COOPERATIVE RESEARCH REPORTS

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REPORT OF THE WORKING GROUP ON STANDARDISATION OF SCIENTIFIC METHODS FOR COMPARING THE CATCHING PERFORMANCE OF DIFFERENT FISHING GEAR

and

PROCEDURE FOR MEASUREMENT OF NOISE FROM FISHING VESSELS

Proposed by the ICES Working Group on Research on
Sound and Vibrations in Relation to
Fish Capture

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REPORT OF THE WORKING GROUP ON STANDARDISATION OF SCIENTIFIC METHODS FOR COMPARING THE CATCHING PERFORMANCE OF DIFFERENT FISHING GEAR

1. INTRODUCTION

At the Council's 59th Statutory Meeting in Helsinki the following Resolution (C.Res.1971/2:4) was passed:

"It was decided, that:

(a) a Working Group shall be set up to be concerned with the standardisation of scientific methods of comparing the catching performance of different fishing gear.

It is anticipated that a document (manual) providing guidance on experimental procedures and analysis will be produced.

The Convenor will be Dr H Bohl.

(b) the Group should meet in Hamburg for three days at a date to be agreed."

The Working Group met for the three days 19-21 April, 1972. The participants were:

Dr H Bohl, Convenor	F.R.G.
Mr J P Bridger	England
Mr P G J Carrothers	Canada
Mr O Cendrero	Spain
Dr S J de Groot	Netherlands
Mr C Nédélec, Guest	F.A.O.
Mr J A Pope, Secretary	Scotland
Mr J G de Wit	Netherlands.

2. TERMS OF REFERENCE

In order to facilitate interpretation of its terms of reference, the Group formulated the following definition of comparative fishing:

DEFINITION: Comparative fishing is the term applied to the experimental procedure conducted in the field for evaluating quantitatively the differences in catching ability of different full-scale fishing units operating under specific conditions.

In accepting this definition the Group was of the opinion that, whilst its terms of reference mentioned only fishing gear it would to some extent be failing in its task if some attention was not paid to experimental principles relating to the comparison of fishing vessels and complete fishing units of different characteristics. However, the Group realised that in the time available it could deal only with procedures relevant to comparisons of different versions and types of bottom trawls. It was also clear that there was insufficient time for the proper preparation of a manual of methods. A further meeting of the Group would therefore be necessary.

3. GENERAL PRINCIPLES OF EXPERIMENTAL DESIGN

It is of paramount importance that every comparative fishing experiment be designed in such a way as to provide answers to the questions posed. The first principle of a good experimental design is therefore:

> Principle 1: The questions which require answering must be carefully and clearly stated prior to designing the experiment.

The second principle of a good experimental design is:

> Principle 2: The experimental units to be compared must be precisely defined prior to the start of the experiment.

This means that no adjustments are allowed during the course of the experiment. It is necessary, therefore, to ensure that the gear is fishing in the desired way before any comparative hauls are made.

Unlike many laboratory experiments in chemistry and physics in which closely reproducible results can be obtained, comparative fishing trials are characterised by large uncontrolled variations. Comparative fishing experiments must, therefore, be conducted in such a way as to allow the separation of the effects on catches of real differences in the experimental units from the effects of variations in uncontrolled factors. This may be achieved by arranging for the major known sources of uncontrolled variation to influence the experimental units equally, i.e. by balancing the effects of uncontrolled variation. For instance, if it is thought that systematic differences in catch may be produced when towing with, as opposed to against, the tide, making an equal number of tows by the experimental gears being compared both with and against the tide will remove the tidal effect from the differences in catches. If this is not done there would be a danger of a systematic bias in favour of one or more of the gears being compared. The third principle of a good experimental design is therefore:

> Principle 3: Bias should be absent.

Whilst the effect of some factors, such as tide in the above example, may be systematic, other sources of uncontrolled variation may exhibit no systematic pattern. This is true, for example, of the number of fish in the path of the gear on any tow. The effect of such factors cannot be exactly balanced between experimental units and hence there must always be a certain amount of uncertainty concerning the true differences between the gears being compared. Although the effect of random variation cannot be balanced exactly between units, it is possible, by randomizing the order of use of the gear throughout the experimental period, subject to any restrictions imposed in order to eliminate bias, to ensure that any particular random effect has an equal chance of influencing each of the experimental units.

The magnitude of the random error in any particular comparison which the experiment is designed to estimate is usually measured by the standard error (see Section 8). The fourth principle of a good experimental design is:

> <u>Principle 4:</u> Random variation must be capable of being measured.

This principle requires that repeated (replicate) hauls must be made with each gear.

The results deduced from any experiment refer strictly to the particular set of conditions under which the experiment was conducted. The aim of comparative fishing experiments, however, is to derive results which can be widely applied. Extrapolations beyond the conditions under which the experiment was conducted introduces additional uncertainty. The wider the range of conditions which can be investigated within an experiment, therefore, the more confidence will one be able to attach to an extrapolation of the results. Increasing the range of conditions should not, of course, be achieved at the expense of accuracy. Thus we have:

> <u>Principle 5:</u> The range of validity of the experiment should be as wide as possible without decreasing the desired accuracy of the experiment.

The next principle of a good design relates to its execution and analysis. Frequent, complicated and lengthy gear changes between hauls, especially ones which cannot easily be supervised, should be avoided. Similarly, the way in which the results are analysed should be as straightforward as possible. Thus, the next principle is:

> <u>Principle 6:</u> The experiment should be simple to carry out and analyse.

Fortunately with most of the simpler experimental designs which can be used in comparative fishing trials there is a corresponding, relatively simple method of analysis (see Section 8).

Enough data ought to be collected to provide an unambiguous basis for the rejection of hauls from analysis either at the time or subsequently. Rejection of data from analysis should always be made on an objective and not a subjective basis. Where no objective basis exists for rejecting an abnormal or extreme haul some statistical tests may be applied. Perhaps the simplest rule to apply in such situations, however, is to analyse the data both with and without the abnormal haul. If the conclusions indicated by the two analysis are different, this should be reported.

Possible experimental procedures for comparing fishing gears may be divided into major categories, (a) those employing one vessel only and (b) those employing more than one vessel. The advantage of (b) over (a) is that certain systematic factors (particularly environmental ones) will, at any given time, affect all experimental units in the same way. Hence comparisons between catches made at the same time are free from the influence of such common factors.

This, in turn, usually results in the need for a much smaller number of hauls in order to achieve the same accuracy as that provided by single ship experiments. The disadvantage of (b) is that, unless the vessels used are truly "sister" ships, additional systematic biases may be introduced in the form of interactions between ship and gear which cannot easily be eliminated from the comparisons it is desired to make. A further disadvantage of method (b) is that a greater number of personnel, both scientific and non-scientific, are involved and coordination and standardisation of activities become more difficult. If more than one ship is involved, therefore, it is essential that overall coordinators be appointed to direct the scientific and non-scientific aspects of the experiment.Full procedures of communication between ships must be evolved prior to the commencement of the experiment and strictly adhered to throughout.

4. FACTORS POSSIBLY AFFECTING GEAR PERFORMANCE AND CATCHES

Factors which can or may affect gear performance and catches were considered under three main headings, namely, fishing unit factors, environmental factors and biological factors.

4.1 Fishing Unit Factors

4.1.1 General

For fishing operations the fishing vessel, the fishing gear and the skipper and his crew form a unit. During experiments to find out the results of changes in the fishing gear it should be a general rule to change only one factor of the fishing unit at a time. If this is not possible the concomitant changes in other factors should be evaluated. To compare the results of changes in the fishing gear, the "ship" factor of a fishing unit should preferably not change, but if this is not possible, enough properties of the ships involved should be given to evaluate the influence of the vessels on the catches of the fishing gears compared.

Even in the case of sister ships, small differences between the vessels make it necessary to report factors which might influence the catching performance of the fishing unit.

4.1.2 Type of vessel

The type of vessel may influence the catch. Thus there are differences between side and stern trawlers both in shooting the gear, due to the initial spread of the warps on stern trawlers corresponding to the athwartships distance between the warp blocks, and in hauling, due to the different ways of manoeuvring the vessels.

4.1.3 Overall length

This factor serves mainly for purposes of vessel identification. The length is one of the factors influencing heaving and pitching motions. These motions, together with the rolling motions, are transferred to the warps and the fishing gear and can influence the catch results. However, if the differences in the length of the vessels engaged in a comparative fishing experiment are small these effects may be neglected.

4.1.4 Weight of vessel

The weight of the vessel (or displacement) should be distinguished from the volume of the vessel in gross registered tons (grt). The latter measure has often been used to identify the size of a vessel. It has been pointed out that grt as presently measured is useless as a parameter for comparing fishing vessels. Due to the fact that for most vessels a stability calculation is required it is not difficult to obtain the weight, or displacement, from the shipbuilders or from the shipping authorities.

As stated already, wave action has an influence on the vessel. The lighter a vessel is the more it reduces its speed due to oncoming waves. This results in a pulsating movement which is translated to the fishing gear and which may affect the catching performance. If vessels used in comparative fishing experiments are not sister ships and have different lengths their displacements should as far as possible be equal.

4.1.5 Noise

A vessel produces noise while fishing. Each vessel has its own characteristic noise level on which certain peaks are superimposed. Such peaks originate mainly from changes in propeller revs/min, changes in the pitch of controllable pitch propellors, changes of rudder position and the starting of auxiliary machinery.

Although the frightening effect on fish of sudden changes in noise level is not yet fully known it is advisable in comparative fishing experiments to:

(i) keep the ship as silent as possible by stopping auxiliaries which are not required during the experiment,

(ii) keep the noise level as constant as possible during the experiment both by day and by night,

(iii) avoid changes in the main engine setting, the pitch setting and the rudder position as far as possible,

(iv) record all noise-producing changes occurring during the experiment.

Ideally, noise measurements should always be made under fishing conditions on all vessels used in comparative fishing experiments. If one vessel is being used at different times the noise radiated into the sea should be kept as constant as possible. If more than one vessel is employed care should be taken to ensure that the same noise-producing equipment is in operation on each vessel.

4.1.6 Warp load

The propulsive properties of a fishing vessel at its fishing speed is often measured by the horse power of the main engine(s). There are many objections to the use of horse power as a measure of the force produced by the vessel on the fishing gear. The horse power of the main engine(s) takes into account neither the propeller efficiency nor the horse power actually delivered to the propeller shaft. The main force to be overcome by the propulsion machinery of a fishing vessel towing a trawl is the drag of the gear at the speed with which the net is towed through the water. This drag can be estimated by measuring the load on both warps. From the loads measured it can also be seen whether the gear is operating correctly. When the use of load meters on the warps is not possible or not practicable the propeller thrust can be calculated and used together with the exhaust-gas temperatures to estimate the horse power being delivered to the propeller shaft by the main engine. For this it is necessary to have certain propeller and hull data together with the revs/min and speed. To avoid complicated propeller calculations a simple way of calculating the propeller thrust from easily obtainable propeller data and the revs/min is being devised by E J de Boer (Netherlands). Using this together with the exhaust-gas temperatures a rough estimate or cross-check can be made of the horse power being delivered to the propeller shaft by the main engine. It is to be noted, however, that the propeller thrust is affected by sea conditions.

4.1.7 Winch

It is important to know the pull and the hauling speed of the winch. Though the interaction between propulsion machinery and winch operation is a rather complicated one the following points can be made:

(i) when the maximum pull of the winch is too small for the fishing gear, which is especially the case when fishing in deep water, the winch operation may have to be interrupted to cool the overloaded winch drive;

(ii) any interruption of the hauling operation increases the total hauling time and may enable fish to escape from the gear.

It is necessary therefore to note:

(a) the period of time from the beginning of the hauling operation till the cod end is on board;

(b) the period of time for which the winch had to be stopped;

(c) the speed of the vessel during the period of time the winch was stopped.

The pull of the winch should be noted at a diameter corresponding to half the space on the drum carrying the warp.

As the use of net drums results in a smoother hauling of the net it is probable that fewer fish escape when using a net drum. If a net drum is used this should therefore be noted.

4.1.8 Actual fishing time

In addition to recording the time of shooting and hauling, the time when the gear starts and stops fishing should also be noted. A good way to determine this is by means of a netzsonde. If this is not available then, on a side trawler, a bottom trawl may be taken as starting to fish when the warps are blocked up and ending when the warps are released from the block. On a stern trawler the period of time a bottom trawl is fishing starts when the agreed warp lengths have been payed out and the load on both warps is equal (within limits of say 5%) and ends when hauling the warps starts.

4.1.9 Towing speed

All vessels employed in a comparative fishing experiment must be capable of towing the gears being compared at an adequate speed. Unless it is desired to measure the effects of different towing speeds on the relative performance of the gears, the speed of towing should be kept constant for all gears at all times.

4.1.10 Course of tow

Any change of course during towing affects the operations of the gear. Each change should, therefore, be noted. Records of any accurate positioning systems used should be noted at sufficiently frequent times in order to allow actual courses to be reconstructed.

4.1.11 Gear factors

Small, often unintentional, differences between the gears being tested can lead to considerable differences in catch. At times the effect of these unintentional differences can be greater than that of the intentional differences between the gears being tested.

For the proper understanding of the results of a comparative fishing experiment by other workers it is necessary to describe fully the gears tested and the method of operation. A full list of the relevant information which should be collected and described is given in Section 11. Further, after every haul the gear should be carefully examined for signs which suggest that it has not been working properly; for example, (a) otter boards, bobbins etc., not polished, (b) twists in wires or netting, (c) damage to the netting etc. Unless it is obvious that damage occurred only during hauling and that none of the catch was lost such hauls must be excluded from the analysis. Only the man on the spot can decide whether the haul is a valid comparison or not. If he decides it is not, then no information as to the quantities caught should be recorded. In this way no analysis can be done subsequently when the fact that some damage was sustained has been forgotten.

4.1.12 Human factors

The most uncertain and unmeasurable factor is that related to the ability of the skipper and his crew. Some reduction in the effect of this factor may be achieved by interchanging the gear from one ship to another. Whilst it would be desirable also to interchange skippers and crews, this is not practical in reality. However, it is possible, and likely to be useful, to interchange some of the scientific staffs.

4.2 Environmental Factors

4.2.1 Light and turbidity

Light intensity and turbidity at the bottom should be measured whenever possible. These two factors have a direct influence on visibility which may affect the vision of fish and thus facilitate or impair their ability to escape from the approaching trawl. Therefore, "good visibility" and "poor visibility" hauls must not be combined. If there are no means for measuring light and turbidity, hauls should at least be classified as day, night, dawn or dusk hauls.

4.2.2 Temperature and salinity

Experimental hauls should be made where the bottom temperature is within the range of the main species sought. Should large variations of salinity be known to exist in the area where the experiments are carried out, differences in salinity must also be recorded.

4.2.3 Currents and tides

Sideways currents may hinder the normal work of gears. Should a strong sideways current be observed during a tow this must be recorded and its effects on the gear noted. Generally, tides and currents can change the factors dealt with in 4.2.1 and 4.2.2.

4.2.4 Condition of the sea

Hauls in a swell or rough sea may not be comparable with those carried out in calm weather since conditions of tow can vary greatly. An even tow can be made in a calm sea but a swell makes the towing speed suffer rapid and continuous changes which disturb the operation of the gear.

4.2.5 Wind

Wind is closely related to sea condition and has the same or similar effects on towing speed and gear.

4.2.6 Type of bottom

It is a well known fact that gears have different working efficiencies depending on the type of bottom. If a gear is towed on gravel its catch may be quite different from that when it is towed on mud. Dwelling or feeding habits of fish are also closely correlated with the type of bottom. At least some previous knowledge of the bottom is desirable before designing the experiments and the gear to be tested.

4.2.7 Depth

Depth is often related to feeding or spawning habits or to the distribution of fish according to age groups. Catches of hauls done over a wide depth range should not be combined or grouped. The quantity and composition of the catch depend to a large extent on the depth at which the tow was done. Depth may also influence the behaviour of the gear.

4.3 Biological Factors

4.3.1 By-catch

The amount of unwanted species (species not actually fished for), invertebrates, organic and inorganic material caught by the net is grouped under the name by-catch. The amount of by-catch may greatly influence the catching performance of the gear. For instance, the shape of the net may be altered, meshes may be blocked by jellyfish and weed, or the whole net may be torn. It is therefore important to note the amount (by weight) and the composition of the by-catch.

4.3.2 Diurnal behaviour

The diurnal behaviour of the commercially important species has to be known, as this may alter their availability. Some species may be burrowed for long periods on the bottom or carry out vertical migrations during the 24 h period.

4.3.3 Feeding

Feeding is a part of the diurnal behaviour. Depending on the species, fish may feed during the day or night. They may feed for a relatively long time and their feeding may be influenced by the temperature (digestion rate) and by their maturation stage. Juvenile species may reduce their food intake during a cold season, while spawning fish may cease feeding completely, resuming only after the spawning time.

4.3.4 Spawning behaviour

Spawning behaviour may change the "normal" diurnal activity pattern. This may lead to systematic variation in the amount caught per hour in the 24 h period. For instance, during spawning, night catches of plaice in the southern North Sea exceed day catches whereas, at other times, this pattern is reversed. The alertness of fish in spawning condition to the approaching gear may be reduced.

4.3.5 Sex-ratio

In some part of the season a school of fish may be composed of fish predominantly one sex. Spawning behaviour may also influence the sex-ratio. For instance, females may stay for a shorter time on the spawning ground than males. Such sex-ratio effects may have an effect on catches.

4.3.6 Spatial distribution

Some species may be widely dispersed over the fishing ground while others may be aggregated into schools. A species which is evenly distributed is ideal for comparative fishing experiments since differences in the catches of schooling species may be attributable more to uneven distribution than to differences in the gear. In some species their spatial distribution may be related to differences in length or age.

5. GEAR FACTORS WHICH ARE EITHER DIFFICULT TO CONTROL OR CANNOT BE CONTROLLED INDEPENDENTLY

Because most fishing gears are not rigid structures they will change shape as the forces acting on them change. Except in flat calm weather with a heavy ship, short-term fluctuations in towing speed cannot be eliminated. These fluctuations will affect both otter board spread and the drag of the net and will in turn affect the spread of the wings and headline height and may even cause the net to lift off the sea bed for a moment. This is an example of a factor over which the experimenter can have little or no control. Some other factors can be controlled but not independently. Thus, to measure the effect of otter board spread on catch one net must be fitted with larger or more efficient otter boards. This will result in the angle of attack of the bridles and wings being increased and the headline being pulled down. From this one experiment it will be impossible to say whether the observed difference in catches of the two nets is due to:

(a) the difference in otter board spread
(b) the effect of differences in otter board disturbance
(c) the different angle of attack of the wings and bridles
(d) the difference in headline height
(e) the sum of all the above differences.

Thus, what at first seems a simple question, which could be settled by a single experiment, is in fact a complex one calling for a long series of comparative fishing experiments.

6. THE AMOUNT OF INSTRUMENTATION REQUIRED FOR RELIABLE RESULTS

Ideally, all the conditions of the gear, vessels, environment and fish at the time of an experiment should be known. Many of these conditions are highly variable even in the same tow and should, therefore, be measured during comparative fishing tows. However, the presence of a comprehensive set of instruments, particularly those for gear measurements, seriously alters the shooting and hauling of the gear and may adversely affect fishing results. If so, it is necessary to measure the towing characteristics of the experimental gear during tows separate from those used for comparative fishing. These gear-measuring or "calibration" tows should be fully instrumented to describe completely the behaviour of the gear. They should be conducted over a range of conditions which includes everything anticipated for the comparative fishing tows. Also, they should be conducted at the same place and preferably either just before or interspersed among the comparative fishing tows so that uncontrollable and unmeasured variables are as nearly constant as possible for all tows.

During comparative fishing tows there are certain variables which can be measured relatively easily and should be used frequently to check whether or not the gear is behaving normally. The detailed behaviour of the gear can then be inferred from these "check" measurements made during comparative fishing tows plus the previously made "gear calibration" measurements. Instruments which produce a record require the least attention during towing and provide maximum information for use after the tow. The tensions in the two towing warps, measured separately, indicate whether the gear has been set properly and the doors are operating normally, and can be used to compensate for changing effects of wind and ocean currents. Either the spread of the doors or the angles of the warps at the towing block monitor the changing effect of the sea floor on door performance. Headline weight and wing spread indicate the changing shapes of trawls. Preferably the speed of the trawl through the water should be measured, but adequate instrumentation for use during fishing tows has not yet been developed. Alternatively, measurement of ocean currents by moored meters near the surface and near the sea floor, plus measurement of ship velocity through the water, preferably by an electromagnetic or doppler log, plus measurement of ship velocity over the sea floor from its timed course by radar or radio navigation (e.g. Decca) will provide adequate information to describe gear behaviour from "gear calibration" data. On the vessel, engine speed, propeller pitch, propeller thrust, exhaust-gas temperature, anemometer readings, etc. are easily measured and may help to duplicate general conditions during successive tows and to warn of grossly abnormal conditions, but they are of little help in defining normal variations in conditions during the tow. Echosounder readings are essential. Data on fish distribution from netzsonde, sonar sector scanner, fish counter, etc. can aid the interpretation of comparative fishing results.

7. TREATMENT OF CATCHES

The extent to which the catches can be examined will depend largely on the available facilities and the number of scientific staff present. On a research vessel or specially chartered vessel it should be possible to collect information on all the biological factors listed in Section 11. On a commercial vessel this will normally be impossible and in the extreme case the only information may be an estimate of the catch or of the amount of marketable fish retained. Much depends too on the size of the catches and the number of different species caught in each haul.

Given that sufficient time and staff are available the following treatment of catches is recommended:

(1) the species should be separated and the quantities of each recorded.

(2) if the catch is so big that it is impractical to examine it all then sub-sampling must be resorted to. There are several ways of doing this correctly and the guiding principle is the same for each method. The sample must be representative of the total catch and also a known fraction of the catch so that a simple raising factor can be used. This will be more accurate if those fish not examined are at least counted.

(3) the quantity of any undersized fish rejected should be noted as well as the volume of detritus, invertebrates etc. (by-catch).

(4) printed log books should always be used in preference to odd sheets of paper to record the results of any examination of the fish undertaken.

8. STATISTICAL ANALYSIS OF DATA

Effective analysis and correct presentation of the results produced is an important part of an efficient experimental methodology. The assumptions on which any statistical analysis of data is based need to be carefully framed and stated. They must be compatible with the experimental situation in question.

8.1 A Simple Statistical Model

The simplest statistical model is that in which the observation (catch) is assumed to be represented by two additive quantities, one depending on the particular gear being used and the other on the specific conditions holding at the time of making the haul. The former quantity is regarded as unchanging with time and place while the latter assumes values particular to the time and place. This model may be expressed mathematically as

$$y_{ij} = \gamma_i + \epsilon_{ij}$$

where γ_i represents the effect on catch of gear i and ϵ_{ij} represents the collective value of all other effects operating on gear i at time j. If only two gears are involved and if n_1 hauls are made with the first and n_2 with the second it is easy to see that the difference in average catches, $\bar{y}_1-\bar{y}_2$, is equal to $(\gamma_1-\gamma_2) + (\bar{\epsilon}_1-\bar{\epsilon}_2)$. The variance of the estimate $\bar{y}_1-\bar{y}_2$ is also seen to be $\sigma^2/n_1 + \sigma^2/n_2$, assuming the ϵ_{ij} to be statistically independent with the same variance for all values of i and j. For example, the catches (in baskets) of two trawls A and B fished in a random sequence from the same vessel were:

gear A:	5	12	7	8	4	6
gear B:	3	9	2	7	7	

The mean difference is 1.4 with a standard error (square-root of the variance of $\bar{y}_1 - \bar{y}_2$) of $\pm \sqrt{(3.0637)} = \pm 1.75$.

8.2 A Two-way Experimental Design

A more elaborate model may be required if comparisons are made over a period of several (not necessarily consecutive) days and if fishing success is not constant from day to day. In this case each catch may be considered as the result of three additive components, one due to gear, one due to day and a random component due to all other specific conditions holding at the time of the tow. That is

$$y_{ij} = \gamma_i + \delta_i + \epsilon_{ij}$$

The expected average value of y_{ij} over all gear types and days involved is $E(y_{ij}) = \bar{\gamma} + \bar{\delta} = \mu$ (say). Thus we write:

$$y_{ij} = \mu + (\gamma_i - \bar{\gamma}) + (\delta_i - \bar{\delta}) + \epsilon_{ij}$$

$$= \mu + g_i + d_j + \epsilon_{ij}$$

where g_i and d_j are quantities, taking positive and negative values, with zero means. That is, they represent effects which are added algebraically to the overall mean. The quantities representing gear effects are usually to be regarded as fixed quantities representing the effects of the specific finite set of gears included in the experiment. Those representing day effects are to be regarded as random variates representing a sample of days from a large number of possible days. The decision as to which effects are fixed and which random in any analysis is often a matter of defining the way in which the results are to be interpreted.

The model $y_{ij} = \mu + g_i + d_j + \epsilon_{ij}$ may fail to hold for a number of reasons. It may, for instance, be more realistic to assume that the gear, day and random effects are multiplicative rather than additive. i.e. that

$$y_{ij} = \mu \times g_i \times d_j \times \epsilon_{ij}$$

This would apply, for instance, in the case of a two-gear comparison in which apart from random fluctuations, one gear caught more than the other by a fixed percentage rather than a fixed absolute amount. The multiplicative model may be transformed into an additive one by using the logarithms of the catches, thus:

$$\log(y_{ij}) = \log \mu + \log g_i + \log d_j + \log \epsilon_{ij}$$
$$= \mu' + g'_i + d'_j + \epsilon'_{ij}$$

A more serious breakdown in the additive model occurs if there is an interactive effect (interaction) between some or all of the factors. This would occur if the differences between gears varied significantly from day to day being (say) large on those days when fishing was good and insignificant on days when fishing was poor. Additional terms would be required in the mathematical model applicable to such a situation.

As an example of the analysis of an experiment for which a model without interaction is considered applicable, consider the following set of data giving the catches of plaice by two gears, referred to as gear A and gear B. Four hauls were made on each of four days the gear being used in a random order each day. The grounds fished on days 1 and 2 were slightly different from those on days 3 and 4 and this has clearly affected the level of fishing.

Day	Gear A		Gear B	
1	130	190	180	230
2	70	60	80	80
3	420	580	600	740
4	390	430	400	470

The ratios of the average catch by gear B to that of gear A are reasonably constant from day to day suggesting a multiplicative rather than an additive model. The logarithms of the catches (to the base 10) are

Day	Gear A		Gear B	
1	2.11	2.28	2.26	2.36
2	1.85	1.78	1.90	1.90
3	2.62	2.76	2.78	2.87
4	2.59	2.63	2.60	2.67

Using the transformed data the observations on the first day may be written as

$$\mu' + g'_1 + d'_1 + \epsilon_{111} = 2.11$$
$$\mu' + g'_1 + d'_1 + \epsilon_{112} = 2.28$$
$$\mu' + g'_2 + d'_1 + \epsilon_{211} = 2.26$$
$$\mu' + g'_2 + d'_1 + \epsilon_{212} = 2.36$$

Similar equations may be written for days 2, 3 and 4. On adding all the equations for gear A together and similarly for gear B we get:

$$8\mu' + 8g_1' + 2(d_1' + d_2' + d_3' + d_4') + \sum_{j,k} \epsilon_{1jk} = 18.62$$

$$8\mu' + 8g_2' + 2(d_1' + d_2' + d_3' + d_4') + \sum_{j,k} \epsilon_{2jk} = 19.34$$

Subtracting the first of the above equations from the second gives

$$8(g_2' - g_1') + \sum_{j,k} (\epsilon_{2jk} - \epsilon_{1jk}) = 0.72$$

$$\therefore \quad (g_2' - g_1') + \Sigma \ (\epsilon_{2jk} - \epsilon_{1jk})/8 = 0.0900$$

Thus, apart from random error, the gear effect $(g_2' - g_1')$ is 0.0900. This difference is in terms of the logarithms of the catches. In terms of the catches themselves the analysis shows gear B to be 23% better at catching plaice than gear A (log 1.23 = 0.0900). The variance of the estimate on the logarithmic scale is the variance of the random error $\Sigma(\epsilon_{2jk} - \epsilon_{1jk})/8$. This is easily seen to be $(8\sigma^2 + 8\sigma^2)/64 = \sigma^2/4$. The value of σ^2 may be computed by calculating the value of ϵ in each observational equation after estimating μ', g_1', g_2', d_1', d_2', d_3' and d_4' from the equations with all ϵ's set equal to zero. The first of these is simply the mean of all (logarithms of the) data, i.e., $\mu' = 37.96/16 = 2.372$. Next, since $g_1' + g_2' = 0$ and $-g_1' + g_2' = 0.0900$, $g_1' = -0.045$, $g_2' = +0.045$. In a similar fashion it will be found that $d_1' = -0.120$, $d_2' = 0.515$, $d_3' = 0.385$ and $d_4' = 0.250$. Substituting the appropriate values in the first observational equation gives

$$2.372 - 0.045 - 0.120 + \epsilon_{111} = 2.11$$

and so on. The sum of squares of the estimated ϵ's (viz. 0.04590) must be divided by 11 to give an estimate of σ^2 since 5 independent quantities (μ', g_1', g_2', d_1', d_2', d_3', d_4' but $g_2' = -g_1'$ and $d_1' + d_2' + d_3' + d_4' = 0$) have already been estimated from the original 16 observations. The estimated value of σ^2 is thus $0.04590/11 = 0.004173$. This value might have been obtained more readily by carrying out a two-way analysis of variance of the data. The appropriate technique is explained in most modern textbooks on statistical analysis.

The 95% limits for the estimated gear effect on the logarithmic scale are given by

$$0.0900 \pm 2.201 \left(\frac{0.004173}{4}\right)^{\frac{1}{2}} = 0.0900 \pm 2.201\ (0.0323) = 0.0900$$

$\pm$ 0.0711 = 0.0189, 0.1611, where 2.201 is the 5% value of Student's-t for 11 degrees of freedom. The anti-logarithms of these limits are 1.04 and 1.45. It may be concluded, therefore, that gear B is superior to gear A by probably at least 4% but not more than 45%.

8.3 A Model for a Two-ship Experiment

The following data are the logarithms of the catches of cod by the two research vessels "Ernest Holt" and "Explorer" during a comparative fishing experiment designed to test two trawls fitted with 40 fm and 60 fm bridles respectively. One set of each gear was carried aboard each vessel and it was arranged that the vessels would use the different trawls at the same time, frequent gear changes being made throughout the experimental period.

Gear A (60 fm bridles)		Gear B (40 fm bridles)		Difference
Log catch	Ship	Log catch	Ship	(A - B)
1.74	"Explorer"	1.61	"Ernest Holt"	0.13
1.78	"	1.86	"	-0.08
1.86	"	1.52	"	0.34
1.67	"	1.57	"	0.10
1.32	"	1.20	"	0.12
1.92	"	1.96	"	-0.04
1.67	"	2.10	"	-0.43
1.72	"	1.30	"	0.42
1.18	"	0.78	"	0.40
1.38	"Ernest Holt"	1.90	"Explorer"	-0.52
1.72	"	1.97	"	-0.25
1.11	"	1.45	"	-0.34
1.11	"	1.18	"	-0.07
1.66	"	1.18	"	0.48
1.11	"	1.70	"	-0.59
1.30	"	1.38	"	-0.08
1.18	"	1.32	"	-0.14

The vessels were not sister ships and, apart from arranging to shoot and haul at the same time and to tow on parallel courses, further standardisation of ship factors was largely impossible.

If the following model for the observations is assumed

$$y_{ij}(k) = \mu + g'_i + s'_j + \epsilon_{ijk}$$

where $y_{ij}(k)$ represents the logarithm of the catch, g'_i represents the effect of gear i (i = 1, 2), s'_j represents the effect of ship j (j = 1, 2), both being fixed effects, and k refers to the k^{th} pair of hauls (k = 1,2,...,17) then the difference between observations in the first pair is

$$1.74 - 1.61 = y_{11}(1) - y_{22}(1)$$

$$= (g'_1 - g'_2) + (s'_1 - s'_2) + (\epsilon_{111} - \epsilon_{221})$$

and similarly for the 2^{nd} to 9^{th} pair, while for the 10^{th} pair the difference is:

$$1.38 - 1.90 = y_{12}(10) - y_{21}(10)$$
$$= (g_1' - g_2') - (s_1' - s_2') + (\epsilon_{1210} - \epsilon_{2110})$$

and similarly for pairs 11 to 17. Writing $\delta(k)$ for the difference between the k^{th} pair then we have

$$\delta(k) = (g_1' - g_2') + (s_1' - s_2')d + \eta(k)$$

where $d = +1$ if $1 \leqslant k \leqslant 9$ and $d = -1$ if $10 \leqslant k \leqslant 17$ and $\eta(k)$ is a random error term equal to the difference between the ϵ values for the two observations in the k^{th} pair.

It should be noted in passing that the values of ϵ in the same pair are likely to be highly positively correlated and, since the variance of $\eta(k)$ is $2\sigma^2 (1-\rho)$, where ρ is the correlation coefficient between ϵ's belonging to the same pair, the effect of pairing is to reduce substantially the variance of the error term in the differences.

The values of $(g_1' - g_2')$ and $(s_1' - s_2')$ may be estimated in a manner similar to that described in the previous section. This is equivalent to carrying out an ordinary regression analysis of $\delta(k)$ on the dummy variate d defined above. If this is done the following regression equation is obtained

$$\delta = -0.0411 + 0.1477d$$

the standard error of both the constant term (which is the difference between gears) and the regression coefficient (which is the difference between ships) being $\pm$ 0.0730. The gear difference is thus estimated to be A/B = 0.91/1.00 (0.91 = antilog (-0.0411) with 95% limits 0.65/1.00 and 1.27/1.00 while the ship effect is Explorer/Holt = 1.41/1.00 (limits 0.99/1.00 and 2.00/1.00).

From the results of several other similar experiments it seems likely that the model used here is not correct in not including terms to represent a ship x gear interaction. Had such terms been included in the model they could not have been estimated from the data given here.

9. ESTIMATION OF NUMBERS OF HAULS REQUIRED

In the planning stages of an experiment it is desirable to know, at least approximately, the number of hauls which are likely to be needed in order to arrive at a useful conclusion. This number depends on the magnitude of haul-to-haul variability and on the particular aim of the experiment.

The magnitude of the haul-to-haul variability (i.e. the variance of the ϵ terms of the previous sections) cannot be exactly known, of course, until the experiment is at least partly underway, so that initially some reasonable estimate of this quantity must be used. This estimate will have to be revised as the experiment progresses if the initial estimate appears too high or too low.

The aim of an experiment involving two gears might be only to establish whether or not they differ in their catching rates or to determine, with specified accuracy, the magnitude of the difference in catching rates. Fairly obviously the second aim would require a larger number of hauls than the first.

As an example of how the number of hauls required to establish the existence of a difference would be determined, consider, as an estimate of variance the variance of the first 9 catches (on a logarithmic scale) of "Explorer" given in Section 8.3 (p.17). This is 0.0596, corresponding to a standard deviation of a single haul of $\sqrt{(0.0596)} = 0.24$. If n hauls are made with each gear the standard error of the difference between the mean (log) catches is $2\sigma^2/n$ = 0.1192/n. If the observed mean difference exceeds $t(0.1192/n)^{\frac{1}{2}}$, where t is the value of Student's-t corresponding to the 5% probability level with 2(n-1) degrees of freedom, the difference will be judged to be significantly different from zero. The following table gives examples for various values of n.

No. of Pairs of Hauls	s.e. of Difference	Difference Required for Significance	Percentage Superiority of Better Gear
2	0.24	1.032	979
10	0.11	0.231	70
15	0.09	0.184	53
20	0.08	0.162	45
30	0.06	0.120	32
40	0.05	0.100	26

The table above shows for instance, that if the difference in the mean log catch of 20 hauls with each gear is 0.162 it will be judged significant at the 5% level of probability. Such a difference is equivalent to the better gear of the pair catching 45% more fish than the poorer gear (i.e. being 1.45 times more efficient). However, if the superior gear were really 45% better than the other, the probability of observing a mean difference of 0.162 or more would only be 0.50. If the true difference were only 30% (corresponding to a mean difference of 0.114) the probability of observing a value of 0.162 in 20 hauls with each gear would only be a little over 0.25. In fact if one wishes to be say 80% certain of detecting a real difference after 20 hauls with each gear the true difference would need to be 70% and not 45%.

Whilst the estimate of error variance used here for illustration (0.0596) may be an overestimate for some situations it is not considered to be in any way abnormal. Using the same value, the number of hauls required with each gear to give 80% certainty of detecting a significant value at the 5% level of probability is given below for various assumed real differences.

Percentage Superiority of Better Gear	No. of Hauls Required
25	111
50	22
100	10
200	6

Although these results may be taken as upper limits which may be reduced by more careful experimentation, more elaborate statistical design and the use of paired (matched) hauls, they do indicate the near futility of attempting to look for small differences in gear performance.

10. OBSERVATIONS COMPLEMENTARY TO COMPARATIVE FISHING

As the final proof of the superiority of one gear over another there can be no substitute for some form of comparative fishing in the opinion of the fishing industry. To prove conclusively that a new gear catches more fish, or is easier to handle so saving time, manpower, or fuel, a full-scale trial at sea against the old gear is vital. Scientifically, however, as a means of understanding how fish react to a particular gear this form of experiment leaves much to be desired. At best a single comparative fishing experiment can show only that at a certain time and place under certain conditions, many of which are either unknown or unmeasured, one gear caught more fish than another. It can never show conclusively why it was more effective and, further, it gives an answer only in relative rather than absolute terms. Ideally the total number of fish within reach of the gear, the number which were caught, the number which escaped and the route by which they did so should be known. Comparative fishing alone cannot achieve this and so it is highly desirable that any other means available should be employed during the experiment. Echosounders, sonar, netzondes, underwater cameras, TV, divers, submersibles etc. should be used to the full whenever possible. Since few scientific institutions possess all the types of equipment and technical skills available in the world there is a growing need to arrange international cooperation whereby several countries could combine their resources to solve a problem which no one country could achieve alone. Such collaboration would be difficult and expensive to arrange but if properly planned and executed could yield a definite answer in a fraction of the time taken to piece together the separate bits of evidence forthcoming from reports published by the various countries concerned with the problem of improving the efficiency of fishing gears.

11. PRESENTATION OF RESULTS

Whilst it is fully appreciated that the following list represents an extensive and ambitious set of requirements it is considered that every effort should be made to obtain information on each item. The units of measurement used should be clearly stated.

I. FISHING UNIT

1. Ship

a. Type	general layout (side or stern trawler with or without ramp, double rig). gear handling equipment (gallows, gantry, net drum etc.).
b. Size	length o.a. tonnage (gross). displacement.
c. Power	propulsion engine(s). towing pull/warp load. trawl winch (nominal pull and warp speed).
d. Operation	duration of tow (actual time of fishing on the bottom). time needed for shooting. time needed for hauling. towing speed and/or distance covered on the bottom. course while towing (each change to be recorded). crew factor (number, skill). fish-locating and gear control equipment used.
e. Ship noise	frequency spectrum.

2. Gear

a. Type of net (e.g. otter trawl, pair trawl, beam trawl, high or low opening trawl). Constructional drawing to be supplied.

b. Net size (length of headline and footrope, circumference in number of meshes multiplied by length of mesh).

c. Net design, material, and construction (netting yarn Rtex and/or runnage, twisted or plaited; single or double braided; knotted or knotless; treatment; mesh sizes; length, material and diameter of lines).

d. Cod end mesh opening (as measured by the ICES gauge) and type and rigging of chafer used.

e. Rigging warps (length, construction, diameter).

otterboards (type, material, size and weight).

bridles (length, material, diameter).

connecting devices, e.g. dan lenos, ponies, butterflies, etc. (material, size and weight).

legs (number, length, material and diameter).

groundrope (length, material, diameter and weight) including number, size and material of sinkers, bobbins, spacers, rollers, links etc.

floats (number, material, size, buoyancy) and other lifting devices. e.g. kites (type, material, size).

f. Gear parameters while towing, i.e. distances between otter-boards and wing tips, opening height.

g. Contact of the groundrope/footrope with the bottom.

h. Damage to the net and/or anomalies of the gear.

i. Gear noises (frequency spectrum).

j. Flow of water at net opening.

II. ENVIRONMENT

1. Date and time of all sequences of the fishing operation.
2. Geographical positions at the end of shooting and the beginning of hauling.
3. Depth range.
4. Bottom type, i.e. profile and nature (including occurrence of stones, shells, etc.).
5. Current and/or tide strength and direction at the surface and at the bottom relative to course while towing.
6. Temperature at the bottom.
7. State of the sea.
8. Wind (direction, strength).
9. Light intensity at the bottom.
10. Turbidity at the bottom.

III. BIOLOGICAL FACTORS

1. Weight of the catch per haul, total and by species, and the same expressed by unit of time.
2. Length composition for all species.
3. Maturation stage and sex ratios of the main species.
4. Stomach contents of the main species.
5. Spatial distribution of fish as obtained by echosounding.
6. By-catch, i.e. invertebrates, shells, weeds, sponges, stones, etc., estimated in weight and volume.

PROCEDURE FOR MEASUREMENT OF NOISE FROM FISHING VESSELS

(Proposed by ICES Working Group on Research on Sound and Vibrations in Relation to Fish Capture)

1. INTRODUCTION

A preliminary edition of this Report was given at the Council Meeting in 1972. The Report has been prepared by the Working Group on Research on Sound and Vibrations in Relation to Fish Capture. - In order to enable scientists to compare data from underwater noise measurements, a standardisation of techniques, methods of data collection and presentation of results is most desirable.

This Report is intended as a proposal for a standardised procedure of noise measurements from fishing vessels. The described measuring technique is commonly used by SINTEF at the Technical University of Trondheim (Norway), and at the SIMRAD Noise Measuring Range, Horten, Norway. Some modifications have been made in accordance with opinions of members of the Working Group. A bibliography of recent research work in this field is listed on page 30.

2. NOISE MEASUREMENTS IN FISHING VESSELS

The purpose of the measurements is to describe the noise radiation into the water and the noise situation within the boat itself. Measurements of underwater noise are necessary for the evaluation of its possible influence on fish behaviour and of the working conditions of hydroacoustic instrumentation. Inside noise measurement give information about the comfort of the crew, and knowledge of noise and vibration transmission patterns throughout the boat is essential for noise abatement work onboard.

3. MEASUREMENT PROCEDURE

3.1 Underwater Noise Measurements

Underwater noise is measured with a pressure hydrophone of omnidirectional sensitivity and with a frequency response of at least 400 - 8000 Hz. The noise should be recorded on tape for later analysis.

Care should be taken for the choice of measuring range. A sheltered area away from traffic noise is most advisable for controlling the acoustic environment. Swift currents should be avoided, as these may exite the measuring hydrophone mechanically and thus generate unwanted noise.

The measuring range should fill requirements for an assumption of spherical sound propagation between vessel and hydrophone. The hydrophone should be suspended at a depth of at least 10 metres. The depth at the measuring range should be at least 1.5 times the distance from the hydrophone to the boat, and this distance ought to be at least one boat length and not less than 50 metres.

3.2 Inside Measurements

3.2.1 Airborne noise

Measurements of airborne noise should be carried out with a precision sound level meter according to IEC Standard, Publication 179. The noise level should be measured directly in octave bands, linearly and weighted according to weighting curves A, dB (A).

More exact noise measurements for assessment of possible annoyance or hearing damage risks, for instance according to ISO Draft Recommendation 1999, require that the noise level be recorded for later analysis.

3.2.2 Vibration measurements

Vibrations are measured by means of an accelerometer mechanically or magnetically coupled to the structure. The vibration is expressed as acceleration level. The vibration levels may be measured directly in octave or 1/3 octave bands (see para. 4.3) or recorded for later analysis.

4. PRESENTATION OF RESULTS OF MEASUREMENTS

4.1 Underwater Noise

The noise should be analysed in 1/3 octave bands according to IEC Recommendation 225 covering the frequency range from at least 40 to 8000 Hz. An estimate of the measuring accuracy and standard deviation should be included.

The noise level should be stated as index value of noise spectrum level in dB referred to 1 μBar, 1 Hz and a distance of 1 meter from the apparent centre of the noise source.

The following equation is used to calculate the resulting noise level:

$$L_{is} = L_r + 20 \lg R - 10 \lg \Delta F; \text{ where}$$

L_{is} = index value of noise spectrum level
L_r = recorded noise level
R = distance from source to hydrophone in meters
ΔF = filter bandwidth in Hz.

The results should be presented in tables and diagrams as noise pressure level versus frequency.

For a more detailed investigation more narrow filters have to be used. The results may be given as spectrum lines or as noise spectrum levels. The actual filter bandwidth should then be clearly stated. - The background noise at the measuring range should be recorded and analysed in a similar way.

If the noise is recorded for dynamic operating conditions, e.g. a real and simulated catching routine, the results should be presented both as broad band noise pressure levels versus time, and as pressure levels of discrete frequencies (e.g. at 40, 160 and 630 Hz). A timed description of the catching procedure should be included.

4.2 Airborne Noise

The sound pressure level should be given as octave band levels in dB re $2 \cdot 10^{-5}$ Pa (dBSPL) for the frequency range 31.5 to 8000 Hz. The overall noise level should also be given in dB (A) and measured linearly. The results should be presented in tables and diagrams for different measuring positions and operating conditions.

4.3 Vibrations

The vibration measurement results should be given as acceleration band levels in dB re 10^{-5} m/s^2.

Octave bands in the range 20 - 2000 Hz are used for a general vibration survey. 1/3 octave bands in the range 2-100 Hz are used for vibration measurements to investigate possible physical damage risk or annoyance effects (ISO Proposal).

The results should be presented in tables and diagrams as acceleration level versus frequency for different measuring positions and operating conditions.

4.4 Instrumentation and Measurement Conditions

The following information should be included in the report: data and location of measurements, wind speed and sea state, the water depth of the range, and a description of bottom conditions.

A block diagram showing the instrumentation used for measurements and analysis should be given together with information about make and type of instruments. Possible integration constants should be specified. A brief description of the rooms where airborne noise has been measured, including possible absorbing panels etc. should be stated.

4.5 Ship Parameters

A detailed technical specification of the ship should be given along with other relevant data (see the following check list).

Ship's name, year of construction, ship yard and yardnumber

Owner's name

Type of boat

Main dimensions:	length o.a., length p.p.
	moulded breadth
	moulded depth
	size
	hull construction
Main engine:	type, power, rpm, mounting
Auxiliaries:	type, power, rpm, location and mounting
Propellers:	type, number of blades, reduction gear, thrusters (if any)

Main drawings indicating measuring points should be included.

5. COMPLETE MEASUREMENT PROGRAM

5.1 Underwater Noise

A. Main engine turned off
   - a) starboard auxiliary engine
   - b) port auxiliary engine
   - c) auxiliary + other machinery, pumps etc.

B. Main engine idleing, propeller disconnected.
   - a) main engine at different speeds at suitable intervals from min. to max. rpm.
   - b) possible side thrusters working.

C. Service conditions, main engine max. rpm
   - a) full propeller pitch
   - b) 3/4 propeller pitch
   - c) half propeller pitch.

   Boats with fixed-pitch propeller:
   - a) full ahead
   - b) half ahead.

D. Simulated catching routine.

5.2 Airborne Noise

A. Service speed

a) Wheel house

b) Mess room

c) Engine room

d) Cabins on all decks

e) Typical working areas.

B. Catching conditions, pumps, winches etc. working.
Same measuring points as above.

C. Engine room, main engine idleing

a) starboard auxiliary engine working

b) port auxiliary engine working

c) auxiliary engine plus other machinery, one at a time.

5.3 Vibrations

A. Service speed

a) vertical acceleration of frame on all decks (cross section through wheel house)

b) acceleration in 3 axes of main engine frame. Both sides of possible elastic mountings.

B. Engine room, main engine idleing
Measurements on both sides of possible resilient mountings.

a) vertical acceleration of starboard auxiliary

b) vertical acceleration of port auxiliary

c) acceleration in 3 axes of main engine

d) vertical acceleration of other machinery.

C. Low frequency vibration measurements in typical working areas.

In Figure 1 - 4 (p.28 and 29) examples of curve sheets for data presentation are shown.

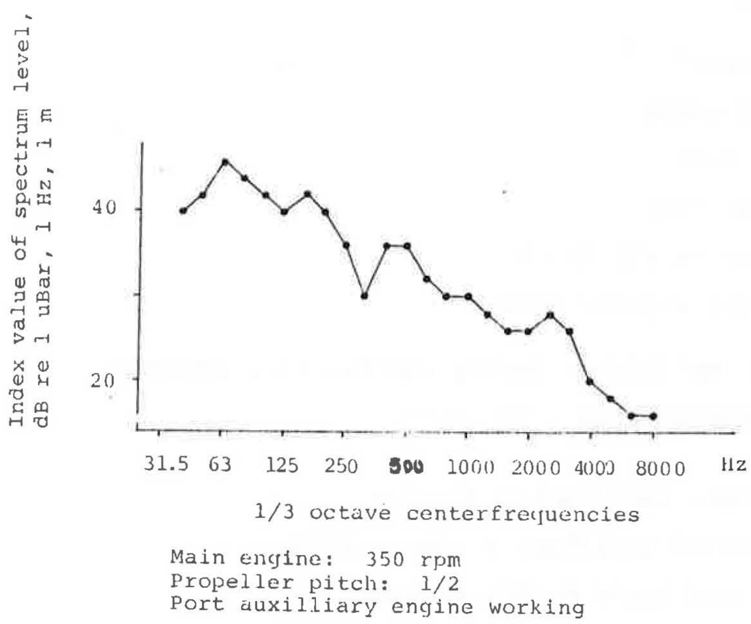


Figure 1. Example of presentation of underwater noise measurements.

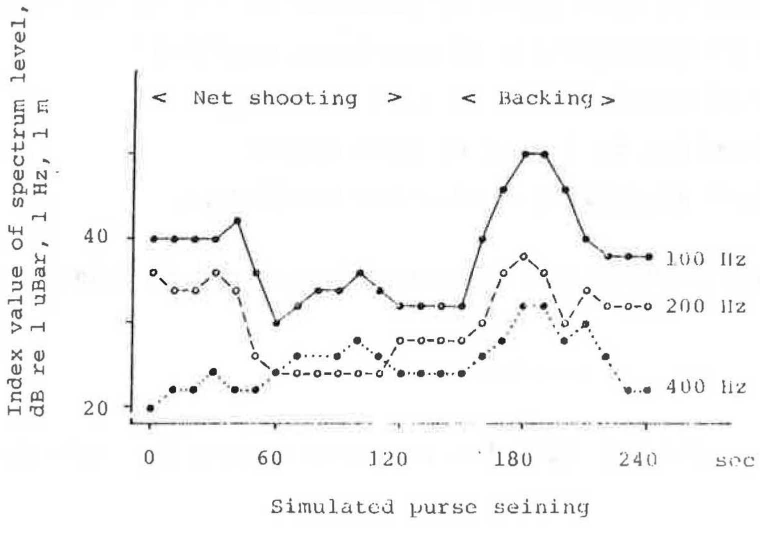
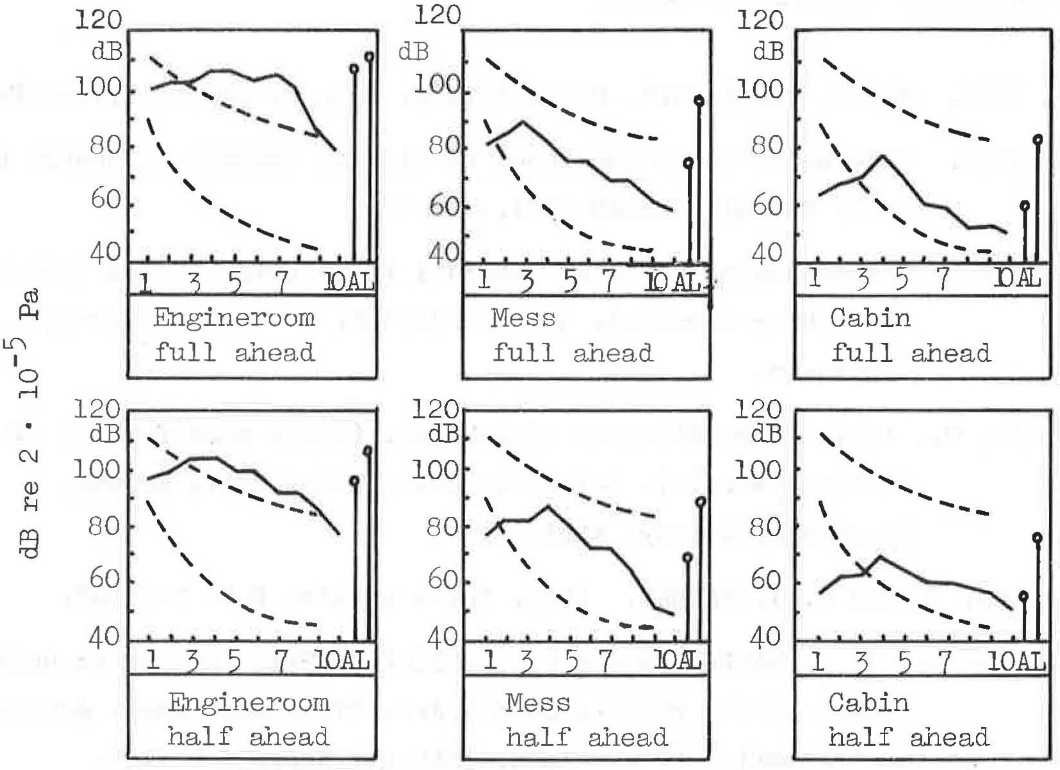


Figure 2. Example of presentation of underwater noise measurements obtained during catching operation.



Octaveband no.	1	2	3	4	5	6	7	8	9	10
Centerfreq.	31.5	63	125	250	500	1000	2000	4000	8000	16000

Figure 3. Example of presentation of airborne noise measurements. Dashed lines are noise rating curves N 60 and N 90.

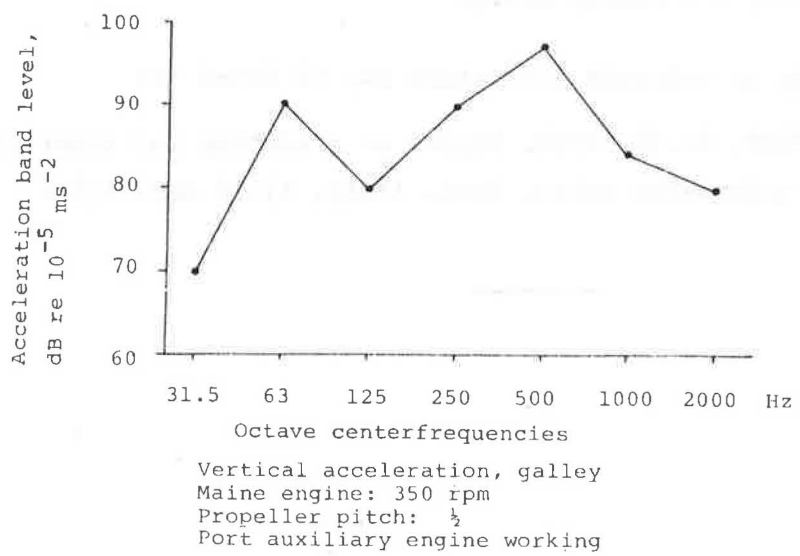


Figure 4. Example of presentation of vibration measurements.

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ANON., 1972. Underwater noise generated by fishing vessels. Simonsen Radio A/S, Oslo, Norway. SIMRAD Bull., No.8.

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HAWKINS, A. D. and C. J.CHAPMAN, 1969. Noise trials, F.V. "Selma".

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OJAK, W., 1972. Vibration and noise on fishery research vessels. Andre Mayer Fellowship Rep., FAO, Rome.

VATZ, J. P. and R. F. WILLIAMS, JR., 1962. Development of noise control specifications for the Woods Hole oceanographic research vessel. SNAME, New England Section, Bethlehem Steel Company, Quincy 69, Mass., U.S.A.

Further references on relevant literature may be found in:

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