DIAGNOSIS OF THE CONDITION OF A FISHERY†

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Summary

The expression "condition of a fishery" refers to the intensity and efficiency of exploitation of a resource. In broad categories, a fishery may be in a condition of under-development, of full development, or of gross inefficiency through over-exploitation of the resource or through other defect in the industry itself. This paper examines more closely the definition of "condition", presents an examination of the history of fisheries as a background for studies of "condition", and discusses a general strategy for assembling and analysing information as a means to diagnosis of condition, in particular giving a list of indicators of "condition" to be drawn from such analysis.

INTRODUCTION

Since the function of a fishery is to draw materials from living aquatic resources for the use of Man, either for food, (directly or indirectly) or for other purposes*, and since the success with which each fishery discharges this function is a matter of concern to its operatives and to the community at large, the community should establish means of examining each fishery from time to time to ascertain how well it is functioning. An examination of this kind is sometimes referred to as an "analysis of the condition of a fishery": a review of methods developed for making such analyses and a discussion of results obtained from their application are basic steps in a discussion of fisheries management.

The "condition" of a fishery is, obviously, essentially a relative matter. At a particular time a fishery is either the same as, or it differs from, what it was at some previous time, or from what it could be at some time in the future, and according as we prefer its present state or that which it had or might have, we make some value judgment with regard to its present state. There are several matters to take note of in this statement.

First, if we say that a fishery is the same as etc., we would seem to mean that it is unchanged in certain particular respects or that those respects will remain unchanged. However, we cannot mean that it is absolutely unchanged, because that would be impossible. Some changes, however slight, must take place, even from moment to moment. If on the other hand, we assert

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*This formulation includes the reservation of a resource for recreational purposes.

a change, we must speak of some particular aspect; and since there are very many respects in which a fishery may change, each of different importance, and since the importance of a change in a particular respect differs between respects, and from time to time for each respect, it follows that anyone wishing to discuss the condition of a fishery should state quite clearly the respects he has chosen to examine.

Next, in examining a particular fishery, we are unlikely to be able to consider every feature and characteristic of that fishery. We must make some selection, even if to do so presents difficulties. Workers have thought from time to time that the behaviour of one or other major characteristic could serve as reliable indicator of condition, but they have found that in unexpected circumstances the chosen characteristic ceased either to behave in the expected way or to hold the relation with other characteristics necessary for its usefulness as an indicator. A graphic record of the behaviour of characteristics such as total catch, number of men employed, and average age of fish in the stocks, shows these to move towards maxima or minima, possibly at different rates, and reaching their maxima and minima at different times. The consequences of these are: first, that a demonstration that any characteristic has reached a maximum (even supposing this to be the final maximum the chosen characteristics could have) does not mean necessarily that the entire system is in its most favourable condition; second, that each analysis must deal with a combination of characteristics.

The third matter from our original statement concerning condition of which we should take note is that we must distinguish sharply between establishing the facts as to change (or to maintenance of a condition) and judging the significance of a change or of there being no change.

Fourth, even if a number of observers should choose the same set of respects with regard to which they would examine a fishery, they might disagree about evaluation of changes disclosed (or expected) in the chosen respects. Thus, whilst a fisherman might consider a rise in price of fish to be a favourable change, a consumer might hold an opposite view of that change. Such views are obviously ex parte; each represents an estimate of the success with which the industry approaches a special objective, and therefore to understand and correctly appreciate one of these estimates one must know the viewpoint from which it is made. There may be a third position from which these and other views could be matched to provide an objective judgment with regard to the relative claims of different interested parties; presumably this is a function of government.

Fifth, since an examination of condition involves a comparison of states at various times there must be a considerable historical element in such studies, so much so that we shall find that much of the discussion can be systematized by adopting an historical plan for it. That is to say, we can at once admit, without prejudice to our examination of causes and effects, that each fishery passes through a number of typical phases, from the first discovery of its resource, through various developments, arriving at a condition of stability, either temporarily or permanently, and perhaps subsequently falling into decline. A close examination of some representative case-histories might enable us to identify diagnostic syndromes characteristic of each of a series of typical historical phases.

These five observations lend support to an earlier, more general, statement; namely, that an appraisal of condition is an act of comparison, chiefly of the current status of the industry with some status it has had in the past, or might have in the future; in some instances a comparison can be made with some other industry which it resembles sufficiently closely for a comparison to be of value.

To summarize these observations:

(1) In making an appraisal of the condition of a fishery, we must state the respects with regard to which we have made our appraisal.

(2) The more respects with regard to which we make our appraisal the more useful is our appraisal likely to be.

(3) We must make a distinction between establishing the facts as to the status of an industry and making a judgment as to the significance of that status.

(4) Evaluation of a judgment expressed about the status of an industry must take into account the viewpoint from which the judgment is made.

(5) There is a strong historical element in any study of the condition of a fishery.

(6) Appraisal of the condition of a fishery is essentially a comparison, of the industry's present condition with its past or possible future condition, or with that of some other similar industry.

A Note on Terminology

In this paper we make a distinction between

(1) analysing information with respect to a fishery;

(2) making an appraisal of the condition of a fishery;

(3) making a judgment on the disclosed condition of a fishery.

In our usage, the first term refers to the procedures for setting out the facts as to various characteristics of a fishery under study, in its current state, in its past, and prospectively in its future. The second refers to a more diagnostic operation of testing the significance of assembled facts (or more precisely, of the conditions they represent) and of prognosticating the course that events are likely to follow under various specified conditions. The third implies a choice of objectives for the industry, and suggests a judgment as to the success with which the industry is moving toward that objective. Whether such a judgment is translated into action to preserve the course of events, or to change them, is a different matter.

The word "condition" is defined in the Shorter Oxford Dictionary as: "Mode or state of being. State in regard to wealth; circumstances; hence, social position, estate, rank." The word seems at risk of taking on an esoteric meaning in fisheries literature and discussions, although this seems unnecessary; it is used in this text synonymously with "state" and "status".

ASCERTAINING THE FACTS AS TO A FISHERY

We must allow that almost any fact whatsoever, relating to a fishery under investigation, may be relevant to an enquiry as to the condition of that fishery. This is not to say that of necessity every conceivable fact must be ascertained and appraised. Nevertheless in a reliable approach to the problem we must take a systematic view of the entire complex, and establish procedures for identification of the truly significant characteristics.

In this sense, we should have an account of the structure and operation of an industry under investigation, and the thoroughness and accuracy of that account will determine the reliability and accuracy of the analysis.

An account of structure gives, in its qualitative section, the categories of components of the system and the characteristics of each category of component; it also reports the geographic and institutional relations between components in each category, and between the categories. The quantitative section reports the numbers of individuals of each category and, where possible, gives measurement of the characteristics of each category; it also gives measurement of relations between individuals, separately and between their categories. The qualitative section is what is often presented as a description of an industry. Data for the quantitative section are provided in part by the administrative procedure of registration of boats, etc., from which an inventory can be constructed.

The basic categories of structural components are

(1) resource;

(2) equipment and operational supplies in primary, secondary and tertiary sector;

(3) manpower in each sector.

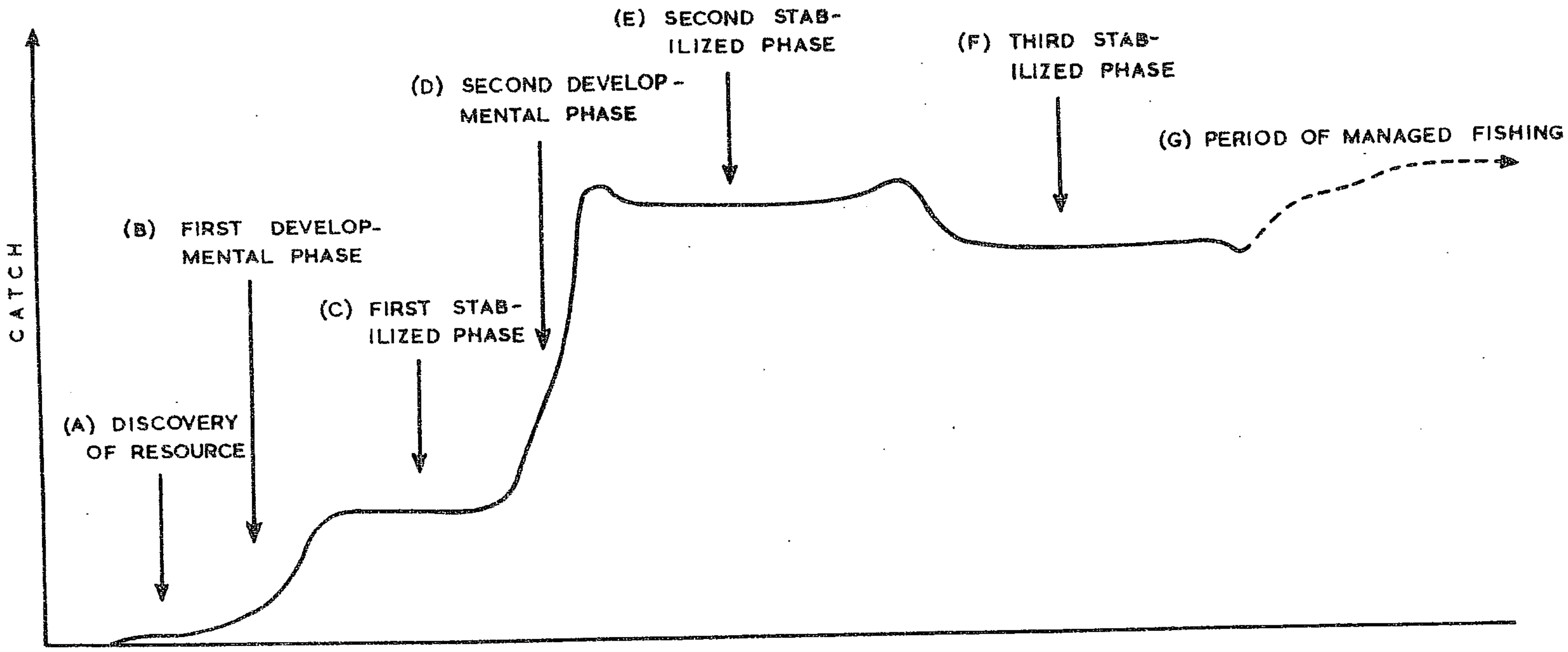


Fig. 1.- Hypothetical and generalized curve of historical development of a fishery.

Detailed classification of types within each of these categories is available in a number of works; some such classifications are given in the draft of the F.A.O. Manual of Fisheries Science (Kesteven 1960).

An operational account of an industry also must be both qualitative (descriptive) and quantitative. The qualitative section describes the behaviour and dynamics of the resource, especially with regard to its response to exploitation; it describes the methods employed in each industrial sector and gives an historical account of the employment of these methods and their results; it also describes the forms of raw materials obtained from the resources and the forms of commodities produced and marketed. Much of the raw data for the quantitative section of an operational account is obtained from records of catch and effort in fishing and from the accounts of enterprises; however, special studies must also be made; for example a study of resources by biologists, of operations and methods by gear and food technologists, and of production and distribution costs and of prices and earnings by economists.

THE HISTORY OF FISHERIES

A fishery begins with the first knowledge of the existence of its resource. From this point it grows with the recruitment of operatives and the accumulation of knowledge, skill, equipment, and organization in both its primary and tertiary sectors (and in the secondary sector if that exists) until it reaches a condition of stability, in which it may remain indefinitely or from which it may change, either to decline or to grow still further. A representation of these events is given in Figure 1.

Although the actual course of events in particular fisheries may <u>seem</u> to follow some sequence other than that presented in Figure 1, the sequence is of sufficient generality to permit us to derive from it a set of primary categories of industrial status in historical sense. These are (a) nascent, (b) developing, (c) stabilized, (d) declining, and (e) extinguished.

If, looking at various fisheries which by general consent have been assigned to these categories, we could ascertain the appearance of a number of characteristics in each, we should obtain some idea of the kind of <u>facies</u> we may expect to find in each. This approach is justified by the fact that a popular conception of the condition of a fishery is that each fishery must be unequivocally in one or other of these categories; such an absolute view is mistaken, but despite the looseness with which these terms have been applied, the terms undoubtedly have a place in our vocabulary and we can gain by trying to bring precision to their use.

(a) Nascent Fishery

Since by definition, the industrial components of this phase, if they exist at all, are represented by, at most, one or two experimental units with possibly little correspondence with the units eventually employed, we can consider only the resource itself.

An instance of this category, in Australian waters, is the demersal fishery in the Great Australian Bight. This is of special interest because in it we have, at the latest attempt to establish a permanent fishery in exploitation of this resource, an instance of a single vessel working alone and, one might say, out of industrial context. A detailed account of the operations of the Southern Endeavour (Kesteven and Stark 1967) provides interesting material on the problems of a first vessel in a fishery.

At the time of initiation of an industry the stocks, of course, are in a primitive condition in which they are assumed to be in a state of stable equilibrium with their environment. The term "stable equilibrium" must, however, be understood to cover a wide range of states of both composition and magnitude. There seems to be no reason to suppose that fluctuations in population size and changes in age structure, such as are observed in exploited populations, did not occur in those populations before they became subject to exploitation.

(b) Developing Fishery

As examples of fisheries in this category we can consider the east coast trawl fishery in the early 1920's, the east coast tuna fishery up to the season of 1960, the South Australian tuna fishery of 1962, and the Western Australian crayfishery in the 1940's. There may be difference of opinion as to the implication here that the east coast tuna fishery and the Western Australian fisheries are at present stabilized, but there can be no dissension from the assertion that they were developing in the periods indicated. Ocean fishing for prawns on the east coast in the 1950's is another example, and undoubtedly this fishery is still developing on the Queensland coast, even if this is not the condition of the prawn fishery on the New South Wales coast.

The technological changes that take place in a developing fishery are, of course a most noticeable feature of fisheries of this category, apart from their increasing catch. Such changes, however, may continue beyond an optimum level, and may induce retrogressive changes in other characteristics of the industry and these may pass unnoticed for a time; that is, the end-point of technological development may lie later in time than the end-point of other characteristics.

Development of an industry with respect to its equipment and manpower may be qualitative or quantitative, or both. Quantitative development consists simply of numerical increase in the number of operational units, whereas qualitative development involves modifications of those units to bring about an increase in their individual operating power and efficiency. For example, the mechanization of a fleet of indigenous craft or the addition of electronic equipment to a fleet of powered craft is a qualitative development, whereas simply adding more boats of an existing type is a purely quantitative development. Although both types of development bring about an increase in total fishing power and may result in an increase in the expenditure of effort, a qualitative development may obtain those increases without an increase of human effort, thus giving a reduction in the amount of human effort per unit of fishing-unit effort, in other words an increase in human productivity. In some cases there may also be an increase in the number of men engaged, but at the same time an increase in productivity. Parallel examples can be found in development of secondary and tertiary equipment.

A distinction in practice between qualitative and quantitative developments is not always easy to find. A quantitative increase has a positive qualitative effect when it accelerates the accumulation of knowledge and the development of skill, and when an increase in exchanges between operational units (made possible by their greater numbers) helps to increase the efficiency of individual operations and to reduce risks; this happens in the early stages of development. In contrast quantitative increase at other stages has negative qualitative effect because of increased competition. In consequence of interactions between these types of development, realizable operational capacity may decline although numbers of operational units, men employed, potential operating capacity, and so forth may continue to increase.

Development of the primary sector may be induced by a rise in demand for the commodity produced, or, conversely, if there is no demand for its product a fishery may remain undeveloped. Again, a pressure for growth in the primary sector may force the industry to take action to bring about an increase in demand (market promotion), and to increase and develop the facilities in secondary and tertiary sectors.

These changes in the industry can be recorded in statistical and other form. Certain primary data, such as number of men engaged, catch taken, and quantity of commodity sold provide the first superficial indications of the changes taking place. More significant information is provided by derived statistics such as catch per unit of effort, proportion of operational capacity actually used, and so forth. These and other indices are discussed in a later section.

These developments of an industry are directed towards securing a fuller and better utilization of the resources; or the reason may be stated more simply as greater catch, greater incomes, etc. At some stage the industry is expanded fully to the limits of the resource and no further increase of catch is possible, and we may note that the ultimate size of each fishery is determined by the size of the resource. The fishing mortality brought about by fishing effort itself brings about changes in the stock and these are reflected in the catch. Generally, fishing operations reduce the overall size of the population, the range of size and the relative strength of different age classes in the population, and hence the average size and average age of the individuals.

(c) Stabilized Fishery

As examples of this category we may cite the east coast trawl fishery of the late 1920's and early 1930's before the advent of the Danish-seiners, and the mullet fishery at present; consideration of the present condition of the east coast tuna fishery and of the Western Australian crayfishery would prove quite decisive in reaching a definition of this category.

By the late 1920's, after more than ten years of operation, the operators of the east coast trawl fishery had established a fairly reliable understanding of the fishing grounds and of the main features of seasonal changes in composition of stock. The fleet had already reached, if it had not already passed, its highest level of fishing power. Servicing arrangements had become more or less routine. Arrangements for disposal of the catch had become firm, even if these did not prevent that from time to time the landings could exceed the capacity of those arrangements. Despite evidence that some of the stocks (e.g. that on the Botany ground) had been severely reduced from their original condition and that significant changes had taken place (or were taking place) in the composition of the stocks (relative abundance of species, and of age groups within each species population), the fishery appeared to be in at least a temporary condition of stability. Subsequent events proved that whatever period of stabilization there might have been must have been very short.

Although the total catch of mullet (*Mugil cephalus*) varies from year to year, it does so without any persistent trend. At the same time there has been little change in the equipment and manpower in the fishery; true marine engines have replaced the old car engines used two or three decades ago; other technological changes have taken place but seem to have served to maintain the fishing intensity. No important changes have been made in the arrangements for disposal of the catch; even the gluts at the time of the spawning migration continue to appear.

From these examples, it will be clear that the general appearance of a stabilized fishery, as we recognize it, is of minimal change. Perhaps the main feature is sustained total catch; this does not mean sustained maximum catch, since most fisheries can be stabilized at any level over quite a wide range. In addition there must be constancy in the fishing effort, otherwise if the catch is maintained with increasing effort, the stock must be diminishing. Constancy of fishing effort does not mean unchanged fishing equipment; qualitative development of craft and gear may permit the same catch to be taken by less manpower or less operating time of the fishing units. Equally well there may be development of secondary and or tertiary sectors whilst the primary sector remains stable.

Thus, we cannot use the term stabilization to mean constancy of all the characteristics of a fishery, nor should we imply by using the term that this is a condition which will persist indefinitely. On the contrary a stabilization period may be very brief and/or the stability or constancy may be present in only few characteristics. Probably the more characteristics that remain constant, the longer will the period of stabilization extend. We, therefore, should distinguish two types of stabilization: firstly, those cases where the constancy could continue indefinitely and could be followed only by decline; secondly, those cases in which the stabilization period may be relatively short and may be followed by a period of further development with achievement of stability at some higher level.

The principal ground for discrimination between these two types is the degree of exploitation of the resource. In the first type the resource is fully exploited and there is no opportunity of intervention in the resource to change its characteristics and thus to permit further development of the fishery. Cases of the second type are those in which there is, (1) only partial exploitation of the resource because further exploitation is restrained by technical inadequacies of the fishing boats and gear, or by limits set by secondary and tertiary sectors, or (2) full but inefficient exploitation of the resource and hence increase could be achieved by adoption of appropriate management measures, or (3) opportunity for positive intervention in the resource so as to increase its productive capacity (e.g. by transplantation or cultural practice).

We may look closer at some of the characteristics of a stabilized fishery. So far as the resource as stock of fish is concerned, the essential characteristics are that natural and fishing mortality are more or less in balance with growth and reproduction. Various structural features of the population are sustained with this condition. So far as equipment is concerned the experimental attempts of the developmental phase have ceased when stabilization is achieved. There is a general tendency in the fishing industry to converge upon and be satisfied with a standard type of boat and fishing gear. Similarly, in secondary and tertiary sectors there is a convergence upon uniform practices, with the establishment of standard of quality and hygiene and the use of more or less standard equipment. For the economist, the approach to a condition of stabilization is measured in terms of a reduction of the marginal increment of return or profit; in a stabilized fishery this marginal increment is at a minimum.

(d) Declining Fishery

As example of this condition, we may take the west coast whaling over the five or more years up to 1962 and the east coast whaling over the years 1959-62. A principal feature of this condition is a steady reduction of the stock, the onset of which may be concealed by an intensification of fishing so as to ensure the maintenance of the catch. Action of this kind, however, simply accelerates reduction of the stock, and in the long run means a smaller total return from the stock than if these mistaken efforts to maintain the catch were not taken. The reduction of the stock is indicated economically by a fall in the catch (and hence in the return) per unit of effort. The marginal increment for each additional unit of effort is, in this condition, negative. The stocks themselves not only reduce in abundance, but significant changes take place in composition. Typically, the equipment in a fishery in this condition becomes neglected and is kept in operation beyond its normal life. All these characteristics can be seen in the history of Australian whaling.

(e) Extinguished Fishery

The east coast whaling industry is now in this condition. The operations in this industry have ceased not because the whales have disappeared completely, but because their numbers have been reduced to a level at which it is no longer possible economically to maintain the whaling vessels and the shore stations in operation.

We should note, however, that decline could also take place because of a disappearance of demand for the product. As example of this situation we may take the Australian pearlshell fishery from Darwin and Thursday Island. This is, of course, a special case since the Japanese industry still is able, apparently, to find a profit in taking shell from the grounds in the Arafura Sea; for the Australian fishery the quantities demanded by the market and prices offered are not sufficient to support continued operations.

INDICATORS OF CONDITION

The discussion in the preceding section has indicated some of the ways in which a fishery changes in the course of its history. Some of these are relatively simple and their sense can be obtained from quite simple indicators. Primarily the total catch of a fishery increases to a maximum which is held indefinitely, or after a time the catch is further increased to another maximum, or is reduced. To obtain these increases the industry changes its equipment, manpower and organization in its primary and tertiary sectors and in some cases also in its secondary sector. The changes of these kinds produce certain changes in the stocks and may result in changes in earnings, profit margins, and so forth. These relatively superficial aspects are reflected in statistics such as the following:

Structure

Men	Number	Qualifications	Earnings
Boats	"	Fishing power	Value
Gear	" of units	?	Value
Fishing Units	"	Fishing capacity	Value
Ports	"	Servicing capacity	Value
Storage	" of units	Capacity	Value
Transport	" " "	Capacity	Value
Processing	" " "	Capacity	Value
Marketing	" " "	Capacity	Value

Operations

Fishing	Amount of effort	Cost
Storage	Degree ton days	Cost
Transport	Ton miles	Cost

Processing	Intake tonnage	Cost
Marketing	Handling, sales	Cost

<u>Production</u>

Catch	Quantity	Price
Commodities	Quantity	Price
Investment	Amount	Interest

However, the value of data of these kinds is limited, since, as indicated earlier, we need to consider several characteristics simultaneously; accordingly we must employ methods which enable us to determine the meaning of values of sets of characteristics.

So far we have not mentioned any standards against which the fishery characteristics may be measured. We mean here, for instance, that the total weight of catch of a certain species taken in a particular year may be compared with the maximum ever taken previously, or with the catch of that species taken by other countries, or with the catch estimated as the maximum possible from that stock, or with some other standard. Whilst the implied preference for maximization of weight of catch will hold for most species, in most countries, this is not necessarily the only objective; in some fisheries the maximization of income can be obtained other than by taking a maximum weight of catch. In contrast, maximization of the other components (the items under <u>Structure</u> above) probably cannot be an objective in itself; instead the objective must be a maximization of ratios given as derived statistics below, both those given for actual events, and a parallel set for potentials against estimates of what is required for maximum resource utilization. If, however, the market is limited, then the simple objective of catch maximization is ruled out and the standard with which to compare the above ratios becomes a little uncertain. For example, if we are unable to make a statement such as "the storage capacity is only 50% of what should be available for the catch", we are obliged to seek other ways of judging the appropriateness, to the rest of the system, of such storage capacity as is available.

Similar difficulties confront us with regard to each of the other components and characteristics of the system. We are here becoming involved in an area of decision function for which complicated mathematical procedures have recently been developed. The word maximize is being used in this context to refer to bringing toward the maximum value which a particular characteristic can have. However, we must distinguish between the maxima possible for each characteristic to be maximized, since for a particular characteristic under one set of conditions there may be one maximum, whereas the maximum under other conditions may be quite different. That is, maximization of a characteristic is subject to certain constraints imposed by other characteristics of the system. Moreover, in dealing with characteristics we have some items, e.g. cost, which as functions are to be minimized. Therefore, to generalize our discussion we must speak of optimizing the characteristics, or functions.

When we attempt to optimize a number of characteristics together, we have to recognize that optimization of each imposes constraints on the optimization of all the others, and indeed the mathematical problems of some situations are such as to be soluble only with the use of formidable computational equipment.

In default of such equipment we find ourselves obliged to talk of optimum values at which we can arrive by empirical or elementary mathematical techniques. In this category falls the use of certain derived statistics as indicators of condition.

(a) Technological Indicators of Condition

The technologists' responsibility is to seek to maximize the physical efficiency of operations. This can at present be done in situations such as we must consider only in terms of comparative indices of which the following are examples.

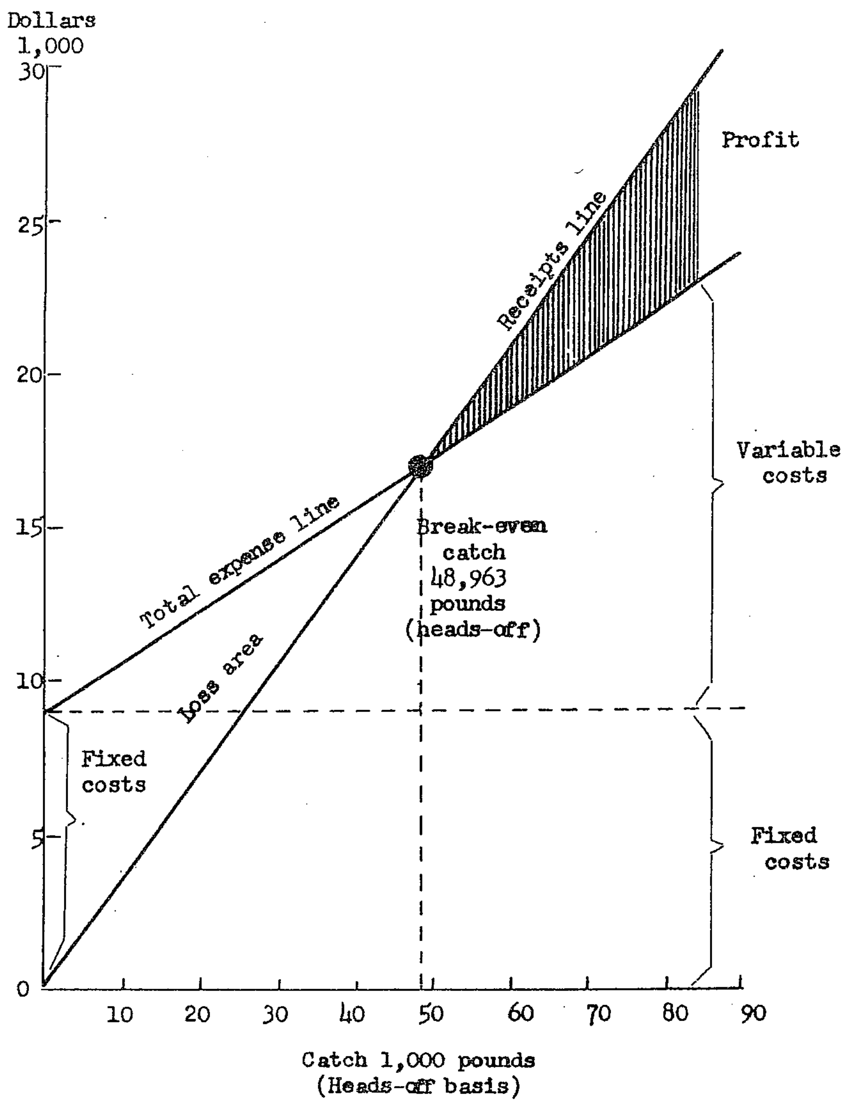
(i) Realized fishing power/potential fishing power
(ii) Used storage capacity/potential storage capacity
(iii) Used transport capacity/potential transport capacity
(iv) Used processing capacity/potential processing capacity
(v) Used marketing capacity/potential marketing capacity
(vi) Processing: quantity of raw material-intake/quantity commodity output.

The above indicators relate to real situations. The numerator in each of the above ratios is to be obtained from the operational statistical record, the denominator is to be obtained from the inventory. Ratios such as these can be followed in a time series in order to show the change in operational efficiency. In addition, the value of one of these ratios for a particular fishery can be compared with the value for some other fishery in order to assess relative efficiency. The value of comparisons of the latter kind would depend upon the degree of similarity of the fisheries.

We can construct a similar set of ratios by taking as numerators the estimates of potential which are the denominators in the set of ratios above, and the new denominators would be estimates of the total fishing power and the total capacities required for full development of the fishery to meet some chosen objective. These ratios also could be set up in time series with the objective of showing the rate at which the industry was approaching the chosen objective.

(b) Economic Indicators of Condition

The basic indicator employed by the economist is the ratio of input to output expressed in financial terms. The economist, therefore, can establish sets of ratios in parallel with those considered by the technologist, but his ratios will be in the form "earnings from fishing related to fishing costs", and similarly, "earnings from use of storage related to the costs of



Average for 38 vessels

Catch (heads-off)		84,575 pounds
Receipts		$29,526
Variable)		$13,952
Fixed	) Costs	$9,014
Total)		$22,966
Profit		$6,560

	Cents per pound (heads-off)
Average ex-vessel receipts	34.9
Average total costs	27.2
Average profit (before Federal taxes)	7.7

Fig. 2.- Break-even chart, based on average data for 38 vessels engaged in shrimping in the United States of America in 1953 (from U.S. Bureau of Commercial Fisheries 1958, p. 228).

storage", and he will seek to analyse costs into their components. However, the economist will carry his analysis further, for example, by constructing a break-even chart in which both costs and earnings are plotted against catch, output or handlings. Such a chart (Fig. 2) shows a line for total expenses and another for receipts. For successful operations these lines must cross; the cross-over point is the break-even point indicating the level of catch, output, or handlings at which the total receipts equal the total expenses. Below this point the operations are carried out at loss, above it they are carried out at profit. The economist then will wish to go still further in order to study marginal increments. As mentioned earlier in "The History of Fisheries", the marginal increments in the development stage are likely to increase for a while and then to decrease until they become nil in the period of stabilization. However, different combinations of the components of the system may yield different marginal increments and in the stabilization period the economist will be confronted with difficult decisions as to the profitability of making increases in productivity.

(c) Resource Information

The primary indicators of resource condition are average length ($\bar{l}$), average age ($\bar{t}$) and average weight ($\bar{w}$) of the individuals in the catch. Changes in these averages are indicative of changes in the structure of the population. In some cases structural changes in a population may also be indicated by a change in the sex ratio. Change in abundance of the stock is indicated by catch per unit effort.

The value taken by these indicators in the catches from a virgin population must change, generally downward, with the impact of fishing. Consequently a change in them is not of itself something to be deplored, the task is to ascertain the degree of change which will be consistent with achievement of the objectives in utilization of the resource and other objectives with regard to the industry. This is to be found by the more involved investigations which seek to measure the processes taking place within a population (growth, reproduction, natural mortality, and fishing mortality) and from these to estimate, by use of appropriate models, the yield that could be obtained from the population under specified conditions. The processes are measured as instantaneous coefficients which in themselves convey a certain amount of information, especially if values for them can be obtained over a number of years; but a statement that, for instance, the rate of fishing has been doubled (as shown by the instantaneous fishing mortality coefficient) may not of itself be indicative of whether damage is being done to the resource or of the expenditure of effort being wasteful; conclusions of this type can be reached only by consideration of the effect of all processes in combination, and with reference to cost and earnings functions. For this purpose several workers, notably Beverton and Holt (1957), have proposed methods for estimating the yield to be obtained at various combinations of values of the instantaneous coefficients and various patterns of fishing. An estimate of the yield-potential of a stock of fish provides a valuable standard against which to measure the actual catch taken, and since the estimate of yield-potential is obtained by an analytical method which specifies the conditions for taking each level of yield, it gives a possibility of identifying some of the determinants of the disclosed condition.

METHODS OF ANALYSIS

Since a change in any feature or characteristic of fishery may be an indicator of its condition, the whole array of methods of studying the structure and dynamics of a fishery could come under review in this discussion. A list of major texts relevant to this discussion is given at the end of this paper. For present purposes we deal here with a selective array of methods employed to obtain the data to be used as indicators in the sense of the discussion in the previous section.

(a) Technological Analysis

Most of the data required for the ratios discussed above are obtained from statistical systems. However, correct estimate of potentials requires special studies relating to the detailed characteristics of each kind of operational unit used in each sector of the industry. The ratios above probably do not make distinctions fine enough between various levels of possible performance. In the first set of ratios (the technological) the numerator is obtained simply from the record of performance achieved. On the other hand the denominator, namely potential power or potential capacity, may be an estimate of the potential of the equipment in its current state or the potential which it could have under certain ideal conditions, or, finally, the potential according to the ratings of the equipment manufacturers. The difference between these three potentials could have considerable significance whose measurement and assessment would involve much research. Interpretation of a value for one of these ratios calculated with any form of denominator would require an analysis of the conditions causing the difference between the realized power or used capacity and the relative potential. At this stage, there would be close collaboration of the technologist with the economist on one hand, and the biologist on the other hand, in so far as economic and resource considerations contributed to this difference.

However, there would be many aspects of the operations which it would be the responsibility of the technologist alone to examine; as example we may consider the simple statistic of fishing time for a particular class of fishing units. The total time of the year of a unit can be broken down under the following headings:

Time in Port	Time at Sea
Normal turn-around	Travelling to fishing grounds
Maintenance and overhaul	Hove-to, for weather or other reasons
Lost to other causes	Fishing

The principal determinants of the proportion of time spent under each of

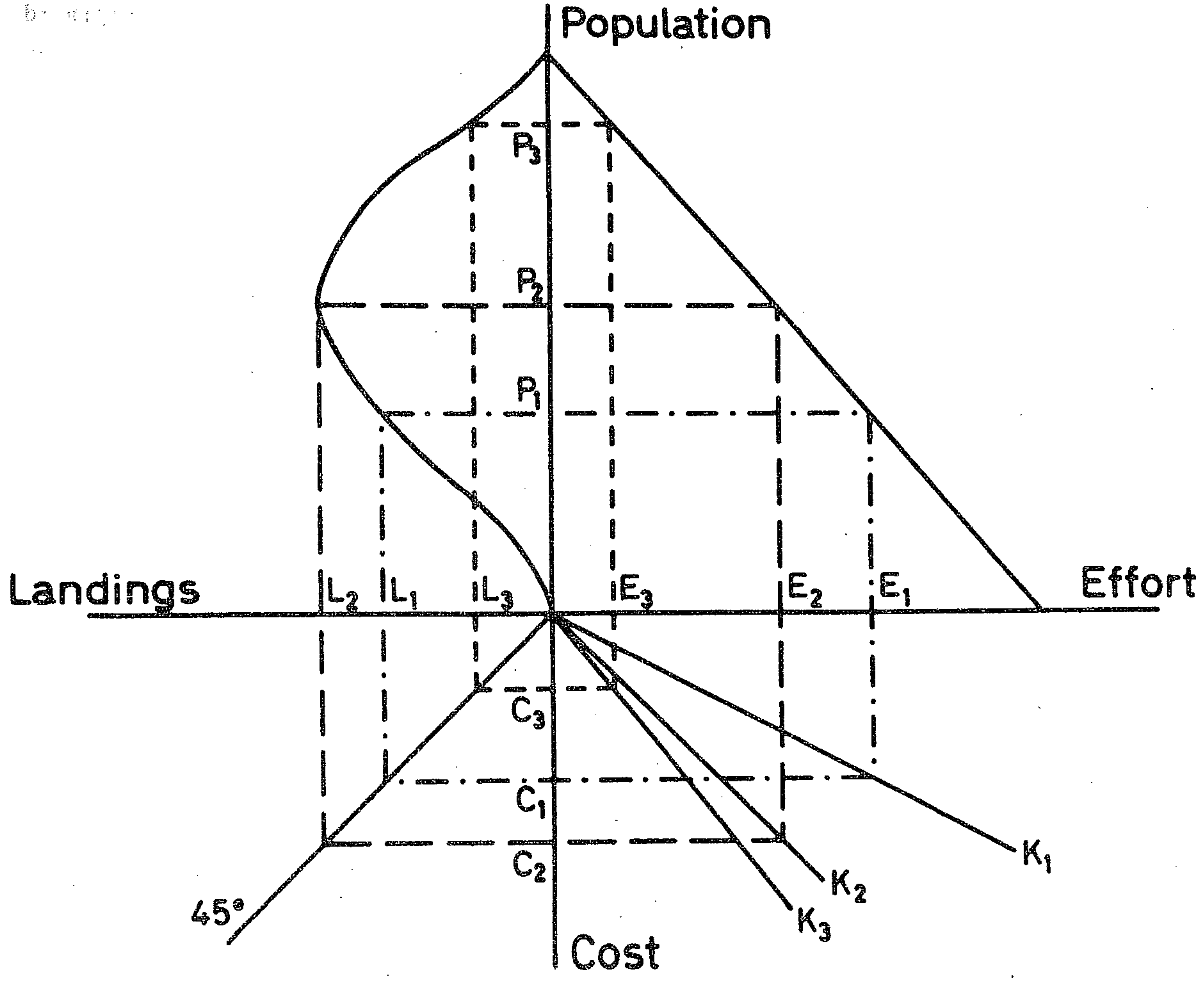


Fig. 3.- Equilibrium picture of a competitive fishery, in which equilibrium in the economic system coincides with an ecological equilibrium. In this diagram the operative variable is the cost function, K. For each line of K there is a unique equilibrium for the whole system, given that cost, C, is equal to L, the value of landings. Thus for a given point on the line K_1, there is a value C_1 to which corresponds a value L_1 of landings for which an effort E_1 is expended, bringing the population to the level on the population curve, corresponding to P_1. The straight lines in the SE. and NE. corners would be curved in particular systems; the population curve in the NW. corner is to be drawn appropriately to the character of the exploited resource.

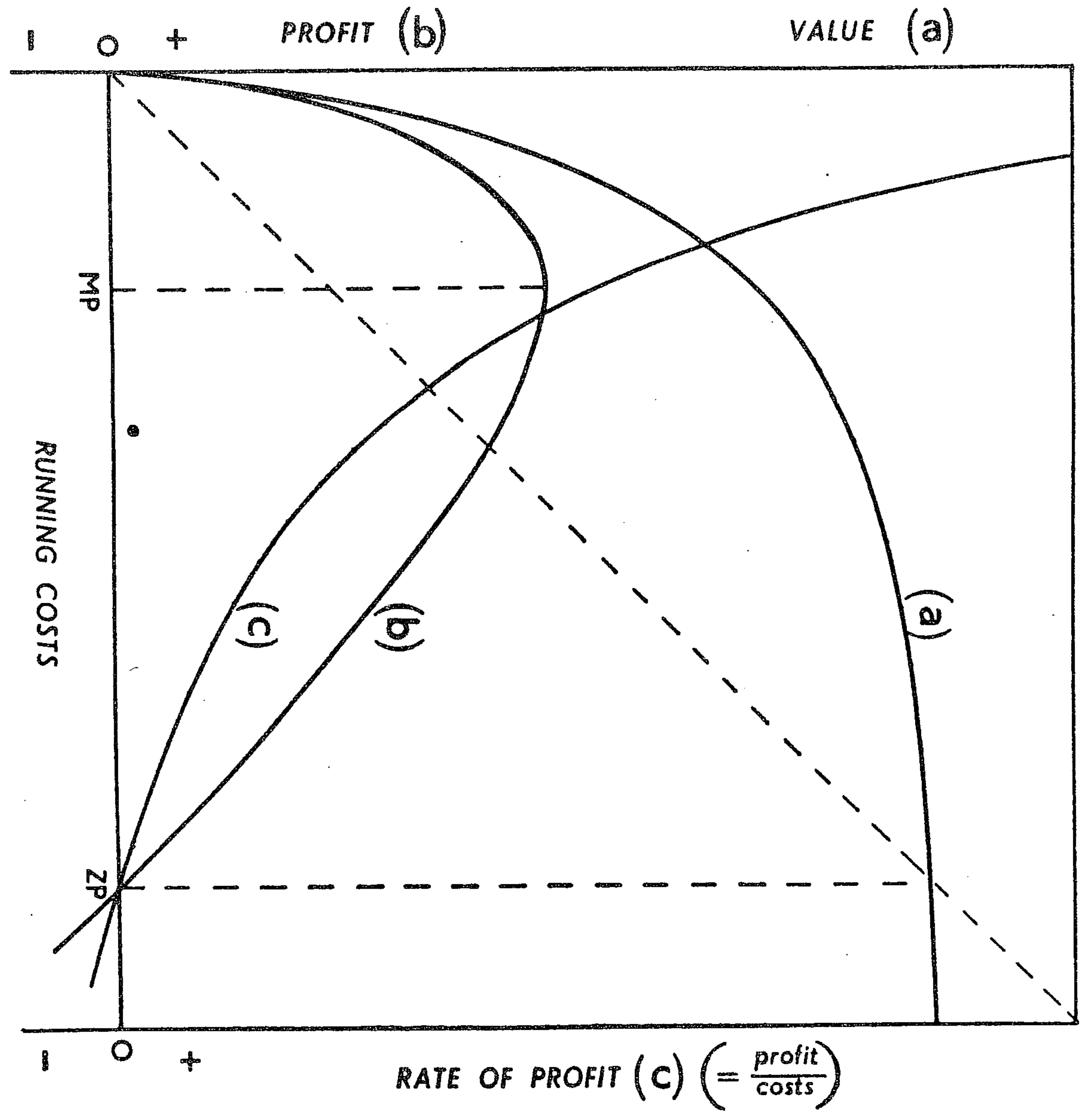


Fig. 4.- An exercise in bionomics: Curve (a) is a eumetric curve in which steady yield instead of being expressed in weight is now in money value, which is plotted against the economic equivalent of intensity fishing, namely, running costs. From those are derived (b) the annual profit, and (c) the profit expressed as a rate on running costs, which in many situations bear a constant relation to capital outlay. MP = a maximum profit point; ZP = zero profit point. (From Beverton and Holt 1958, p. 417.)

these headings are technological. Turn-around time and time for maintenance and overhaul depend largely on the efficiency of the shore facilities and on the efficiency of the fishing unit itself. Again, the amount of time lost in having to stop fishing because of weather or other operational conditions depends upon the suitability of the vessel for working the chosen grounds.

(b) Economic Analysis

Again, many of the data required for economic analysis are drawn from normal statistical systems, but special enquiries will be needed for deeper analysis. The most characteristic operation for collection of data is analysis of production and distribution costs, which will result in identification of fixed and variable costs and distribution of these costs over different phases of operation in each sector.

Two approaches have been made to effecting a synthesis of economic and biological results. Anthony Scott (1957) has presented a diagram (Fig. 3) representing equilibrium in a competitive fishery, if equilibrium in the economic system coincided with a biological equilibrium. His diagram combines: (1) stock (population), (2) effort, (3) cost and, (4) value of landings. The other, (Fig. 4) from Beverton and Holt (1956), presents yield curves in money-value terms. This figure was further developed by Kesteven and Holt (1955); their figure (Fig. 5) shows an area representing profitable combinations of factors, and other areas representing undesirable features in stock or fishing or both.

(c) Resource Analysis

The biological programme of analysis consists basically of sampling techniques by which to take a census of a population under analysis, at appropriate times, in order to be able to determine the composition of the population and to study changes in the population in association with changes in factors (fishing, natural environment) which are thought to determine population structure. The sampling programme is in general a multi-stage (or at least, two-stage) operation of which the first stage is provided by commercial fishing operations, and in order to be able to use commercial landings as samples of the population reliable records of fishing effort - as sampling instrument- are of considerable importance. An important element of this programme consists of work to calibrate fishing effort and in this there must be close collaboration between technologists and biologist probably also with economists.

A census of a fish population should be conducted against a background account of the general biology of the species under investigation, covering identity, distribution, and life-history. In addition, recent researches show that deeper analysis of the basic population processes is necessary and that this calls for research into physiology and behaviour.

In addition to census methods, more direct methods of measurement of population processes are available; these include tagging, and the use of electronic equipment for direct observations.

PREDICTION AND APPRAISAL OF CONDITION

Implicit in all work for analysis of the condition of fishery is a suggestion that evidence upon which the determination of condition has been made will permit a prediction of the condition in which the fishery will be if certain action is taken. To be able to make predictions is, of course, an objective of this, as of all other scientific activities, and as with those other activities, the value of the predictions will depend upon the completeness of the array of determinant factors comprehended within the predictive system. None of the primary indicators, and few of the derived statistics, can alone serve as a basis for prediction; in some cases where the significance of a given amount of change in a particular indicator has been determined by analysis of all factors contributing to that change, observation of the indicator may serve as warning of a change to prevent or encourage which action may be taken. But for effective predications on which extensive plans of action (such as regulation of a fishery) are to be made, more soundly based methods are required.

The idea of prediction is implicit also in the wish to appraise the condition of a fishery, since, as stated at the beginning of this paper, making a judgment with regard to an appraised condition implies that a choice has been made as to the objective of the fishery and further implies that this action may be taken to ensure that the chosen objective will be reached; this can only mean that an assumption is made that the future course can be predicted from the same evidence as that from which the appraisal of condition was made.

Several objectives for fisheries have been nominated from time to time. These relate to

(1) exploitation of resources;
(2) use of equipment;
(3) use of manpower;
(4) satisfaction of market;
(5) contribution to national income.

In some instances attention has been focussed on the first of these in the expression "maximum sustainable yield", but many workers have argued against setting this as an objective, pointing out that among other things this formula neglects the possibility that an undesirable social cost might be involved. In some cases the taking of maximum quantity might mean a lowering of quality or of income. Moreover, several workers have pointed out that there is no single maximum value to the yield to be taken from a resource. In the Canadian document (Gordon 1957) a statement is made that "the optimum intensity of fishing is that which maximizes the margin between production costs and returns". This too could be an objective, but whether a fishery could be managed by regulation to achieve this is another question. Perhaps the most that could be hoped for would be a set of regulations which would maximize the likelihood that the fishing intensity will be at a level at which the cost/return margin could be maximized.

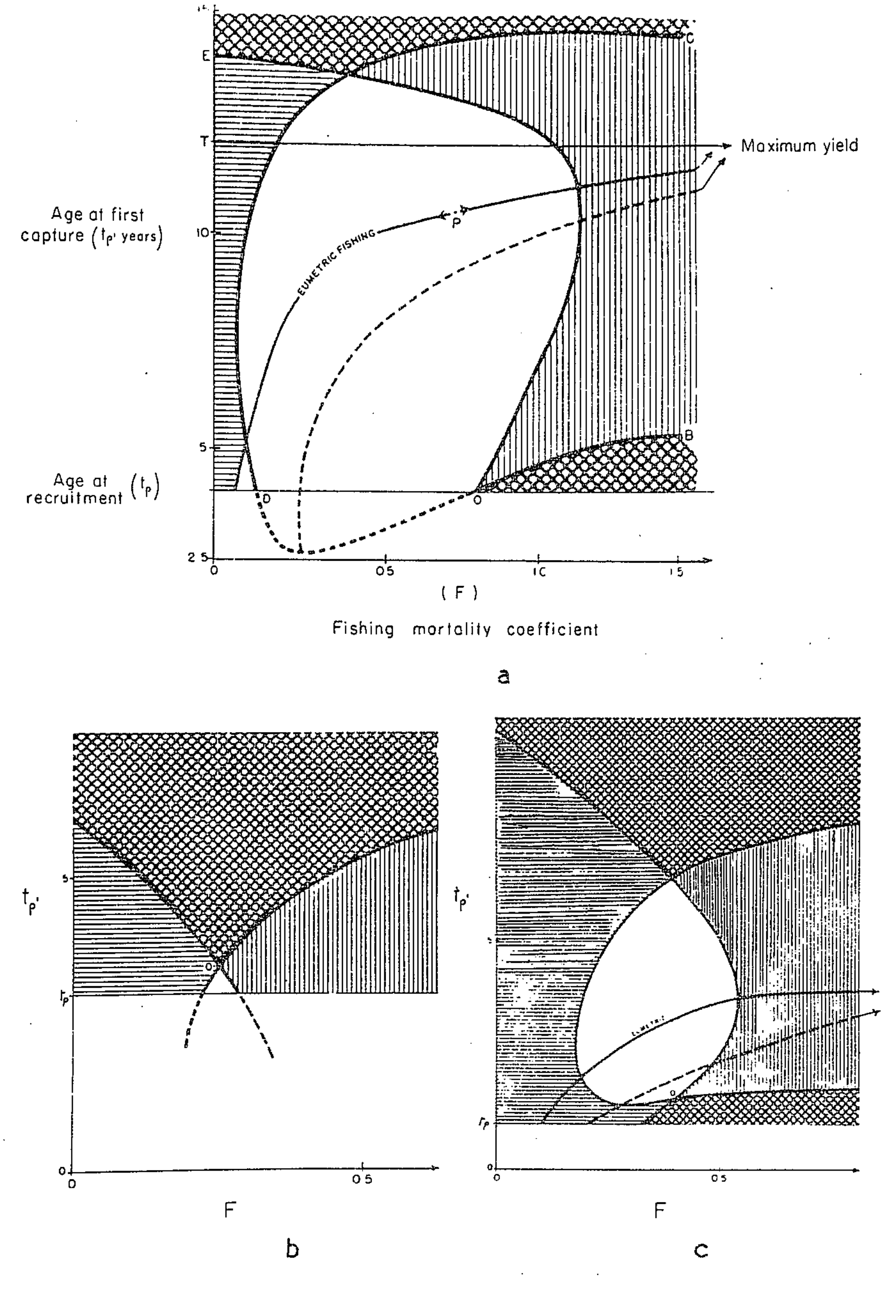


Fig. 5.- a. Stock Assessment Diagram, based on calculations made for North Sea Plaice (Pleuronectes platessa) (from Beverton 1953). Point O represents the situation at the time of measurement of population parameters. OB and CD are isopleths of steady yield equal to the yield being obtained at the time. OE is likewise the corresponding isopleth of yield per unit effort. Crosshatched areas indicate combinations of fishing intensity and selectivity giving both a decreased yield and a decreased yield per unit effort. Horizontal shading shows region of decreased yield but increased yield per unit effort; vertical shading, increased yield but decreased yield per unit effort. Unshaded region is of both increased yield and increased yield per unit effort. Dashed line connects points of maximum yield for any given age at first capture (amount of fishing adjusted to best value). Eumetric Fishing Curve connects points of maximum yield for any given amount of fishing (age at first capture adjusted to best value); P is the point of maximum net gain, the position of which on the eumetric curve is determined by economic factors. For ages at first capture above T years, the curves of sustained yield against fishing mortality have no peak.

b. Stock Assessment Diagram for St Mary's Bay Flounder (Pseudopleuronectes americanus) (from Dickie and McCraken 1955).

c. Stock Assessment Diagram for Georges Bank Haddock (Melanogrammus aeglifinus), before mesh regulation (from Taylor 1954; from Kesteven and Holt 1955).

In any case, the condition of a fishery can be appraised only against some standard representing characteristics which policy or individual aspirations believe it should have. And the making of an appraisal implies an intention that, if the disclosed condition differs from what is desired some action will be taken with the objective of bringing it to that condition, or, if it is in the desired condition, action or no action (according to the circumstances) will be taken to preserve it in that condition. In either case there is a further implication that the action taken will result in the condition desired.

CONCLUSION

To conclude, an examination of a fishery, with a view to assessing its condition,

(1) requires an analysis of the structure and operations of the fishery in all its sectors, and with regard to its relations with national economy;

(2) permits a diagnosis of the determinants of the disclosed condition, and a prognosis as to the future of the fishery;

(3) furnishes a basis for judgments as to actions, by operatives and government, with the object either of preserving the fishery in its current condition, or of changing its condition in some chosen direction.

Such an operation has some analogy with a clinical examination of a person, and is in essence an exercise in operational research. As a clinical examination, this operation makes use of various indicators, or symptoms, of conditions; various features of a fishery take on characteristic values in each of an array of typical conditions. However, the interpretation of such symptoms depends upon the development of a general theory with respect to the dynamics of fisheries, and is increased in reliability by deeper studies and extended records of each fishery. As operational research this work relies on the results of tests of its conclusions to provide it with data for further development of those conclusions.

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