) - (C + M)$

where S_1 = size of the stock at the beginning of the year; S_2 = size of the stock at the end of the year; R = recruitment; G = growth; C = catch; and M = death due to natural causes. If the stock is to be in equilibrium ($S_2 = S_1$), then R + G = C + M or C = R + G – M. This is a very simple way of considering the factors that govern stock size. During the last 70 years, fishery biologists have devised methods to estimate the parameters in the equation.

Data Requirements for Stock Assessment

Stock assessments require three primary categories of information: catch, abundance, and biology. To ensure the highest quality stock assessments, the data used must be accurate and timely.

(i) Catch Data (*The amount of fish removed from a stock by fishing)*:

A national network of fishery monitoring programs should continuously collect catch data for stock assessment. Sources of catch data include:

- Commercial catch monitoring: Often conducted in partnership with state agencies and research institutions, monitoring catch gives an accurate measure of commercial landings and provides biological samples for determining length, sex, maturity and age of fish.
- Logbooks: Records from commercial fishermen of their location, gear, and catch.
- Observers: Biologists observe fishing operations on a certain proportion of fishing vessels and collect data on the amount of catch and discards

(ii) Abundance Data (*A measure, or relative index of the number or weight of fish in the stock):*

Data ideally come from a statistically-designed, fishery-independent survey (systematic sampling carried out by research or contracted commercial fishing vessels separately from commercial fishing operations) that samples fish at hundreds of locations throughout the stock's range. Most surveys are conducted annually and collect data on all ecosystem components.

(iii) Biology Data (*Provides information on fish growth rates and natural mortality):*

Biological data includes information on fish size, age, reproductive rates, and movement. Annual growth rings in fish ear bones (otoliths) are read by biologists in laboratories. The samples may be collected during fishery-independent surveys or be obtained from observers and other fishery sampling programs. Academic programs and cooperative research with the fishing industry are other important sources of biological data.

Complexities in Stock Assessment of Tropical Fishes

The dynamics of the tropical fish stocks are more complex than those of the temperate stocks (Pauly, 1983). Nevertheless, the methods of fish stock assessment available today are basically those designed for the temperate stocks. Perhaps the most conspicuous difference in stock assessment between the tropical and temperate fishes is in the nature of the basic input data, rather than in the models, as explained here: (i) As age determination is difficult in tropical fishes, length frequencies have to be converted into age frequencies. There are several techniques now available for the conversion of length groups into age groups. (ii) Unlike in the temperate fishes, prolonged spawning makes it extremely difficult to assign seasonality to spawning patterns in tropical fishes. Hence, identification of different cohorts and tracing the length frequency progression of each cohort of tropical fishes has to be carried out under conditions of high subjectivity. The recruitment patterns are also not properly understood at present. (iii) Tropical fishes are characterized by faster growth and shorter life span unlike the temperate fishes. It is more realistic and appropriate to estimate the population parameters of tropical fishes for shorter time units of age, say, one month, and then raise the values to annual basis. (iv) Another complexity of the tropics is that they support multispecies fisheries where a large number of species are caught in the same ground in some important gears like the bottom trawl in almost every haul. Hence, the interspecies relationship and natural mortality under tropical conditions must be very different from those under temperate conditions. As the stock assessment models are tailored to suit the biological characteristics of temperate fisheries, it becomes very difficult to apply them to tropical fisheries. These models are very sensitive to seasonal patterns of recruitment, catchability and mortality. Therefore, appropriate adjustments or modifications in the existing models to suit tropical fisheries are necessary.

Limitations

All the stock assessment and prediction models contain uncertainties in the estimates of specific parameters. This is particularly true for length-based assessment methods, which are mostly applied on tropical species. The length-based assessments depend critically on the estimation of the highly sensitive and variable growth parameters. In a length-based VPA, overestimating the K will mean that the time required to grow through a length interval will be underestimated. This implies that the fishing mortality for that interval will be overestimated. In turn, the exploitation rate, which is an input for later analysis, will be overestimated.

Most of the studies on stock assessment suffer from one or other deficiency relating to the estimation of population parameters. A few typical cases are: (i) Estimation of growth and mortality parameters based on samples of larger pelagics collected from selective gears like the large mesh gillnets, which exploit mostly larger fishes. (ii) Growth and mortality estimates of shoaling smaller pelagic such as the oil sardine and the Indian mackerel sampled from the purseseines. The smaller pelagics tend to form schools of fish of same size. (iii) Estimating the stocks of migratory fishes like the tunas without considering the characteristics of the cohorts and the stocks in the fishing areas from where the samples were collected. It is possible that the samples represented different cohorts and also different stocks. Systematic aerial surveys are conducted regularly in some countries for assessing the stocks of migratory pelagic fishes. (iv) Often, there is bias in the selection of the length frequency modes. (v) Collection of data from an array of gears without properly standardizing the effort. (vi) Selecting inappropriate methods especially for the estimation of the total mortality coefficient. Results obtained from discrepant analyses would lead to distorted conclusions on the status of the stocks. When working with mathematical models, it is essential that the fisheries scientists check whether the basic assumptions of the models are fulfilled.

Fisheries assessments are highly sophisticated scientific exercises calling for a variety of skills, a sound knowledge on the biology of the system and a good understanding of the fishing operations and the industry. Fisheries scientists often face the problem of lack of information, or even if information is available, it is either inadequate or could not be processed in time. This is because the stock assessment studies have to rely on the quantity and quality of the data and knowledge, which depend to a large extent on the cooperation provided by the fishing industry. In India, the cooperation from the fishing industry in providing the basic data on catch and effort is zero or minimum.

Further, the resource system itself varies with time in such a way that the basic scientific conclusions of today may have to be modified, often radically, within a short time in the future. For data analysis one has to wait. By the time the catch and biological data become available and put to analysis, the assessments get outdated by several years. The importance of such delays cannot be underestimated, considering the need for timely assessments to understand the status and resilience of the tropical multispecies fish stocks in withstanding overfishing over a good deal of time because of their characteristic multiple spawning frequency and fast growth. Most of the fast growing and short lived tropical fishes, penaeid prawns and cephalopods have high potential increase rates, *vis-a-vis* rapid decline rates within a short duration. Furthermore, the interactions between the trophic levels are too great that one could not expect consistence in the stocks and in the stock estimates over the time-scale. The existing single species stock assessment models are often found inadequate to accommodate the resilience of tropical stocks.

Moreover, any change in the exploitation pattern of commercial fisheries like the introduction of a new gear or a change in the mesh size may considerably alter the assessment estimates. Change of fishing areas from time to time is another major causative factor for the tentativeness and inaccuracy of the estimates. With the induction of more large vessels and the consequent extension of fishing to deeper grounds all over the coastline, this factor has assumed greater importance in stock assessment.

Stock assessment models provide estimates of the optimum yield, usually taking into consideration only the biological factors. These models consider that the environment is invariable, which is not true. In addition to the environmental factors, the economic factors, such as the escalation of operational cost and fluctuations in the value of the catch, also play an important role in arriving at appropriate management decisions. It is necessary that each of these considerations and their alternatives are investigated and addressed thoroughly.

Discards and Their Effects on Stock Assessment

An important factor that could not be ignored in stock estimates based on fish landings is the discard. Discards are fish thrown back into the sea because they are too small, of little market value or unmarketable. The problem of discards arises mainly because of mobile gears like the trawl, which catch everything accessible to it on the bottom in front of its sweep, and there is no space in the fish hold of the vessel to accommodate the entire catch. In general, discards are not recorded. The discard factor has assumed alarming proportions in recent years with every fishing cruise lasting for 7 days and more. These trawlers discard almost the entire tiny fishes caught, especially during the early part of the cruise. Ignoring the discard leads to the underestimation of the catch as well as the number recruited to the fishery. The exact quantity and nature of discards could be observed only onboard the fishing vessels. The discards comprise of large number of species, ranging from the gastropods and the echinoderms to the juveniles of economically important fishes, the crustaceans and cephalopods. Considerable effort has been made in many countries to account for the effects of discards on stock assessment by adjusting the data on the reported landings and their age composition. It is apprehended that the exploitation of small fishes may affect the food balance in the ecosystem.

Other Indicators of Stock Status

If fish stock assessments and predictions fail, the ways by which the stocks respond to exploitation provide an opportunity to gain an understanding of the status of the fishery. Changes in catch per unit effort, mean length in the catch, length at first maturity and other biological characteristics are the responses of fish stocks to exploitation. For instance, as the intensity of fishing increases, there is a progressive decrease in the abundance of the stock, the mean length of the fish in the catch and the length at first maturity. By continuously monitoring these changes, a clue, though of limited value, could be gained on the effects of fishing pressure on the stock. There are many responses, such as drastic fluctuations in the catch, which do not provide specific answers. The factors mentioned in Table 2, though not exhaustive, reflect the response of stocks to fishing pressure or to environmental changes. Reasons for responses for drastic fluctuations in catches, for example, do not provide specific answers.

Table 2. Indicators of decline in fishery resources and the causes

Nature of decline	Indicators	Causes
Decrease in catch	Decrease in catch rate	Environment, fishing competition
	Change in species composition	Environment, changes in gear & area of fishing,market preference etc.
Decrease in recruitment	Sudden increase in mean age/length	High vulnerability to fishing
	Spawners exploitation	Target fishing
F = M or F>M	Reduction in mean age/length	Environment, fishing pressure exploitation of juveniles
Deviations from normal pattern	Changes in spawning pattern	Environment, biological
	Changes in length at first maturity	Environment, biological
	Changes in fecundity	Environment, biological
	Changes in size composition	Fishing, market preference

Summary

- Due to their incredible collective abundance in the ocean, fishes are typically managed by species; species are further divided into stocks and populations.
- A fish species is divided into stocks for management purposes.
- A fish species is divided into populations to reflect actual differences in geographic range or biological characteristics.
- An evaluation of the stock-recruitment relationship (the relationship between the number of adult fish in a stock and the number of new fish entering the stock) allows scientists to estimate the carrying capacity and surplus production of a stock. This information forms the basis of management decisions designed to maximize the output and sustainability of a fishery.

The most common use of the results of stock assessment is to provide advice to the fisheries administrators about the development and management of the fisheries. In spite of the limitations and uncertainties in stock estimates, it is highly desirable that advice is suggested on the basis of stock estimates, even if the advice tends to be approximate. This would in no way diminish the value of the advice. A reasonable professional estimate of future trends appears acceptable than lack of any information.

Suggested Reading

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