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International Council for the Exploration of the Sea

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Gear and Behaviour Committee

Second Report of the Working Group on Standardisation of Scientific Methods for Comparing the Catching Performance of Different Fishing Gear

1. Introduction

The Working Group first met in Hamburg in April 1972 and presented its first report to the 60th Statutory Meeting of the Council in Copenhagen. A revised version of this report was submitted to the 61st Statutory Meeting at Lisbon (ICES Doc. 1973/B:7) and published in April 1974 (Cooperative Research Report No.38, p.1-22). Although much of what it contained was of wider application in the field of comparative fishing, the Working Group emphasised that the report had been written with bottom trawling specifically in mind and that features particular to experimentation with many other gears required separate discussion. Accordingly the Working Group was invited to continue its study of the standardisation of methods of comparing different fishing gears and in particular to extend its discussions to gears other than bottom trawls. A second meeting of the Group was held in Hamburg from 13-15 March, 1974. The participants were:

Dr.H.Bohl (F.R.G.)	Convener
Mr.H.B.Becker (Netherlands)	
Dr.U.Buerkle (Canada)	
Mr.J.J.Foster (UK Scotland)	
Mr.S.Lens (Spain)	
Mr.C.Nédélec (FAO)	Guest
Mr.J.A.Pope	Secretary
Mr.M.Portier (France)	
Mr.G.Vanden Broucke (Belgium)	
Mr.J.G. de Wit (Netherlands)	

2. Terms of Reference

The Group considered that, for the purpose of its discussions, fishing gear could be broadly classified into two categories (a) active gears and (b) passive gears. It attempted no formal definition of such classes of gear, assuming that the allocation of at least the more important gears in the ICES area to one or other of these categories would cause no conflict of

*General Secretary, ICES, Charlottenlund Slot, 2920 Charlottenlund, Denmark opinion. Thus, active gears, which imply the movement of the catching device, include trawls, dredges and seines while passive gears, which rely on the movement of the animal to effect capture, include gill-nets, traps and static hooked lines.

In addition to the need for procedural advice on the execution and analysis of experiments between different versions of the same gear within either of the above categories, the Group recognised the vital need for guidance on the comparison of the catching performances of different gears within categories (e.g. trawls versus seines) and of gears in different categories (e.g. trawls versus gill-nets). The results of such comparisons find their application in, for example, modes of allocating effort quotas in any multi-gear fishery regulated either nationally or internationally in this way. However, although there was some discussion of this important topic it was necessarily brief as the terms of reference for this meeting specifically excluded it (P.-v.Réun. 1973, p.57).

The Group also considered that in the time available for the meeting it could not deal adequately with a wide range of gear types and it was agreed that attention should be devoted to some of the more important active gears, namely mid-water trawls, two-boat bottom trawls, and purse-seines.

Of the methods of fishing associated with these three gear types, one (two boat bottom trawling) employs broadly similar tactics to those employed in single-boat demersal trawling while in mid-water trawling and purse-seinig additional features are present. These include the employment of a high degree of hunting for fish (aimed fishing) as opposed to gathering and the need for skill in the manoeuvring of fishing gear in three rather than two dimensions. These introduce qualities such as human skill which are difficult or even impossible to either alter or control. Special consideration was paid to those distinctive features particularly as they affect the design of comparative fishing studies and the analysis of information (see Section 4).

Comparative fishing techniques for each of the three gear types were discussed with particular reference being paid to the various factors, fishing unit, environmental and biological, which were identified in the previous report as possibly affecting gear performance and catches (Coop. Res. Rep. No. 38, Sections 4 and 11).

3. Comparative Fishing with Two-Boat Bottom Trawls.

The vessels forming the pair in a comparative fishing experiment must be of the same type and power and the lengths of the vessels should be as nearly equal as possible. When comparing catches by different pairs the lengths of all vessels should be similar. The vessels of a pair should have similar towing arrangements, either over the side or over the stern, and warp loads must be equal on each side of the trawl. A description of the towing points and the method of gear handling (net drum, gallows) should be made.

Changes of course during towing should be avoided. If course changes have to be made the haul should be considered invalid. The distance between the two ships must be kept constant and this distance measured and recorded. Experiments shoud not be carried out in ~~the~~ sea conditions that do not allow accurate distance keeping.

With regard to the fishing gear itself, the construction and material of the warps and the length paid out should be recorded; also the magnitude and placing of weights and the length, material, diameter and weight of the groundrope. A constructional drawing of the net should be supplied.

The gear factors which are either difficult to control or cannot be controlled independently are less complicated for bottom pair trawling than they are for bottom otter trawling. Differences in the angle of attack of the bridles may occur when the direction of the current at the bottom deviates notably from the direction of the current at the sea surface. Variations of the headline height occur when the weights and the groundrope touch the bottom heavily. This can happen at an upward sloping bottom or when the vessels are steaming against a heavy swell.

4. Comparative Fishing with "Aimed" Gears

4.1 General Considerations

There are close similarities between pelagic (mid-water) trawling and purse-seining. Both methods of fishing rely largely on the detection of suitable shoals of fish and the ability to manoeuvre the gear effectively in three dimensions. The accuracy and reliability of the fish detection equipment carried by the vessel and the skill of the skipper and his crew in interpreting the information provided by such equipment as well as in operating the gear itself may well outweigh any gear design factors. Any comparative study of the catching performance of different versions of such gears must recognise and allow for these important non-gear items.

Since the detection of dense shoals is of prime importance to the success of this type of fishing and as the existence of suitable shoals in a given area at a specified time is unlikely to be within the control of the experimenter, comparative fishing experiments of this type may take a considerably longer time to conduct than in the case of bottom trawling where a more even distribution can usually be more readily found.

Whilst comparative fishing with pelagic trawls and purse seines should give less variable results if conducted at times when the fish are more evenly distributed in space and therefore may provide a possible way of shortening the period of study it must not be overlooked that such conditions do not correspond to those under which the gear would usually be expected to operate most efficiently.

Increasing the length of time required for an experiment can raise the costs to such an extent as to make it prohibitive for the study to be carried out by research vessels and the use of commercial vessels may be necessary in order to provide enough information. Increasing the duration of an experiment also increases the possibility of major changes occuring in conditions many of which cannot be controlled in any way by the experimenter. The need to collect a large amount of information on many factors known or suspected to influence catching performance becomes necessary in such situations. This state of affairs is, of course, not peculiar to comparative fishing experiments and many statistical techniques have been proposed to assist the analysis and interpretation of such observational studies. This topic is pursued further in Section 5.

4.2 Mid-Water Trawling

With the above general considerations very much in mind the Working Group reviewed specific aspects of comparative fishing with mid-water trawls. It regarded the approach by way of studies of the performances of similar commercial vessels using standard and experimental gears as being the one most likely to provide reliable conclusions. When working with commercial vessels it is very desirable to have experienced observers on board both the experimental and standard (control) vessels to make accurate records of all information to be collected. If enough observers are not available it is essential that properly designed log books be issued to the skippers of all participating vessels with clear and adequate instructions as to how records are to be kept.

Items of particular relevance to mid-water trawling which should be noted are the type of equipment used for locating shoals and the means employed for varying the levels of the net (by main engine or winch or using both). Notes on fish locating equipment should include the method of operation, manual or automatic, details of scale expander and whether steering is automatic during location. During a tow any changes in length of warp (level of fishing) should be noted and the tactics employed by the skipper should be observed. The use of modern techniques of psychology to study the behavioural tactics of the skipper in response to the information presented to him by his equipment is recommended as a valuable new area of research in this field.

It is to be expected that on commercial vessels adjustments to the gear will be made during the course of a trip. However, only changes necessary to permit the application of the best tactics in a given situation should be allowed. Changes in the basic design of the net and otter boards should not be made at any time. It is absolutely essential to note any adjustments made and their effect on the gear.

4.3 Purse-Seining

The Working Group noted that developments in purse-seines had taken place over the years and it was suggested that this was evidence that the fishing industry had succeeded in carrying out at least some kind of comparative fishing evaluation. Over recent years purse-seines had gradually become bigger, both in length and depth, sinking rates had increased through changes in hanging ratio and total lead line weighting, and maximum fishing depths had been considerably extended. The Group recognised that it could be argued that some of these "improvements" were achieved not by comparative evaluation of alternative approaches but simply by recognising the direction in which changes for improvement had to be made (e.g. " the bigger the net the better"principle). But some comparative evaluation must have been made at some stages in the evolution of the purse-seine, even if only on a trial and error basis.

Several types of purse-seine exist and each is operated in rather different ways. Those types include

(a)shallow water purse-seines (e.g. those used for fishing sardines).

(b)deep water purse-seines (e.g.those used in nothern waters for herring).

(c)purse-seines used in association with fish attraction and aggregation procedures (e.g. the use of light attractants).

The latter group is a special case in that it may not matter which design of gear is used provided the size matches the aggregation power of the light. Yet this could be the one case when, by controlling the density of fish available, a <u>direct</u> comparison of the effectiveness of different gears in catching the known concentration could be made.

It was agreed that a number of alternative comparisons should be considered which cover the groups (a) and (b) above. In particular, attention should be given to exploring comparisons of fishing units (vessel, gear and crew) in a similar way to that used by fishing organisations.

Short term comparisons of purse-seines were considered to be unfeasible in general. Comparison of the catching efficiency of different purse-seines in shallow water on scattered, reasonably uniformly distributed fish shoals might be possible but in general circumstances long term studies would be necessary. Two main categories under this heading were considered, namely (1) comparisons between gears on <u>similar</u> vessels when the catch per unit fishing time is used as the measure of efficiency and (2) between fishing units (vessel, gear and crew) when economic profitability over a fishing season or equivalent time is used as the measure.

In comparing different purse-seines used by similar vessels, experiments should be conducted basically along the same lines as described for mid-water trawling and these need not be repeated again here. It is essential that throughout the net shooting and hauling operations the sinking speed and pursing speed should be noted and also the fishing depth. Essential environmental data to be recorded are water turbidity, surface temperature, occurrence and depth of thermocline, general weather conditions, current strength and direction and, for shallow water operation only, the depth and type of the sea bed.

When comparing different purse-seines used by different vessels, separate assessment of the influence of all factors related to either ship or net is not likely to be possible. A "global" comparison could be made by taking into account the economic aspects of the fishery, the results of each fishing unit being recorded and analysed in terms of profitability (i.e. sales minus exploitation and depreciation costs). A sufficient indication of the difference between gears may be given where several vessels of similar capital and running costs are operating on the same grounds. Although the value of such comparisons for profitability analysis is not denied it was considered that techno-economic studies of the extend required are beyond the scope of comparative fishing. No definite technical recommendations are given, therefore, for conducting comparisons of this type.

5. Observational Studies

5.1 General Remarks

The Working Group devoted a good deal of its time to discussing the possibility of being able to draw correct conclusions from data gathered from " undesigned and uncontrolled" experiments. The appropriateness of the statistical techniques given in the Working Group's first report to the analysis of data from such studies, and indeed the comparative fishing experiments in general, was also debated. The main conclusions, which are more fully dealt with in succeeding sections of this report, were that (a) while care must be exercised in collecting, analysing and interpreting data from observational studies, such studies are capable of providing a wealth of useful and meaningful information as evidenced by their increasing use in a wide range of research investigations (e.g. medical research), (b) the advice of a professional statistician should be sought before such studies are begun and (c) the techniques explained in the Group's first report provide a sound basis for data analysis. Adaptation of these techniques to meet the requirements of specific situations may, of course, be necessary.

5.2 Definitions, Principles and Procedures

An observational study is a survey of a process which seeks to explain the response of a variable quantity in terms of one or more explanatory variables. The process cannot be interfered with by the observer nor can any of the major explanatory variables be controlled or adjusted as in a designed experiment.

The first step in organising such an observational study is to define its objectives and the variables to be measured. At the outset it is advisable to prepare a written statement of the aims of the study. This ensures that all participants have a precise formulation of the hypothesis to be tested and also ensures that, as the study progresses, the objectives do not become altered and that different participants do not develop conflicting views as to what is to be done.

This statement should lead logically to the definition of the response variable to be measured and to how the measurements are to be taken and what comparisons are to be made. In comparative fishing studies the response variable needs to be carefully selected so that all appropriate information can be collected throughout the entire period of study. Possible response variables include (1) total catch in numbers per haul, (2) catch in weight per day's absence, (3)proportion of a given species which is of a certain size caught per haul, (4) value of all catches per vessel over a fishing season. There may be many more possibilities and the one or ones chosen must be stated.

In addition, all other variables to be measured during the study must be decided. Such "explanatory" variables may be truly causal variables (e.g. the number of weights on a purse seine) or simply classificatory variables (such as time of day). Particularly for the latter type, binary variables may be sufficient (e.g. 1= day, 0= night). In other situations a multi-pointed scale may be required. Also, when a variable is difficult to measure it may be sufficient to record it as an ordered variable (e.g. none, few, average, many).

If the study is likely to continue over a long period and particularly if the effect on the response variable is not expected to be observed quickly it will be necessary to include a large number of explanatory variables in the study.

When the explanatory variables (x_1, x_2,...) are measured on a continuous scale a comparison of the response variable (y) for the group using the standard gear can be made by first calculating the regressions of y on x_1, x_2,... for each group and adjusting the mean responses to remove the effects of the regression. When some variables are classificatory the regression analysis may be extended to become an analysis of covariance.

An extreme form of classification is that known as matching in which pairs of units with identical values of all explanatory variables are chosen, one being used as a control and the other as an experimental unit. Clearly the use of sister ships in a study should be an advantage but non-ship factors may still differ appreciably even in such situations.

It will be useful to conduct a pilot study before the main exercise is undertaken. Such a pilot study will serve to identify possible explanatory variables on which information should be collected in order to check the adequacy of log books and to provide a comparison between the vessels of the control and experimental groups before the experimental gear is introduced.

5.3 The Validity of the Analysis of Variance

Criticism has been levelled at the validity of the type of statistical models described in the first report of this Working Group when applied to data on fishing operations on highly aggregated species. The models described are of the form y (catch)=f(gear, other measured factors) +e where f() stands for "a function of" and e is a random component. Criticism is usually based on the misconception that what is referred to as the error term in these models somehow or other implies a Normal distribution of the species in space so that when the species is distributed in a highly aggregated fashion, as many are, this assumption fails and brings down the entire model with it.

The spatial distribution of a species may be classed conveniently into one or other of three groups, namely, (a)uniform,(b) random and (c)aggregated. A uniform distribution occurs when the fish are regularly spaced in a symmetrical square lattice in two-dimensions or cubic lattice in three-dimensions. The density per unit area or per unit volume would, in such a situation, be constant at all points. Probably no fish species is distributed precisely in this way although some may approximate to this.

When fish are randomly distributed in space they may be thought of as exerting no force of repulsion or of attraction on each other. The number of fish in any volume is neither influenced by nor itself influences the number of fish in any other volume. In such a situation the number of fish in the different unit volumes into which the total habitat may be divided will have a frequency of occurrence exactly predictable by a statistical probability distribution known as the Poisson distribution. This type of distribution is unaffected by the size of volume chosen as unit although, of course, the average number of animals per unit volume will depend on the size of the unit volume. When the mean number of fish per unit volume is large the frequency distribution of the number of individuals in different volumes will be closely approximated by a Normal distribution. This is a mathematically verifiable property of the Poisson distribution. Further, catches from such a population will have a Poisson, or for large numbers caught, a Normal distribution.

When fish are aggregated into shoals then the occurrence of individuals in any specific unit volume will increase the probability that individuals occur in neighbouring volumes. The entire habitat will be characterised by having a number of volumes with no individuals present and others with a large number present. The frequency of occurrence of different numbers of individuals per unit volume will in this case not be given by the Poisson distribution law but will follow some other statistical distribution such as the Negative Binomial distribution. Catches by fishing at random on such a population will also follow a Negative Binomial distribution, but, if fishing is "aimed" at schools this will no longer be true as zero catches will either not occur at all or be under-represented.

It is theoretically possible to find a mathematical transformation of the stochastic element which will have a Normal distribution and, in practice, some convenient transformation can usually be derived which will be, to a sufficient degree of approximation, Normally distributed. The point of this is to allow standard statistical tests of significance to be made where otherwise they would be invalid. The Normality requirement is a prerequisite of the figures actually used in the computations, not of the basic original data. If tests of significance and confidence limits are not required it is not essential to demand Normality of the stochastic term or any transformation of it although for other, analytical, reasons the statistician may prefer to work with transformed data. If the normality assumption is satisfied for a model of the form

$$y_{ij} = \mu + g_i + e_{ij} \qquad (i= 1,2;\ j= 1,\ldots\ldots n_i)$$

∞% confidence limits for the difference in the effect on catches of two versions of the same gear are provided by

$$(\bar{y}_1 - \bar{y}_2) \pm t\sqrt{V}$$

where $\bar{y}_1$ and $\bar{y}_2$ are the mean catches of n_1 hauls by gear 1 and n_2 hauls by gear 2, t is the appropriate ∞% of Student's t and

$$V = \left\{ \sum (y_{1j} - \bar{y}_1)^2 + \sum(y_{2j} - \bar{y}_2)^2 \right\} \left(\frac{1}{n_1} + \frac{1}{n_2}\right) / (n_1 + n_2 - 2)$$

The form of the other part of the model (i.e. the part embodied in the term involving f()) is more crucial. The mathematical representation of this response function (black-box) will depend entirely on how catches respond to changes in the levels of those factors included in the function. Although the simplest response function is a linear one it is not universal and if non-linear responses are known or thought to exist they should be so specified. The form of the function f() is a matter of judgement and will be based on the experimenter's knowledge and experience of the process under study. A wrongly specified model will lead to incorrect conclusions.

Non-linear response functions may be handled by ordinary least-squares procedures although the existence of non-linearity may result in mathematical complexity. This may be avoided by seeking a linearizing transformation of the response function suitable for analysis. As with the normalizing transformation this linearizing transformation is introduced solely for mathematical simplicity. If enough information is available, both transformations may be deduced from the data.