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Report of the Workshop to Assess the Ecosystem Effects of Electric Pulse Trawls (WKPULSE)

24-26 February 2010

IJmuiden, the Netherlands

ICES International Council for the Exploration of the Sea
CIEM Conseil International pour l'Exploration de la Mer

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H. C. Andersens Boulevard 44–46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Executive summary

Following the ICES Advice on Pulse Trawling on flatfish of 2006 further studies were carried out by IMARES, the Netherlands on catsharks (*Scyliorhinus canicula* L.), cod (*Gadus morhua* L.) and a range of benthic species (ragworm (*Nereis virens* L.), common prawn (*Palaemon serratus* L.), subtruncate surf clam (*Spisula subtruncata* L.), European green crab (*Carcinus maenas* L.), common starfish (*Asterias rubens* L.), and Atlantic razor clam (*Ensis directus* L.) under pulse stimulation of the Verburg-Holland system. These studies were reviewed and discussed at the meeting of the Workshop to Assess the Ecosystem Effects of Electric Pulse Trawls (WKPULSE). The reviewing experts concluded that there is primarily more information needed on the effect on cod before the pulse trawl can be allowed on a commercial basis. The reviewing experts could not be convinced that the simulator provided an adequate representation of the *in situ* pulse, due to the fact that they were not able to review the specifications of the pulse characteristics resulting from confidentiality issues. They recommended that a three-dimensional temporal-spatial model of exposure of cod inside the trawl using information about behavioural responses validated by direct underwater observation would be useful. Furthermore it was suggested to investigate the effect of pulses on the electro-receptor organs of elasmobranchs, and determine the catch rates of these fish in beam trawls. Also to look at other gadoid species: e.g. haddock, and whiting. It was also suggested to investigate the effect of the pulse on the reproductive capabilities of benthos, but weigh this against the mortality in the conventional tickler chain beam trawl. In addition concerning enforceability and control it was noted that there are indications that the limits used in the present derogation that are deemed needed for fraud-resistant control (electrical power limited to 2.5 kW/m beam length, and amplitude to maximum 15 V) will not be sufficient to ensure that fishing efficiency with pulse trawls will not be raised in future, and it is recommended to investigate this aspect further and suggest limits that can. A presentation was also given about the development of a pulse trawl for the brown shrimp (*Crangon crangon* L.) fishery in Belgium. When both flatfish and shrimp trawling are considered pulse trawling will be an important issue for hundreds of fishing vessels in countries around the North Sea and the suggestion to set up an ICES Study Group on electrical fishing was mooted.

1 Opening of the meeting

The Chair welcomed the participants and explained some practical arrangements. A list of participants is given in Annex I.

1.1 Terms of reference of this meeting

2009/2/SSGESST01 The **Workshop to Assess the Ecosystem Effects of Electric Pulse Trawls (**WKPULSE), of the ICES–FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) chaired by Bob van Marlen*, Netherlands will meet in IMARES, the Netherlands, 24–26 February 2010 to:

a) To review the *in situ* and tank experiments conducted following the request for additional information mentioned in the ICES Advice of 2006 on the electric pulse beam trawl;

b) To review data on the measurement of field strength and pulse characteristics used in the pulse trawl system.

WKPULSE will report by 4 May 2010 (via SSGESST) for the attention of SCICOM and ACOM.

Supporting Information

Priority	The current activities of this Group will lead ICES into issues related to the effectiveness of technical measures to change size selectivity and fishing mortality rates. Consequently these activities are considered to have a very high priority
Scientific justification	Term of Reference a) The use of electricity in fishing is banned Regulation EU No. 850/98. To address ecosystem effects of conventional beam trawling a system using electric pulses has been developed in The Netherlands and is currently being used on a small number of commercial fishing vessels. This involves substantial investments that are stimulated by the Dutch Ministry LNV. In order to lift this ban and/or continue to work under derogation additional information on ecosystem effects of introducing this technique in the EU beam trawl fleets was requested by ICES and the EU's STECF in 2006. Since 2006 additional trials have been conducted to try to address the issues raised by ICES and STECF and the results to need be reviewed to assess whether the concerns raised have been satisfied.
Resource requirements	The research programmes which provide the main input to this workshop 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 Workshop will be attended by some 8–15 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 and also the Working Group on the Ecosystem Effects of Fishing (WEGECO).
Linkages to other organizations	This workshop is of particular interest to the European Commission DGMARE.

2 Confidentiality issue

At the beginning of WKPULSE the Chair requested all participants to sign a declaration concerning protection of knowledge of electrical pulse trawling. IMARES has signed a similar agreement of Protection of Knowledge with Verburg-Holland Ltd., who have developed the pulse trawl system. This was at the direct request by the Verburg Company, and was due to the fact that a second Dutch company, (HFK Engineering of Baarn,) has started to develop another pulse trawl and Verburg felt that the details of his pulse system should not be freely distributed to their competitor. Some of the participants, however, were not in a position to sign this declaration as they felt it was impossible to distinguish their own knowledge of electric fishing from the workings of the Dutch system. The view was expressed that as the system was already under patent then this declaration was unnecessary. Some also felt that it may lead to difficulties or compromise their own work in this area in future. As a consequence, WKPULSE has been unable to fully address TOR b regarding the pulse characteristics of the Verburg system as this information could not be divulged to the participants. Nevertheless, general comments were given how Verburg and IMARES can work on the issue to adapt the experimental pulse to the in situ pulse, experienced by underwater fauna.

It was fully acknowledged by the participants of the need to protect the intellectual rights of the company, particularly with respect to pulse generation, but that it is not unreasonable the general characteristics of the pulse be released. The participants of WKPULSE concluded this issue will continue to prevent a full scientific assessment and subsequently prevent ICES recommending this fishing gear be accepted into EU legislation unless it is fully resolved. This should not, however, be seen as an obstacle to similar developments with pulse trawls in other countries, notably Belgium, where such issues have not arisen and the specifications of the system being developed are fully open to scientific and public scrutiny.

Consequently the Chair decided to restrict the information to the group and to exclude the technical details of the pulse characteristics, and focus on the methodology and results of the experiments conducted by IMARES. This decision did hamper some of the detailed discussions under the Terms of Reference (TORs), meaning that ToR b) could only be addressed in terms of a presentation of and discussions on the methodology used, but reviewing of the three reports (ToR a) was still possible as they contained no detailed information on the pulse used. A fourth report on preliminary studies was also included; see Van Marlen *et al.*, 2007.

3 Adoption of the agenda

The agenda was adopted although the confidentiality issues described below meant that much of the detailed information on the pulse trawl was not presented, recognizing the position of the Verburg company. A presentation of the development of a pulse trawl for the brown shrimp (*Crangon crangon* L.) fishery in Belgium, and discussions about policy and implementation were added to the list.

4 Proceedings

4.1 History and background presented by Bob van Marlen

4.1.1 Nature of the problem

There is growing concern about the impact of fishing on marine ecosystems, and particularly on the benthic fauna. Beam trawls are intensively used in the North Sea fisheries of the Netherlands, Belgium, Germany, and the UK. Beam trawling for flatfish is an efficient fishing method, but it requires a high level of energy input, due to the high gear drag caused by the relatively heavy groundgear and towing speeds (e.g. 6.5 to 7.0 kts), and this technique is causing substantial mortality and possible changes in the species composition of invertebrates (Anon., 1988, 1995; Jennings and Kaiser, 1998; Lindeboom and De Groot, 1998; Kaiser and De Groot, 2000; Fonteyne and Polet; 2002; Piet *et al.*, 2000). A study revealed that the penetration depth of beam trawls varies between 1 and 8 cm, depending on the type of gear and substrate (Paschen *et al.*, 2000).

In addition the sharp rise in fuel costs in the second half of 2008 called for measures to reduce the fuel consumption in many sectors of the fishing fleet, in particular those fishing with high towing speeds and heavy gears, such as beam trawlers. This can be achieved by reducing the towing speed and the drag of the gear, and electrical stimulation, replacing tickler chains, is a potential alternative.

The idea is not new, and research was carried out in earlier times. It was found that electrical stimuli evoke reactions in fish ranging from a startling response to narcosis (McBary, 1956). In freshwater direct current can be used to attract fish by forced swimming (anodic attraction).

4.1.2 Research carried out by IMARES

Research in 1970–1988

Research on electrical or pulse stimulation in beam trawling was carried out extensively from 1970, in the Netherlands (De Groot and Boonstra, 1970, 1974; Agricola, 1985; Van Marlen, 2000), but also in other nations: Belgium (Vanden Broucke, 1973), Germany (Horn, 1976), and the UK (Horton, 1984).

It was found that in seawater a pulsing electric field can be utilized to catch brown shrimp (*Crangon crangon* L.) and also flatfish, in particular sole (*Solea vulgaris* L.). An array of electrodes can be used to replace tickler chains in beam trawls (De Groot and Boonstra, 1970, 1974). The possibility of size selection was raised, as longer fish were expected to react more strongly (Stewart, 1975), although not clearly confirmed later by experiments (Stewart, 1978, Agricola, 1985).

The primary motive at that time was to save fuel by decreasing gear drag. In spite of the development of various prototypes introduction in commercial practice never happened (Van Marlen and De Haan, 1988; Van Marlen, *et al.*, 1997). At present a main objective is to reduce the impact of groundgear on the seabed. Any successful new stimulation technique should offer adequate catch levels on target species, sound economics, a decrease in bycatch levels, similar chances of survival for escaping and discarded animals, and no effect on the reproductive capabilities of the species affected.

The development stopped when fishing with electricity was banned in the European Union (EU) in 1988 (See EU Council Reg. 850/98). The reason for this was fear of in-

creasing catch efficiency in a time when the discrepancy between the state of the resources and the ever increasing fishing effort became problematic. In the late 1990s the development of beam trawling with electrical stimulation was continued, but now the focus was on reducing adverse ecosystem effects (Van Marlen, *et al.,* 2001a).

Research after 1997

IMARES, part of Wageningen UR (former RIVO) became again involved in an existing trilateral cooperation between a private company (Verburg-Holland Ltd.), the Dutch Fishermen's Federation and the Ministry of Agriculture, Nature and Food Quality in 1998. A series of trials were conducted on board FRV "Tridens" on a 7 m prototype electrified beam trawl, called 'pulse' trawl, resulting in sole (*Solea vulgaris* L.) catches matching those of conventional tickler chain beam trawls, plaice catches being reduced by about 50%, and benthos catches reduced by 40%. These promising results led to follow-up experiments in 1999 with a modified gear. The first objective was to improve the catches of plaice, appraise the effect of towing speed, compare the warp loads of both gears, and appraise the effect of the electrical stimulation on short-term fish survival. The second objective was to further improve the catching performance of the net attached to the beam of the pulse trawl, and to collect more data on short-term survival, also of benthic animals (Van Marlen, *et al.,* 1999; Van Marlen, *et al.,* 2000; Van Marlen, *et al.,* 2001a, 2001b).

A study on differences between a conventional 7 m tickler chain gear and the 7 m prototype electrical gear in direct mortality of invertebrates living on and in the seabed was conducted in June 2000 on board FRV "Tridens" and RV "Zirfaea". Benthos samples were taken from the Oyster grounds prior to fishing, and from trawl tracks caused by the two gear types. The direct mortality calculated from densities in these samples was lower for an assembly of 15 taxa for the pulse trawl, indicating the potential of electrical fishing to reduce effects on benthic communities (Van Marlen, *et al.,* 2001).

After these experiments it was decided to develop a prototype for 12 m beam length, being the most common value in the Dutch fleet. Technical trials with the new prototype were carried out in November-December 2001 on board FRV "Tridens", and continued in 2002 and 2003, resulting in catch rates for sole and plaice equalling those of conventional 12 m gear.

Recently the bycatch and discarding of undersized fish, particularly plaice (*Pleuronectes platessa* L.) gained attention. Comparative studies were undertaken in 2005 on FRV "Tridens" on the differences in catches and on differences in survival of undersized sole and plaice between a 12 m pulse beam trawl and a conventional 12 m tickler chain beam trawl (Van Marlen *et al.,* 2005a, b). A higher survival rate for plaice, but not for sole, was found for the pulse trawl, whereas the level of blood parameters (glucose, free fatty acids, cortisol, and lactate) and the changes over time in blood samples taken from both species showed no significant differences between both stimulation techniques.

In autumn 2004 it was concluded that the 12 m prototype was technically ready for a series of long term trials on a commercial fishing vessel. The Motor Fishing Vessel (MFV) UK153 "Lub Senior" was outfitted with a complete system of two pulse trawls and cable winches. A series of experiments was carried out on the UK 153 in the period between October 2005 and March 2006 and compared to the performance of similar beam trawlers fishing with the conventional gear type in the same period, and on the same fishing grounds in the North Sea, on the Dutch continental shelf. The

MFV UK153 was outfitted with a complete system of two pulse trawls and winches with feeding cables. Nine trips in total were undertaken. Five trips were used to make actual comparisons with a second vessel (Van Marlen *et al.*, 2006). The main findings were that landings of plaice and sole were significantly lower, but there was no significant difference in the catch rates of undersized (discard) plaice between the pulse trawl and the conventional trawl. In the pulse trawl, the catch rates of undersized (discard) sole were significantly lower than in the conventional beam trawl. The catch rates of benthic fauna (nrs/hr of *Astropecten irregularis*, *Asterias rubens*, and *Liocarcinus holsatus*) were significantly lower in the pulse trawl. Also, as found before, there were indications that undersized plaice is damaged to a lesser degree and have better survival chances in the pulse trawl.

4.2 ICES Advice 2006

4.2.1 History

In March 2006, the European Commission issued a request to ICES to evaluate the use of a "pulse-trawl" electrical fishing gear to target plaice and sole in beam trawl fisheries. ICES was requested to give advice on the ecosystem effects of a potential implementation of pulse beam trawling.

An Ad Hoc Expert Group on Electric Fishing was formed and this group made a report that was discussed by members of the group, and in a plenary session at the meeting of the ICES Working Group on Fishing Technology and Fish Behaviour (WGFTFB) in Izmir, Turkey in April 2006. This report and the additional data analyses undertaken after the WGFTFB meeting were the basis of the ICES advice that ICES provided in May 2006 of which the results are summarized below.

4.2.2 Questions raised by the European Commission addressed to ICES

The questions raised by the European Commission to were:

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?*

4.2.3 ICES conclusion and recommendation in 2006 on additional data needs

ICES Concluded:

"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 sole above the minimum landings size from research vessel trials were higher but the commercial feasibility study suggested lower catch rates. Plaice catch rates decreased for all size classes. No firm conclusions could be drawn for dab, turbot, cod and whiting but there was a tendency for lower catch rates.

The gear seems to reduce catches of benthic invertebrates and lower trawl path mortality of some in-fauna species.

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.

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."

The recommendations of ICES were:

"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."

4.2.4 Suggested further research topics following the ICES Advice of 2006

As a response to the ICES Advice on Pulse Trawling (see Annex and the report by the Expert Group of WG-FTFB) <u>three</u> topics for further study were selected, namely:

1) Study into spinal damage in cod (*Gadus morhua* L.)

2) Research into the effects of electrical stimuli on elasmobranch fish.

3) Further study into the effects on benthic invertebrates that are subject to the electric field generated by the electrodes in the gear.

4.3 Presentation of studies following the ICES Advice of 2006

4.3.1 Preparatory studies

As a response to the ICES Advice on Pulse Trawling (see Annex and the report by the Expert Group of WGFTFB (ICES, 2006), <u>three</u> topics for further study were selected, namely:

i) Study into spinal damage in cod (*Gadus morhua* L.)

ii) Research into the effects of electrical stimuli on elasmobranch fish.

iii) Further study into the effects on benthic invertebrates that are subject to the electric field generated by the electrodes in the gear

These activities involved:

1) Measurements on the detailed stimulus applied in the pulse trawling system developed by the company Verburg-Holland Ltd., i.e. the amplitude, pulsewidth, rise and fall times, repetition rate and field strength along the electrodes. These measurements were done on board of the commercial fishing vessel MFV "Lub Senior" (UK153), and in tank facilities of the manufacturer of the pulse beam trawl.

2) Simulation of this stimulus in the seawater recirculated aquaculture system available at IMARES.

3) Development of a protocol for keeping small-spotted catsharks alive and well, including dietary requirements.

4) The exposure of small-spotted catsharks (*Scyliorhinus canicula* L.) to a simulated pulse under laboratory conditions and observation of behaviour, including foraging, and monitoring mortality.

5) Investigation of possible spinal damage of cod caught by a commercial vessel using pulse beam trawls by X-ray photography.

The details of this work are reported in Van Marlen *et al.,* 2007.

4.3.2 Research on cod (Dick de Haan, IMARES)

Short outline

Research on the response of cod to electrical stimuli commenced in 2008, but with a differing research protocol from the experiments conducted in 2007, in which the stimuli were applied on fish that were positioned in the electrical field in a more or less fixed position, to attempt to assess precisely the exposure and reaction to the electrical pulses.

The electrical stimuli were generated with a system of two parallel electrodes with a duration matching, as close as practically possible, the expected duration *in situ* of fish inside a trawl. The experiments on cod were carried out in close cooperation with Institute of Marine Research (IMR) Austevoll, Norway. They have experience in hatching and rearing of cod for aquaculture and therefore seemed ideally suited for carrying out this work. This research station facilitated the research, through provision of fish from their own aquaculture research stock and also supplied video observation equipment. The electric pulse simulator was made available by Verburg-Holland Ltd. with pulse characteristics similar to the commercial Verburg pulse system.

Preliminary studies on cod were undertaken in the period between 1 September 2008 and 01 March 2009. These activities involved the exposure of cod to a simulated electric pulse under laboratory conditions and observation of behaviour, including the foraging response; monitoring mortality and assessing possible internal injuries such as vertebral damage by X-ray photography.

Groups of 20 fish with similar lengths (0.41 – 0.55 m) were exposed to the electric stimulus, with each group placed in one of three distance ranges:

1) A “far-field” range with the fish exposed at 0.4 m side ways of a conductor element,

2) A “medium field” range with the fish exposed at 0.2–0.3 m above the centre of a conductor pair,

3) A “nearfield” range with the fish exposed at 0.1 m from the conductor element;

To exclude the effects of transfer and other unknown influences a control group of 20 fish was confined in the same way, but not exposed to the electric stimulus.

The fish exposed in the “far-field” range, representing the fish just outside the working range of the trawl, showed hardly a reaction to the exposures and responded normally to the feeding cycles. The fish exposed in the “medium field” range showed a moderate contraction of the muscles, but all recovered well and responded normally to the feeding cycles. The effects on the fish exposed in the “nearfield” range were more pronounced, 4 fish died shortly after the exposure, and another 2 died in the observation period thereafter. In the observed period of 14 days after the expo-

sures the surviving fish packed together outside the feeding zone and hardly responded to the feeding cycles.

The fish of the control group, exposed to a similar treatment as the exposed groups except receiving no pulse stimulation, showed a decrease in appetite compared to the fish exposed in the "far-field" and "medium field" ranges. This could have been related to the fact that this group was treated towards the end of the experimental period and thus stayed the longest time in the transfer tank.

Post mortal analysis using X-ray scans revealed that 5 out of 16 remaining fish exposed in the "nearfield" range had haemorrhages close to the vertebral column, and of these five, 4 had vertebral bone fractures. No injuries were found on the fish exposed in the "medium field" range, which showed weaker reactions to the electric exposure.

More details are given in De Haan *et al.,* 2008.

4.3.3 Research on catsharks (Dick de Haan IMARES)

Short outline

This study involved the exposure of lesser spotted catsharks (dogfish) to a simulated electric pulse under laboratory conditions, and the monitoring of mortality, injuries and behavioural responses, in particular feeding response. The electric pulse simulator was made available by Verburg-Holland Ltd. with pulse characteristics similar to the commercial Verburg pulse system. On 4 December 2008, three groups of 16 fish with similar lengths (0.3 – 0.65 m) were exposed to the electric stimulus, with each group in one of three distance ranges:

1) A "far-field" range with the fish exposed at 0.4 m side ways of a conductor element.
2) A "medium field" range with the fish exposed at 0.1–0.3 m above the centre of a conductor pair;
3) A "nearfield" range with the fish exposed at 0.1 m from the conductor element

Furthermore, in order to be able to monitor the effects of transfer and other unknown influences a control group of 16 fish was confined in the same way, but not exposed to the electric stimulus. Each fish was exposed four times in a row. All fish were examined for injuries directly after the end of the last stimulus. Feeding response was monitored for 14 days after. Other behavioural responses (in particular contractions, swimming patterns) were monitored during stimulation and in the 14 days period following it. Finally the fish were kept in husbandry for another 9 months. Additionally long-term mortality and other behaviour such as egg production were monitored.

No evidence was found of differences in feeding response or likelihood of injury or death between the exposure groups. There was also no evidence that fish sustained injuries as a result of the exposures. Respectively 8 and 9 months after the experiment a single specimen of the "medium field" category and "nearfield" category died. In the 14 days observation period after the exposures no aberrant feeding behaviour could be seen. Fish in all tested groups started feeding normally the same day directly after the exposures. In a period of 7 months after the exposures all exposed groups produced eggs in numbers varying between 5–39 per group. Surprisingly the control group did not produce eggs. Regarding the other behavioural responses

(mainly reflexes and muscle contractions, and post-reactions, such as a rapid body reverse, short-curled body rotations and acceleration towards the water surface), there were some clear differences between exposure groups. The responses of the fish exposed in the "far-field" range, representing the fish just aside the fished area of the trawl, were minor and ignorable. However, the responses of the fish exposed in the "medium field" range were more pronounced with contractions, rapid body reverses, short-curled body rotations and acceleration towards the water surface occurring. The responses of the fish exposed in the shortest possible range, the "nearfield" range, were the strongest with increased incidence of contractions and rapid body reverses, short-curled body rotations and acceleration towards the water surface. Although this experiment has not been set up, or designed, to investigate differences between exposure groups in terms of behavioural responses other than feeding responses, the authors noted that a common behavioural response in the "nearfield" group was to 'accelerate upward'. Because, in field situations this behaviour has been observed to lead to dogfish becoming entangled in the meshes of the top panel of the full-scale trawl this merits further investigation. In this cause it would help these animals to escape when larger meshes would be used in the top panel, as studied in Van Marlen, 2003.

More details are given in De Haan *et al.*, 2009.

4.3.4 Research on benthic invertebrates (Dirk Burggraaf and Ad van Gool IMARES)

Short outline

Experiments were carried out in July 2009 on a range of benthic invertebrates (ragworm (*Nereis virens* L.), common prawn (*Palaemon serratus* L.), subtruncate surf clam (*Spisula subtruncata* L.), European green crab (*Carcinus maenas* L.), common starfish (*Asterias rubens* L.), and Atlantic razor clam (*Ensis directus* L.)) under pulse stimulation based on the Verburg-Holland stimulus.

Groups of twenty animals per species were exposed to three treatments of four 1 s bursts of electrical pulses using a pulse simulator: nearby (0.10–0.20 m distance), at medium distance (0.20–0.30 m), and further away (0.40 m) of the electrodes. A 1 s pulse burst is deemed to represent the in situ passage of the pulse field of the gear beneath a non-moving fish. A control group was used for all species to correct for handling effects. The animals were caught with methods minimizing catch effects, and kept in water quality controlled circulating seawater tanks, and regularly fed. Survival, food intake and behaviour were monitored for a period of some two weeks after the exposure. The data were analysed with generalized linear models in the SAS statistical package.

For two species (ragworm and European green crab) a 3–5% statistically significantly lower survival was found compared to the control group, when all exposures were lumped together. For the nearfield exposure a 7% lower survival was also found for Atlantic razor clam. For the other species (common prawn, subtruncate surf clam, and common starfish) no statistically significant effects of pulses on survival were found. Surf clam seemed not to be affected at all, common prawn seemed to show lower survival in the highest exposures (near and medium field), whereas common starfish showed lower survival, but not for the highest (nearfield) exposure.

Food intake turned out to be significantly lower (10–13% less) for European green crab, except in the far-field exposure for which the reduction (~5%) was non-significant. No effect at all was found for ragworm, surf clam and razor clam, lower

food intake for common prawn, and higher for common starfish, but all these results were statistically non-significant.

Surf clam and starfish did not show any behavioural reaction at all, they did not move. The other species showed very low responses in the far-field exposure range. In the medium and nearfield ranges the reactions were stronger. Food intake and behaviour recovered after exposure.

In general terms the effects of the pulse stimulus in terms of mortality and food intake can be described as low. It is therefore plausible that the effects effects of pulse beam trawling, as simulated in this study, are far smaller than the effects of conventional beam trawling.

More details are given in Van Marlen *et al.*, 2009.

4.4 ICES Advice of 2009

In consultation with the European Commission, in September 2009 the Dutch Ministry requested ICES 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. This was coordinated by the Chair of WGFTFB. 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. This advice was submitted to ICES ACOM and based on the expert reviews, ACOM concluded that:

- *The experiments are a valuable further step to evaluate the ecosystem effects of fishing with pulse trawls.*
- *Laboratory experiments on elasmobranchs, 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.*
- *The experiments indicate minimal effects on elasmobranchs and benthic invertebrates.*
- *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.*
- *Although 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.*
- *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.*

The Report of the WGFTFB Ad hoc Group of 2006 specifically mentioned potential spinal damage to cod exposed to electrical stimulation, potential effects on invertebrates and possible disruption of the electric sensory systems of elasmobranchs. 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 elasmobranchs, 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:

- i) 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).
- ii) The effects of pulse stimulation on biota – Research in relation to ICES advice – Effects on dogfish (De Haan *et al*., 2009b).
- iii) 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)

4.5 WKPULSE Comments

4.5.1 General Comments

Methodology and Pulse Characteristics

The methodology used for the experiments was discussed at length. It was felt that the experiments were carried out to a very high standard although a number of questions remained as to whether the experiments were directly representative of the full-scale in situ pulse. It was felt that there was still a major task in linking the data of laboratory and field trials. Possible solutions discussed were more direct video observations and further data collection for commercial and research catches for both conventional beam trawls and the pulse trawls.

Of most concern was the reasoning behind using 4 pulses in the experiments instead of 6 in the full-scale system. Some of the participants believed that the field strength will gradually rise and fall due to peaks along the length of an electrode (See Figure 1 below). De Haan explained that with the frequency and pulse shape used the fish will feel the field strength at once when above the electrodes and will react accordingly.

Regarding the pulse characteristics, it was identified that three aspects must be distinguished: the pulse characteristics themselves, the pulse composition (e.g. 1 second bursts), and the dynamic trawling situation with fish behaviour in the field. Given the problems over confidentiality of the pulse being used, it was put forward that ideally the critical parameters of the pulse need to be defined and what might be seen as less important parameters and the technology behind pulse generation actual generates the pulse should be left confidential as these have less relevance for scientists. Safety aspect also must be considered in developing the pulse system and suitable limits imposed.

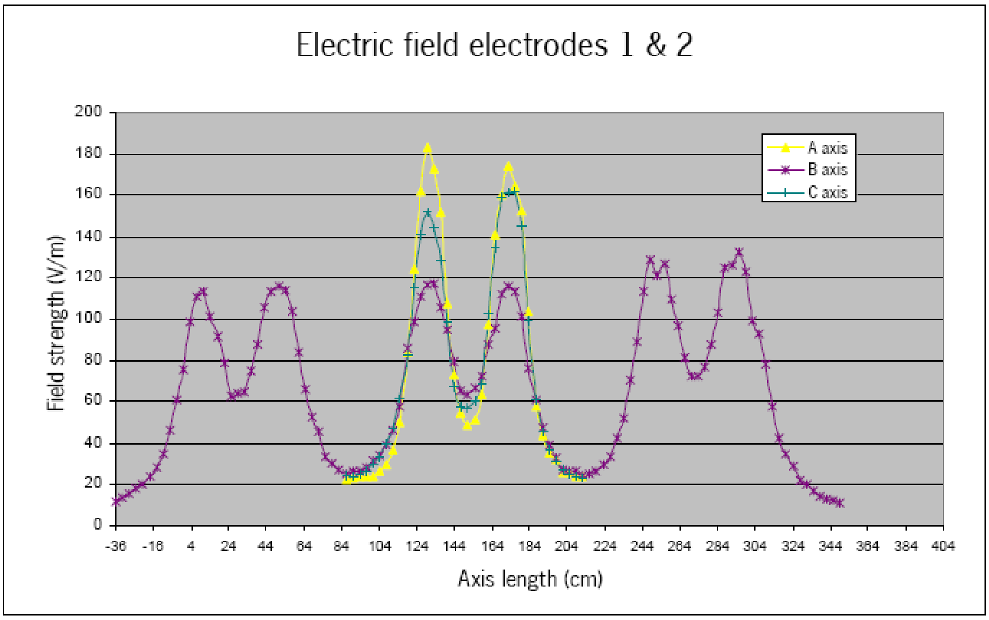

Figure 1. Field strength along the electrodes (De Haan *et al.*, 2008, Figure 4).

4.5.2 Cod

Observations on the Trial Results

The methodology used was felt to be quite robust although the reasoning behind just experimenting with cod and not other species such as dab, turbot and whiting, which are important bycatch species, was raised.

There were also queries regarding the different intensities of pulse used in the experiments and whether this was representative of the in situ pulse. It was suggested in the report that in winter the line voltage is increased by 20% to improve catches of sole. This corresponds to the time of the year when cod are expected to be closer to the bottom and easier caught. The question was asked if the pulses used in the experiments were at the high or low level and whether there was an assessment as to what the difference in reaction would be. It was explained that the experiments were designed to mimic the worst case situation.

It was noted that the 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. Why these injuries, however, are not seen in every fish is unknown. It was mentioned that tetanus (“spinal injury”) is not only a function of frequency, but also depends on the rise and fall times of a pulse and also the towing speed. Izvekov asked about spinal damage in the target species but it appears that this has not found been reported for species other than cod.

Level of Cod Catches

Van Marlen showed two datasets on cod catches per unit of time: one from FRV “Tridens” where two nets were fished simultaneously side by side, the pulse trawl and the conventional tickler chain beam trawl, at the optimal speed for the pulse trawl, i.e. 5.5 kts, and the other from a comparison of a fully equipped commercial beam trawler fishing with two pulse trawls with trawlers fishing with conventional tickler chain beam trawls in the same area and time (Tables 1 and 2 below). In the first set a higher cod catch was found (ratio pulse/conventional 2.28), and in the sec-

ond set the catch was lower (ratio pulse/ conventional 0.48). This might be caused by fishing a smaller area because towing speed is lower than with a conventional beam trawl. However, it was generally felt by the Group that the data are inconclusive. On the one hand the data from the "Tridens" does not necessarily represent commercial reality whereas on the other hand the commercial data are based on landings not catches. Therefore it is impossible at this juncture to properly assess the catchability of the pulse trawl compared with a conventional beam trawl for cod. It was suggested as a first step that it may be better to look at these data in terms of catch per swept-area rather than simply catch per unit of effort but ultimately more data are required. It was also commented on that juvenile cod below the minimum landing size (MLS) were not studied. It was suggested that response thresholds for various length classes ; the spatial pattern of electric fields generated in the trawl and the swimming capacity of fish should be considered and perhaps computer simulations run on the likely overall effects by size of fish.

Table 1. LPUE of pulse beam trawl (PULSE) and conventional tickler chain beam trawl (CONV) for various pulse field settings, with mean, stdev and p-value for category cod > MLS. Boldface values are significant (p <= 0.05). See De Haan *et al.*, 2008.

GEAR TEST	PULSE SETTING	NO OF HAULS	KG/HOUR MEAN PULSE	CONV	PULSE/CONV	STDEV PULSE	CONV	P-VALUE
1	b+10	14	0.99	0.62	159.7%	1.59	0.94	0.687
2	b+20	12	2.55	0.81	314.8%	2.33	1.12	0.062
3	b-10	2	3.32	0.00		1.7	0	0.104
4	h+10	16	0.84	0.71	118.3%	1.13	1	0.620
5	h+20	10	0.64	0.51	125.5%	0.94	0.44	0.864
6	h-10	2	0.60	0.00		.	.	.
7	h-20	1	0.43	0.00		.	.	.
8	nominal	10	2.24	0.67	334.3%	1.96	0.8	0.246
9	total	67	**1.39**	**0.61**	**227.9%**	**1.71**	**0.86**	**0.017**

Table 2. Comparison of landings of cod based on auction data between a beam trawler fishing with two pulse trawls and two conventional beam trawlers fishing in the same area and time (See Van Marlen *et al.*, 2006 and De Haan *et al.*, 2008).

EFFECT	LENGTH RANGE (CM)	DEPENDENT	GEAR	LOWERCL	LSMEAN	UPPERCL	PROBT	SIGNIFICANCE
GEAR	> 88	cat1_CPUE	Conv	0.0607	0.4371	0.8135	0.2012	n.s.
			Puls	-0.1815	0.1949	0.5713		
	72 - 88	cat2_CPUE	Conv	0.2036	0.7612	1.3188	0.1170	n.s.
			Puls	-0.1069	0.3251	0.7570		
	55 - 72	cat3_CPUE	Conv	-0.1199	0.9058	1.9316	0.4074	n.s.
			Puls	-0.3316	0.5059	1.3434		
	46 - 55	cat4_CPUE	Conv	-0.0037	0.5161	1.0359	0.2256	n.s.
			Puls	-0.4965	0.1746	0.8457		
	35 - 46	cat5_CPUE	Conv	0.2139	0.2348	0.2557	0.0392	s.
			Puls	0.1334	0.1752	0.2170		
		cat6_CPUE	Conv	n/a	0.1281	n/a	n/a	n/a
			Puls	n/a	n/a	n/a		
	All	**tot_CPUE**	**Conv**	**0.7664**	**2.2559**	**3.7455**	**0.1954**	**n.s.**
			Puls	**-0.4117**	**1.0778**	**2.5674**		

Behaviour

Izvekov summarized earlier work in Russia and by other scientists. He mentioned the work by McBary in 1956, Zonov, and Lemarque in the 1970s in which the threshold to various responses of fish in electrical fields were investigated. The reaction also is affected by the length of the nerves in the fish body.

In the experiments the escape reactions of some cod observed were quite strong. In some cases fish nearly jumped out of the tank at the surface on exposure to a pulse or pulses. It was concluded from this that at full-scale it is unlikely that fish would stay

in the nearfield exposure, but swim away from it once inside the net most likely at a distance above the electrodes.

The need for more underwater observation to learn more about fish (cod) behaviour in the real *in situ* pulse trawl was clearly identified. Without knowledge of the behaviour of cod when subjected to the pulses it is difficult to equate the reactions seen of fish in the tank experiments to what happens at sea, particularly given the behaviour was not necessarily uniform. It was also noted from the experiments conducted it is still not possible to ascertain whether spinal injuries happen after the first or subsequent pulse trains. So whether the experimental setup with four rather than six pulses is representative of the full-scale system in this respect is still open to question. However, it is worth noting that similar injuries to the ones observed in the tank tests have been documented in cod landed by the boat fishing with the pulse trawl.

Some questioned whether the electrodes are indeed on bottom during fishing. From earlier observation with cameras and the fact that parallel chains in-between showed shine due to abrasion suggests that the electrode arrays do have bottom contact.

4.5.3 Elasmobranches

The same methodology was used as for the experiments with cod and there were no injuries, and no mortality. The main effect was in behaviour at exposure: body curls, swimming upward. Smaller fish showed hardly any reaction. Following the experiments the fish in the test group produced more eggs in the long observation period after the experiments then the control group, but the sex rate was not recorded. This again was an indication of no adverse effects on this species. It was commented by the Russian scientists that the results do not show whether there are any effects on the electro-receptor organ of these fish, as they were offered food which they need not detect themselves. It was explained that the field generated had no constant DC component. Izvekov experienced that these fish are especially sensitive to frequencies below 1 Hz.

4.5.4 Benthic Invertebrates

The methods of capture and husbandry of the six invertebrate species were explained in detail. Water quality was measured using a CTD, and control groups used treated the same way (except the pulse). The animals were tested in the same three distance ranges to the electrodes as with cod and catshark. The question was raised why helmet crab was not tested. The IMARES researchers said they chose a range of species, realizing that not all could be addressed with the limited time and budget.

A query was raised about how the behaviour results had been reported in the report. Various levels of reaction were averaged out in a qualitative manner and this was felt misleading, based on the actual observations.

The field strength was measured with the probe inside the plastic bottles or bins which were used to restrict the movement of the animal under test to ensure that the actual value the animal would feel was taken.

It was noted that surf clam, although not seemingly reacting directly to the pulse, were found to move up and down in the sediment. During the tests on some occasions they were all observed on the surface of the sediment, but on other occasions they were all buried inside the sand. It was acknowledged that temperature might have an effect as well as seasonal variations e.g. in *Ensis*, a similar species, whole banks might succumb in changing conditions. *Ensis* were also placed in a vertical position in the sediment on one occasion and subjected to the pulses, but no reaction

was observed. Common starfish were observed to disintegrate and becoming spongy and swollen, both in the exposed and in the control groups (van Gool) and no sign of any food adaptation or rejection of food was noted. The conclusion was that the starfish were not adversely effected by the pulses. The Russian scientists also made the point that the action of electric current on the reproductive processes in the invertebrates was not considered and previous work had indicated this did have an effect on certain invertebrates.

5 Relevant Research in Other Countries

5.1 Research on pulse trawling in Russia, presented by Evgeny Izvekov

An outline was presented on research done in Russia. The following parts are from a written contribution by Izvekov, Gerasimov and Lapshin.

"It is generally accepted that electric field stronger affects the larger fish, thus providing a basis for higher size selectivity. But it should be born in mind that the actual relationship between fish size and their susceptibility to electric current is very tangled. And if we have time available, I'd like to share our experience with you. This concerns the results of our long-term studies of these effects in freshwater fish, including laboratory experiments and field trials.

In the series of laboratory experiments, we examined size dependence of threshold values in the three fish species (bream, perch and pike). Thresholds of first reaction and electroshock were determined beginning with hatching larvae to the largest size groups of adult fish. At least 20 different age classes were tested for each species. Sinusoidal 50 Hz current, ascending and descending direct current were used as basic model stimuli. Additional tests were conducted with pulse current varying in shape and frequency, but for less number of size groups.

As the length of fish increase, thresholds of two studied reactions fall in different ways, see Figure 2. Until the sexual maturation, thresholds of first reaction decrease faster than stun thresholds. Afterwards, an opposite relation is observed. These changes can be described by the power function. In case of electroshock, empirical and rated values correspond to each other much better. It is corroborated by the higher correlation factor R^2. As a result, young fish possess a wider dynamic range of response from detection of approaching electric field up to the onset of immobilization. At the same time, small fish have a lower swimming speed, which may hamper their escape from the gear *in situ*.

Therefore, in real conditions, we deal with a very complex interaction of several factors: fish length, thresholds of their excitation and electroshock, swimming performance, voltage on the electrodes, mesh size and, finally, size distribution of target population.

At the next step we performed a complex study on the influence of a real electric fishing gear on aquatic ecosystem. This analysis was conducted for the two river-bed sections of the Gorky reservoir (Russia), where a twin pulse trawl ELU-6M was used, (Figure 3). Studied areas were close to Kineshma and Kostroma cities. During these trials, we measured electric field tension values directly in the trawl (both for vertical and horizontal components). The maximum tension (about 3 V/cm) was observed near the electrodes. At a 2 m distance from the electrode the vertical and horizontal components of electric field were about 40 and 34 mV/cm, respectively. Later on, a simple model allowed us to compare the electric field parameters with the response thresholds for various size groups of fish.

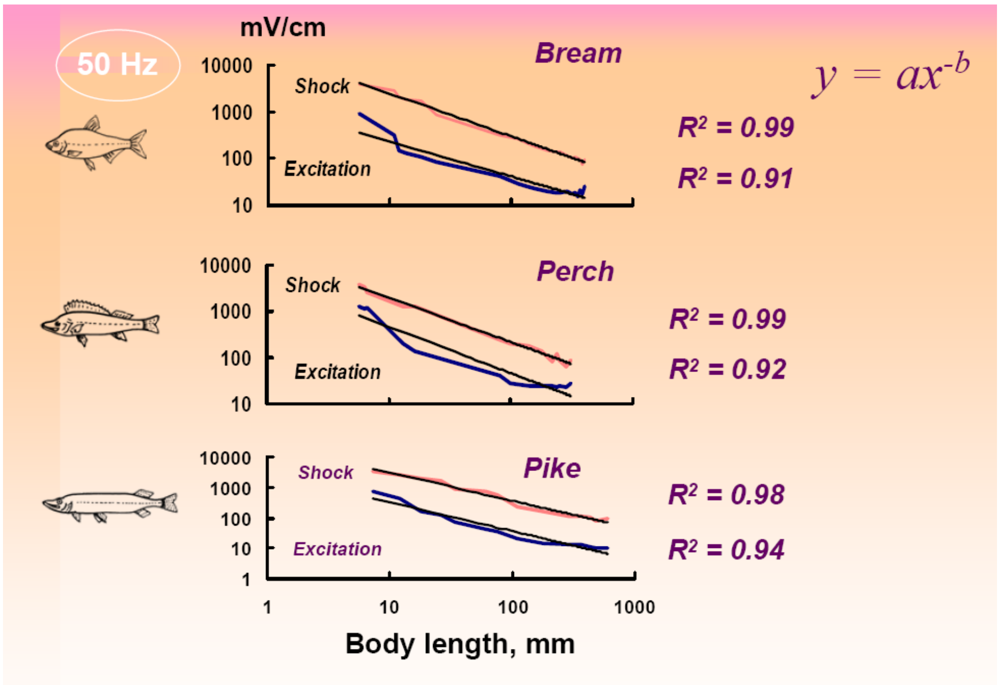

Figure 2. Actual and rated thresholds of fish response to alternating current (50 Hz) as a function of body length.

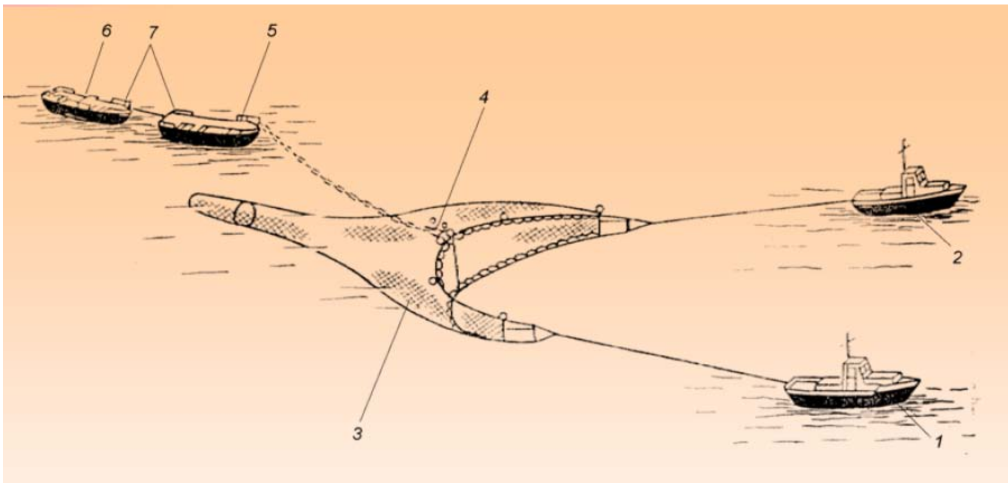

Figure 3. Electrofishing complex ELU-6M. Legend: 1, 2 – tow-vessels; 3 – electrified twin trawl; 4 – underwater pulse generator; 5 – control unit with an electrical winch; 6 – petrol current generator; 7 – boats.

Size and mass distribution of electrified catches did not differ to the worse from the non-electrified catches of the same trawl. Percentage of undersized bream in the test catches (with electric current) and in the control catches (without electric current) was equally high and amounted to 64–65% at Kineshma city and up to 89–92% at Costroma city (judging by fish number), see Figure 4.

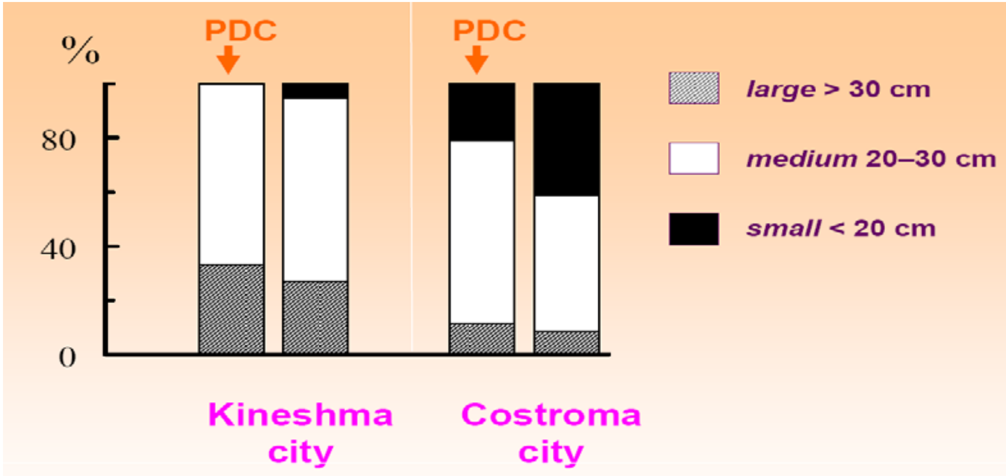

Figure 4. Proportions of large, medium and small bream in the test and control catches.

Further analysis showed that application of a twin electrotrawl in the Gorky reservoir could only slightly improve a size composition of the catch. Mainly it was due to the lower share of small fish (below 20 cm), and partly due to a higher catch rate for the largest fish. This provided an increase in average length of the bream by 5–10% and its average weight by 17–26%. However, an essential decrease in bycatch of undersized bream is possible only when the target population is abundant with large individuals (with body length above 40 cm). This is not characteristic of the investigated river-bed portions of the reservoir.

Size distribution of the bream in the catches of electric trawl was in accord with the results of laboratory experiments. In the marketable bream (about 30 cm) and in the undersized individuals of 25 cm body length, the thresholds of first reaction are almost equal, with a little difference in the stun thresholds. Such a slight difference (below 26%) cannot provide a precise selectivity and prevent undersized fish from getting into the trawl. In practice, such difference in thresholds is usually levelled by the heterogeneity of electric field or water conductivity in the haul sites, and by other factor.

Thus, the results of field trials become more transparent when the size-threshold relationship is known and can be compared with electric characteristics of the gear.

The Dutch researches have detailed information available on the actual electric parameters of a pulse trawl. Then it seems reasonable to determine the size-threshold relationships (at least for the target fish species) to optimize the trawling regime *in situ*."

5.2 Research on shrimp pulse trawling by Bart Verschueren

An overview is given of the Belgian work by Verschueren. The prime motive today is to reduce discarding in brown shrimp fisheries. There are also economic consequences that are estimated at a loss of 1.5 M for the Belgian fleet. Sieve nets and grids were extensively tested in the DISCRAN-project and shown to be effective on fish larger than 10 cm, but not for the smallest length classes. Also they may lead to clogging problems by e.g. seaweed, hampering their use at times. Both methods are based on filtering fish after entering the net, and further improvement can only be expected when such entering can be avoided. We hope that this can be achieved through pulse stimulation. A second motive is to reduce seabed disturbance. EU Council Regulation 850/98 of 1988 forbids fishing with electricity and should be addressed therefore.

In 2007 and 2008 trials were done on a commercial boat on a prototype electrotrawl for shrimps, called the "hovercran" (Figure 5). It features 12 electrodes of 3 m length (maximum) and placed 0.6 m apart in front of the footrope. The bobbin footrope was taken out. We used pulsed DC with 5 Hz frequency.

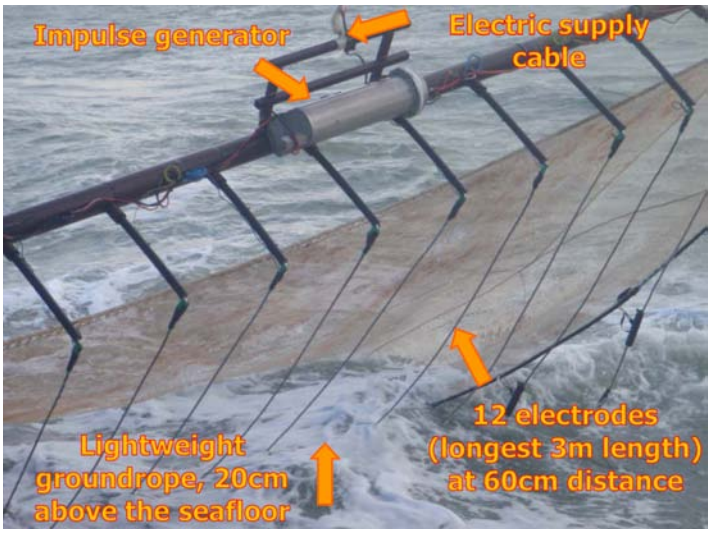

Figure 5. Prototype "hovercran".

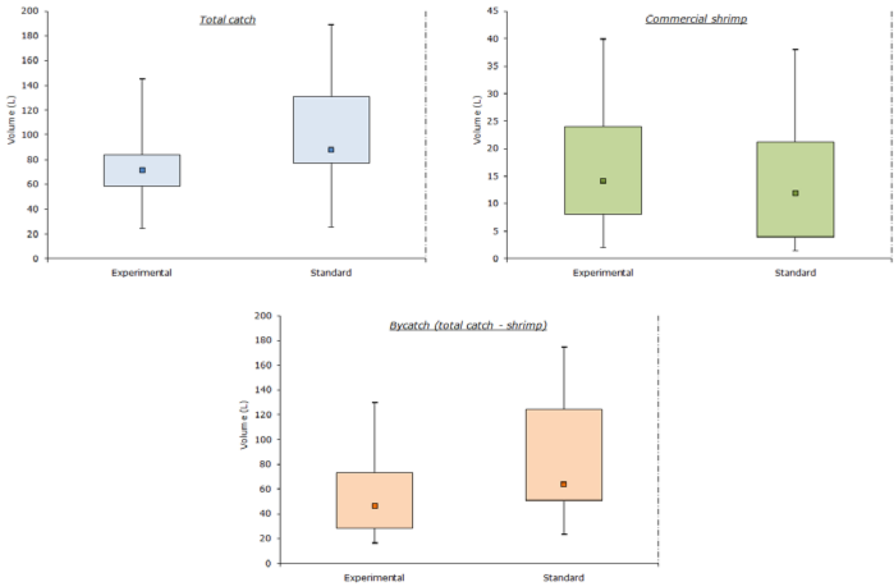

Figure 6. Box plots comparing catch volumes of pulse trawl (experimental) and standard shrimp trawl; substantial reduction of bycatch (below) leads to smaller total experimental catches (left), while experimental commercial shrimp catches slightly exceed the standard catches (right).

Maintaining commercial catch levels and reducing discards and seabed contact are the decisive objectives in the evaluation of the 'hovercran'. Extensive tests of the prototype, by direct comparison with a standard catch shrimp trawl, revealed important and hopeful results. First and foremost it could be shown that at least as much shrimp can be caught with the new technique compared with the traditional gear,

while the seabed contact was reduced by 75% (Figure 6). On top of that, an average reduction of 35% in volume of discards is a major step forward in this respect.

Apart from shrimps catches also sole bycatch could be increased using this pulse, although they showed a different reaction than with the Verburg-pulse, swimming upwards. Also plaice and dab can be caught, but not in the same rate as in the standard trawl, but flounder does not seem to react to this pulse. Lower bycatches were found, for sole: -16% (<18cm), plaice: -38%, dab: -26%, and flounder: -53%.

Future developments will feature:

- Combination with a sieve net
- Smaller and/or closed net opening
- Shorter groundrope, closer to the beam
- Combination with the "Sumwing"

It was noticed that when taking flatfish and shrimp fisheries together the development of pulse trawling affects hundreds of fishing companies and a substantial share of earnings in the European North Sea fisheries involving: Denmark, Germany, Netherlands, Belgium, and UK (van Marlen).

6 Policy and Implementation

On the final day of the workshop, Mr J. J. van Dijk, senior policy adviser of the Dutch Ministry of Agriculture, Nature and Food Quality attended to discuss policy and implementation issues surrounding the pulse trawl. He explained the viewpoint of the Dutch Ministry and their desire to have the pulse trawl allowed in the new Technical Measures to be discussed in the next eighteen month period by the European Commission.

Further research can be done to solve problems, e.g. with cod. The Dutch government cannot take a stand between various producers of pulse trawl systems in the Netherlands. The future of these systems is open to market forces, and it is believed that clients will get the best value for money under these forces. Protection of knowledge plays a role in it, and the Ministry can only respect commercial interests, but will not force any producer to step away from knowledge protection.

It is acknowledged that lifting the EU-ban on fishing with electricity is a political problem in which science plays an advisory role. The Ministry recognizes the advantages of less bottom impact, fewer bycatch of benthos, lower fuel consumption with associated lower green-house emissions, and better economy of fishing, and thinks they outweigh the disadvantages and wish to support solutions to the problems raised by the ICES advice and WKPULSE. It is the Dutch ministry's opinion that the 2006 advice was fairly positive with specific comments on some areas i.e. cod and a request for further information which have now been largely addressed through the extensive tank experiments. In conclusion the Dutch Ministry felt that in their opinion this should be enough to allow the introduction of pulse beam trawling.

During the discussions the various standpoints were identified. The scientists want to advice in this development in such a way that fisheries can be developed in a sustainable manner and any adverse ecosystem effects can be reduced. The Ministry supports innovations in the industry aimed at similar objectives and wants to facilitate further developments meeting these objectives and help the industry in their transition. But is should be noted that in the advice of 2009 some reviewers still are very reluctant to approve of pulse trawling (van Marlen).

The developments in the 1970s were based on saving energy and improving economy of fishing, and ecosystem issues came in later (van Marlen). Views in society have indeed changed and new demands from ecosystem management asking for limiting bycatches discards and bottom impact became more important (Stepputtis).

During the discussions in 2006 in WGFTFB some scientists expressed the opinion that to allow a new technology that later, after making high investments, would turn out to lead to severe ecosystem damage, would be the wrong approach and therefore advised to take a precautionary approach. On the other hand by continuing to ask for more research and evidence one allows an unfavourable practice (namely conventional tickler chain beam trawling) to continue and innovation is stifled. A gradual introduction in commercial fleets whilst addressing and trying to solve new problems might be a better option, and with changes in stimulus and gear technology (adding separator panels) we might be able to solve the concerns regarding cod (van Marlen).

The issue of enforceability and control were also discussed. There are indications that the limits used in the present derogation that are deemed needed for fraud-resistant control (electrical power limited to 2.5 kW/m beam length, and amplitude to maximum 15 V) will not be sufficient to ensure that fishing efficiency with pulse trawls will not increase in future through mis-use of the system. It is recommended to investigate this aspect further and suggest limits that can be easily monitored. It was also suggested that the control unit for the system should be "tamper proof" similar to the Vessel Monitoring System (VMS).

7 Conclusions and recommendations

The following conclusions were drawn by WKPULSE:

- Cod susceptibility: there is more information needed on the effect on cod before the pulse trawl can be allowed, in particular it is suggested to:
    - Monitor the current (by)catches with the latest version of the system (TX68) and compare these with a conventional beam trawler
    - Sample cod from current (by)catches with the latest version of the system (TX68) and compare the occurrence of spinal damage with those from a conventional beam trawler
    - Investigate the effect on fish not necessarily caught in the trawl after being subjected to the pulse system and determine whether this is a source of unaccounted mortality.
    - Investigate behaviour of cod inside the pulse field and subsequently inside the net by direct observation.
    - Study whether the pulse trawl can affect population structure for this species.
- *In situ* vs. pulse simulator: the group could not be convinced that the simulator provided an adequate representation of the in situ pulse. It is therefore recommended to:
    - Look closer at temporal and electrical dynamics inside the net
    - Make a 3-D temporal-spatial model, use behaviour responses found by underwater observation of cod
    - Determine the field strength a cod will experience from this model by simulating various behavioural responses

- Based on the cod experiments assess the effects of the pulse trawl on other gadoid species. This should be restricted to gadoid species which form an important component part of the catches from Dutch beam trawl fleet, e.g. haddock, and whiting.
- Elasmobranches
  - Investigate the effect of pulses on the electro-receptor organs of key elasmobranch species.
  - Review all available catch data from the Dutch beam trawl fleet to determine the key elasmobranch species caught in the fishery
- Reproduction of benthos: there is general lack of information, and therefore it recommended to:
  - Investigate the effect of the pulse on the reproductive capabilities of benthos, but weigh this against the mortality in the conventional tickler chain beam trawl.
- Enforceability and control: there are indications that the limits used in the present derogation that are deemed needed for fraud-resistant control (electrical power limited to 2.5 kW/m beam length, and amplitude to maximum 15 V) will not be sufficient to ensure that fishing efficiency with pulse trawls will be raised in future, and it is recommended to investigate this aspect further and suggest limits that can be easily monitored.
- There was a suggestion that an ICES study group on electric fishing or some other communication platform for researchers working in this field should be set up, given that there are several countries working in this area and more other countries interested. This will be explored further with WGFTFB at their meeting in May/June 2010.

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Annex 1: List of participants

Name	Address	Phone/Fax	Email
Bob van Marlen **Chair**	IMARES, PO Box 68, 1970 AB IJmuiden, The Netherlands	+ 31 317 48 71 81 + 31 317 48 73 26	bob.vanmarlen@wur.nl
Dick de Haan	IMARES, PO Box 68, 1970 AB IJmuiden, The Netherlands	+ 31 317 48 71 70 + 31 317 48 73 26	dick.dehaan@wur.nl
Dirk Burggraaf	IMARES, PO Box 68, 1970 AB IJmuiden, The Netherlands	+ 31 317 48 71 63 + 31 317 48 73 26	dirk.burggraaf@wur.nl
Ad van Gool	IMARES, PO Box 68, 1970 AB IJmuiden, The Netherlands	+ 31 317 48 70 26 + 31 317 48 73 26	ad.vangool@wur.nl
Dominic Rihan	Bord Iascaigh Mhara (BIM), Irish Sea Fisheries Board, Crofton Road 8, Dun Laoghaire, Ireland	+353 1 2144 104 +353 1 230 0564	Rihan@bim.ie
Bart Verschueren	ILVO - Institute for Agricultural and Fisheries Research , Unit Animal Sciences – Fisheries. Ankerstraat 1, B-8400 Oostende, Belgium	+ 32 59 56 98 44 + 32 59 33 06 29	bart.verschueren@ilvo.vlaanderen.be
Daniel Stepputtis	Johann Heinrich von Thuenen-Institute, Institute for Baltic Sea Fisheries, Alter Hafen Süd 2, 18069 Rostock, Germany	+49 381 8116136	daniel.stepputtis@vti.bund.de
Oleg Lapshin	Federal Research Institute of Fisheries and Oceanography, V. Krasnoselskaya, 17, Moscow, 107140, Russia	+7 499 264 9310	lapshin@vniro.ru
Evgeny Izvekov	Institute for Biology of Inland Waters RAS 152742 Borok, Nekouz, Yaroslavl region, Russia	+485 4724042 +485 4724042	eiizvekov@gmail.com izvekov@ibiw.yaroslavl.ru
Yury Gerasimov	Institute for Biology of Inland Waters RAS 152742 Borok, Nekouz, Yaroslavl region, Russia	+485 4724152 +485 4724042	gu@ibiw.yaroslavl.ru

Name	Address	Phone/Fax	Email
Jan van Dijk	Ministry of Agriculture, Nature and Food Quality, Prins Clauslaan 8, 2595 AJ The Hague, The Netherlands	+31 70 378 56 10 +31 70 378 61 53	j.j.van.dijk@minlnv.nl

Annex 2: Agenda

DAY 1	TIME	ACTIVITY	PERSON(S)
24/02/2010	09:00	Opening and welcome	Bob van Marlen
	09:05	Practical arrangements	Bob van Marlen
	09:20	Confidentiality issue	Bob van Marlen
	09:20 - 10:00	Short introduction of participants and relevant expertise	All
	09:30 - 10:00	Presentation of work on pulse trawl and history of ICES advice	Bob van Marlen
	10:00 - 10:15	Coffee/Tea break	
	10:15 - 10:30	Discussion	All
	10:30 - 11:30	Presentation of work in 2007 in response to ICES advice 2006	Dick de Haan
	11:30 - 12:30	Discussion	All
	12:30 - 13:15	Lunch at IMARES canteen	
	13:15 - 14:00	Presentation of work in 2008 on cod in response to ICES advice 2006	Dick de Haan
	14:00 - 15:00	Discussion	All
	15:00 - 15:15	Coffee/Tea break	
	15:15 - 16:00	Presentation of work in 2008 on cat-sharks in response to ICES advice 2006	Dick de Haan
	16:00 - 17:00	Discussion	All
	17:00 - 17:30	Short round through tank facilities of IMARES	All
	18:00 - 21:00	Dinner in Hotel Augusta	
DAY 2	**TIME**	**ACTIVITY**	**PERSON(S)**
25/02/2010	09:00 - 10:00	Presentation of work in 2008 on benthic invertebrates in response to ICES advice 2006	Dirk Burggraaf and Ad van Gool
	10:00 - 10:15	Coffee/Tea break	
	10:15 - 11:00	Continued presentation of work in 2008 on benthic invertebrates in response to ICES advice 2006	Dirk Burggraaf and Ad van Gool
	11:00 - 12:30	Discussion	All

	12:30 - 13:15	Lunch at IMARES canteen	
	13:15 - 15:00	Towards a practical use of electric pulse trawls: recent knowledge and future concerns	Izvekov, Gerasimov, Lapshin
	15:00 - 15:15	Coffee/Tea break	
	15:15 - 16:00	Development and demonstration of a selective electro-trawl for the brown shrimp fishery	Bart Verschueren
	15:15 - 17:00	Discussion	All

Day 3	Time	Activity	Person(s)
25/02/2010	09:00 - 10:00	Discussion on future work	All
	10:00 - 10:15	Coffee/Tea break	
	10:15 - 12:30	Discussion on policy issues	All
	12:30 - 13:15	Lunch at IMARES canteen	
	13:15 - 15:00	Drafting conclusions and recommendations	All
	15:00	Closure	Bob van Marlen

Annex 3: Recommendations

Recommendation	For follow up by:
1. Carry out further research on the effect on cod when using the pulse trawl in commercial conditions and extend this to other gadoid species if deemed necessary	IMARES
2. Make a three-dimensional temporal-spatial model of exposure of cod inside the trawl using information about behavioural responses validated by direct underwater observation	IMARES
3. Investigate the effect of pulses on the electro-receptor organs of elasmobranchs, and determine the catch rates of these fish in beam trawls.	IMARES
4 Investigate the effect of the pulse on the reproductive capabilities of benthos and compare this against the mortality in conventional beam trawls.	IMARES
6. Investigate aspects of enforceability and control and develop acceptable limits to be set in any future regulation	IMARES researchers in collaboration with fisheries managers
7. Develop TORs for a proposed ICES Study Group on Electric Fishing (SGEF)	WGFTFB in conjunction with WKPULSE participants