ICES SGFARV Report 2007

ICES Fisheries Technology Committee
ICES CM 2007/FTC:10

Report of the Study Group on Fish Avoidance of Research Vessels (SGFARV)

28-29 April 2007

Dublin, Ireland



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Recommended format for purposes of citation:

ICES. 2007. Report of the Study Group on Fish Avoidance to Research Vessels (SGFARV), 28-29 April 2007, Dublin, Ireland. ICES CM 2007/FTC:10. 25 pp.
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Executive summary

The Study Group on Fish avoidance to Research Vessels (SGFARV) was created to answer one major question: how important is the avoidance reaction of fish to a research vessel? This question was originated by divergent observations on avoidance reaction to research vessels, and especially to vessels fulfilling the noise limited conditions recommended by the Cooperative Research Report 209, compared to "noisy" vessels.

After a general overview of the problem "*Fish avoidance to research vessels: an old question not yet elucidated"* (Julia Parrish and François Gerlotto), five presentations were given during the meeting, on "*Fish Escorting Vessels: attraction, density dependence or avoidance reactions"* (Mariano Gutierrez), *"Herring behaviour in response to approaching vessels"* (Nils Olav Handegard), *"Comparing noisy and sound-reduced vessels"* (Chris Wilson), *"Tank experiments on effect of vessel noise"* (Bjarne Stage, Bo Lundgren and Karl-Johan Staehr).

The definition of sound characteristics was discussed. Sound spectrum graphs of high frequency resolution can be used to characterize emitted sound from all vessels. From historical reasons most recorded emitted sound from vessels has been analysed within third octaves bands. From sound reception and related behaviour in living organisms we know that both tonal and broadband components as well as the critical bandwidth play important roles in sound reception. Which of these components is of greater importance in sound reception in fish as well as their impact on behaviour alterations must be elucidated and explained.

It is known that animals integrate all information available to them and pay attention to particular, critical stimuli. A response is only elicited if it is important to survival. There is a need to distinguish what fish can detect and how they deal with the stimuli. Reactions are often adaptive and a critical point is the habituation and learning effects on fish reactions.

An important point arose on the weakness of the SG in fish physiology knowledge, especially on Fish hearing and ability to locate of source (directivity capabilities); Electromagnetic sensitivity; Sound emission by fish; Cognitive – neural physiology; Cyclic changes in sensitivity and physiological threshold capacities. The lack of physiological expertise currently within the group was recognized and a forthcoming conference on Marine Bioacoustics was highlighted as a potentially useful source of information and collaborators.

The SG defined two different approaches to document the general question:

- The stimulus: what parts of the acoustic signal transmitted by a vessel make fish react?
- The reaction: what behavioural mechanisms are responsible of the fish reaction?

One major output of the SG will be a Cooperative Research Report on "Vessel (or platform) induced fish behaviour". It will consider several points:

- State of the art (vessel and fish)
- The platform
- The environment (surrounding)
- The fish behaviour
- The fish physiology
- Experiments
- Results / Recommendations

The SGFARV will be organised into two groups: a permanent group who will work by correspondence during the year and produce documents to be discussed during the annual meeting; and a wider group who will mostly participate in the annual conference and provide

punctual help if needed. The next meeting of SGFARV will be held at Bergen, Norway, 21–22 June 2008.

1 Introduction

The Study Group on Fish Avoidance to Research Vessels [SGFARV] (Co-Chairs: François Gerlotto, France and Julia Parrish, USA met in Dublin, Ireland from the 28–29 April 2007. A list of participants at the meeting can be found in Annex 4. Emma Jones, (UK) was appointed as Rapporteur for the SG meeting.

1.1 Agenda

The following agenda was approved by the SG members:

- Saturday morning: cases studies, examples, definitions of the terms
- Saturday afternoon: organisation of the work for 2008 and agreement on next meeting
- Sunday morning: writing of the report to FTC; first draft of the CRR plan
- Sunday, 13h: closure of the meeting

1.2 Objectives of SGFARV

- Presentation and discussion on some cases
- Analysis of the Terms of Reference: what is the precise scope of the SG (avoidance? Reaction? Vessel? Platform? Etc.)
- Organise the SG
- elaborate a working plan and agenda for the 3 years coming
- Write a first plan for the future CRR and activities of SGFARV
- Agree on meeting dates in 2008 (June, Bergen)

2 Case studies

A number of presentations were given to the group about recent work carried out in the field.

2.1 Fish Escorting of Vessels: attraction, density dependence or avoidance reactions

(Mariano Gutierrez)

The authors observed that when the research vessel returns to trawl on a transect line, sometimes higher densities of fish were observed on the echo-sounder compared with the previous transect. The second transect is made immediately after the first, but the speed is slower as the vessel is fishing (3 knots compared to 8 knots). The EK60 was used with a variable ping rate. The species in question is Anchovy and densities are very high, in shallow water (50 m). The authors speculated that perhaps fish do not always avoid the vessel but instead may be escorting it and that this may be related to the high densities present. A series of examples were presented which showed varying results; in some the biomass was estimated to have increased by a factor of 10, in others the increase was less dramatic and in some a lower density was observed and in others a very different school structure.

The group commented that the timing of these examples in terms of season as well as time of day may explain some of the behaviour of the fish although there appeared to be a problem with bubbles at the higher speed in some examples, despite the sea conditions being generally calm (Bo). It was suggested that in order to establish if the change in speed was the reason, an experiment could be conducted where both transects were completed at the same speed.

(Kjell) Another recently published study in a fjord in Norway has shown that herring schools can be attracted to large vessels in the area although the reason is unclear? (Kjell). Attraction has been shown to be a strong behaviour in pelagics in FAD studies, whilst most studies of pelagic behaviour towards vessels are on small prey fish rather than large predator fish and to compare reactions of prey vs. predators may be very helpful to elucidate the "Love-Hate" relationship between fish and vessels (Marc and François).

It was commented that it is important to know exactly what is meant when "noise" is referred to as the reaction of fish is likely to be a result of a potentially complex trade off between different competing requirements (Marc). The Figure from Fernø and Huse (2003) illustrates this "Fleeing versus staying" decision making process. An important aim of the Study Group should be to evaluate what behaviour needs to be studied in order to improve fisheries research and to assess whether we can predict the behaviour of fish to the level of accuracy required to quantitatively solve the problem and produce a model. If we cannot do this, then what should we measure? The input from behavioural ecologists and ethologists will be essential (Nils). It was pointed out that this requires understanding the context in which fish is receiving and processing information e.g. changes in pressure being correlated to changes in depth (Andrzej)

2.2 Fish (herring) behaviour in response to approaching vessels

(Nils Olav Handegard)

Tracks of individual fish were measured using a free floating buoy-mounted echo-sounder passed by a trawling vessel (RV "G.O. Sars", built in 1970)[1]. The results show some evidence of a horizontal swimming component towards the vessel track, but the main component of the reaction induced by the vessel is diving, beginning as early as 15 min before the vessel passes the buoy. However, the strongest behavioural changes occurred towards the trawl warps [2] not towards the vessel itself.

A recent comparison between a "noisy" and "noise-reduced" vessel showed no changes in abundance between the vessels or between passes and the "null situation", but very different reactions, with the strongest reaction to silent vessel[3].

The group discussed other studies including the Fernandes et al paper where the reaction of herring towards a "noise-reduced" vessel was compared to the reaction to an AUV ahead of the vessel. This study showed no significant difference between avoidance of these two platforms, but it was argued that this did not represent a true comparative study in the context of the question, do we need to make vessels silent, since there was no noisy vessel to compare the results to[4]. The possible reasons for the behaviour were discussed and whether changes such as the use of fixed-pitch propellers were important. It was suggested that the change of a stimulus may be more, than or as important as the stimulus itself: The "scare factor" (Dick).

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1 Handegard, N.O. and Tjøstheim, D. When fish meets a trawling vessel: examining the behaviour of gadoids using a free floating buoy and acoustic split-beam tracking *Canadian Journal of Fisheries and Aquatic Sciences*, 2005, 62, 2409-2422

2 The main warp vibration frequencies was measured to 7 Hz and 14 Hz

3 Ona, E.; Godø, O.R.; Handegard, N.O.; Hjellvik, V.; Patel, R. and Pedersen, G. Silent research vessels are not quiet The Journal of the Acoustical Society of America, 2007, 121, Express letter online

4 Note that the observations are consistent between Fernandes et al 2000 , Ona et al 2007, and De Robertis et al (in prep), i.e. that no impact on avoidance is observed by the vessel mounted echo sounder.

Noise-reduced and traditional vessel comparison – real need to collect adequate amounts of data, not just one or two passes. Adequate sample sizes and power analyses is crucial before making inferences.

2.3 Comparing noisy and sound-reduced vessels

(Chris Wilson)

The reactions of walleye Pollock to the new NOAA sound-reduced vessel were compared with the old vessel through a series of experiments with the vessels running one in front of the other and side by side. The new vessel is larger and more powerful as well as being "quieter"; therefore the reactions observed are not necessarily a response to the reduction in sound alone[5]. The results are consistent with the Norwegian experiments. In most configurations, the overall S_A measured was the same, but when split into shallow and deep depths; it was observed that, when the sound-reduced vessel went ahead of the noisy vessel, the second vessel recorded a lower S_A for the shallow pollock. However, the S_A in both layers were similar when the noisy vessel led or when the vessels travelled side by side. This is believed to be a result of fish at shallower depths reacting to the sound-reduced vessel, but *after* it has passed. Therefore the sound-reduced vessel appears to measure the fish before it they are disturbed.

Discussion:

What is tonal quality? - Multiples of 15Hz Generator tones

Fixed pitch propeller same on 2 new vessels - ~100 RPM

The total emitted sound from a vessel will include all sound, including pumps, generators and the propeller, with some kind of directivity pattern that has areas of higher sound levels. The results of the Norwegian and American experiments show that we do not know the governing stimuli. Other experiments may give some indication of these differences in directivity pattern

However, it was pointed out that, in the case of Chris' experiments, fish may be reacting to both vessels in similar amounts (but that claim is not supported by their data; there is clearly a difference) Although the study show differences between the vessels, and they are consistent with the Norwegian experiment, there is a need to further investigate the cause of this difference by using bottom-mounted or buoy-mounted echo sounders. This will give information of fish density prior to the vessel passing. However, this requires greater resources, entails greater logistical problems and being able to work in an area where enough fish are reliably present in one place.

No strong distinctive reaction detected with a buoy during the day

20–40% reduction in s_A for juvenile Pollock at night

20% decline in Pollock s_A when vessel is trawling compared to free-running

Paired trawl comparisons are being done…differences in catchability by different vessels

Undisturbed fish backscatter. Tilt changes. Moderate behavioural reactions could increase the estimated biomass.

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5 Here we mean noise as defined by ICES CRR 209. Note that low frequency components or tonal spikes in the "silent" vessel may exceed the level in the "noisy" vessel, thus making it more "noisy" if another metric is used.

2.4 Tank experiments on effect of vessel noise

(Bjarne Stage, Bo Lundgren and Karl-Johan Staehr)

Vessel noise measurements are planned in collaboration with the Danish Navy. A buoy-mounted hydrophone positioned 40m below the surface with radio-communication direct to the vessel will be used to record the noise of the passing research vessel. This recorded sound will then be replayed to fish in a large fish tank (20m diameter, 10m depth) in the North Sea Museum. The reactions of the fish (herring, mackerel, horse mackerel, garfish and others) will be observed on video.

2.4.1 Questions and discussion

The group discussed possible problems with standing waves being set up in the tank, the issue of background sound from the pumps, water running into the tank etc and habituation of the fish. Some ideas and possible experiments about pre-distortion to obtain selected frequencies and the use of vibration sources to simulate the low frequencies were suggested. It was felt that the sound picture in the tank would not be relevant to a field situation and that particle displacement would be a "mess" (Kjell). Whilst direct extrapolation to open sea conditions was not possible, the advantage of being able to monitor the stimuli and change parameters one by one was thought to be a useful approach.

3 Revision of the Terms of Reference

The ToRs were revised by the SG and a few minor changes were suggested as followed (new words are underlined)

The general ToR suggesting the creation of SGFARV are the following:

Term of Reference a-i)

Many ICES nations have or are procuring ~~quiet~~6 noise reduced fisheries research vessels, at great additional costs relative to conventional vessels. To study the benefits of these new vessels, it is first necessary to understand the physical stimuli produced by vessels that could elicit avoidance reactions.

Term of Reference a-ii)

Several countries are conducting or have recently completed significant studies in this area and the subject would benefit from a review of progress and an evaluation of the results obtained.

Term of Reference a-iii)

Monitoring of physical stimuli produced by vessel is necessary to determine when and why some fish avoid some survey vessels.

Term of Reference a-iv)

Characterizing fish avoidance behaviour is challenging and a review of effective methods will aid researchers.

6 The SGFARV recommends "noise reduced" as defined by CRR 209 should be preferred to "quite" or "silent" .

Term of Reference a-v)

New methods and experiments will be needed to better characterize fish avoidance reactions to survey vessels.

Term of Reference a-vi)

The SG should disseminate findings via an ICES CRR.

From these recommendations ToR for the Study Group were defined:

006/2/FTC10 A **Study Group on Fish Avoidance of Research Vessels** [SGFARV], (Co-Chairs: François Gerlotto*, France, and Julia Parrish*, USA) will be established and will meet in Dublin, Ireland from 28–29 April 2007 to:

a) the Study Group will explore when and why fish avoid research vessels:
   - i) elucidate and expand the list of the possible physical stimuli produced by research vessels (platform related stimuli - PRS) that could elicit avoidance reactions in survey-targeted species;
   - ii) produce a literature review to improve our understanding of fish hearing and their reaction to *sound* stimuli;
   - iii) generate a list of ~~required~~ *recommended* items to be monitored and measured on research vessels, wider than just noise related;
   - iv) produce a review of methods for measuring avoidance to aid in the design and development of new methods to independently monitor fish reaction to PRS;
   - v) design explicit experiments to further examine the causes of fish reactions to PRS; and
   - vi) produce an *ICES Cooperative Research Report* on fish response to anthropogenic ~~pressure~~ *sounds*.
   - vii) SGFARV will report by 31 May 2007 for the attention of the Fisheries Technology Committee.

From the list of ToR an important point arose on the weakness of the SG in fish physiology knowledge. The main characteristics of fish physiology to be explored for a good understanding of fish reaction to sound are:

- Fish hearing and ability to locate of source (directivity capabilities)
- Electromagnetic sensitivity
- Sound emission by fish
- Cognitive – neural physiology
- Cyclic changes in sensitivity and physiological threshold capacities

The lack of physiological expertise currently within the group was recognized and a forthcoming conference on Marine Bioacoustics was highlighted as a potentially useful source of information and collaborators. It was proposed that an abstract be submitted to advertise the work of the Study Group and attract external collaborators (see Annex 2). Chris Wilson was committed by the SG to contact the Steering Committee of the Conference www.NoiseEffects.umd.edu, e-mail: Lidia.Wysocki@univie.ac.at

It has been also decided that “sound” should be preferred to “noise” as a term.

4 Scope of the SG

A proposal for defining the scope of the SG to be used as a first draft of the CRR plan was discussed. The revised proposal is given below. The SG agreed on changing the title of the future CRR as “Vessel induced fish behaviour”. Indeed there are several effects to fish, from

attraction to repulsion at various levels (from “precautionary avoidance” to fleeing), the avoidance being the sum of these different tropisms.

4.1 Vessel (platform?) induced fish behaviour

State of the art (vessel and fish) on the effect of sound reduced vessels and on fish hearing

Comparison between vessels fulfilling the CRR 209 specifications and those that do not fulfil these

The platform

- Characteristics of the stimulus (scaring vessel)
- Noise (sound field) (acoustic energy) = from ultrasound to infra sound, low pressure static, gradients (respect to time, respect to distance)
- 3D directivity patterns
- repeated measurements to monitor performance
- Establish a list of the relevant parameters that more fully characterise the sound signature of a research vessel
- The other platforms (e.g. buoys, AUV etc.)
- Interactions between fish and platforms (natural and artificial)

The environment (surrounding)

- Physical surrounding (thermocline, temperature, depth, etc.)
- Study of other sources of stimulus (light, etc.) as ancillary var.
- “Ecological surrounding”: extract of all the recorded information on the echogram (different characteristics of the fish echo, and other species)
- masking (effect of natural sounds interfering with (masking) vessel sound)

The fish behaviour

- “Analyse the signal the same way the fish do” (filtering abilities)
- Behavioural modelling
- Species specific response: driven by age, by physiological characteristics, by spatial behaviour? (small pelagics, large pelagics, demersal)
- Definition of vessel induced fish behaviour (elements including avoidance patterns)
- The data that are affected by fish reaction to vessel
- (List of the characteristics of the reactions (avoid, attract.))
- Adaptive response of fish (cascade of stimuli, learning, habituation, etc. threshold for response type: avoidance, fleeing, “nervousness”, non linear effects)
- Species effect
- Solitary vs. collective
- interference

The fish physiology

- (sensoring capabilities)
- Fish hearing and location of source (directivity capabilities)
- Electromagnetic sensitivity
- Sound emission by fish
- Cognitive
- Cyclic changes in sensitivity and physiological threshold capacities

Experiments:

- at sea and in lab.
- Fishing gears

Results / Recommendations

- Table of thresholds and types of reactions

The group discussed several points of the list.

4.2 The definition of "Noise characteristics"

Sound spectrum graphs of high frequency resolution can be used to characterize emitted sound from all vessels. From historical reasons most recorded emitted sound from vessels has been analysed within third octaves bands. One consequence of this is that emitted tones and very narrow-banded sound components are smeared out and not presented and seen in the spectrum graphs. From sound reception and related behaviour in other organisms we know that both tonal and broadband components as well as the critical bandwidth play important roles in sound reception. For instance, it is known that $1/6^{th}$ or $1/12^{th}$ octaves are critical to marine mammals, but not which bands are critical to fish. Which of these components is of greater importance in sound reception in fish as well as their impact on behaviour alterations must be elucidated and explained. This implies that future sound spectrums should be analysed within very narrow bands for instance 1 Hz or a few hertz bands as well as presented in that way. The relationship between tonal peaks and mean spectrum levels should be investigated for various types of vessel – and particularly older/ noisy research vessels as against modern noise reduced vessels as well as CP versus FP propellers.

How many platforms should be included? Everything from attractive stationary platforms to moving, noisy research vessels. The inclusion of FADs, buoys, and other platforms will also be useful in determining and how attractiveness of these platforms may change/interfere with studies of avoidance. Tuna boats, noisy catamarans and sailing in the Caribbean also mentioned.

Under the heading of "Platform", the sound produced by the acoustic systems themselves should also be included, since any reaction to this sound would have fundamental consequences.

The archiving of the sound signatures of current research vessels was recommended in the 2006 Topic Group discussions. This was seen as an important part of the study group's activities. The CCR report should define the relevant information required to characterise the signatures. The ICES CRR 209 underwater radiated noise curve is used by biologists, which is not necessarily sufficient to characterise vessel sound signature. Directivity from the vessel, measurements of gradients when speed changes etc. Spatial distribution of energy around the vessel and describing by its directivity patterns is important. May be more to it than the spectral and tonal descriptions, i.e. a three-dimensional picture and how it changes with frequency and depth is needed (John) beyond the standard measurements of port, starboard and keel. Whether the Group should recommend that such measurements be undertaken was questioned. The process is complex and time / cost consuming, but useful to know if this is actually important to the fish. New quiet vessels may have a totally different directivity pattern to noisy ones. There was some discussion on how this could be achieved; e.g. running the vessel at different distances from a line of hydrophones to elucidate the pattern. To analyze lower frequencies, e.g. infrasound the distance to vessel must be bigger and measurements must be done by pressure gradient hydrophones, particle velocity hydrophones or accelerometers (Runs are always done in pairs to average out the effects of tide/ current and wind). It was acknowledged that it would be important to know how many runs are required to

get a statistical significant results (typically 3), depending on ambient sound conditions, right depth and a good set-up.

Despite potentially high cost of such work, it was recognized that if this full, three-dimensional description is not available, then the reactions of the fish cannot be correctly described. As an example, the results of a recent work[7] where fish were observed to be attracted to boats were discussed and it was suggested that an apparent movement towards the vessel could be a result of fish avoiding a butterfly-shaped sound pattern into a perceived silent area. Another (not yet studied) possibility is that fish schools may react within the same "fountain effect" avoidance reaction as do individuals, and if this is the case, such behaviour could be in part an answer to the results provided by Chris Wilson: schools could be observed in greater quantities below the second ship than below the first one (M. Soria).

Whether these measurements are required only for the purposes of experiments for observing fish behaviour or whether they should be recommended for all new research vessels was discussed and further to this, how often over the life of a research vessel should such measurements be repeated to make sure that the sound-signature remains the same. Whether such data could these be modelled was asked and it was proposed that this would be very complex, especially with variable pitch propellers.

Whether measurements from inside the vessel can be directly related to the external sound field and therefore used to monitor over time was asked. However, the relationship between internal and underwater radiated sound is not straight-forward and such internal measurements should not be a substitute for sound-range work, but could be used as a warning for when such measurements might be required.

4.3 Vessel-Induced Fish behaviour

How the platform sound characteristics are interpreted in terms of the fish brain is very important. Definitions are required of the behavioural responses of the fish and what "noisy" means in the context of fish hearing. Studies on human hearing make use of a scale that approximately follows the dB scale; if the dB is doubled, the increase in intensity is much higher than the perceived loudness. A similar fish-specific scale that relates the actual energy output to the perception by the fish is required. It was recognized that this will need an input from expertise currently out with the Study Group such as Arthur Popper's Research group.

It is known that animals integrate all information available to them and pay attention to particular, critical stimuli. There is a need to distinguish what fish can detect and how they deal with the stimuli. Reactions are often adaptive. A response is only elicited if it is important to survival. This can produce great variability, e.g. spawning versus on-spawning. Another critical point is the habituation and learning effects on fish reactions: there is often need of a stronger stimulus to trigger the same reaction when this stimulus is often present in the fish surroundings (i.e. lower reaction to noise in a place where boats are numerous). What result do we need, how much certainty will be useful?

Other information that can be obtained from echograms was discussed. School shape and what it tells us about stress levels, predator presence could be very important in interpreting the behaviour of fish schools.

How best to group fish was discussed. By species; pelagic (small and large) demersal. Small pelagics as a group may cause problems if reactions are varied. May need to group by

7 Røstad, A.; Kaartvedt, S.; Klevjer, T.A. and Melle, W. Fish are attracted to vessels ICES Journal of Marine Science, 2006, 63, 1431-1437

response. Could also be divided by anatomy; physotomes and physoclysts or by hearing ability; specialists and generalists. May help to determine if the response is determined by environment or physiology, species, age.

4.4 Further discussion

The group agreed that key outputs should include carefully thought out recommendations for experiments that can answer the question: *"Are we producing a better estimate for stock assessment using sound-reduced vessels?"*

It was recognized that, for many Fisheries Management Stakeholders, this is the key question and information on the nature of reactions that may occur after measurement may not be deemed important, although the group recognized that a consistent answer could only be given once we have a fuller understanding of the behaviour, including the motivation and variability of the response. It was noted that this was the first Study group to deal with behaviour specifically

Whilst the scope of the Study group was broad, it was agreed that the CCR will be limited to sound stimuli although other stimuli may be explored as ancillary variables if needed (e.g. difference of sound effect by day and by night). A question then remains and will be considered during the first year: "What if sound is not the main stimuli?" There is need to some literature reviewing before to decide whether this question is consistent or not for the SG.

4.5 Recommended studies – A number of points were mentioned

If we don't know what the most important "scaring" frequencies are, any future experiments should start with what is used in normal survey conditions and then carry out comprehensive studies based on those settings.

The study of individual vs. collective reaction of fish to vessel sound was recommended. Fish can have very distinct reactions depending on their aggregation characteristics. Moreover the school structure, morphology and shape could give valuable information on the fish reaction or reactivity to vessel.

A question arose on recommendation to develop new research in the scope of the SGFARV. How can we ask that research is undertaken if no funding is available? Perhaps the study group should propose some funding opportunities. What we want to get into is new recommended methods and experimental designs. Will this report bring in new knowledge or not? One of the results of the study group is to recommend the designs that should be used. Some members of the group may be able to initiate experiments within the time period of the study group.

Mentioned on a regular basis was the issue of reactions to survey trawls and more generally whether the SGFARV should work on avoidance to fishing gears. Argued that this was part of the sampling tool and therefore any behaviour that results in an alteration of the density or composition of the fish observed on the echo-sounder is important to understand. Some simulation studies mentioned but didn't get what they were about. However, it is recognized that fish response has already been observed to be closely linked to changes in sound associated with trawling activities. The input of FTFB was suggested for this subject. In any case the effect of fishing gears will not be studied alone, but on its incidence to vessel sound.

4.6 Definition of the tasks of SGFARV

The group discussed what stimuli should be covered? It was suggested that the focus should be on sound, but with mentioning of other stimuli such as the lights on the vessel, the shadow of the vessel, bioluminescence[8] etc. These have been shown to have an important influence on the behaviour , e.g. when working at night with polar cod, lights on the vessel are important; another example is the likely influence of bioluminescence and reactions of herring to each other.

It was suggested that the group focuses on primary stimuli mainly, rather than secondary stimuli e.g. effect of day and night and other environmental conditions. Whilst sound may be the first stimulus, a complex chain of reactions involving reaction to sound, visual stimuli and others may occur and to cover all this would be very difficult. Whilst sound can be monitored and controlled, other conditions can be measured but not necessarily controlled. The best approach being to try and work with the same sound stimulus in different situations and measure as many other parameters as possible. In this field, tank experiments may provide valuable information, although not necessarily extrapolable to open field.

Discussion was long on this point, and here too it was agreed that some decision will be taken in the course of the first year after some literature reviewing: if the primary stimuli is our only focus, secondary stimuli like darkness/light, food no food etc will be disregarded. Nevertheless these are important for the motivational state of the fish. Should this be disregarded? Further, what if bioluminescence is the initiating stimulus? Should this also be disregarded? The general opinion was that "secondary stimuli" should only be disregarded if the=re is evidence (in the literature) that they can really be considered as "secondary".

It was suggested that a key task would be to compile a list of what species react to which frequencies. Previous reviews (CCR 206) have not covered the lower frequencies such as 10 kHz and below, which may be relevant to certain species such as gadoids.

5 Organisation of the SG and future activities

As not all the participants of SGFARV could be present at the meeting (including the co-chair Dr Julia Parrish), it was agreed that before to write a final document the report would be disseminated to all the members for revision and input. Therefore an agenda was defined for the activities of SGFARV in 2007–2008.

2007

- 30 May report delivered to everybody
- 1 July input and revision of report by SG members;
- Mid July: presentation of draft of CRR structure by co-chairs and list of non-CRR activities
- Mid-July to mid September: discussion by correspondence on CRR structure
- End September: approval of CRR structure and agreement for involvement of authors (or participants) and distribution of contributing author names

2008

- 15 May: delivery of contribution from authors to SG members
- 21–22 June: second meeting SGFARV

8 Jamieson, A.J.; Godø, O.R.; Bagley, P.M.; Partridge, J.C. and Priede, I.G. Illumination of trawl gear by mechanically stimulated bioluminescence ICES Journal of Marine Science, 2006, 81, 276-282

The next meeting will take place in Bergen, Norway, before or after the symposium on fisheries acoustics (SEAFACTs). Two options are submitted to the WGFAST chair.

- best option (for SGFARV members): after the symposium: Saturday 21 and Sunday 22 June, 2008
- second option: before the symposium: Friday 13 and Saturday 14 June, 2008. This last option presents a difficulty to some of the SG members who also participate in the SGFOT meeting (14–15 June).

The table below presents the two options.

FRIDAY	13	*SGFARV (2)*
SATURDAY	14	SGFOT *SGFARV (2)*
SUNDAY	15	SGFOT
MONDAY	16	FACTS
TUESDAY	17	FACTS
WEDNESDAY	18	FACTS
THURSDAY	19	FACTS
FRIDAY	20	FACTS
SATURDAY	21	SGFARV
SUNDAY	22	SGFARV
MONDAY	23	FAST

Expected results of first year (to be discussed during the second meeting in Bergen, Norway):

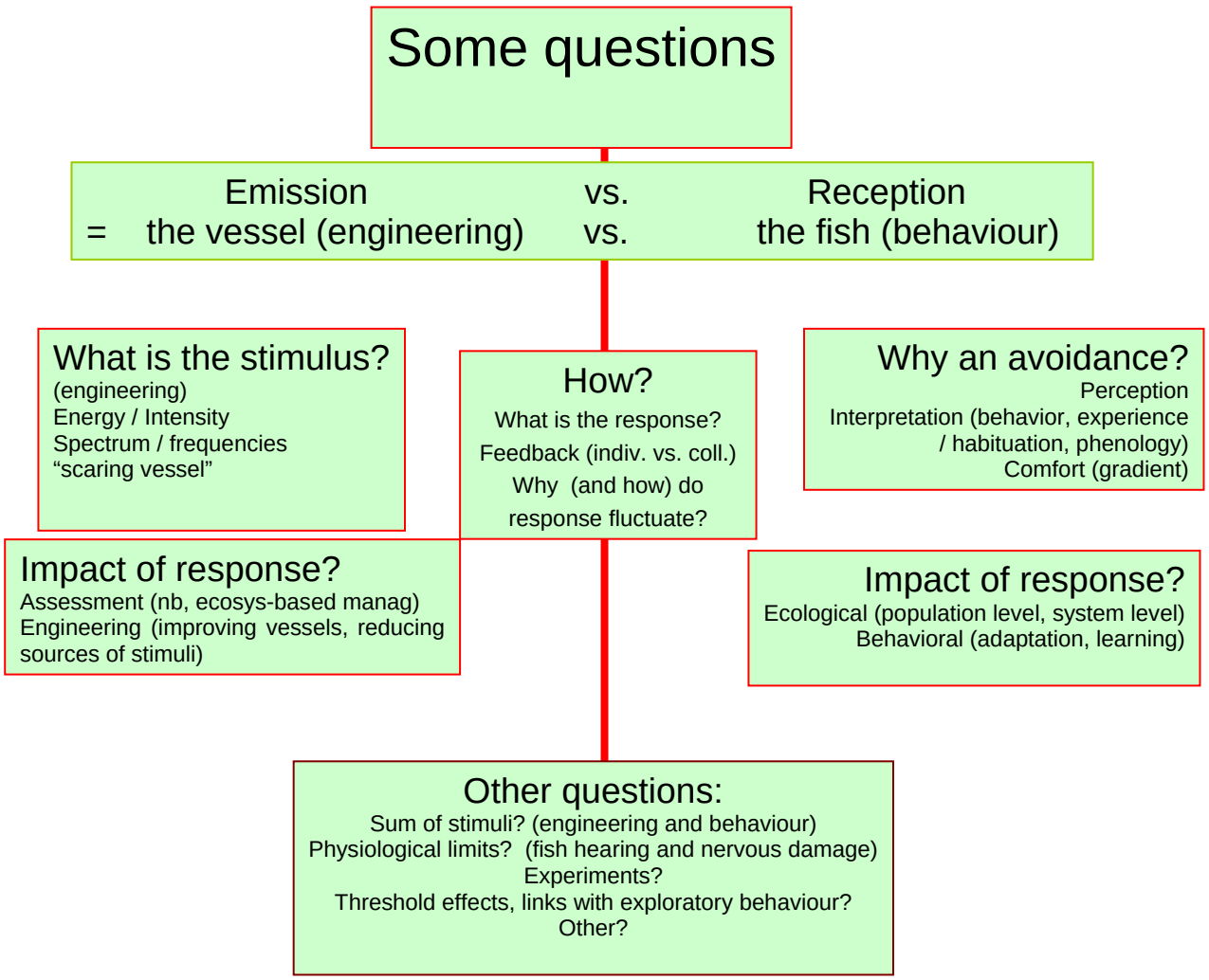
- State of the art for everything
- Chosen chapters, selected authors for each “box”, elaborate a CRR structure
- Progress reports

Expected activities during the second year

- Revision of chapters based on SG member reviews
- Non-CRR activities?
- Meeting in April 2009

The meeting closed on Sunday, 29 April, at 14:00.

Annex 1: Diagram of the main questions to be considered during the SGFARV (proposal from F. Gerlotto and J. Parrish)



Annex 2: Abstract to be presented at the Symposium on "Effects of sound on fish" by Chris Wilson

Announcement of opportunity to participate in: ICES Study group on fish avoidance to fisheries research vessels (SGFARV).

Researchers within the international ICES Fisheries Acoustics and Science Technology (WGFAST) working group are investigating the potential behavioural response of fishes to underwater radiated noise from fisheries research vessels. These behavioural avoidance reactions may bias survey-derived estimates of abundance if the fish move out of the path of the survey vessel or dive to the sea floor where they may avoid detection by acoustic survey methods. Based on the results of numerous field and laboratory studies, ICES recommended underwater radiated noise levels for fisheries survey vessels in 1992. Several countries have designed and built new noise-reduced fisheries survey vessels that meet the 1992 vessel noise specifications.

Recent comparative studies between the new, noise-reduced vessels and conventional research vessels have provided unexpected results, and in some cases, the fish response has been greater for the noise-reduced vessels than conventional vessels. These findings have prompted ICES WGFAST to form a group of fisheries acoustics experts to review the knowledge of vessel-induced fish behaviour. The group is referred to as the Study Group on Fish Avoidance to Research Vessels (SGFARV). The SGFARV identified 4 areas of study to better understand vessel-induced fish behaviour, which are vessel factors (noise transmission), environmental factors (bio-physical conditions surrounding the fish), behavioural mechanisms involved in fish reaction to noise, and the physiological aspects of hearing (use of sound by fishes, detection, reaction thresholds). The efforts of the 3-year SGFARV will culminate in the publication of an ICES Cooperative Research Report in 2010, which will provide new information and recommendations for researchers involved in vessel-induced fish behavioural studies.

Although the ICES community has extensive knowledge of vessel-induced fish behaviour based on field measurements of fish reactions to sound, it lacks the knowledge and expertise to fully understand the physiological aspects of sound detection in fishes. ***Thus, ICES encourages physiologists working in the area of fish hearing to participate with SGFARV members to facilitate the exchange of information in this important area of research.*** Involvement would include participation in SGFARV meetings and potential collaborative research opportunities. More information on the activities of SGFARV can be found at: www.ices.dk/iceswork/wgdetail.asp?wg=SGFARV or by contacting the SGFARV Chair, François Gerlotto (f.gerlotto@ifremer.fr).

Annex 3: Study Group on Fish Avoidance to Research Vessels: SGFARV_ 2007: General comments by Ron Mitson

"*If the language is not correct then what is said is not what is meant*"

1) We should at this stage make some definitions of words and wording to be used in the SG. If this is not done there is a risk of words being incorporated into reports that will convey a wrong impression especially to non-acoustically minded persons! In particular, the use of the word 'silent' is incorrect in the context of vessels. The term "noise reduced" is correct but maybe a little too clumsy? Perhaps 'quieter' would be preferable; we would then understand it to mean a vessel which had been noise reduced. Whatever term is used it should not be 'silent'.

2) Terms of Reference a-i. Use of the word 'great' to describe additional costs may in itself be excessive. Typically the additional costs have been between 10 to 15% once the techniques were understood and put into practice so 'great' is not appropriate.

3) Vessel (platform?) induced behaviour. The CRR 209 is not a 'specification'. ICES does not specify – it makes recommendations. If the ICES 209 recommendation is to be used as an aim when building a vessel a specification is then drawn up for the vessel and used as a contract between owner and shipyard. Complication can arise when the specification is interpreted according to spurious factors, e.g. use of different manufacturer's machinery from one vessel to the next and methods of mounting produce different signature characteristics but may still meet the CRR 209 levels.

4) Use of 'hydrophone necklace' measurements under stationary vessels may be useful to indicate potential 'acoustic hot spots' at particular frequencies. An example of this technique was shown at a WGFAST meeting last year.

5) Vessel-Induced Fish Behaviour

6) A proposal is given to contact Professor Blaxter (retired) to become involved in some way with the SG.? He has a distinguished record of investigation of the effects of noise on fish.

Annex 4: List of SGFARV Participants

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Annex 5: List of contacted persons

Persons contacted (lined names: colleagues who answered that they could not participate in the work of the SG)

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Present at First SGFARV meeting

François Gerlotto, Emma Jones, Ken Cooke, Laurent Dagorn, John Dalen, Nils Olav Handegard, Erwan Josse, Bo Lundgren, Ian McQuinn, Kjell Olsen, Andrzej Orlovski, Marc Soria, Karl-Johan Staehr, Bjarne Stage, Chris Wilson, Dick Wood

Organization of the groups. It was agreed that the SG would work at two different levels:

- a small group of scientists who will actively work on the SG ToRs and produce the main chapters of the CRR. Such a group should not gather more than 5–10 scientists. All members agreed that they would belong to the group until the end of the SG.
- A wider group of colleagues who have interest and knowledge on the ToRs, but cannot get involved in a permanent way. They will mostly work with the SQG during its annual meetings, and will answer some specific questions to members of the first group if needed.

Already volunteered to belong to "group 1".

François Gerlotto, Julia Parrish, Dick Wood, Nils Olav Handegard, Jorge Paramo

Already volunteered to belong to "group 2".

Ron Mitson, John Dalen, Laurent Dagorn, Marc Soria, Janet Coetzee, Jacques Massé

Annex 6: SGFARV Terms of Reference for the next meeting

The **Study Group on Fish Avoidance to Research Vessels** [SGFARV] (Co-Chairs: Julia Parrish, USA and François Gerlotto, France) will meet in Bergen, Norway, from 21–22 June 2008 to:

a) elucidate and expand the list of the possible physical stimuli produced by research vessels (platform related stimuli - PRS) that could elicit avoidance reactions in survey-targeted species;

b) produce a literature review to improve our understanding of fish hearing and their reaction to sound stimuli;

c) generate a list of recommended items to be monitored and measured on research vessels, wider than just noise related;

d) produce a review of methods for measuring avoidance to aid in the design and development of new methods to independently monitor fish reaction to PRS;

e) design explicit experiments to further examine the causes of fish reactions to PRS; and

f) produce an *ICES Cooperative Research Report* on fish response to anthropogenic sounds.

SGFARV will report by 1 July 2008 for the attention of the Fisheries Technology Committee.

Supporting Information

PRIORITY:	The current activities of this Group will lead ICES into issues related to fish behaviour in relation to conventional and quiet fisheries research vessels, and the resulting uncertainty in survey and stock assessment results. Consequently, these activities are considered to have a very high priority.
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	Action Plan No: 1. **Term of Reference a-i)** Many ICES nations have or are procuring noise reduced fisheries research vessels, at great additional costs relative to conventional vessels. To study the benefits of these new vessels, it is first necessary to understand the physical stimuli produced by vessels that could elicit avoidance reactions. **Term of Reference a-ii)** Several countries are conducting or have recently completed significant studies in this area and the subject would benefit from a review of progress and an evaluation of the results obtained. **Term of Reference a-iii)** Monitoring of physical stimuli produced by vessel is necessary to determine when and why some fish avoid some survey vessels. **Term of Reference a-iv)** Characterizing fish avoidance behaviour is challenging and a review of effective methods will aid researchers. **Term of Reference a-v)** New methods and experiments will be needed to better characterize fish avoidance reactions to survey vessels. **Term of Reference a-vi)** The SG should disseminate findings via an ICES CRR.
RESOURCE REQUIREMENTS:	The research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.

PARTICIPANTS:	The Group is normally attended by some 15-20 members and guests.
SECRETARIAT FACILITIES:	None.
FINANCIAL:	No financial implications.
LINKAGES TO ADVISORY COMMITTEES:	There are no obvious direct linkages with the advisory committees.
LINKAGES TO OTHER COMMITTEES OR GROUPS:	There is a very close working relationship with all the groups of the Fisheries Technology Committee. It is also very relevant to the Working Group on Ecosystem Effects of Fisheries.
LINKAGES TO OTHER ORGANIZATIONS:	None

Annex 7: Recommendations

RECOMMENDATION	ACTION
1. The study of individual vs. collective reaction of fish to vessel sound was recommended. Fish can have very distinct reactions depending on their aggregation characteristics. Moreover the school structure, morphology and shape could give valuable information on the fish reaction or reactivity to vessel.	
2. Mentioned on a regular basis was the issue of reactions to survey trawls and more generally whether the SGFARV should work on avoidance to fishing gears. Argued that this was part of the sampling tool and therefore any behaviour that results in an alteration of the density or composition of the fish observed on the echo-sounder is important to understand. It is recognized that fish response has already been observed to be closely linked to changes in sound associated with trawling activities. In any case the effect of fishing gears will not be studied alone, but on its incidence to vessel sound	The input of WGFTFB was suggested for this subject.
3. The lack of physiological expertise currently within the group was recognized and a forthcoming conference on Marine Bioacoustics was highlighted as a potentially useful source of information and collaborators. It was proposed that an abstract be submitted to advertise the work of the Study Group and attract external collaborators.	Chris Wilson was committed by the SG to contact the Steering Committee of the Conference www.NoiseEffects.umd.edu e-mail Lidia.Wysocki@univie.ac.at
4. About what stimuli should be covered, it was recommended that the focus should be on sound, but with mentioning of other stimuli such as the lights on the vessel, the shadow of the vessel, bioluminescence etc., including secondary stimuli eg effect of day and night and other environmental conditions. These have been shown to have an important influence on the behaviour , eg when working at night with polar cod, lights on the vessel are important; another example is the likely influence of bioluminescence and reactions of herring to each other.	The chair of SGFARV will contact the SCOR Technical Panel and invite experts in optical and visual observation techniques to participate in the next meeting.