THE ACCUMULATED STOCK

Dr. K. V. Sekharan,
Central Marine Fisheries Research Institute, Cochin - 18.

The concept of accumulated stock explains the fall and subsequent stabilisation, at a lower level, of the catch in an expanding fishery. When demand for a particular fish increases, the trade concentrates the effort on it. When the effort increases, the catch rises for a few years, it reaches a peak and then drops and stabilises at a lower level. The catch per unit of effort and the average size of the fish also decrease. It would be erroneous to regard such a situation as an indication of overfishing. (It may be noted that the catch does not go on decreasing but only stabilises. But if effort goes on increasing even at this stage, the catch would go on decreasing, leading to the typical overfishing situation.) This may well be illustrated by considering the growth of a bank account under certain special conditions as mentioned below.

Growth of a bank deposit

In an earlier article (Sekharan, 1971), the present author had shown that, in a restricted sense, the growth of a population can be compared with the growth of a bank deposit. Suppose a bank pays compound interest at the rate of 10% per annum on a fixed deposit for 10 years. Then, the growth of an initial deposit of Rs. 10,000/- will be as indicated in the following Table.

Table 1. **The growth of bank account during the first 10 years**

Year	Amount at the beginning of the year (Rs.)	Interest (Rs.)
1920	10,000	1000
1921	11,000	1100
1922	12,100	1210
1923	13,310	1331
1924	14,641	1464
1925	16,105	1611
1926	17,716	1772
1927	19,488	1949
1928	21,437	2144
1929	23,581	2358

The Curve A in Fig. 1 shows the interest and capital at various stages during this phase of growth. The vertical lines represent the surplus obtained from the capital at various stages. The interest becomes greater and greater every year and the amount in the bank grows at an increasing rate (increasing absolute rate). This stage

Published with the permission of the Director, C. M. F. R. Institute, Cochin - 18.

is called the exponential growth phase (in the present case it would be represented by the equation $Y = 10000 \times e^{0.09533 t}$, where Y is the

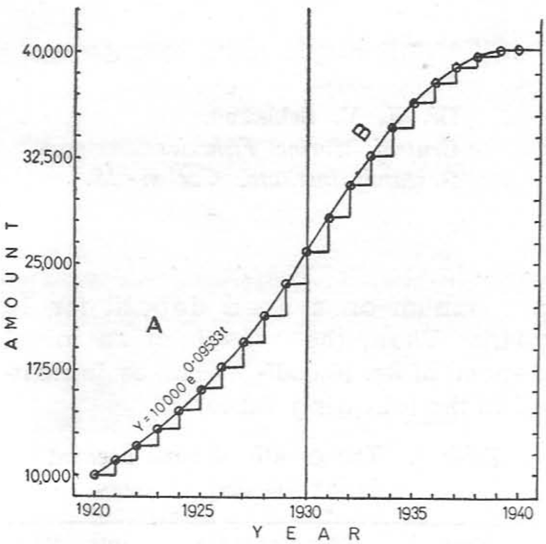

Fig. 1. The growth of a hypothetical bank account. During period A, the amount grows at an increasing rate and during period B, it grows at a decreasing rate.

amount at the end of t years.) If the bank does not allow compound interest then the deposit will grow only by a particular amount (Rs. 1000) every year, and the growth of the account will be represented by a simple straight line $Y = 10000 + 1000 t$. The human population also grows at the rate of compound interest; hence the term "population explosion" is used.

Suppose from the 11th year onwards, the bank reduces the interest rate, the actual rate depending on the balance, based on the principle that the larger the balance the smaller the interest rate, except that the interest rate would always be restored to 10% per year when the balance touches or goes below that of the 10th year (year 1929 in Table 1); and withdrawal is allowed, but only on 1st of January every year (this makes the arithemetic simpler). Let the growth of the account, when no amount is withdrawn, be represented by the following Table.

Table 2. **Growth of the bank account when interest rate decreases**

Year	Balance at the beginning of the year (Rs.)	Rate per year	Actual interest (Rs.)
1930	25939	9%	2335
1931	28274	8%	2362
1932	30536	7%	2138
1933	32674	6%	1960
1934	34634	5%	1732
1935	36366	4%	1455
1936	37821	3%	1135
1937	38956	2%	779
1938	39735	1%	397
1939	40132	0%	0
1940	40132	0%	0

From the 11th year onwards also the account grows, but only at a decreasing rate (provided of course there are no withdrawals). This is shown by part B of the curve in Fig. 1. The sum of Rs. 40132 represents the amount accummulated over 19 years. A person who feels secure when the bank balance is high would not withdraw anything, but nothing would be added to his account after the 19th year. Let us assume that the account-holder decides to make withdrawals after the 19th year (which he can do only on 1st January). From

1939 onwards, if he withdraws only Rs. 397 or less per year, the balance would remain steady at Rs. 40132. If he withdraws Rs. 397 in the first year of withdrawal and Rs. 1176 in the second years (i.e., the sum equal to the accumulated interests of 1937 and 1938), the balance will be Rs. 38956 and it can be kept steady at this level by withdrawing only Rs. 779 per year afterwards. It may thus be seen that the balance can be kept steady at any chosen level (it can be kept steady even at Rs. 10,000 by withdrawing the accumulated interest of 19 years in one or several stages and restricting the later withdrawals to Rs. 1000/- per year). But a wise decision would be to maintain the stock at Rs. 23581, because it is this balance which gives the maximum annual yield (Rs. 2358). In this process the annual withdrawals would touch a peak, then it will come down and shall stabilise at Rs. 2358. But keeping the account at such a level has a drawback. The balance will have nothing to buffer the stock if a larger withdrawal in times of adversity is made, since reducing it to less than Rs. 23581 will automatically reduce the interest. Therefore, it would perhaps be better to maintain it at a slightly higher level, say at Rs. 25939 or Rs. 28274. It will have to be decided after considering several factors.

Population accumulation

If we substitute the "amount" given in the above example by "population", we shall have a classical model of an animal stock. This is very similar to Schaefer's model of a fish population; only he has taken into account the catches (i.e., the withdrawals) in computing the possible net increase (net interest) at each level of the population size (balance in the account) and has shown that the biggest net increase takes place when the stock abundance is about 50% of the maximum possible abundance. In the above example it takes place at the 60% level. There are of course a number of differences between the population increase and the growth of bank account; e.g., the entire amount in the bank balance will fetch interest, whereas in a population only the reproductively active groups will add numbers. But, for the sake of simplicity such differences could be ignored and the population abundance could be referred to in terms of weight.

Let us assume that a virgin stock occupies 10000 sq. km. in the sea. There has been no fishing in the stock and it has been allowed to accumulate over a number of years, as indicated in Tables 1 & 2. The population would not be able to increase at a steady rate indefinitely. After a particular level of density is reached, it would increase at a decreasing rate (as in Table 2) until it occupies the entire area of the sea available to it. After this, the weight increase due to recruitment and growth and the weight loss due to natural causes would just balance each other. Let the weight at this steady state condition be 40132 kg. and let the fishing start at this stage. A particular example of fishing and the change in population (natural mortality ignored; fishing takes place only on the first day of each year) has been given in Table 3.

Table 3. **A hypothetical population in an exploited state**

Year	Weight of stock at the beginning of the year	Density of stock (kg./sq. km.)	Catch at the beginning of the year (kg.)	Net increase of the stock during the year (kg.)
1	40132	4.01	397	397
2	40132	4.01	1176 (2 years' accumulated growth)	779
3	39735	3.97	5101 (4 years' accumulated growth)	1723
4	36366	3.64	8092 (4 years' accumulated growth)	2262
5	30536	3.05	6955 (3 years' accumulated growth)	2358
6	25939	2.59	2358 (one years' growth)	2358
7	25939	2.59	2358	2358

It is obvious that from the sixth year onwards, we would be able to catch only a maximum of 2358 kg. per year; otherwise the natural increase will not be able to replace the loss due to fishing with the result that overfishing would develop. Much larger catches were taken in earlier years, but these represented several years' accumulation of stock, not one year's growth. What was accumulated over several years has largely been fished out and the stock has now been reduced to its most productive level. Now fishing will withdraw every year what is to be added during the course of the year. The catch trends up to this level may therefore be represented by the curve A of Fig. 2. The peak represents the catch

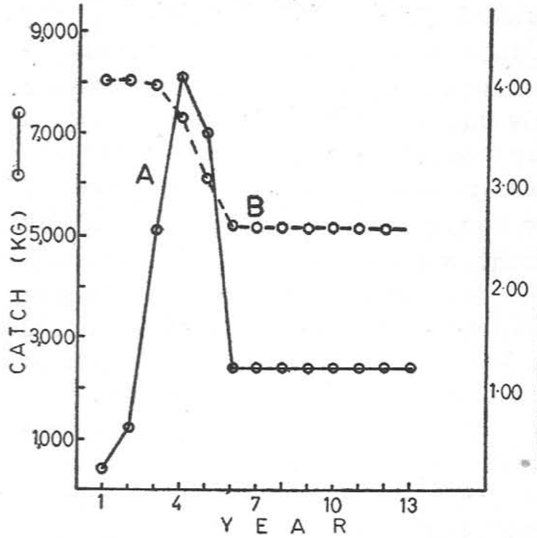

Fig. 2. Catch (A) and catch per unit of effort (B) from a hypothetical fish stock.

of several years' accumulation as mentioned above. It is futile to hope for such large catches again, unless due to drastic changes in environmental conditions, there is an unusually large recruitment. But we are dealing with situations wherein recruitment does not vary within wide limits. The assumption that the catch can be raised to the level of the previous peak within just one year, would be unsound.

It may be seen from Table 3 (col. 3) that the density of population has been decreasing over the years' 1–6. Therefore the catch per unit of effort (e.g., the average catch per boat per day) would decrease although the total catch (col. 4) and the net production in the population (col. 5) increase—a very common experience in an expanding fishery. However, this is the price we have to pay, if we want the fishery to prosper.

Examples from marine fisheries in India

There are two cases of marine fisheries in India where apparently the concept of accumulated stock applies. The first one is the prawn fishery of the Cochin area. In an interesting article, Qasim (1972) has shown that the catch of all prawns put together reached a peak in 1965–66, but later declined and came to a more or less steady state; the catch per unit of effort also declined. The same trend is seen in the catch of the individual species also. The variation from the steady state can be attributed to recruitment variations. The "prawn rush" of the early sixties had taken a toll of the accumulated stock, and much of it was probably wiped out by 1965–66, the year of peak catches. A similar case is that of the Bombay duck. Here the catches touched a high peak in the late fifties, but dropped and stabilised around 70000–80000 tonnes in sixties (Bapat & Alawani, 1972). The introduction of mechanisation had obviously led to a big increase in the effort in late fifties, which resulted in mopping off the stock accumulation of many years. There has however been a drastic decline in 1972, the reasons for which have to be investigated in detail. It may also be mentioned here that the oil sardine and mackerel fisheries, the other two single-species fisheries on the west coast, also had lean seasons in 1972.

Conclusion

From the point of view of the fishing industry, a few points may be emphasised:

a) In an expanding fishery, the annual average catch per unit of effort (e.g., the catch per boat per day) is bound to come down. The only way not to allow such a thing to happen is to stop fishing. There is some theoretical evidence to show that the production potential is the highest, when the magnitude of the stock is of the order of 40–50% of the maximum. The view expressed by some persons that the maximum potential catch from a population is equal to 60% of its size in the virgin state, has now become scientifically invalid. There is no point in our making such estimates, without computing or making assumptions regarding the potential for increase of stock and the probable loss as a result of fishing and natural mortalities. Therefore, it would be prudent to plan ahead, taking into account the probability that when the fishery develops fully the annual catch per unit of effort is likely to decrease at least to 40–50% of that obtained from the virgin stock. In other words, a wise management would keep a watchful eye on production charts, based not only on the performance of their vessels but also on the performance of others' vessels.

b) When the total catch shows a slump and then stabilises for a number of years that is the time when the industry should take a serious note of the situation and then come to an appropriate decision regarding conservation; for continued increase in effort at this stage would lead to reduction in the total catch.

c) The need for accurate statistics is most urgent. The fishery scientists should be given complete catch and effort data so that they should be able to monitor accurately the changes in the stocks.

Acknowledgement

The author thanks Dr. S. Z. Qasim for his valuable suggestions.

References

Bapat, S. V. & Alawani, S. A. 1972. The Bombay duck fishery of Maharashtra with special reference to Versova. *Symp. pelag. fish. resour., CMFRI, Cochin, Abstract* : 29–30.

Qasim, S. Z. 1972. Are there enough shrimps in the sea? *Seafood Export Journal, 4* (1) : 1–12.

Sekharan, K. V. 1971. The Fisheries Problem. *Seafood Export Journal, 3* (7) : 31–35.