1.5.6.3 Answer to The Netherlands' request on Electric Pulse Trawl

Request

The Netherlands requested ICES to review experimental results aimed at advancing knowledge of the ecosystem effects of electric pulse trawls. Limited use of these trawls has been granted to The Netherlands via an EC derogation.

In response to the request, ICES arranged for the experimental results to be reviewed by appropriate experts.

Response

Based on the expert reviews, ICES concludes that:

1. The experiments are a valuable further step to evaluate the ecosystem effects of fishing with pulse trawls.
2. Laboratory experiments on elasmobranches, benthic invertebrates, and cod to test the effects of electric pulses were generally well designed and interpreted correctly. However, the experimental results have some weaknesses as discussed below.
3. The experiments indicate minimal effects on elasmobranches and benthic invertebrates.
4. Electric pulses resulted in vertebral injuries and death of some cod which were in close proximity (<20 cm) to the conductor emitting the electric pulses. There is inconclusive evidence that the capture efficiency of cod by pulse trawls is higher than for conventional beam trawls (see attached review by Norman Graham). Widespread use of the pulse trawl has the potential to increase fishing mortality on cod as a result of injuries caused by electric pulses (and possibly higher capture efficiency) but further research is needed to draw firm conclusions.
5. While the results of laboratory experiments are informative, many factors could result in different effects during actual fishing operations. In particular, specifications contained in the derogation for the pulse trawl allow a wider range of electric pulse characteristics than were tested in the experiments. Therefore, pulse trawls permitted under the EC derogation may generate substantially different effects than those observed in the experiments.
6. This advice is narrowly based on the review of three reports provided by The Netherlands. Concerns and uncertainties raised in the advice may be addressed by further research, refinement of the derogation, and monitoring the fishing operations and performance of vessels using pulse trawls.

Background

In March 2006, ICES received a request from The European Commission to provide scientific advice relating to the use of beam trawls equipped with the capability to generate an electric pulse aimed at stimulating flatfish to enhance their vulnerability to the gear. ICES was specifically asked to give advice on the ecosystem effects of allowing electric pulse trawling on a commercial scale.

The request was considered by an *ad hoc* subgroup of the ICES-FAO Working Group on Fish Technology and Fish Behaviour (WGFTFB) in April 2006 (ICES, 2006). Based on the groups report, ICES gave advice in May 2006 which is summarized as follows:

- *"The available information shows that the pulse trawl gear could cause a reduction in catch rate (kg/hr) of undersized sole, compared to standard beam trawls. Catch rates of marketable sole above the minimum landing size from research vessel trials were higher but commercial trials suggested lower catch rates. Plaice catch rates also decreased for all size classes. No firm conclusions could be drawn for other species but there was a tendency for lower catch rates"*
- *"Because of the lighter gear and the lower towing speed, there is a considerable reduction in fuel consumption and the swept area per hour is lower".*
- *The gear seems to reduce catches of benthic invertebrates and lower trawl path mortality of some in-fauna species.*
- *There are indications that the gear could inflict increased mortality on target and non-target species that contact the gear but are not retained.*
- *The pulse trawl gear has some preferable properties compared to the standard beam trawl with tickler chains but the potential for inflicting an increased unaccounted mortality on target and non-target species requires additional experiments before final conclusions can be drawn on the likely overall ecosystem effects of this gear".*

ICES therefore made recommendations on additional data needed:

- *"Further tank experiments are needed to determine whether injury is being caused to fish escaping from the pulse trawl gear. The experiments need to be conducted on a range of target and non-target fish species that are typically encountered by the beam trawl gear and with different length classes. In these trials it should be ensured that the exposure matches the situation in situ during a passage of the pulse beam trawl. Fish should be subjected to both external and internal examination after exposure".*
- *"If the pulse trawl were to be introduced into the commercial fishery, there would be a need to closely monitor the fishery with a focus on the technological development and bycatch properties".*

The Report of the WGFTFB Ad hoc Group specifically mentioned potential spinal damage to cod exposed to electrical stimulation, potential effects on invertebrates and possible disruption of the electric sensory systems of elasmobranches. Subsequently, the European Commission granted The Netherlands a derogation for 5% of the fleet to use the pulse trawl on a restricted basis provided attempts were made to address the concerns expressed by ICES. This derogation has been granted every year since 2007.

The Netherlands (specifically IMARES) has studied the effect of the electric pulse trawl during the period 2007-2009 to fill these gaps in knowledge through a series of tank experiments on elasmobranches, invertebrates and cod. The experimental species were subjected to electrical stimuli believe to be representative of *in situ* fishing conditions. The findings from these experiments are given in three reports:

1. The effect of pulse stimulation on biota – Research in relation to ICES advice – Progress report on the effects to cod (De Haan *et al*., 2009a).
2. The effects of pulse stimulation on biota – Research in relation to ICES advice – Effects on dogfish (De Haan *et al*., 2009b).
3. The effect of pulse stimulation on marine biota – Research in relation to ICES advice – Progress report on the effects on benthic invertebrates (Van Marlen *et al*., 2009)

In consultation with the European Commission, in September 2009 The Netherlands requested ICES to review the reports and to provide updated advice on the ecosystem effects of the pulse trawl.

The reports were independently reviewed by a group of experts in the fields of electric fishing techniques, fishing gear technology, benthic ecology, unaccounted mortality and fish survival experimentation. The reviewers were specifically requested to consider the questions raised by ICES in the 2006 advice and whether the additional experiments had successfully addressed these issues. Documentation on the reviews is contained in Annex 1.

The following is a summary of issue raised by the reviews that ICES considers worthwhile to highlight:

1. The work carried out by IMARES as a response to the ICES advice on pulse trawling is notable for the high quality of the experiments. Detailed measurements of electric field parameters both in natural environment and during the experiments are noteworthy. A particular attention was given to the control groups of animals which were subjected to the same manipulations as the test groups but not electrically exposed to minimize the influence of transfer and handling. An additional positive point of the study is the use of an electric pulse simulator with pulse characteristics similar to the commercial Verburg pulse system. The numbers of fish both in the test and control samples were adequate. The presentation of the mortality results (as proportions), as well as the occurrence of spinal injuries in cod, along with their associated binomial confidence intervals (at 95%, say) (using "Statxact" for example) is informative. Moreover, at the same time a simple power analysis could be performed indicating the necessary sample size for future experiments (based on the deviance in these preliminary results).

2. With respect to benthic invertebrates, the results clearly show a low level of impact on the complete range of species tested. These species are considered representative of those encountered in the beam trawl fisheries. Based on all known literature on the expected mortalities of such species from traditional tickler chain beam trawls, it is therefore reasonable to assume that the impact of a pulse trawl with a pulse configuration corresponding to the experimental pulses on benthic invertebrates is less by a higher order of magnitude. It is important, however, that for the gear to be used with low impact that the existing prohibition on the addition of tickler chains in front of the electrode arrangements contained in the EU derogation should be maintained. Otherwise, tickler chains will cause additional ecosystem impact.

3. The experiments carried out on elasmobranches show only a very limited effect on the species tested and it is unlikely the pulse trawl system will have a major impact on elsamobranch species. It was shown that general well-being of exposed dogfish was good in that they produced eggs and exhibited no aberrant feeding behaviour.

4. The results show that the system is capable of inflicting vertebral damage leading to mortality of cod that were in close proximity (<20 cm) of the conductors. Also, inconclusive evidence suggest that the system may have a higher fishing efficiency for cod than the conventional gear (See attached review by Norman Graham of De Haan D., van Marlen B., Kristiansen T.S., Fosseidengen J.E., 2009a in Annex 1), but further research is needed to address this question and reduce cod mortality.

5. The derogation for use of the pulse trawl in Council Regulation (EC) No 43/2009 defines the voltage (V) and current power(KW =V*A) that can be used. However, it is not altogether clear from the reports how representative the experimental set up is with respect to the limits set within the derogation. The author's note that the tank tests were conducted "*with pulse characteristics equivalent to the nominal menu settings….which represent the* ***average*** *settings of the pulse properties….*" They then go on to note that these can be varied by +/- 20%. This raises concerns that the full range of settings were not tested and it is unclear what the impact of the 'maximum' setting could be.

6. ICES previously advised that the effects across different length classes encountered by the fishery should be considered. This issue has only been partially addressed as the experiments on cod were conducted on a narrow range of fish (41–55cm). Fish length has been shown to be important in terms of reaction and the results can not be extrapolated beyond the length groups tested. The effects on small fish and larger fish can only be estimated based on previous experimentation and in this respect the authors refer to the work by Stewart (1975), which showed lower effects for smaller fish. Based on all known literature, large fish are expected to be more negatively affected (e.g., more vertebral damage) (Snyder, 2003). The relative impact on the catchability of larger fish is unclear.

7. Due to commercial confidentiality, details on the pulse frequency, pulse shape, pulse duration, voltage/power of the pulse trawl are not widely available which hinders review of the potential impact of the system on target and non-target species. All of these factors are important as discussed by Snyder (2003).

8. It is also noted that the specifications in the derogation granted by the EC are not specific enough to assure that the results of the experiments discussed in this advice are applicable to all of the pulse trawls allowed under the derogation.

Source of information

De Haan D., van Marlen B., Kristiansen T.S., Fosseidengen J.E., 2009a. The effect of pulse stimulation on biota-Research in relation to ICES advice – Progress report on the effects to cod. IMARES Report Number C098/08. 9th October 2009. 25p.

De Haan D., Van Marlen B., Kristiansen T.S., Fosseidengen J.E., 2009b. The effect of pulse stimulation on biota-Research in relation to ICES advice – Effects on dogfish. IMARES Report Number C105/09. 16th October 2009. 32p.

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Stewart, P. A. M., 1975. Catch selectivity by electrical fishing systems. J. Cons. int. Explor. Mer, 36(2): 106–109.

Snyder, D.E., 2003. Electrofishing and its harmful effects on fish, Information and Technology Report USGS/BRD/ITR -2003-002: US Government Printing Office, Denver, CO, 149p.

Van Marlen, B., De Haan D., Van Gool, A., Burggraaf D., 2009. The effect of pulse stimulation on biota- Research in relation to ICES advice – Progress report on the effects to benthic invertebrates. IMARES Report Number C103/09. 21st October 2009. 53p.

ANNEX 1

Review of test experiments in relation of practical using Dutch pulse trawl system
(notes from Russian sub-group)

Researches carried out by IMARES in cooperation with the Institute of Marine Research as a response to the ICES advice on pulse trawling are notable for high quality of the experiments. Optimum conditions were provided for catching fish and benthic invertebrates, their transfer to the laboratory, subsequent keeping in circulating sea water and feeding. Detailed measurements of electric field parameters both in natural environment and during the experiments are also noteworthy. A particular attention was given to the control groups of animals which were subjected to the same manipulations as the test groups but not electrically exposed to minimize the influence of transfer and handling. An additional positive point of the study is the use of the electric pulse simulator with pulse characteristics similar to the commercial Verburg pulse system. The numbers of fish both in the test and control samples were adequate.

The researches tried to approximate test conditions to the real conditions *in situ* as much as possible. However, this conformity was not perfect yet. It seems to be somewhat inconsistent that individual fish were exposed to the electric stimulus only four times instead of six exposures which would be expected during the passage of 6 consecutive conductors along the stationary fish in a full-scale system. In this respect, the experimental impact appears to be milder compared to the worst possible case in the natural environment. At the same time, a simulated electric stimulus was switched on and off sharply, while in the full-scale there will be rather smooth increase and decay of the field strength. Thus, in the given respect, the experimental influence may be considered as a stronger impact. As a result, some uncertainty arises in the interpretation of the obtained data. Therefore, it would be probably better to use more realistic model stimuli, i.e. 6 gradually changing exposures instead of 4 sharp ones. Another possible variant is to use an array of 6 conductors (in this case the cage with a test fish moves at the required speed above the electrode system).

However, the major problem is rather a yawning gap between the obtained experimental data and a real situation during the trawling. Indeed, experiments with cod have shown that in the “near field” range serious spinal injuries and some disturbances in food behaviour are possible. However, we do not know exactly what share of fish would be subjected to such strong influence during the trawling; it is unclear what percentage of these fish will get in a trawl, which at worst would have a negative effect on their appearance and quality. And above all, what happens with those fish that contact the gear but are not retained?

For example, in the rivers, where electrofishing is regularly carried out, a significant share of morphologically abnormal fish is caught every year as a result of previous spinal injuries (McMichael, 1993). Also it is known that repeated influence of the electrofishing gear causes more spinal injuries than single-pass electric fishing (Ainslie *et al*., 1998). Therefore, it seems necessary to investigate fish behaviour in the real pulse trawl using multiple underwater video cameras located in the different parts of the gear. This may give a clear view of fish leaving the trawl, immobilized specimens remaining on the bottom and retained fish. Such studies should be attended by a large-scale X-ray photography of the caught fish. We believe these measures will make it possible to build a bridge between the laboratory and field data.

Concerning the influence of electric current on the elasmobranch fish, it should be emphasized that these fish possess a high-sensitive electro-receptive system which helps them in orientation and searching for their food. Whether this delicate perceptive system suffers from a strong electric field generated by the pulse trawl? The experiments carried out give no clear answer to this question. It was shown that general well-being of exposed dogfish was rather good; they produced eggs and exhibited no aberrant feeding behaviour. However, these dogfish offered sardine as a food under quite simple foraging conditions, where the sharks could find the food items without any electro-receptors. Ideally, special experiments are needed to show that electroperceptive system still works in elasmobranches exposed to a strong electric field. As the nearest analogue of such tests the classical experiments by Dijkgraaf and Kalmijn (1966), could be mentioned. In these tests, the rays (*Ray clavata*) displayed a steady conditioned reflex in response to electric signals of their food organisms (i.e. flatfish *Pleuronectes platessa*) which were reproduced by the electrodes masked with a substrate.

As regards to invertebrates, it was clearly demonstrated that the effects of the pulse stimulation on the mortality and food intake of these animals can be described as low and the effects of pulse beam trawling are probably smaller as compared to the effects of a conventional beam trawl. At the same time, authors did not estimate the influence of the pulse stimulus on the reproductive system of the invertebrates. Meanwhile, such influence is quite possible. For example, the Lithuanian researchers (Rachounas, 1977) observed that electric field can change the type of reproduction in daphnia (bisexual type changed into parthenogenesis). Besides, electric stimulus accelerated hatching of the larvae and reduced life-span and growth rate of the daphnia in subsequent generations.

Thus, a great deal of research work was carried out. However, many questions still remain unacknowledged. Nowadays, only cod is investigated among the non-target fish species. Other species, such as dab, turbot and whiting are not

studied yet. The possible influence of a pulse trawl upon the electroperceptive system of elasmobranch fish is also unclear. Another problem is the action of electric current on the reproductive processes in the invertebrates. The possible effects of the pulse trawling on smaller fish remain unknown and require further attention.

One of the main problems is to link the data of laboratory experiments and field trials, which particularly can be solved through the analysis of video recordings from the underwater video cameras and accumulation of more reliable statistics on the commercial and experimental catches. *In our opinion, the available data are insufficient to recommend the large-scale commercial use of the pulse trawl in fisheries. As a whole, additional tests (both laboratory and field) are needed*.

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Rachounas L. Reproduction of daphnia, freshwater shrimp and brine shrimp // Post effects of the electric fields upon the water animals. Vilnus: Mokslas, 1977. P. 81-86. (In Russian)

A Critique of:- "The effect of pulse trawl stimulation on biota – Research in relation to ICES advice – Progress report on the effects to cod. By D. de Haan *et al* (2009)".

Mike Breen.

This critique will consider the methods used in the assessment of survival and injury described in the above paper and consider the validity of the discussion and conclusions drawn from the experimental results, as requested by the ICES Working Group on Fish Behaviour and Fishing Technology (WGFTFB).

<u>1) Captivity Controls</u>
Using a captive population to monitor the effects of any potentially fatal stressor is always at risk of over-estimating the true mortality, unless it can be demonstrated that captivity itself does not kill the subject and, ideally, does not stress the subject. This was a major criticism of an earlier survival experiment for this project.

In this experiment, a simple control has been used to assess captivity effects: where control subjects were held in almost identical conditions to the experimental subjects, but without exposure to the experimental effects. Moreover, these control specimens demonstrated no observable mortality within the monitoring period (14 days). However, their feeding behaviour appears to have been disrupted post-treatment, which was explained by the authors as possibly being due their extended exposure to the holding tank in comparison to the treatment groups.

<u>Conclusion:</u> Well controlled experiment, demonstrating no observable fatal captivity effects. However, the treatment of specimens may have induced a stress response sufficient to disrupt feeding behaviour post-treatment. This is not an alarming observation, as feeding inhibition is a well established response to handling stressors in many species.

<u>2) Pulse Characteristics</u>
I have limited experience in the physics of electrical fields in water, so I will not formally criticise this component of the experimental design. However, I do have questions as a "lay person" that I would like considered:

i) Why were "nominal" settings for pulse properties used, as opposed to the theoretical maxima that could be seen during commercial operations? An impact assessment should really consider the worst case scenario.
ii) Only two pairs of electrodes were used in this laboratory based study, as opposed to six pairs used on the full scale gear. I appreciate this is likely to be due to size constraints within the laboratory tank. But does the difference mean this experiment will under-estimate the likely effects of the full scale gear? The ethical limitations placed on this experiment (ie. four pulses, as opposed to six) would suggest this is true.
iii) The expose to the four electrical pulses lasted "on average 3 minutes". However, *in situ* a fish could experience six pulses in only two seconds. Does this also lessen the potential impact of this experiment, in comparison to those experienced on the full scale gear?
iv) Are there any anticipated salinity effects (experiment conducted at $32.95^{o}/_{oo}$) due to differences in conductivity?
v) Are there any anticipated temperature effects (experiment conducted at 8.2^{o}C)? ie. In the S. North Sea, where warmer temperatures are experienced, could any damaging effects be more pronounced? The contraction speed of the swimming muscles in the tail will certainly be faster (Özbilgin and Wardle, 2002).

<u>3) Behavioural Observations – during treatment</u>
Although the behaviour of individual specimens was recorded on video during treatment, there is only a limited description of this in the results. I am particularly interested in the ability of the fish to "swim" or at least be propelled by the electrically induced rigor of its tail muscles; the observations from the preliminary study suggests they could. My concern is that the electrically induced rigor in the fishes' swimming musculature may be sufficient to propel an injured fish the short distance required to avoid capture.

<u>Action:</u> provide a more detailed summary of the behavioural response of individual specimens during the treatment. In particular, despite their restraints, indicate / discuss the potential for individual specimens to "swim" and hence avoid capture by the gear.

<u>4) Post Mortem Injury Assessment</u>
The post mortem examination for potential injuries was limited to the swimming musculature and associated vertebrae. Although this precludes the potential for identifying other injuries, as a preliminary study it appears to have been a well targeted and thoroughly conducted investigation of the most likely site of traumatic injury. I was disappointed to see that not all fish were systematically examined for spinal/muscle injuries (as suggested by table 2(?)). While injuries in the Control and Far Field groups were unlikely, it is feasible that musculo-skeletal injuries could have occurred during the transfer and restraint of specimens in the experiment.

5) Presentation of Mortality & Injury Results
The presentation of the mortality and injury results is confusing and contradictory. Other than detailing when after treatment each fatality occurred, I see no benefit in differentiating between the "immediate" and "delayed" mortalities.

The injury results are confusing and seemingly contradictory, that is:

- Results para 4, line 2 & 3: 5/16 had tail haemorrhage & 4/16 had bone fractures;
- Results para 4, line 5: 9/20 had injuries;
- Results table 2(?): 5/(16 or 20?) had injuries; and
- Discussion para 3, line 2: 9/16 fish showed spinal injury.

Action: Please simplify the presentation of these simple results:

i) avoid differentiating between "immediate" and "delayed" mortalities;
ii) detail (in hours or days) when fatalities occurred after treatment; and
iii) present as simple proportions (with binomial confidence intervals – see below).

6) Statistical Analysis
There has been no formal statistical analysis of the mortality or injury results. However, it could certainly be argued that the experimental design presented here is simple enough, and the results sufficiently clear, not to warrant any formal analysis. Moreover, the relatively small sample sizes would mean that little significance could be place in the conclusions from any between-group comparative analyses.

Suggested Actions: presentation of the mortality results (as proportions), as well as the occurrence of spinal injuries, along with their associated binomial confidence intervals (at 95%, say)(using "Statxact" for eg.) would be informative. Moreover, at the same time a simple power analysis could be performed indicating the necessary sample size for future experiments (based on the deviance in these preliminary results).

Concluding remarks

This experiment has clearly demonstrated that cod (size 0.41–0.55 m) can be detrimentally affected (with severe musculo-skeletal injuries) when exposed, at close range (0.1 m), to the electrical pulses emitted by this prototype gear. Moreover, these injuries have the potential to induce a substantial mortality, in what is generally perceived to be a robust species (Ingolfsson *et al.*, 2007).

Without a more thorough understanding of the behaviour, and ultimate fate, of cod (& potentially other gadoid species) immediately ahead of the electrified beam trawl, it is impossible to extrapolate the relative impact upon the exposed population. It is uncertain what proportion of the population encountering the electrified beam trawl would pass sufficiently close to be injured by the electrical impulses. In the discussion it was argued that any fish close enough to the electrodes to be injured, would be unlike to escape the gear and therefore could be landed with the catch (accepting the injuries may reduce the value). However, it is also feasible that the electrically induced rigor in the fishes' swimming musculature may be sufficient to propel an injured fish the short distance required to avoid capture.

The results from this experiment suggest that the use of this prototype gear may lead to an increased and unaccountable mortality in any population of cod (& potentially other gadoid species) exposed to it. Careful consideration should therefore be given to assessing and mitigating for this impact before this gear is introduced into a commercial fishery.

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Ingolfsson, O´. A., Soldal, A. V., Huse, I., and Breen, M. 2007. Escape mortality of cod, saithe, and haddock in a Barents Sea trawl fishery. – ICES Journal of Marine Science, 64: 1836–1844.

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De Haan D., van Marlen B., Kristiansen T.S., Fosseidengen J.E., 2009. The effect of pulse stimulation on biota-Research in relation to ICES advice – Progress report on the effects to cod. IMARES Report Number C098/08. 9th October 2009. 25p.

Review by Norman Graham

Background

In December 2005, ICES received a request from The European Commission to provide scientific advice and evaluation of the following three points relating to the use of beam trawls capable of delivering electrical stimulus for the capture of flatfish species.

a) What change in fishing mortality could be expected following the adoption of such gear in the commercial fishery, assuming unchanged effort measured in KW-days at sea?

b) What effect would such a widespread introduction have in terms of (i) the mixture of species caught; (ii) the size of fish caught?

c) What, if any, effects would such introduction have on non-target species in the marine ecosystems where this gear was deployed?

This was considered by an *ad hoc* sub-group of WGFTFB in April 2006 (ICES, 2006). In response to point (c) of the request, ICES (2006) made the following observations:

> "Research in the freshwater environment has demonstrated that if excessive stimulus is applied, electric fishing is damaging (Snyder, 2003). It can lead to mortality from stress, haemorrhaging, respiratory failure and spinal damage. Often mortality does not occur for some days after exposure to the electric field. The extent depends on exposure duration, pulse frequency, pulse shape (critical), pulse duration, voltage/power, conductivity, size and species of fish/other organisms and proximity to the pulse source. All of these factors must be considered when evaluating the effect of this gear on the ecosystem.
>
> There are indications from the literature provided for this evaluation, that physical damage to fish may also occur in the marine environment also, which could result in negative effects on both target and non-target species that contact the gear but are not retained.
>
> Stralen (2006) notes that cod have been observed with spinal damage (snapped). Such observations were only noted in cod retained in the experimental (pulse) trawl and not in the conventional (control) gears.
>
> This is a somewhat worrying observation as it may indicate that the pulse being used is excessive and fish are being damaged in a similar manner to the observations made in the freshwater environment. This is likely to be attributed to extreme muscle contraction caused by the pulse system. It is important to ascertain the extent of this problem and also to assess if this occurs with other species (target and non-target).
>
> The expert group concludes that more experimentation (aquarium trials) is needed in order to assess if any negative effects (caused by excessive stimulus) are occurring. Data is required for a range of fish species (and length classes) that typically encounter beam trawls. Such experiments have not been conducted to date."

In response to the latter paragraph, IMARES has conducted further work to ascertain whether the earlier observations by Stralen (2006) and other national work.

Methodology

Due to commercial confidentiality, the requirement that data on the pulse frequency, pulse shape (critical), pulse duration, voltage/power is still not available which hinders the delivery of a full review of the potential impacts that the system may have on target and non-target species. Notwithstanding, the further work on cod presented does provide additional information as to the potential impact and the authors are commended for this.

The author's note that tank tests were conducted "*with pulse characteristics equivalent to the nominal menu settings….which represent the **average** settings of the pulse properties*", they then go on to note that these can be varied by +/- 20%. This raises concerns as the full range of settings were not tested and it is unclear what the impact of the 'maximum' setting could be. There are indications from the text that the upper end of the settings could be detrimental as one fish died from vertebral injury. It is important to note that subsequent tests were conducted with a 15% reduction in pulse amplitude. The earlier ICES response (ICES, 2006) recommended that test be conducted with a range of fish lengths typically encountered by the beam trawl. The experiments were conducted on a narrow range of fish (41-55cm) and as fish length is important in terms of reaction (a stronger response is noted with larger fish) the results can not be extrapolated beyond the length groups tested. It is also worth noting that only 4 exposures were applied, when in

practice this would be 6 under normal conditions. Therefore the tank tests can not be considered fully representative of commercial conditions. ICES (2006) note:

> "These need to be conducted on a range of fish species that are typically encountered by the beam trawl gear, and with different length classes, both above and below MLS. In these trials it should be ensured that the exposure of the fish matches the situation *in situ* during the passage of the pulse beam trawl."

There is insufficient information presented and there are also indications in the text (4 v 6 exposures) that the latter comments above have not been fully dealt with and the narrow size range of fish and species reported fail to adequately consider the first point above. Furthermore, ICES (2006) note:

> "The orientation of the fish relative to the uniform field used in the tank experiments needs to be varied, as this can significantly affect the stimulus applied to the fish. The intensity of the field should also be varied up to the maximum field strength delivered by the electrodes given the non-uniform nature of the field. The precise 3D distribution of the field in the area of the electrodes needs to be described. Data from these experiments can then be used to help determine the effect of fish position, orientation and length relative to the electrodes under commercial conditions. The fish should be subject to both internal and external examination post exposure."

It is unclear from the work presented whether the orientation of the fish was considered, nor is it clear that the full range of field strength setting were tested. In summary, it is not possible to ascertain whether the laboratory experiments were comparable with the system under commercial conditions.

Results

The work presented demonstrates that the observations of vertebral damage observed by Stralen (2006) are a direct result of electrical pulse stimulus. The results show that 25% of the fish subjected to the 'near field' conditions were injured and 20% of this test group died. The authors note that such close proximity could be experienced under commercial conditions as cod tend to enter the net in a low position, and that "*vertebral injuries may be higher in this condition*". It is also worth noting that catch comparison data contrasting CPUE (kg/hr) between the conventional and pulse system show that the efficient of the pulse system is 228% higher than conventional gear (although with a lower towing speed). It is possible that this increase in efficiency is caused by a reduction in the escape response of cod (via disorientation) and therefore the pulse system could represent a significant increase in cod catches through technological development and could contribute a significant source of unaccounted fishing mortality if the system causes damage to fish not retained by the gear.

Conclusions

The results show that the system is capable of inflicting vertebral damage leading to mortality of cod. If the system resulted in the same levels of cod mortality as conventional gear, this only raises ethical animal welfare issues and this need to be contrasted to the possible positive benefits of the system i.e. absence of tickler chains and associated reductions in habitat and benthic invertebrate mortality. However, the system appears to have a higher fishing efficiency for cod than the conventional gear and also has the potential to contribute to unaccounted mortality through fish encountering the gear but not being retained. Given that there is a need to further reduce fishing mortality on cod, widespread introduction of this system could potentially increase cod mortality rather than reduce it. As a result, this reviewer considers that the introduction of this type of fishing equipment should not be permitted.

References

ICES. 2006. Report of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB), 3–7 April 2006, Izmir, Turkey. ICES CM 2006/FTC:06, Ref. ACFM. 180 pp.

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