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International Council for the
Exploration of the Sea

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Fish Capture Committee

REPORT OF THE STUDY GROUP ON RESEARCH VESSEL NOISE MEASUREMENT

Gothenburg, Sweden, 19 April 1993

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International Council for the Exploration of the Sea **C.M. 1993/B:5**

Interim Report of the Study Group on Research Vessel Noise:

Terms of reference: *To specify and summarise available information on the essential noise requirements for research vessels with a view to recommending measuring procedures.*

In accordance with C.Res. 1992/2:12 the group met in Gothenburg on 19 April 1993. It was agreed to organise the work under the four headings below.

1. FISH REACTION TO UNDERWATER RADIATED NOISE

A crucial question is, "What stimulus, or stimulii, could be responsible for the fright reaction of fish in the path of a vessel ?"

The possibilities include:

a) tones (line spectra)

b) pressure level (wideband)

c) pressure gradients

d) infrasound

e) transients

f) solitons

Indications of the great variability of many aspects of vessel noise are given by Mitson (1993) but there is little published work to differentiate between the relative importance of the above effects, individually, in combination, or collectively.

(a) & (b) ***tones and pressure levels*****:** The experimental work by Bercy and Bordeau (1987) is the largest scale investigation in terms of the number of vessels whose noise characteristics were measured and correlated to catches (tuna) over a one year period. These workers concluded that vessels with a relatively smooth noise spectrum, even though the overall pressure levels were high, caught substantially more fish than those with significant line frequency peaks (tones) in the low-frequency portion of the spectrum.

The French RV "Thalassa" was re-engined in 1984 and suffered an immediate dramatic drop in herring catches (Sparholt, 1990). Other species were affected but not so badly. No noise signature was available for this vessel prior to the engine change but a detailed noise ranging, including a loaded condition to simulate trawling, was carried out when the problem of low catches persisted. The noise ranging revealed that the overall pressure levels were extremely high and also that very high level tones existed within the frequency range of fish hearing.

Herring have a much wider hearing response than that of species such as plaice, cod, haddock, saithe, etc., so it is possible that a tone, or tones, might have affected the herring but was out of the hearing range of other fish. Herring also have a very high sensitivity to sound so it is feasible that the abnormally high overall pressure levels radiated from this vessel could also be responsible for the marked reduction in catches and the observed avoidance behaviour (Diner & Masse, 1987). However, cod have a similar sensitivity to herring but over a much narrower band of frequencies.

c) ***pressure gradients*****:** W. Ojak, the FAO André Mayer research fellow in 1972/73, produced a substantial report on many aspects of noise generation from vessels in which he gave seperate measurements of pressure gradients for the engines and propeller of the Norwegian RV. G.O. Sars and suggested that such gradients might have the potential to scare fish. There are no reported studies differentiating between pressure levels and pressure gradients.

d) ***infrasound*** **(0.1 to 20 Hz):** Infrasound frequencies can be generated at high pressure levels by resonance induced in parts of a ships structure. These levels can be extremely dynamic as a result of relatively small changes in vessel speed or loading. Interest in infrasound as detected through the otolith organs has increased following publications by Karlson and Sand (1991) and Enger (1993). Fright reactions in a number of species including plaice, cod, salmon, have been observed when the fish have been subjected to these extremely low frequencies. As yet no observations appear to be available to link infrasound generated by a vessel to fright reactions of fish. Although this does not rule out such a source, the levels of particle acceleration are low in the lower frequency portion of the infrasound spectrum for ranges of more than a few metres .

e) ***transients*****:** Seismic exploration requires the use of transient pressure pulses of exceptionally high levels. Engås et al. 1993, have reported dramatic effects of fish moving away from a very wide area where such work is in progress, resulting in a 70 % decrease in the availability of fish. Little work has been reported on the study of avoidance by adult fish and planktonic organisms of seismic pulses.

f) ***solitons*****:** A soliton is an underwater displacement wave caused by the forward movement of a vessel. It has a circular motion which, in shallow water, "rolls" along the seabed and returns to the underside of the vessel. There is a possibility that this form of disturbance could cause fish to move away from its path but it is felt that such circumstances would be limited.

1.1. Fish Hearing Thresholds

Many data are available on hearing thresholds and bandwidths for most of the species of interest; mackerel, sandeels and sprat and being exceptions. The group concluded that sufficient work has been done for present purposes but in order to properly collate existing data, matching is required between the audiograms taken some 20 years ago and the recent infrasound measurements. A question was raised about the possible differences in the hearing of young fish and adult fish; data exist for the latter, because the usual experimental techniques are less suited to small fish. The opinion of suitable specialists could be sought regarding the matter of hearing in young fish. Packard, Karlsen and Sand, 1990, reported that cephalopods are sensitive to low frequency sound well into the infrasound range.

1.2. Fish Behaviour in Relation to Noise

None of the group members knew of current work programmes involving fish behaviour in relation to noise. Some recently completed work in Norway used the recorded noise of fishing vessels being played back to fish in pens to observe their reaction. This work is being written up and will be available later in 1993.

It is recommended that work on fish behaviour in relation to noise should be encouraged if suitable experiments can be devised. The playback method for measuring fish reactions should be further investigated as part of the planning of such work. Also, the use of acoustically tagged fish is particularly suited to the study of detailed movements in the open sea, such as are necessary for observing fish reaction to noise, for example, Engås, et al, 1991 and Arnold et al, 1990.

2. POTENTIAL EFFECTS OF UNDERWATER RADIATED NOISE ON TRAWL AND ACOUSTIC SURVEYS

Underwater radiated noise from vessels has the potential to frighten pelagic and demersal fish from the path of the vessel due to one or more of the factors listed in Section 1, (a) to (f) and also to degrade measurements of abundance made by acoustic survey.

There are three aspects:

2.1. Trawl survey

If, during a pelagic or demersal trawl survey the numbers of fish available for capture in the path of the trawl are changed because of a fright reaction to noise from the vessel an indeterminate bias is introduced to the results. Many instances are recorded of pelagic fish moving out of the path of a vessel (Olsen et al. 1983a and Diner and Masse, 1987) but there is also evidence (Shevelev et al. 1989) that the vertical distribution of cod and haddock in the Barents Sea can be affected by vessel noise. The fish are driven down by the noise and under some circumstances the density of fish near the bottom may increase significantly after the vessel has passed. This effect could make more fish immediately available for capture than if the natural distribution had been unaffected by vessel noise.

2.2. Acoustic survey

(a) Trawling is often necessary to obtain verification of the proportion of species and their size distributions during acoustic surveys to validate the acosutic estimates. A change in numbers and composition of fish by species and size in the path of the vessel could bias the results (2.1 above).

(b) Avoidance or disturbance of the natural distribution with the vessel operating at survey speeds will lead to an underestimate of abundance by the acoustic method of assessment.

2.3 Acoustic survey instrumentation

As acoustic instrumentation usually operates at high frequencies of approximately 10 kHz and above, only these frequencies have the potential to degrade the equipment performance by adding to the integral signal obtained from fish aggregations and obscuring the measurements of single fish echoes. Because this type of noise is mostly propeller induced it varies with speed and as a result it often restricts the speed at which a vessel can operate, thus reducing the efficiency of data collection. Little data appear to have been published on the extent of such limitations although much anecdotal evidence is available. The echo-sounder frequencies are vulnerable to high frequency noise from propeller cavitation and flow-noise (hull apertures, or projections, pump outlets, etc.). Propeller cavitation starts very suddenly at a critical speed, or loading, for fixed blade propellers but for variable pitch propellers (which may cavitate throughout the full set of operating conditions) it changes with blade pitch and propeller shaft speed settings.

The commonly used frequency of 38 kHz is most likely to be affected by radiated noise, particularly when the vessel is operating in relatively shallow waters and the bottom is hard. Under such conditions a substantial proportion of the noise may be reflected back to the transducer. It is very important to remember this and to ensure that adequate measurements of the noise are made via the echo-sounder when in shallow waters (section 3.4).

It is important to know the detection limit of the survey echo-sounder in terms of a given size of fish or organism at a specified range. The minimum target strength for most practical purposes is suggested as -80 dB. For a given equipment and set of operating conditions the signal at the echo-sounder due to this target strength can be calculated. It can then be compared to the noise level measured in the same bandwidth to obtain the signal-to-noise ratio (SNR). If possible the noise should be measured by using the Simrad EK500 noise measurement facility (section 3.4).

3. METHODS OF MEASURING UNDERWATER RADIATED NOISE SIGNATURES

Most of the noise ranges are naval installations and they operate to NATO specifications, which, despite very different situations, produce almost identical results. As an example, the New Zealand research vessel "Tangoroa" was built in Norway and noise-ranged there before delivery to her owners. A noise ranging in New Zealand a few months later gave a very similar signature to that taken in Norway.

Clearly these ranges can provide measurements of high precision and it is essential that all newly-built vessels should have their noise signatures established under a suitably wide set of conditions on such a noise range. Noise signatures change for various reasons and many of the older vessels were not noise-ranged when built, hence there is a scarcity of data, particularly narrowband measurements. The latter are important because they reveal the presence and levels of line frequencies (tones).

The group considers that noise signature data should be available for all vessels used for fishery research (including chartered vessels) but recognise that there may be difficulties of expense and logistics in the use of naval ranges. One of the requirements for vessels used in fisheries research is to obtain a noise signature under trawling conditions. Generally, there is a strong reluctance to allow the towing of a trawl on naval ranges, although a few are suitably equipped. For these reasons the group recommends a noise ranging procedure based on the naval specification and practise but capable of being implemented by individual institutes and laboratories.

3.1 Specification for noise signature measurements

The objective is to obtain a series of signatures, taken at different speeds and loading conditions, for comparison between vessels to help identify the cause of vessel avoidance/fright reactions in fish. Measurements should cover the overall frequency range of 1Hz to 100 kHz with a precision of ± 1 dB. Results to be presented in a bandwidth of 1 Hz. It is often necessary to make third octave measurements. An octave is a doubling of frequency and the energy is averaged over each third of an octave band. Third octave measurements can be converted to a 1 Hz band (Mitson, 1989).

In addition, narrow-band measurements are especially important and are needed up to a frequency of 10 kHz in order to determine the tonal content of radiated noise. For this purpose different bandwidths must be used over the required frequency bands. Suitable examples are shown below.

Frequency band	Bandwidth of measurement
♦ 0 - 250 Hz	0.31 Hz
♦ 250 Hz - 1 kHz	1.25 Hz
♦ 1 kHz - 4 kHz	5 Hz
♦ > 4 kHz	125 Hz

3.2 Equipment

This consists of a hydrophone and a spectrum analyser (including a display and a means of recording). Spectrum analysers with the capability to perform suitable measurements can be hired readily, although care is needed in the selection of instruments with the necessary sensitivity. Care must also be exercised in the choice of a hydrophone with adequate sensitivity over the frequency range. Measurements of salinity and temperature are needed so that the absorption loss can be calculated for the higher frequencies. Equipment for precisely determining the distance between the vessel being measured and the hydrophone measuring station is essential.

The correct measurement of radiated noise is critically dependent on the precision of the range measured between the vessel (amidships point is the normal reference) and the measuring station which should be to better than ± 2 m if possible. Tape recording is difficult because of the wideband requirements. A particularly high-quality, stable, instrumentation recorder would be needed with a capability to record synchronising signals and these are normally too delicate to withstand conditions in a small boat. An analyser with a built-in recording facility is preferable to cover the full frequency spectrum.

3.3. Method

In principle deep water is required for the measurement of noise *signatures* but in practise depths of the order of 40 m should suffice. Before making any other measurements the ambient underwater noise should be measured and recorded. It may vary widely from place to place especially in coastal locations and with weather conditions. Noise ranging normally cannot be carried out satisfactorily in sea-states greater than 4 to 5. Initially it is desirable to make measurements under a wide range of operating conditions in terms of speed and loading (trawling). Careful note should be taken of the weather conditions for example the strength of wind and if the vessel is going into the wind, or the sea. Time limitations may dictate the number of runs that can be undertaken. For runs during trawling the speeds will of course be limited to what is practical for the gear being used. For operational reasons the vessel will be unlikely to approach much closer than 50 m to the measuring station but should aim for this distance or less. Because of the relatively delicate nature of analysers and the need to keep the hydrophone cable short it is likely that the measuring station will be a small boat.

Measurements should be made both with the measuring station on the starboard side and on the port side of the vessel. This is because significant differences can occur on each side of a vessel due to machinery layout and internal structure.

Fixed blade propellers: For these vessels it is often useful to start with a run during which speed is steadily increased to establish the speed at which the inception of cavitation occurs. It is then preferable to make a series of runs, each at a given speed with, perhaps a two knot increment between runs. A speed of 11 knots is recommended for one of the runs because data exist for comparative purposes from a number of vessels.

Variable pitch propellers (CPP): For vessels with a CPP it is particularly important to determine the best combination (lowest noise level) of blade pitch and shaft RPM. This can be a time-consuming operation but working at these settings can give noise levels 20 dB less than other settings which provide the same speed. When the most favourable operating conditions have been determined they should be recorded: subsequent measurements should always be under these same conditions.

3.4 Noise measurements by echo-sounder

Measurement of noise at the "spot" frequency of the echo-sounder, or sounders, is useful in providing both a realistic result related to specific operating conditions and a cross check with the high-frequency noise signature measurement. The EK500 has an in-built facility but satisfactory measurements can also be made using an EK400 echo-sounder if a suitable measuring technique is used.

After completing a static acoustic calibration of the echo-sounder with standard targets a full dynamic calibration of the acoustic system should be made. This will provide the information on how the equipment will perform in the presence of noise, which is the ultimate criterion.

Noise due to the vessel at the echo-sounder frequencies can only be measured when the echo-sounder is in passive mode. Measurements from the EK500 are taken in terms of power (Watts) and must be converted using the method described in the handbook to the normal units of dB re 1 μPa (1 Hz band) at 1 m distance.

A series of measurements are required at different speeds to determine when the inception of cavitation takes place. It is always necessary to work at a speed below this when using a fixed blade propeller but with a CPP the best speed condition (lowest noise for a practical operating state) will be determined from the overall noise signature.

It is preferable that this type of noise measurement should be made when going over a known piece of ground where the bottom integral can be measured prior to, or following, the noise measurements and the details recorded. Ideally, the shallowest water in which surveying is conducted should be used in order to be aware of the worst situation (highest levels of noise) but decisions must be made in the light of local conditions and needs.

3.5. Reports on some research vessels

It was reported that the Danish RV "Dana" has not been noise ranged but negotiations are in progress to obtain a noise-ranging either by using a naval, or a commercial, facility.

Details were given of a proposed experiment to measure the noise of RV "Corystes" (UK) in a loaded condition in order to complement the work in 1992 which aimed to measure the effect of a high level 300 Hz tone on trawl catches (Nicholson, et al. 1992) . At that time there was no noise signature for the vessel when towing a trawl. Bad weather prevented the measurements being attempted in 1993 but it is now scheduled for January 1994.

In Bergen the Institute for Marine Research would like to take further noise measurements from RV "G. O. Sars" following damage and subsequent repairs to the propeller.

RV "Scotia" (UK) has not been noise ranged. She maintains a high level of capture for most fish species (Sparholt, 1990) so it could be informative if a noise ranging were undertaken and the results made available.

4. CORRELATION OF EXISTING DATA

4.1. A list of vessels for which noise data exist should be compiled for the purpose of summarising salient features of the noise signatures. This should include a brief classification of data in terms of the type of measurement and the conditions, speed, loading, etc, under which it was made. At this stage of investigation it is probably unrewarding to attempt to correlate such matters as engine power, method of propulsion and propeller design with the noise signatures.

4.2. A bibliography should be compiled under the headings of:

a) Ambient noise b) Fish hearing

c) Fish reaction to noise d) Vessel radiated noise

Members of the noise study group agreed to search for references under the above headings and undertook, in groups, to summarise the information. This work will be carried on by correspondence and is to be completed by the end of 1993. The information will be collated by the chairman and circulated amongst the group for comment.

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The references below relate to this report.

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CONCLUSIONS and RECOMMENDATIONS

The group agreed:

1. that the information immediately available is insufficient to determine the essential noise requirements for vessels used in fisheries research in connection with fish reaction to noise. It is however, possible to specify the noise requirements at echo-sounder frequencies.

2. that any existing noise signatures of vessels used for fisheries research should be made available to the study group.

3. to recommend that where noise signatures are not yet available they should be measured for all vessels used for fisheries research (including chartered vessels) preferably using established noise ranges but if this is not feasible the method provisionally outlined in this report should be used.

4. to recommend that work on fish behaviour in relation to noise should be encouraged using whatever methods are deemed most suitable.

MEMBERS OF THE STUDY GROUP

Attendees at the meeting

Dr G. P. Arnold: UK
Ms C. Goss: UK
Dr D. V. Holliday: USA
Mr H. P. Knudsen: Norway
Mr C. Lang: Canada
Mr B. Lundgren: Denmark
Mr J. Milne: Ireland
Mr R. B. Mitson: UK (chairman)
Mr E.J. Simmonds: UK
Mr I. Svellingen: Norway

Unable to attend in Gothenburg

Dr H. Bethke: Germany
Mr E. Götze: Germany
Mr J.A. Jacobsen: Faroe Islands, Denmark
Mr D. Swain: Canada
Mr B. Thomsen: Faroe Islands, Denmark