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THE MEASUREMENT OF FISHING POWER[1)]

by

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Explanation and Summary

Preparation of thispaper followed a suggestion made during the 1958 Annual Meeting of the International Commission for the Northwest Atlantic Fisheries that an account be presented to the Second FAO Fishing Boat Congress of the results of research on the performance of fishing units conducted for purposes of resource assessment and fisheries management. The paper defines the fishing power of a fishing unit and describes how it is measured by comparative fishing trials and analysis of catch and effort statistics. The results obtained in correlating fishing power with measurable characteristics of the craft are briefly summarised and the uses to which this information is put for purposes of resource assessment and management are outlined. Needs for future studies are discussed.

Introduction

Measurement and analysis of the performance of fishing units has interested fisheries scientists since they first started, towards the end of the nineteenth century, to examine statistics of fish catches and measure the sizes of fish caught in an endeavour to understand why intensive fishing sometimes became unprofitable, and to find remedies for this condition. They have therefore been trying to discover and understand the quantitative relations between fishing activities and the sizes and compositions of exploited fish stocks, and of the catches obtained from the, with the principal aim of predicting the changes in fishing activity that will results in better catches.

Fishing activities comprise a collection of discrete operations by fishing units (each consisting of vessel, gear and crew). During each operation an input of fishing effort results in an out-take of catch. Measurement of these two elements - effort and catch - provides the basic information used for the assessment of fish stocks. For this purpose, effort and catch data for single operations have to be combined in such a way that the sum of the catches divided by the sum of the efforts in a given area and over a given time period is a proportional index of the average amount of fish present in that area during that time. If it were possible to measure stock abundance directly an in absolute terms, by for example the use of echo sounders, underwater cameras, or other such instruments, we should easily be able to determine the appropriate unit of fishing effort for this purpose. So far, however, in the absence of such knowledge it has been usual to attempt to foresee the factors of effort variability of which could result in non-proportionality of catch-per-unit-effort and

1) Contribution to Second FAO Fishing Boat Congress: prepared 5.3.59 (As revised 4.4.59 in light of Keir's comments).

fish density. The hypothesis that any given factor does indeed have such an effect in practice is then examined experimentally by the methods described in later sections of this paper; if no significant effect is detected that factor is ignored in further treatment of the data, but if an effect is great enough to be thus measured, it can be taken into account in devising an appropriate standard measure. It is in this manner that for certain fisheries there has been a progressive modification of the effort unit for trawlers as follows: Number of trips, days absence from port, days spent fishing, hours spent fishing, number of steam-trawler ton-hours spent fishing. (see later)

The compilation of catch quantities presents no special problems other than the definition of the identity of the stock from which they are taken; in general the catches must be of the same kind -species, species group, or perhaps race - and refer to the same condition of product, e.g. whole fresh fish. For the latter purpose, simple conversion by factors is usually satisfactory, and beyond that the only mathematical operation required is simple addition.

A difficulty in combining effort data is that not all unit operations are quantitatively equivalent; thus one haul by a big trawler obviously does not represent the same amount of effort as one by a small trawler. This sort of difference would not matter if the size composition of the fleet did not change, if there were no tendency for small trawlers to operate in different places from large ones, and if the compositions of their catches, by fish species and size, were the same. In practice, this is not so: vessels of different sizes tend to work in different places, the average size of vessels working changes from time to time, and so on. Of course there are also many factors other than vessel size which affect catches and which vary in these ways.

It is therefore necessary to establish standard units of fishing effort so that we may say that on the average x operations by fishing unit A are equivalent to y operations by unit B. By equivalent we mean no more than that if the two units A and B could fish at exactly the same time and place, A would catch in x operations the same amount and kind of fish that B would catch in y operations.

Before examining how such relations are discovered, we should mention two points. Firstly the aim in selecting effort units is to obtain a measure of effort which is related directly and simply to the physical characteristics of the system the processes within which are being analysed. A good unit of effort might be proportionally related to the area of ground or volume of water "covered" or "explored" by the gear during an operation and hence simply related to the probability that a fish present in the area at the time will be captured, and thus be related simply to the <u>fishing mortality</u> caused in the fish population by each operation.

Secondly it should be noted that not only are standard fishing effort measurements used initially to determine the condition of the stock and to analyse its dynamic properties of change in size, composition and yield in response to exploitation but also the standards are required to specify desirable amounts of fishing effort if the analysis shows that some control of the fishing activity would be beneficial to the industry.

<u>Definition of effort</u>

A measure of effort which often satisfies the above conditions is, for any fishing unit, the product of the <u>fishing power</u> of the fishing unit (i.e. its catching power) and the period of <u>time</u> during which it operates. These therefore constitute the two elements of the unit of effort. The total effort exerted by the fleet of fishing units operating in a fishery is the sum of these products for all the units comprising the fishing fleet. The primary tasks in effort measurement for any fishery are therefore first to choose the appropriate time unit for the particular method of fishing engaged in the fishery, and secondly to measure the fishing powers of the units. The time unit may refer in cases where fishing is "blind", as with trawlers not carrying fish detection instruments, to the time during which the gear acts; for other kinds of fishing the time spent searching for fish is more appropriate; probably in most cases a function containing measures both of "searching time" and "fishing time", appropriately weighted, would be better.

In practice, the <u>absolute fishing power</u> of a fishing unit cannot usually be determined, because the absolute abundance of fish in the locality fished is not known. All that can be measured are indexes of <u>performance</u> (e.g. catch per unit operation) of the fishing unit under the particular circumstances of the fishing operations. The performance of a unit will vary from place to place and from time to time as a result of variations in the abundance of fish and other external factors, so that this cannot be used as an index of fishing power for computing total effort. Instead, it is necessary to measure <u>relative fishing power</u>, defined as the ratio of the performance of one fishing unit to that of another operating under the same external conditions (abundance and composition of fish, etc.). The total effort exerted by the fleet can then be computed in terms of one component of the fishery (e.g. steam trawlers of a certain size, seiners, etc.), whose fishing power is taken as unity, the effort units of the other components being adjusted by their relative fishing powers. The relative fishing powers may refer to groups within a single class of fishing units (e.g. motor trawlers of different sizes), to classes of units within a single gear fishery (e.g. steam and motor trawlers) or between different components of a mixed gear fishery. The complexity of the task is a function of the heterogeneity of the fleet and the extent to which its composition changes with time or place.

A consequence of this concept of fishing-effort is that separate effort units and relative fishing powers may apply for the different species of fish caught in a mixed species fishery; the relative fishing powers of two units or groups of units may differ markedly for different species of fish.

<u>The measurement of relative fishing power</u>

The relative fishing power of a unit is the ratio of its performance to that of another unit under identical conditions. The method of measurement must therefore involve the analysis of the catches of vessels working at the same time and place, in their normal manner. The assumption here is that different units fishing apparently at the same time and place are fishing on stock of the same density. Whether this is so can be tested only by having direct estimates of stock density or by searching for differences in catches, such as their size composition, which would indicate that the different units are really fishing different groups of fish. It is necessary to assure such a difference does not exist, until it is detected, interpretation of data for fishery assessment purposes does not however usually depend critically on the validity of that null hypothesis. In testing it by examination of catch compositions it is necessary to know and to take account of inherent differences in the selectivity of the various units.

The most precise method of undertaking such comparisons is by carefully controlled comparative fishing experiments using two or more vessels. With this procedure allowance can be made for the effect of variations in external conditions such as the size and composition of the fish concentrations, the nature of the sea-bed, wind and tide, all of which modify the performance of fishing units. Since many of the characteristics of the fishing units can be carefully measured and controlled, such experiments also provide information on the causes of the observed differences in fishing power.

The relative fishing powers of all units of the fishing fleet can be determined from the results of several such experiments in which either one unit is used throughout as standard (e.g. a research vessel) or successive comparisons made between different pairs of units of the fleet (e.g. A is compared with B, B with C, C with D, and so on). Such experiments are accurate and highly informative, but they are also time-consuming and costly. For reliable estimates of relative fishing power numerous haul replicates are required in each experiment, and these have to be repeated under different external conditions.

In practice, especially in large mixed fisheries, it is often necessary to adopt a rather less precise but more comprehensive method of measurement. This is the analysis of the records of commercial fishing operations giving detailed statistics of the catches and efforts of the various fishing units for each species of fish, for short time periods and for small sub-divisions of the fishing area. The performances are compared of pairs or groups of units fishing in the same area at the same time. The applicability and precision of this method for any fishery are governed by the statistical breakdown; the smaller the area and time sub-divisions in which statistics are given, the less is the danger of variable external circumstances influencing the relative performances of the fishing units. This method is less costly and time-consuming than the more precise comparative fishing experiment, and estimates can easily be made for all seasons and localities fished. It is not applicable, of course, in fisheries in which the different components of the fleet are segregated on the fishing grounds. This is sometimes the case for the vessels of different countries and those using different types of gear. In such instances, the first method must be used to make the comparison between the segregated types of units.

Factors governing fishing power

Ideally, the measurement of total fishing effort exerted in a fishery should involve determination of the relative fishing power of each unit in the fleet. This is seldom possible in practice, and experience has shown that it is usually not necessary. For a large fleet it is impracticable to conduct a comprehensive series of comparative fishing experiments, and in the method of comparing commercial statistics there is a considerable chance variation in the estimated fishing powers of individual units. The fishing powers of units having similar characteristics with regard to vessel, gear and number of crew, however, are not usually found to differ markedly. That is to say, for example the differences between fishing powers of fishing units of clearly identifiable types are greater than the differences between units of the same type which differ in the skill of the skipper or other more subtle ways. The main task is therefore to identify factors closely correlated with fishing power variations within the fleet, and to measure the effects of each.

Some guidance to the identification of these factors can be obtained by a close examination of fishing practices. For convenience, the possible factors might be grouped in the following categories:

(1) Vessel characteristics
(2) Gear characteristics
(3) Crew characteristics (e.g. skill in operating gear, etc.)

In practice, of course, the several factors, in two or more categories, will not vary independently. For example, size and power of vessel and type or size of gear often vary together. In such instances, the fishing power might be expressed in terms of that characteristic which is most easily measured.

The factors of particular relevance to this Congress are those falling within the "vessel" category, and it is in relation to these that most fishing power assessments have been made, especially for trawlers. The two most obvious vessel characteristics which have been investigated are "size of vessel" and "propulsive power", and some examples of the results obtained are given below.

Some results (The following statements summarise findings reported in the publications listed at the end of this paper)

For British and German North Sea steam trawlers, fishing power has been found to increase with gross tonnage and overall length for all demersal species. It is, however, much more nearly directly proportional to the former, and proportionality is a desirable property because it simplifies computation of fishing effort, as "steam-trawler ton-hours". The fishing power of British motor trawlers working in the same area is also proportional to gross tonnage but the constant of proportionality is in this case higher, so that one-ton-hour fished by a motor trawler is equivalent to about 1.4 ton-hours fished by a steam trawler. Comparative fishing experiments with research vessels have confirmed this relation. The fishing power of a motor-trawler is also quite closely proportional to the brake-horse-power of its engine.

Icelandic motor trawlers averaging 660 gross tons and 1,000 h.p. and used for catching cod, have, however, only 40 per cent more fishing power than those in the 320 ton class with 625 h.p. engines. Further, the proportional relations described above do not seem to hold for vessels below a certain size.

Significant correlations have been found between fishing power and gross tonnage, and fishing power and horse-power of U.S. motor trawlers working on Georges Bank in the north-west Atlantic.

In the cases of Dutch motor and steam herring trawlers, and motor cutters trawling for demersal fish in the North Sea, the correlation of fishing power with horse-power is much better than with tonnage, and it appears from statistics that new motor trawlers have higher fishing powers than older trawlers of the same tonnage and horse-power. A detailed analysis has been made of English statistics from this point of view but significant effects of age or year of construction were not apparent. By comparing performances of ships of the same class it is possible to examine the variability due to crew differences but little work has so far been done along these lines. Gulland has however put forward arguments, based on an examination of data for British trawlers, indicating that although it may be that the better skippers tend to be in bigger or newer boats than the less skilful ones, the effect of this in increasing the fishing power of the bigger units is not so great as the direct effect of size of unit.

Studies are now being made of some fisheries by more refined statistical methods, to determine the interdependence of the different factors, particularly those expressing size of unit. Thus it seems that for trawlers fishing power increases with length, horse-power, and tonnage; it increases faster than length (and hence with trawl head-line length), but slower than tonnage so that it would appear that engine power increases in such a way with size that bigger trawlers tow faster than smaller ones, but less than proportionally with their tonnage. These results are highly variable however, with regard to difference in species, fish density and conditions of operation.

Some preliminary studies have been made of the effect of variations in the mode of operating the same fishing unit. For example, increases in towing speed of a Dutch trawler resulted in decreases in catches of flatfish, especially plaice. Such studies have been made to gain understanding of the changes in fishing power which seem to occur when the cod-end mesh size of a trawl is altered. Such changes differ considerably for different fish species - thus catches of one may be increased and of another decreased.

For Scottish seiners catching demersal fish there does not seem to be a relation between fishing power and size of vessel, and one day's fishing by any one seiner is equivalent to one day by a 350-ton trawler in terms of whiting catches.

In comparison between different kinds of gear, the "area swept" by the gear may be computed when it is difficult to define equivalent fishing times. For example, time spent trawling is easy to measure, but the duration of a seine haul is more difficult to define. However, Scottish seiners work in such a way that in each operation the gear sweeps out an area of about six or seven million square feet, which is about the same as that swept by a 30-foot trawl with 30 fathom sweeps towed at 3 knots for 2½ hours. In terms of catch per calculated area swept, it is found that the seiner has, for all demersal species, a fishing power about half that of the trawler, but if catches of small whiting alone are considered, its fishing power is found to be 30 per cent <u>greater</u> than that of the trawler.

<u>Conclusion</u>

Values for relative fishing powers of fishing units within a group, together with specifications of the structural and operational features of the fishing units, constitute the basic information with which critical examination of fishing capacity and performance may be attempted, using the techniques of correlation and analysis of variance. Findings of the kind outlined above can be used to bring the fishing effort statistics of a heterogeneous fleet to a common standard; the most important criterion of usefulness of a discovered relation is for this purpose whether it is a proportional one, since the adjustment of crude statistics is then a simple routine task.

The factors causing differences of fishing power cannot, however, be identified with certainty by these purely statistical methods but from an array of observed attributes clues may be obtained that can help in the design of critical experiments. Such experiments are in principle the same as the comparative fishing tests except that some deliberate and usually small change will be made in the structure or operation of one of two otherwise similar units, or the same unit may make alternate operations with and without the modification. This will be done to test a particular hypothesis as to the magnitude of a particular factor believed to play a part in determining the fishing power of the type of unit being studied. A special case of this kind is a gear selectivity experiment with, say, alternate hauls of a trawl using cod-ends of differing mesh size to test the hypothesis that changes in power rations with increasing size of fish are proportional to the maximum girth of the fish and hence to its ability to escape through the meshes. It should be noted, in this connection, that such experiments revealed the inter-dependence of selectivity and fishing power; thus increasing the cod-end mesh of a trawl to permit small fish to escape can also increase the fishing power with respect to large fish, and even when the towing speed is apparently unchanged. The relative change in fishing power thus caused differs for different species in the catches so that the species compositions of large fish, as well as the size compositions and the total effective effort exerted by a given fleet, are also altered to some extent.

The increased attention being paid to fish girth in net selection studies is a good example of a change in emphasis in gear research towards closer study of causative factors. There has been little sign so far of a corresponding change in studies of the factors relating to the vessel itself, or to the crew. Only the crudest of physical measures, such as gross tonnage, overall length and horse-power, have been examined for their relation with fishing power of trawlers. It seems opportune now for naval architects and marine engineers to contribute to this work.

Those researchers who have started the kind of work described here have often not even been familiar with the several different ways in which the characteristics, such as vessel length or displacement, which they have chosen for consideration are measured in practice and yet one measure of engine power, for example, may be much more closely related to fishing power than another. Surely there are other characteristics of craft, perhaps more complex functions of the apparently simple attributes of hull size and engine power, and of other attributes, which are more appropriate for scientific studies of fishing power?

The methods for comparing performance, which have been quite highly developed for purposes of stock assessment and fisheries regulation, may be worth considering as tools for improving vessel design, though they would need to be elaborated to cover the comparisons of overall performance rather than just performance at the fishing site. One word of warning is, however, necessary with regard to this question. Experiments carried out so far give data of a complexity quite sufficient to show that it is the whole fishing unit and its mode of operation, rather than craft or gear, which must be considered in the analysis. We must not forget that the catch of fish in a particular operation is the result of a complex interaction between the behavioural characteristics of the fish, the hydrodynamic properties of the gear, the kinds of forces exerted by the vessel, and the conditions of the sea at the time, which affect the behaviour of craft, gear and fish. Big trawlers catch more fish than small ones, and roughly in proportion to their sizes but such a statement appears to be near the limit to which we can regard catching fish, even by trawl, as a mechanical process of "sweeping" a certain area or volume. For other types of gear and methods of fishing, it is even more difficult to make quantitative statements with any security.

Further reading

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