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Report of the Study Group on Electrical Trawling (SGELECTRA)

21–22 April 2012

Lorient, France

ICES International Council for the Exploration of the Sea

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Contents

Executive summary

The Study Group on Electrical Trawling (SGELECTRA), chaired by Bob van Marlen, the Netherlands and Bart Verschueren, Belgium, met in Lorient, France, 21–22 April 2012. A total of seven participants attended from Netherlands, Belgium, Germany, Scotland, and France. The meeting began with a short presentation on the history of research of pulse trawling (on flatfish), and the ICES Advice on Pulse Trawling on flatfish of 2006 and 2009. Following the ICES Advice of 2009 further studies were carried out by IMARES.

New research activities of IMARES, IJmuiden, The Netherlands, were presented and discussed, namely: a catch comparison in May 2011 on two pulse trawl vessels and one conventional tickler chain beam trawl boat fishing side-by-side, further analysis of spinal damage in cod (*Gadus morhua* L.) in 2010 and 2011, reference measurements of field strength *in situ* in 2011 and the result of an effect prognosis, using the model developed by Piet *et al*., 2009 and the data from the catch comparison.

A presentation was also given about the development of a pulse trawl (called the "Hovercran") for the brown shrimp (*Crangon crangon* L.) fishery by ILVO, Ostend in Belgium, and work to be carried out by two PhD students from the University of Ghent in cooperation with ILVO. This work has been given follow-up in The Netherlands on three commercial vessels, and a project on shrimp fishery using the "Hovercran" in Germany on a commercial boat is about to begin.

In addition a report was given on the razor clam (*Ensis*) fishery in Scotland in which electrical stimulation is used. In addition a new problem was mentioned related to electrical stimuli of heavy power, i.e. the production of chlorine (it and its derivatives are toxic to marine organisms and soluble in seawater) due to electrolytic reactions.

Discussions in the Netherlands Control and Enforcement Group and draft Procedure for Control and Enforcement were presented and the draft text in English improved.

A recent report by STECF was discussed and comments given on its contents.

The reviewing experts concluded that:

- It was acknowledged that as a result of the studies for ICES more information on the effects is now available than 6 years ago, *e.g.* real numbers on damages in cod in the catches, also dependence of damages on size classes, the effect on sharks, and invertebrates.
- Further long-term investigations be undertaken.
- The pros and cons of each system be taken into account.
- The views of SGELECTRA on pulse trawling are still under development.

SGELECTRA recommended continuing work with Terms of Reference given in Annex 2.

1 Opening of the meeting

The Study Group on Electrical Trawling (SGELECTRA), chaired by Bob van Marlen, the Netherlands and Bart Verschueren, Belgium, met in Lorient, France, 21–22 April 2012 to:

a) Improve knowledge of the effects of Electrical Fishing on the marine environment (reduction of bycatch, impact on bottom habitat, impact on marine fauna, energy saving and climate related issues), in view of current technical developments on electrical fishing and emphasis on the relationship of pulse characteristics (power, voltage, pulse shape) and thresholds in terms of effects on fish and other organisms (mortality, injury, behavioural changes);

b) Evaluate the effect of a wide introduction of electric fishing, with respect to the economic impact, the ecosystem impact, the energy consumption and the population dynamics of selected species;

c) Consider whether limits can be set on these characteristics to avoid unwanted effects (e.g. unwanted and uncontrolled growth on catch efficiency, unwanted ecosystem effects) once such systems are allowed and used at wider scale.

The Chair welcomed the participants and explained some practical arrangements. A list of participants is given in Annex I. Daniel Stepputtis acted as rapporteur. The Terms of reference of this meeting are given in Annex 2.

Then members shortly introduced each other:

Marieke Desender: Started PhD work in January 2012 on the impact of pulse fishing on various organisms (main focus species are not shrimp) in shrimp fisheries, background biology, work is to be supervised by Hans Polet of ILVO and Annemie Decostere (Ghent University).

Maarten Soetaert has a background in bioscience engineering. Started PhD work in January 2012 on the impact of pulse fishery (broad view, playing with the pulse parameters); and on finding a new startle pulse for sole. His supervisors are: Koen Chiers (Ghent University), and Hans Polet of ILVO.

Daniel Stepputtis works in the Baltic Sea Institute, and is head of the Technology Group since 2009. Work topics are Baltic Sea fisheries and shrimp trawls, now also involved in Hovercran introduction in Germany. MFV SD-33 will be fitted out with the Marelec system, starting the end of May or the beginning of June.

Philip Copland reported that Marine Scotland Science is the new name for the Marine lab of Aberdeen. His involvement in electric fishing started in 1974 (together with Peter Stewart). The topics were: thresholds for different species, electric barriers, and this work stopped in 1979. Since then no work was done on pulse fishing in Aberdeen. At present he does acoustic-work (SCANMAR, Multibeam, etc.). Recently the interest in MSS came back since electric fishing was developed on *Ensis* some years ago (an illegal fishery) and likely is still ongoing.

Antony Viera is working on selectivity in mixed fisheries. He started work with focus on selectivity, and is now in charge of environmental impact assessment and the implementation of MPAs in front of Dunkirk, Nord Pas de Calais region, related to Natura 2000 areas. He is interested in the Doggerbank work in The Netherlands, also in wind farm work. Several Dutch pulse trawlers were fishing from Dunkirk in January 2012, and questions were raised by fishers from the region. There is a wish for more information. The leader of CRPMEM is a former fisher. The website is: http://www.comite-peches.fr

Bart Verschueren is a biologist working at ILVO, Ostend. He started in 2007, and works exclusively on the Hovercran.

Bob van Marlen started to work at RIVO (now IMARES) in 1976, with background of naval architecture and hydrodynamics. He worked on gear technology, *i.e.* drag reduction of pelagic gears, improving selectivity in pelagic trawls, beam trawls for flatfish and shrimps, bottom impact reduction of otter trawls and beam trawls, energy saving, pulse trawling, and led large European projects on many gear types.

Discussion (outside SGELECTRA, but related to)

Mike Breen (former FRS, now at IMR Bergen) looked at *Ensis* (razor clam) fishing (illegal!) in Scotland, and this will likely be continued. Bill Lart of SEAFISH did also conduct trials. There is also a project in The Netherlands with company Kramer Machine Factory on *Ensis*.

SGELECTRA should take an objective stand. The term electric/electro/electrical fishing is often interpreted as negative, it was suggested to call it **pulse/impulse fishing**. It may also be recommended to use different names for the different species applications (e.g. flatfish, shrimps) to avoid negative views on one system to spread out over other systems. And the question remains what name should be given if only DC is used and no pulses.

2 Adoption of the agenda

The agenda was adopted with specific points to be addressed in the discussion (See Annex 3):

- A short discussion on the name giving of pulse fishing (in general and for different types of pulse fishing.
- Discussion on the EC-obligation and how this is used to gain knowledge (*e.g.* the fishing industry has to prove the suitability of the new technique).
- Discussion on how to measure field strength which is part of the discussion in the Dutch control and enforcement group.

3 Review of earlier work and recommendations at WKPULSE

3.1 History and background presented by Bob van Marlen

3.1.1 Background and state-of-the-art

BvM gave a short overview of the history of the ICES debate since 2006.

He mentioned some details on the meeting, the Terms of Reference (2012 TOR's), and gave also a short historical overview of R&D in the Netherlands. Research done by IMARES until now covered:

- Catch comparisons 7 m gear – FRV Tridens 1998, 1999
- Survival experiments sole and plaice – Tridens 1999
- Direct mortality of invertebrates – Tridens and Zirfaea 2000
- Catch comparisons 12 m gear – Tridens 2004
- Preliminary study effects on benthos – Yerseke 2004
- Research on damage, blood parameters, survival undersized sole and plaice – Tridens 2005
- Catch comparisons UK153 against conventional beam trawlers - 2006
- Research on ICES requests – IJmuiden 2007–2011
- Catch comparison and reference measurements 2011

The current EU ban (Council Reg (EG) nr 850/98 of 30 March 1988, Article 31 Unconventional fishing methods, stating that: "The catching of marine organisms using methods incorporating the use of explosives, poisonous or stupefying substances or electric current shall be prohibited.") was reminded of, as well as the discussions in ICES and the advice given in 2006 and 2009. The activities comprised of:

- 'Fast track' advice with 'Ad Hoc Topic Group', Izmir April 2006
- ICES Expert Group in the background
- Plenary Discussion at WGFTFB, Izmir April 2006
- ICES Advice formulated by ACFM, Nov 2006
- ICES Advice formulated by ACOM, Nov 2009
- WKPULSE 24-26/02/2010
- SGELECTRA 07–08/05/2011, 21–22/04/2012, and if needed in 2013

3.1.2 Work done by IMARES in response to the ICES Advice of 2006

The ICES Advice of 2006 led to additional laboratory tests:

Measurements on field strengths and pulse characteristics in 2007

- In basin at company Verburg-Holland Ltd., Colijnsplaat, The Netherlands
- On-board MFV UK153 with gear hanging out

Catshark (*Scyliorhinus canicula* L.) trials in tanks in 2007 at IMARES:

- Experience with keeping the animals in good condition
- Development pulse simulator with two electrodes
- Control group and test group
- Initial (n=2) and follow-up test (n=9) in separate tank
- Video-recordings of behaviour under stimulus and feeding behaviour afterwards
- Report to Ministry LNV

X-ray tests on cod in 2007 (*Gadus morhua* L.):

- Carried out by "Vakgroep Experimentele Zoölogie WUR"
- Fish were gutted and landed by MFV UK153
- 2 out of 25 showed clear spinal damage
- 6 out of 25 had deformed spines, but possibly originating from natural causes.

These experiments were followed by:

Further catshark tests 2009, featuring:

- More animals
- No transfers between tanks
- The use of control groups
- Repeated exposure to electrical stimuli
- Observation with cameras and video recording

Cod tests 2008, involving:

- Study spinal damage
- The use of control groups
- Collaboration with Norwegian cod farm, which meant:
    - The availability of large numbers of animals in controlled conditions
    - Growth characteristics that are known
    - The ability of avoiding damage through capture

Benthos tests 2009, featuring:

- More animals (6 species), under representative stimuli
- Collaboration with experts at IMARES, Yerseke
- The use of control groups

3.1.3 Work done by IMARES in response to the ICES Advice of 2009 (See ToR A)

Further tests on cod tests in 2010, involving:

- Study spinal damage
- Collaboration with Norwegian cod farm.
- A range of length groups (12–16 cm, ~50 cm)
- Direct observation by video
- X-ray photography

Reference measurements at sea, 2011

- Ref MFV TX68 done on MFV TH10
- Ref MFV TX36 done on MFV OD17
- Gear vertical hanging on boom
- Gear lying flat on-bottom

Catch comparison trials in May 2011 (08/05/2011–13/05/2011).

- Three commercial vessels fishing same area, same time (side-by-side)
- Gears:
  - TX36 → HFK – pulse wings
  - TX68 → DELMECO – pulse trawls
  - GO4 → conventional tickler chain beam trawls
- All codends were made new from the same netting batch
- Discard protocol was used with emphasis on spinal damage of cod
- Dissection of cod (and whiting) was done on both pulse trawl boats

3.1.4 Work planned by IMARES in 2012

Further work to be undertaken by IMARES will involve:

Monitoring on pulse trawlers 2012, with:

- 10 trips with on-board observers from IMARES and ILVO
- 20 self-sampling vessels
- 1 sample per week throughout the year
- First results expected by July 2012
- Final report by April 2013
- This will provide new data on:
  - Discard percentages of PLE, SOL and COD
  - Discard percentages of benthos related to total catch
  - Spatial pattern of discarding
  - Seasonal pattern of discarding
  - Relationship between outcome observer trips vs. self-sampling

Discussion

The question was raised how representative the former results with TRIDENS are for the systems installed on commercial beam trawlers and hence monitored here? Some of the older results may not be completely transferrable to the new pulse setting, and also when comparing two gears simultaneously, the optimal speed for the pulse trawl was chosen and not that of the conventional one, which may bias the comparison to some extent. Verburg/DELMECO has changed the pulse since former experiments and not all vessels E-fishing for sole fish with the Verburg/DELMECO-system. A total of 8 boats fish now with DELMECO and 28 with the HFK-system.

The question was asked whether the monitoring programme of 2012 is limited to flatfish fishery or will include shrimp fishery. The answer is only flatfish fishery.

It is not clear whether the 5% derogation covers the entire fleet or only the beam trawl segment. There are conditions defined in the derogation The Netherlands, Belgium, and Germany in the licences for individual vessels, that they have to install the system within a given time, otherwise they lose the licence.

The risk was mentioned, that if a system turns out to have negative impacts the fishers have invested substantially and there is also a risk that as a result other pulse trawling might be affected, e.g. pulse trawling for flatfish might cause a negative judgement on pulse trawling for shrimps, although this runs under very different pulse characteristics.

The effect of the combination of electric-field strength and pulse frequency should be investigated further as well as size of fish, duration of exposure.

4 ToR a) Improve knowledge of the effects of Electrical Fishing on the marine environment (reduction of bycatch, impact on bottom habitat, impact on marine fauna, energy saving and climate related issues), in view of current technical developments on electrical fishing and emphasis on the relationship of pulse characteristics (power, voltage, pulse shape) and thresholds in terms of effects on fish and other organisms (mortality, injury, behavioural changes)

4.1 Report on cod studies, catch comparison and reference measurements 2010 – 2011 (Bob van Marlen)

4.1.1 Cod studies

These were laboratory experiments, carried out in December 2010 at IMR Austevoll, Norway by Dick de Haan, and involved:

- Small cod (0.12 – 0.16 m)
- Large cod (~0.5 m)
- Direct observation using video cameras
- X-ray post-mortem analysis

The results were:

For small cod (0.12 – 0.16 m)

- Range of field strength from 250–300 V/m
- N = 168
- No spinal damage at all

For large cod (~0.5 m)

- Range of field strength from 40–100 V/m
- N = 262
- Damage occurred in 50–70% of fish
- Found in all three pulse shapes, but least in the Delmeco TX19 pulse
- At pulse frequencies larger than 180 Hz no more damage was found

Discussion

At the moment, it is not clear what causes spinal fractures of fish (i.e. cod), or in which phase of the electrical stimulation, this injury happens. Is this related to bending, cramping or others? It has to be noted, that when fish are hold in small cages with little freedom, then spinal fractures caused by bending will not occur, which may result in some bias.

It was asked whether in the cod experiments pulse duration and pulse shape were kept constant. This question will be forwarded to Dick de Haan.

It was noted that if a capacitor works at maximum load, then the electric field will drop (automatically) with increasing frequency, which give some implication on the effect.

It was proposed that Maarten Soetaert will write a small paragraph on electric fields (where is which field strength, where to measure, effect of the bottom conductivity, etc.). In the Dutch discussion in the enforcement group the method how precisely to measure field strength will be addressed and the limit in field strength.

4.1.2 Reference measurements at sea, November 2011

These were done on two vessels with comparative electrical fields:

- Reference vessel for MFV TX68 was MFV TH10
- Reference vessel TX36 was MFV OD17
- Measurements were done with the gear hanging on boom vertically
- And with the gear lying flat on the bottom

The measurements resulted in the conclusion that the TX36 pulse was simulated very well in the laboratory experiments, and that the TX68 pulse in the simulation during the tests represented a 54% overdose.

Recommendations from the study were:

- Always measure field strength *in situ* with the trawl on the seabed
- Measure also field strength of the TX-19 type pulse *in situ*, which is now lacking, and has double frequency
- Investigate whether higher frequency (> 180 Hz) still catches sole and plaice
- Investigate ways to guide cod away from electrodes
- Collect more data
- Monitor future developments in pulse characteristics

Figure 1. Measuring device placed between electrodes on TH-10.

4.1.3 Comparative fishing experiments

Comparative fishing trials were conducted in May 2011 (week 19) on commercial beam trawlers fishing with conventional tickler chain beam trawls (on MFV GO4), pulse wings made by HFK-Engineering of Baarn, the Netherlands (MFV TX36), and pulse trawls produced by the DELMECO-Group of Goes, the Netherlands (version used on MFV TX68). The three vessels fished side-by-side as much as possible. Landings and discards of these vessels were monitored. Special emphasis was given on cod and whiting, that were dissected to study possible spinal damage. Result for TX36 and TX68 are expressed in terms of percentages of GO4.

The pulse characteristics were as follows: TX36: voltage 45 $V_{0\ to\ peak}$, pulse frequency: 45 Hz, pulse duration 380 µs; electric power on single gear: 7.0 kW; TX68: voltage 50 $V_{0\ to\ peak}$, pulse frequency: 50 Hz, pulse duration 220 µs; electric power on single gear: 8.5 kW. The fuel consumption recorded over the whole week was considerably lower for the pulse trawls, i.e. on TX36 (40%) and on TX68 (54%), than for the tickler chain beam trawls used on the GO4. The net earnings (taken as gross earnings minus fuel costs) for the TX36 were almost twice as large at 186%, and for the TX68 also considerably higher at 155%. An example of the measurement technique is given in Figure 1.

The vessels with pulse trawls caught fewer (65–69% of original value) target species, but also less (30–50%) immature and non-target fish ('discards', Figure 2), and benthic species (48–73%) than the vessel with tickler chains on these fishing grounds and in this period. The pulse gears caught fewer (19–42%) kg per hour cod than the tickler chain beam trawls, but the catches of cod on all three vessels were very small.

For plaice and dab these differences were statistically proven, for brill, turbot and cod this was not the case. There was no marked difference between both pulse trawl vessels in total landings. The TX68 caught less marketable sole, but not significantly less undersized sole than the GO4. The TX36 caught less undersized sole, but here the difference in marketable fish was not significant. Catches of brill and turbot were so small that no statistically substantiated conclusion could be drawn. Only for undersized turbot the TX36 caught less. For whiting we found a demonstrable reduction in both marketable and undersized fish in both pulse fishing vessels. The TX36 caught less whiting in number per hour.

The cpues found from the auction data and the sampled hauls correlated reasonably well for the most abundant species, such as plaice and sole. However, for less abundant species the results did not match very well, and care should be taken to increase the sampling rate in future comparative fishing studies.

Spinal fracture in cod occurred under pulse stimulation but to a limited extent in both marketable and undersized fish. There is an indication that this happens slightly more on TX68 (11%) than on TX36 (7%). Whiting hardly seems to suffer any damage.

Further detailed analyses were done at the beginning of 2012, focusing on the differences between the conventional (CONV), and pulse (PULS) trawls (averaged out). In addition various species groups of benthos and fish will be investigated, giving data that can be fed into ecosystem models under development. It is the idea to write a peer reviewed publication about this work.

As overall conclusions we can state that:

- Fuel consumption is lower (40–50%)
- Net earnings are higher (150%)
- Fewer landings (60–80%)
- Fewer discards (30–40%)
- Spinal fracture in cod occurs in approximately 10% of the fish caught
- No spinal fracture accountable to the pulse stimulation was found in whiting

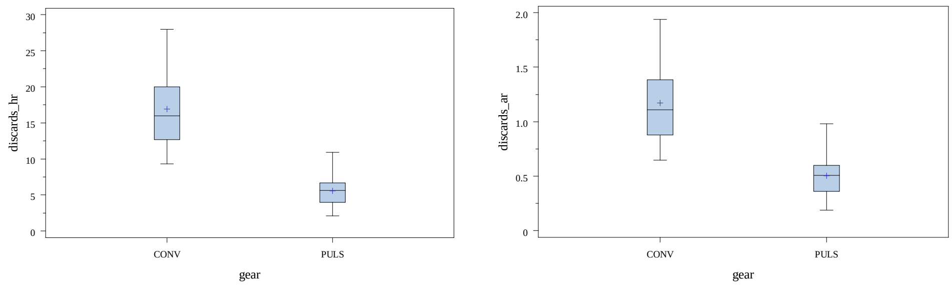

Figure 2. Discard reduction with pulse trawl gear.

Discussion

The group acknowledged, that the number of captured cod in the catch comparison was relatively low and hence statistical validity potentially limited. In addition, the question was raised, whether injuries of cod would increase fishing mortality, if all injured cod would be caught and landed (and therefore counted against quota). The spinal damage occurred in the larger fish, that were above the minimum landing size and are in the landings fraction anyhow, not in the 12–16 cm group, which may have a chance to escape from the gear. It is not a matter of increasing fishing mortality, rather of getting a lower price for these fish, and also an ethical point whether society will accept such damages.

The question was asked whether discard rate was also determined. The answer is that in this presentation only volumes were shown of landings and discards expressed in number of baskets per hour and per hectare fished area. Another point mentioned is that there must be an estimate for the change in discards when trying to achieve the same amount of landings (e.g. when landings are only 50% of conventional gear, than fishers have to fish twice as long to achieve the same amount of landings and this would mean that means discards doubles as well.) The answer is that fishing time will be a limiting factor in this, and in practice the pulse vessels have somewhat lower landings, but higher net earnings due to the large savings in fuel. Also they seem to catch sole in good quantities, contributing most to keeping losses in earnings from catches low.

It may be the case that the pulse designed to catch sole effectively might be suboptimal in relation with the spinal damage occurring in cod. This is also contradictory to the objective of reducing cod injuries. It needs to be investigated whether changes in the pulse characteristics, that avoid the cod problem, still enable good sole catches.

This contradiction is also shown from in the development of the HFK-system (pers. inform. to BV), where different types of modules were built (with increasing input) and it is not sure whether the maximum level of catchability has been reached.

A publication of the work using the Piet *et al.*, 2009 model is in preparation and will be distributed when ready.

4.2 Report on further development of the "Hovercran" (Maarten Soetaert and Bart Verschueren)

The present gear is not deemed selective enough. The MSC calls for less discards and higher selectivity. Gear should not have impact on seabed. The R&D at ILVO was explained, i.e. tank experiments. The Chinese example with uncontrolled growth in effort and subsequent prohibition of electrical fishing was mentioned. The basis responses are: startle (fright) reaction, followed by cramp, forced swimming and electrotaxis. The first reaction is enough catching for shrimps, which can jump after 0-0.40 s, leaving other organisms untouched. A diagram was shown of old and new (Hovercran) gear. The original idea was to only let electrodes touch the ground, while raising the net 10–15 cm off-bottom. The gears used in commercial trials have bobbins, to enable smooth passage over commercial fishing grounds. MFV O-191 was used at the beginning of the experiments. The pulse generator was placed in the middle on the beam. The next vessel was MFV TX-25. Winches are placed on the derricks. On MFV HA-31 bobbins in a straight line are used on the net, and only 24 instead of 36. Wire strain relieves are used between the electrodes. WR-40 "Jogina" uses wheels instead of beam trawl shoes. A total of 12 electrodes were applied across, 12 mm thick, with 65–70 cm spacing, and 5 cm above the seabed, with a length of 1.5 m. The towing speed is 3 knots. Organisms are exposed 0.0005 s. The power used is 1 kW per gear, comparable to a one litre water boiler. The beam width is 9 m.

Experiments are ongoing on the effect of shrimp pulse trawling on the catch rates of shrimp and discards. It was demonstrated that a combination of a conventional gear (standard shrimp beam trawl, with 36 bobbins) equipped with 12 electrodes resulted in a catch increase of up to 54% compared to a conventional gear without pulses. It is important to notice that this experiment was conducted with an experimental and less practical setup. Twelve different electrodes had to be custom made in order to fit them in the conventional gear. Due to high material cost and wear it is not conceivable that this configuration will be implemented in commercial fisheries. It is found that the increase in catch rates of commercial shrimp due to electrofishing strongly depends on the amount of bobbins that is still used in the gears. In the following months modified footrope arrangements on the Dutch boats TX-25 (Figure 3) and HA-31 will be tried. The aim is to find a trade-off between catch increase, and discard reduction. At this moment one vessel is using 9 bobbins in combination with 12 electrodes resulting in a higher shrimp catch 10% compared to the conventional gear. ILVO believes that while fishing without bobbins it is possible to maintain a high level of commercial catches. In another catch comparison experiment a total of 23 hauls were conducted with varying generator output, ranging from 70, 80, 90 and 100%. A power setting at 100% did not result in a higher catch efficiency compared to a power setting of 80% (resulting in a lower amplitude and thus lower electrical field intensity). This would mean that there is an optimum value in pulse amplitude. In this case it is useless to increase the amplitude beyond a threshold level in order to catch more shrimp.

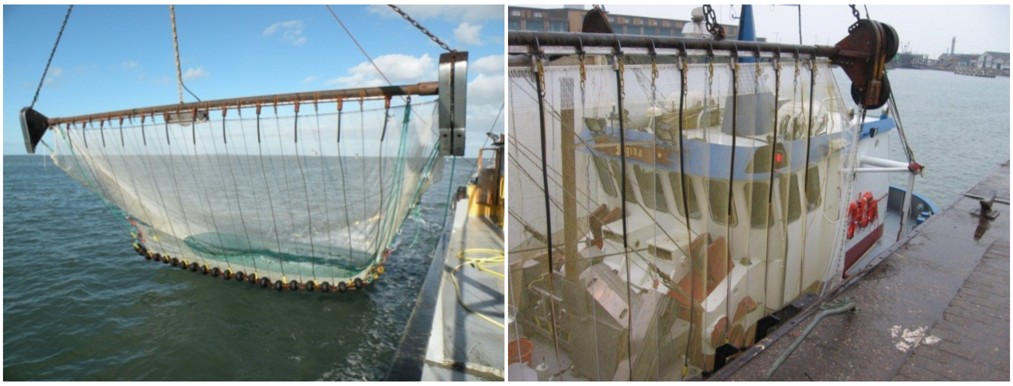

Figure 3. "Hovercran" on HA-31 (left) and WR-40 (right).

Discussion

Now there are four vessels working with the Hovercran, *i.e.*: the TX-25, HA-31, WR-40 (Figure 3) and SD-33.

Some shrimp fishers in the Netherlands and Germany fear higher catch efficiency with the new gear. On a discussion with shrimp fishers in Harlingen, The Netherlands on 30/3/2012 this was mentioned and an emotional debate emerged on this issue. Questions that were raised were: Is there a need for setting limits on pulse trawling, and should the use of bobbins in these gears be prohibited? Or should we set TACs, which do not exist now, and use time restrictions, or other technical measures, or spatial restrictions (e.g. related to the Natura 2000 areas)?

Fuel savings are expected not to be as high as for flatfish-pulse-fishery (particularly when using the pulse wing), as towing speed is low in shrimp trawling (typically 2.5 knots), and not reduced. Nevertheless, the reduced bottom contact will affect fuel consumption. Detailed measurements on differences in warp tension will be done in the German Hovercran project (see below).

The investment costs go up to € 70000 – € 72000 for a complete system with two gears, winches, pulse generators, cables and spare parts, but without nets or groundropes. It is not known whether sieve nets were used in shrimp pulse trawling during these tests. Incentives might come from access to certain grounds getting closed for conventional gears. Fuel saving is another incentive, though not as strong as in the flatfish fishery. The market sets limits, catching more shrimp will cause prices to drop, one may use fewer units for the same catch of shrimp. Real catch comparisons were conducted only on the Belgium test-vessel. Hence, the quantification of differences in catch are only provisional and have to be investigated in more detail (*e.g.* in the German Hovercran-Project). In addition, there are other potential mechanisms to counteract a drop in market price due to (probably) increased catches, such as effort limitation or TAC.

Another point mentioned is the link with MSC certification. The conventional gear may not get this label. Fisheries that are heading in the right direction may get a label with a goal set for future improvements, say in three years. Economy always plays a role in technical developments, some fisheries developed by reducing the number of units, *e.g.* the pelagic fleet in The Netherlands. With the present market conditions with low prices one may wonder whether there are just too many vessels fishing for shrimp. The debate in Harlingen showed diverse reactions ranging from support for the Hovercran to strong opposition. Apparently the group of fishers is very diverse with interests not coinciding. The combination of pulse systems for shrimps and flatfish runs into many technical problems. If pulse characteristics are defined accurately, should the combination in activities (shrimp fishing or flatfish fishing) pose problems?

Since North-Sea *Crangon* fishery is not limited by measures, such as TACs and days at sea, an increase in catchability will potentially result in some problems (decrease in prices, long-term effects due to higher fishing mortality etc.). Therefore, it is important to note, that the management has to be evaluated the need for limits which could be (e.g.):

Technical measures may be issued on:

- landings (free fishery, quota, TACs,…)
- time (free, seasonally, hours at sea, …)
- spatial limits
- 'licence bound market promotion tax?'

Some feel that fisheries economists should be involved more in the analysis of pulse fishing experiments to help answering these questions. The Dutch Economic Institute (LEI) monitors pulse trawling, and reports on the economics of flatfish pulse trawling were written in the DEGREE-project.

Additionally, the question was raised, whether a "greener" gear with less bottom contact and less discards could have the possibility to be used in protected areas (such as Natura 2000-sites).

The question was raised about the combination of shrimp and flatfish pulse fishery. The DELMECO-company is working on the development of such a gear. The problem here is to construct a pulse generator working for both pulse types, and the differences in frequency could be a crucial problem.

The PhD-Thesis of Maarten Soetaert is aimed at finding a new startle pulse for sole (probably with a lower frequency), which could help to develop a new 2-in-1-system.

4.3 A short introduction to the German "Hovercran" project (Daniel Stepputtis)

This study is based on EFF-funding (given by county Schleswig-Holstein). Work started on the SD-33 in Germany (Figure 4). The main aim of the study is an objective evaluation of consequences for an introduction of pulse-fishing for shrimp (*Crangon crangon*) using the Hovercran-system. The analysis will be based on a comparison of a conventional and a pulse-trawl on one vessel (SD-33 from Büsum, with pulse and conventional trawls fished simultaneously) over one entire year to cover seasonal effects. Additional data (e.g. economic data) will also be collected. The seasonal sampling will be conducted as a combination of observer cruises and self-sampling.

On selected cruises, additional experiments will be conducted on the influence of visibility, gear changes, etc.. The system will be delivered at the beginning of June 2012, and first trials will be conducted thereafter. During this test, commercial fishing will be carried out, followed by self-sampling. Samples will be brought into the harbour and processed in the laboratory for a complete year. During some periods (*e.g.* two weeks), a second pulse gear will be used as well to compare certain improvements. Maintenance is still to be considered, as well as the complete data collection, including vessel data such as fuel use. One master student will get involved.

Additional remarks from German gear technology:

- A new ROTV "Juli" is available since 04/2012 (made in Aberdeen by SubAtlantic).
- A new FRV "Clupea" (L= 28 m) came into service in 04/2012.

Figure 4. German Hovercran team (from left to right: Jörg Berkenhagen (fishery economist, vTI-SF), Ralf Vorberg (biologist, MSS), Herbert Schoer (skipper), Daniel Stepputtis (gear technologist, vTI-OSF).

Discussion

Should these trials not be monitored continuously? During the intensive sampling periods (at the beginning and in several periods in between), scientists will be on-board. The self-sampling in other periods will be in close cooperation with scientists and additionally scientists will be on-board in regular intervals.

The reaction of fishers in Germany was sceptical at first, but following the Dutch development more interest was shown. The fishers were stimulated to regard it as their project.

In the fish bins volume marks will be added to estimate total catch. The Dutch use a special device at the end of the conveyor belt to measure the total number of baskets in the catch. The self-sampling protocol used in The Netherlands will be sent to the German colleagues.

4.4 Work on effects of electric fishing on various marine organisms (Marieke Desender and Maarten Soetaert)

4.4.1 Work to be done by Marieke Desender

Brown shrimps are caught with bottom trawls, as is the case for 90% of all demersal fish, shell and crustacean landings in the North Sea. These demersal trawl fisheries are known to produce large amounts of discards and to disturb the seabed habitat of benthic organisms. In order to increase the sustainability of these fisheries and consider ecological certification, technical adaptations are necessary to avoid these problems. Electric pulse fields have proven to be the most promising option for alternative stimulation in fishing gear, replacing the mechanical stimulation.

Since 2008 the Belgian ILVO research institute has been successfully testing their Hovercran electro pulse trawl for brown shrimp fishery. In this device the bobbin rope is replaced by light weight electrodes creating a low-intensity electric field which selectively induces a startle response in the shrimps. Other benthic organisms are left untouched and can escape underneath the hovering trawl that collects the jumping shrimps without disturbing the seabed.

Nevertheless, the effects of suchlike electric pulse field on marine organisms are largely unknown. Preliminary exposure and survival experiments indicated that the use of this low frequency pulse has no immediate significant effects on adult fish and invertebrate species (Vercauteren *et al.*, 2010; Polet *et al.*, 2005). Cod, sole, plaice, pogge, fivebeard rockling, dragonet and armed bullhead were exposed for 10 second to an electrical field of 5hz and 60V/m. Minor and brief fright reactions were observed. After 24 hours these fish were euthanized and investigated for macroscopic and microscopic short-term injury. Histological abnormalities were rarely present in both control and exposed groups. However, long-term effects, electro sensitive fish, like sharks and rays, and polychaete species, which have a key role in the benthic ecosystem, were not included in these studies. Additionally, the influence on different life stages has never before been investigated. Accordingly the aim of this PhD is to investigate these gaps in knowledge to revalue electrofishing.

In a first work package the behaviour of electro-sensitive fish, catshark (*Sciliorhynus canicula*) and thornback ray (*Raja clavata*), will be investigated in a moving heterogeneous electric field (Figure 5) by trawling two electrodes in a 6m test aquarium. In preliminary results one shark swam towards the electrode (electrotaxis), 9 sharks swam upwards en were very active. The control group (10 ind.) behaved normal and showed either no escape reaction. Also the minimal distance between animal and electrode will be measured to know which maximal field strength they encounter. After 1 and 14 days half of the lab animals will respectively be euthanized and macroscopically inspected for haemorrhages and bruises. Furthermore samples for histological research will be taken from the ampullae of lorenzini, gill arch, heart, liver, spleen, intestines and kidney (Figure 6). RX photos will investigate the presence of spinal injury. To exactly know cause and consequence further experiments will be performed in a homogeneous electrical field (Figure 7). In-between two plate shaped electrodes, catshark, thornback ray and sandworm (*Nereis virens*) will be orientated perpendicular to the electrodes simulating the worst case scenario. The maximal and mean field strength examined in WP1 will be applied with a frequency of 5 Hz. Besides macroscopic and microscopic evaluation and RX inspection the behaviour will be analysed as well. With video-tracking software (Noldus ethovision for example) parameters like activity (distance, swimming speed,…) and apatite (number individuals swimming to the food) will be measured. Electrofishing over active spawning grounds may affect survival of embryos, larvae or juveniles if exposed during their more sensitive stages (Bohl *et al.*, 2010). Therefore the third WP of this research will focus on the effect on different life stages of cod (*Gadus morhua*), sole (*Solea solea*), brown shrimp (*Crangon crangon*) and sandworm. Different embryonic, larval and juvenile stages will be exposed to two field strengths (75 and 150V/m) during five seconds. Each experiment will be done in triplicate and the appropriate controls will be included. After exposure of eggs (during morula, epiboly and organogenesis) the development and survival will be followed up daily and the time and amount of eggs hatching will be measured. After hatching the Larvae will be followed up for 14 days, checking growth, yolk resumption and mortality, and remaining larvae will be euthanized and subsequently externally inspected for injuries, malformation and abnormal pigmentation. Of each batch 10 hatched larvae will be further prepared for histological analyses. Also two stages of larvae will be exposed (endogene and exogene phase) and followed up. After metamorphosis 10 larvae will be submitted to further histological research. Finally 30 juvenile fish will be exposed. One half will be euthanized after 24 hours. The behaviour of the other half will be analysed with camera observation. After 14 days they will be euthanized and examined (macroscopically, RX and histology) for injuries.

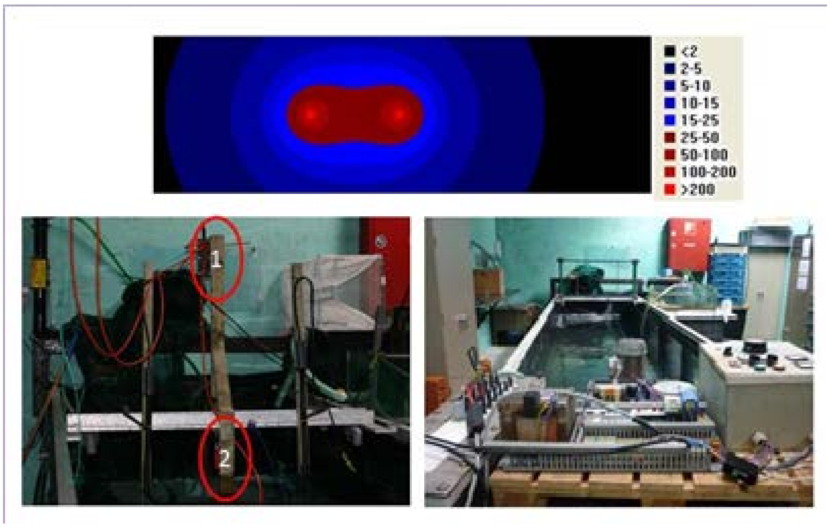

Figure 5. ↑Distribution of the Hovercran heterogeneous electrical field. → experimental setup: camera 1 recording from above the bottom of the test aquarium and camera 2 recording in the water the vertical plane. ↘ the test aquarium wherein the electrodes are hauled.

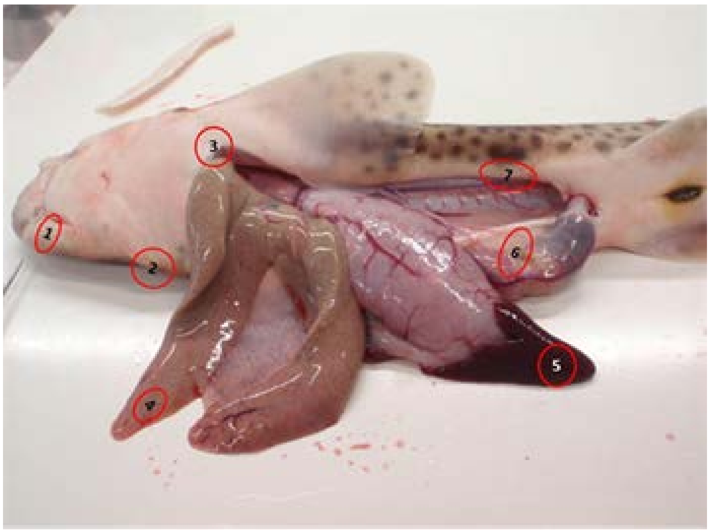

Figure 6. Samples for histological research taken from 1. Ampullae of Lorenzini, 2. Gill arch, 3. Heart, 4. Liver, 5. Spleen, 6. Intestine and 7. Kidney.

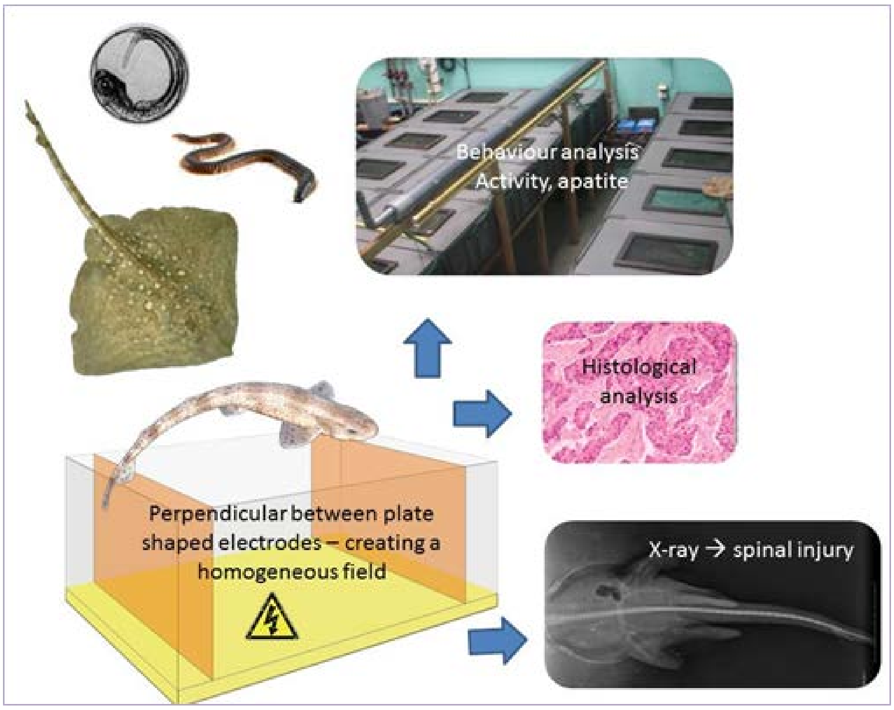

Figure 7. Overview Experimental setup in a homogeneous electrical field.

Discussion

The duration of exposure of catshark was longer than in real fishery, because it was not possible to tow the sledge faster through the tank.

There are two combined effects: a) electrical stimulus; b) mechanical stimulus caused by the moving sledge. It would be beneficial to separate both confounding effects.

The question raised for electro-sensitive fish (sharks and rays) was whether these animals can still sense their prey using their electro-reception organ.

4.4.2 Work to be done by Maarten Soetaert

Maarten explained physical backgrounds in electricity and electrical fields.

Two forms of electrical fields are relevant to pulse fishery research. Generally electrical field lines run from the positive electrode to the negative one. Any line perpendicular through the electrical field lines represents an 'equipotential' ('equi' = same) which means that the potential measured on this line, is the same for all points on this equipotential. Field strength in V/m gives the potential decay in a certain point. The smaller the distance between equipotential lines is the higher the field strength.

A **uniform** or **homogeneous** field is one in which the electric field is constant at every point. It can be approximated by placing two conducting plates parallel with each other and maintaining a voltage (potential difference) between them; it is only an approximation because of edge effects (Figure 8). In this case the field lines between the plates are parallel, which implicates that the equipotential lines are everywhere at the same distance and so the field strength between the plate shaped electrodes will be the same for the whole area between the two electrodes. The field strength will equal the potential difference over the two electrodes divided by the distance between the electrodes. E.g. when the clamp voltage between two electrodes is 50 V and the distance between the two plates is 25 cm, the field strength between the electrodes will be 50/0.25 = 200 V/m everywhere. Thus in a homogeneous field it is not important where (between the electrodes) the field strength is measured.

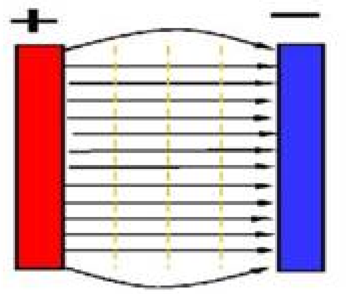

Figure 8. Cross-sectional 2D view of a homogenous field between two plate-shaped electrodes of infinite length. The field lines are in black, the dotted yellow lines are equipotential lines.

Most fields used in pulse trawling, however, are **non-uniform** or **heterogeneous** fields, as generated by wire shaped electrodes. As we can see in Figure 9, the field lines are curved, because of the round shape of the electrodes. This implicates that also the equipotential lines will be curved. For this case the field strength will not be constant, as the equipotential lines are lying closer to each other near to the electrodes. This means that also the field strength will vary between a maximum very close to the electrodes and a minimum in the middle between the two electrodes.

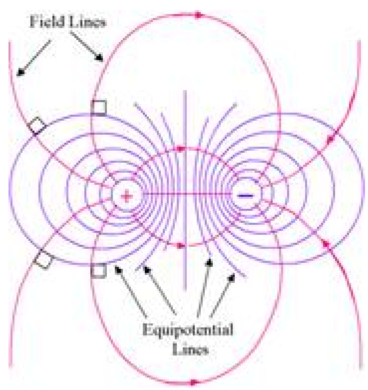

Figure 9. Cross-sectional 2D view of a heterogeneous field between two wire-shaped electrodes of infinite length. The field lines are in purple, while the equipotential lines are in pink.

Figure 10 shows an approximate model of the field between the two wire shaped electrodes as it was between two electrodes of the original Hovercran design. It clearly illustrates that the field strength is limited in the space between the electrodes, but higher in proximity of the electrodes. So it is important where field strength is measured, because it will vary along an axis between the two electrodes. A common practice is to use the field strength measured in the middle between the electrodes to avoid that it is overestimated. The maximum field strength between two electrodes depends on the distance between the electrodes, the surface and thus the diameter of the electrodes or conductors, the potential difference and the medium between electrodes (conductivity of seawater and sediment).

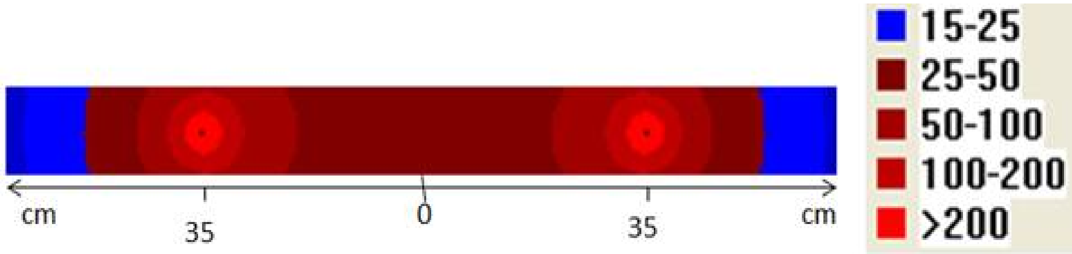

Figure 10. Approximated 2D model of the field strength between the two wire shaped electrodes of the original Hovercran design.

In the section above, we did not assume that the charges on the electrodes, and thus the potential difference changed with time. The fields generated are called the electrostatic fields. In pulse trawling in seawater, charges change with time, and thus we are dealing with **electro-dynamic** fields. This also means that field strength is a function of time.

In order to account for fluctuation in time field strength can be expressed as 'rms' or 'RMS' (root mean square). The RMS value of a set of values (or a continuous-time waveform) is the square root of the arithmetic mean (average) of the squares of the original values (or the square of the function that defines the continuous waveform). Thus it is a statistical measure of the magnitude of a varying quantity.

It is especially useful when the pulse is an alternating current pulse, because it means taking the mean of the root of the square of the field strengths. Otherwise the mean would just equal 0 as the positive pulses are compensating the negative ones.

Maarten presented the content of his PhD-work. He is one of the two new PhD-students that started their research on pulse fishery in January 2012. The two main goals for the first years of his research are to determine the safe upper limits for electric pulse fishery and to find a safe startle pulse to catch sole, as an alternative for the currently used cramp pulse.

The 'safety margin' is the zone of parameter combinations that can be used to catch fish without having unacceptable effects on adults. It will be determined out by exposing two vertebrate (*Solea solea* and *Gadus morhua*) and two invertebrate (*Crangon crangon* and *Nereis virens*) species to a range of frequency – field strength combinations, the two parameters that influence the most the harmful effect of electric pulses. Based on the results, it will be possible to determine what percentage of a certain species will have injuries or die due to exposure to pulses with a given frequency at certain field strength. This makes it possible to have a statistically inferred idea of (i) the importance of a certain pulse parameters in causing injuries or mortality, (ii) the differences in sensitivity between the four species, and (iii) the maximal frequency – field strength combination that should be used in pulse fishery to avoid having harmful effects. This will also give an indication of the risks of the pulse characteristics that are used nowadays for pulse fishery on shrimp or sole.

Further comments during the presentation were made. The tests will be done to determine the injury dose (ID50), and the lethal dose (LD10) for sole, cod, shrimp and sandworm, at 50 and 100 V/m field strength, at frequencies between 5–180 Hz using the Hovercran pulse. Two plate electrodes will be used to generate a uniform electrical field, with 5s exposures. Questions to address will involve:

- Is there difference in sensitivity between species?
- Effect of V/m, Hz? Kind of injuries?

- Is there a safe range?
- Are the existing systems (not only Hovercran) in the safe zone?.
- Can behaviour be added to the list of influential parameters (Fish in cages are restricted. Videos were shown of sole reacting strongly. No cramping but fluttering behaviour occurred.)

In a second study, the startle pulse for sole will be optimized. The aim is to find a 'low frequency' startle pulse that makes sole jump out of the sediment, as an alternative for the 'higher frequency' cramp pulse as used today. Therefore, a sufficiently large group of sole will be exposed to pulses with different combinations of pulse frequency, field strength, pulse duration, pulse type, wave form and exposure time to determine the pulse that gives the best reaction regarding the height of jumping, recovery time and reaction time. The tested frequency – field strength combination should always be chosen below the safe upper limits (see previous paragraph) to avoid optimizing a pulse with possibly harmful effects.

Afterwards the effect of the found startle pulse for sole on the behavior and feeding response will be examined for the same selection of four species as in the first study. Additionally, possible injuries will be taken into account (macroscopic, Röntgen photo (Figure 11), histology). In a last part of the PhD, the effects of the pulses on the fish quality (appearance, decay and taste) might be investigated.

Thus the second part deals with optimization of the startle pulse for sole. Previous studies found, that a total of 25% of sole jump out of the sediment with Hovercran pulse. The idea is to raise this to 60–70% (See Chiers *et al*., 2011. Short-term effects of low frequency pulsed direct current on captive housed sea fish, which was recently submitted).

Pulse duration will be varied between 0.1 and 0.5 ms at an exposure duration of 1–2 s. Various pulse rise times (shapes) will be used, from square to triangular, and pulse type from one to three sequential pulses. Video tracking to be done as well from two sides, scoring height above bottom (3), swimming speed (1), and recovery times (2), into a 'total effect number' a sum of scores * weight, using a weight factor for each (Figure 12). A total of 50 individuals will be used.

The effect of the startle pulse on other marine biota (cod, shrimp, sandworm) will also be investigated. Video tracking after exposure will be done. Also the effect on quality of sole will be studied.

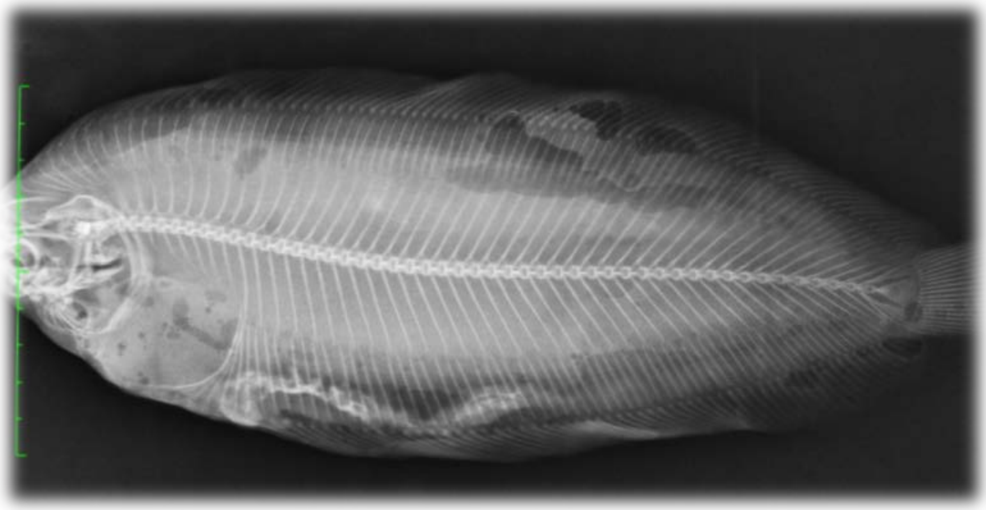

Figure 11. X-rayed sole, PhD work by Maarten Soetaert.

Parameter	Effect score (A)			Weight (B)	Total (T)
	3	2	1		= A x B
1. Height above bottom (cm)	> 15	5 – 15	< 5	3	T_1
2. Swimming speed (% of max)	< 75	25 – 50	< 25	1	T_2
3. Recovery time(s)	> 3	3 – 1	< 1	2	T_3
TOTAL "EFFECT NUMBER" (= assessment number of observed startle response)					$T_1 + T_2 + T_3$

Figure 12. Provisional scoring of behaviour characteristics, PhD work by Maarten Soetaert.

Discussion

The ethical committee of ILVO has approved the experiments, and both Maarten and Marieke are certified to carry out this kind of work. The effect of orientation was discussed: sole have the ability to curl in both planes. Plaice will not be looked at in this study, as the number of variables is already large.

The optimal orientation of fish within the electric field was discussed for experiments. Most studies have used perpendicular orientation in relation to the electrodes. The first experiments by Maarten have shown, that perpendicular orientation could be the worse one (more died in this orientation), so probably one is on the safer side to investigate negative effects in perpendicular orientation.

Several pulses to be applied in the upcoming study were shown, whereas all pulses were shown as sequences of positive pulses. It has to be clarified, whether it is necessary to apply positive and negative pulses alternatively.

4.5 Electrical fishing for *Ensis* – Description of equipment development and trial results (Phil Copland).

Ensis spp. is called razor clams, razor shells, or 'spoots'. Since 1997 14–27 (75%<10m) vessels are involved in this fishery, often using a multi-purpose light trawl. The main market is for life export to Europe and Asia. Burying mechanism of *Ensis* is described by Trueman, 1967. Distribution of landings by ICES rectangle was presented. Total landings and value rising from 2003: 1.8 M UK£, 800000 tons. Techniques used are: intertidal hand collection from the beach by digging, by saline, both techniques by divers, hydraulic dredge, divers with electro gear. This is an illegal fishery. Information is therefore anecdotal. A fly-dragging type of operation is used, and was shown in a diagram. Current legislation was mentioned, including EU Reg. 850/98, Article 31. Gears vary greatly, but not known exactly what is being used. The gear stays on the seabed, generators are used on deck of the boats, e.g. two DC welding generators (5–6 kW), even 100 kW AC seems to be applied. Divers are usually used for catching the clams. Reports of divers suffering from this fishing were given, even lethal accidents were reported. Prosecutions are extremely rare, though.

SEAFISH has made a report, but restricted its spread at first, maybe out of fear that the technology would be copied, which seems not hard to do. The industry sees it as a benign and profitable operation. Pictures of this report are shown (Figure 13). The gear is very slowly moved over the seabed at 2.5–3 m/min. Forms of mechanisation are under development, the 'Leaf Sweeper' operated with compressed air avoiding the use of divers with video monitoring as well, but the system was still unreliable. Heavier collector rigs were also produced made as a square sort of steel box, with electrodes and a water jet, as well as beam trawl collectors. Divers still seemed to be to most effective way of collecting, as *Ensis* often partly emerge from the seabed. Fishing trials were also described, with control areas, grab samplers, use of still and video cameras and vessel and diver observers. Several 100s hours of video footage exist that can be used for further analysis. Post fishing studies also done, 1 and 28 days after fishing. Serious negative effects on benthic communities can be avoided and *Ensis* effectively harvest with this technique. It may be better to try to regulate this fishery and avoid hazardous practices by doing so. The future of these fisheries is still very uncertain. Reference to a derogation is nowhere mentioned in the report. Phil Copland will check the distribution status of this report.

A downloadable reference is:

http://www.seafish.org/media/Publications/SR652_Effects_of_electrofishing_ensis__2_.pdf

Chlorine (it and its derivatives are toxic to marine organisms and soluble in seawater) production due to electrolytic reactions during electrofishing might become a problem due to the long exposures in this kind of fishery. Volumes of chlorine are proportional to electrical power used, and its concentration is depending on towing speed. The problem is recognized to be relevant to salmon farming. The effect could be used for detection of pulse fishing events. With inputs > 140Ah concentrations might get as high as 240–264 µg/l, exceeding EU-levels by a factor of 50, meaning that this will exceed the fatally toxic level e.g. for plaice for long-term exposure (at 96h exposure) by a factor 9 (Breen and Copland). This problem seems not very relevant to pulsed fields travelling at much higher speeds. 'Brown burn tracks' on the seabed were reported when high-powered AC systems are used. There may be a correlation, but this is not known to detail. Unmonitored electrofishing might cause high chlorine concentrations, and the reaction of *Ensis* might be contributable to this. In Ireland pulsed DC systems have been successfully used in catching *Ensis*. The tracks are not expected to be caused by iron oxide from the electrodes using AC systems.

Figure 13. Various devices used in the Scottish *Ensis* fishery.

5 ToR b) Evaluate the effect of a wide introduction of electric fishing, with respect to the economic impact, the ecosystem impact, the energy consumption and the population dynamics of selected species)

5.1 Extension of study LOT3 with new scenarios – effect of introducing pulse trawling in North Sea fisheries on discarding of five major fish species (Bob van Marlen)

The work presented is a follow-up from the EU-tender project FISH 2007/07 LOT3 "Flatnose", with participants from: BE, NL, DK, UK. The subject of this project was the impact of sole and plaice gears in the North Sea. Various scenarios of gear replacements were evaluated e.g. the replacement of pulse trawling for tickler chain beam trawling in the fleet segments with a vessel length of 24–40m, and larger than 40m.

A model produced by Piet *et al.*, 2009 was run in "R" for different scenarios of pulse trawl use and assumptions on gear efficiencies based on recent data collected from the catch comparison of 2011. The model predicted a decrease in discards of cod, haddock, sole, plaice and whiting (under the given assumptions).

Scenario 2d featured:

- New mean catch efficiencies found in week 19, 2011, i.e.:
    - PLE > MLS: 1.0 → 0.71
    - PLE < MLS: 1.0 → 0.50
    - SOL < MLS: 1.0 → 0.50
    - SOL > MLS: 1.0 → 0.85
    - WHG & COD (roundF): 1.0 → 0.30
- Towing speed in pulse trawls reduced from 6.5 to 5.0 kts

The results in terms of percentages discard reduction were:

Species	% LAN TBB	% DIS TBB
COD	-30.2	-39.4
HAD	-51.0	-47.6
PLE	-22.9	-45.4
SOL	-20.5	-38.9
WHG	-62.1	-61.8

In which TBB = Beam trawls,

And:

Species	% LAN All	% DIS All
COD	-11.2	-28.1
HAD	-8.1	-6.5
PLE	-16.3	-39.3
SOL	-16.8	-34.8
WHG	-38.5	-54.8

Where “All” stands for all fishing gears under study, i.e. beam trawls, otter trawls and static gear.

Scenario 2e featured:

- Increase SOL catch efficiencies found in week 19, 2011, but keep PLE efficiencies, i.e.:
    - PLE > MLS: 1.0 → 0.71
    - PLE < MLS: 1.0 → 0.50
    - SOL < MLS: 1.0 → 0.70
    - SOL > MLS: 1.0 → 1.0
    - WHG & COD (roundF): 1.0 → 0.30
- Towing speed in pulse trawls reduced from 6.5 to 5.0 kts

This scenario gave:

Species	% LAN TBB	% DIS TBB
COD	-30.2	-39.4
HAD	-51.0	-47.6
PLE	-22.9	-45.4
SOL	-8.6	-26.6
WHG	-62.1	-61.8

And

Species	% LAN All	% DIS All
COD	-11.2	-28.1
HAD	-8.1	-6.5
PLE	-16.3	-39.3
SOL	-7.0	-23.9
WHG	-38.5	-54.8

The conclusions of this study are:

- Pulse trawling has a potential for a substantial discard reduction in major target species
- The model should be extended to benthic species and should be improved
- The results can be brought into the debate with the EU
- Despite some pitfalls (cod damage) pulse trawling is a good alternative for tickler chain beam trawling at present.

6 ToR c) Consider whether limits can be set on these characteristics to avoid unwanted effects (e.g. unwanted and uncontrolled growth on catch efficiency, unwanted ecosystem effects) once such systems are allowed and used at wider scale.

6.1 Discussions in the Netherlands Control & Enforcement Group and draft Procedure for Control and Enforcement (Bob van Marlen)

Recently IMARES started a project for the Dutch Ministry EL&I to prepare a document on Control and Enforcement of Pulse trawling. A draft procedure document was drafted and discussed within the project group, which consisted of representatives of the fishing industry, the pulse trawl producers, the policy-makers, the scientists, and control agencies. This was reviewed by staff of the Ministry and rewritten. The draft was translated into English by Bob van Marlen and presented at SGELECTRA for further consideration. Then a new draft was made, presented in Annex 6.

The concept-paper was also presented to the fishers and resulted in heavy debates (especially to limit maximum energy sent down to the gear and the ban of additional tickler chains).

Discussion

SGELECTRA discussed the draft of the Pulse Fishing Control And Enforcement Group, and raised the following comments:

- Is the limit of 1.0 KW/m not too high, as the current systems use less?
- The measurement of field strength should take into account the pulse type and shape and therefore the sampling rate should also be specified (see Nyquist–Shannon sampling theorem), see also the Annex 7.
- There was a thorough discussion of the paragraph on whether or not to allow tickler chains.
- The tickler chains itself have a tickler effect. The Dutch conducted an experiment in the past and found that tickler chains in tow-direction have a stronger tickler effect. Additionally, the design of the electrodes for flatfish systems could result in an increased tickler effect (electrodes with many slubs, or thicker parts).
- The length of electrodes in the HFK-system was questioned. Could the side effects be reduced by reducing the length of electrodes?
- The minimum length needed of the electrodes can be determined by measuring the reaction time of sole and relate this to the towing speed of the vessel.
- There was also a discussion on the need of strain relief-chains and on whether they touch the bottom, and how large should plastic discs be to protect the electrodes.
- Concerns were expressed that the pressure in The Netherlands to allow the pulse trawls seems high. The group acknowledges that they may not possess the information needed on how to set safe limits (yet).
- The group recommend engaging international experts (such as SGELECTRA) in those discussions in The Netherlands. Some group members stated that the high pressure from The Netherlands should not lead to a

general permission to use pulse-fishing in EU-waters until more knowledge is available and rules are set.

The text as adapted accordingly by Phil Copland, and is given in Annex 3.

6.2 Presentation and discussion on the STECF report on Pulse Trawling April 2012 (Bob van Marlen)

A recent report came out from STECF in which pulse trawling was addressed. Some of the most striking sentences were shown by Bob van Marlen and discussed.

Reactions to STECF report April 2012:

"Although cod catches were low, the evidence from these trials does not support previously expressed concerns that the cod catchability may be higher in pulse beam trawls than with the traditional beam trawl which was demonstrated in earlier work undertaken on research vessels."

It was commented that the Dutch work suggests the opposite!

"It is unclear whether some of these fish are fatally exposed in the process (avoidance mortality) and if so what proportion are killed in this way. It should also be noted that low levels of cod catches encountered in the catch comparison trials. The statistical comparison of cod catches is not wholly persuasive that the differences observed are significant. It is recognized that field experiments are always problematic when a species of interest are caught at low levels, however further comparative data on cod catches would help to provide more clarity on this particular concern raised by ICES in 2009."

It was acknowledged that more data need be collected. In beam trawls cod catches are usually low.

"This research effort is to be commended and this shows that with the exception of the vertebral damage, many of the concerns relating to benthic organisms and elasmobranchs have been addressed for the systems under current investigation. However, the range of pulse characteristics tested in recent experiments is limited to the output range of the commercial systems under development. It is noted that different manufacturers of pulse trawls are already developing systems with different pulse fields, with potentially differing effects in the field. Even within the existing regulatory boundaries, it is possible that alternative pulse trawls (with different and untested pulse fields – possibly damaging) subsequently could emerge and be used in the fisheries yet conforming to existing legislative boundaries."

SGELECTRA stated that limits should be set to avoid this.

"A multivariate analysis of the data presented by de Haan et al. (2011) may be useful and provide further insight into the specific pulse characteristics that require limitation. However, while de Haan et al. (2011) demonstrates the potential to define pulse characteristics which limit the extent of vertebral damage, it is not possible to contrast the results from the aquarium experiments directly with the system tested in the field (van Marlen et al., (2011) as the pulse characteristics used during the field experiments were not evaluated during the aquarium experiments."

The comment was made that reference measurements were made to show that the *in situ* cases were simulated to satisfaction. This was indeed the case.

"Without a clear documented understanding of which particular attributes of a pulse trawl field are environmentally harmful, which are not and also where thresholds lay, it is difficult to envisage how legislation which defines technical specifics to control and enforce pulse trawl technology could be formulated. This difficulty would potentially become further compounded

as more manufacturers develop their own unique designs of pulse trawl. For instance, equipment which can generate adjustable pulse fields may be potentially problematic and harmful; particularly where harmful thresholds have not been properly identified."

Systematically testing all variables of pulse characteristics on all relevant species would be very time-consuming and expensive. It might be a better idea to freeze the current technology to ensure that more harmful effects may not result. The producers declared in the Dutch Control and Enforcement Group that they can work with a specification lower than in the current derogation, *i.e.* 1 kW/m electrical power (whereas this limit seems to be rather high, since all current systems use much less energy).

"Pulse trawl technology appears to have many potential positive benefits if used in a responsible manner. The technology and its future face the risk of reputational damage and widespread opposition if environmentally harmful designs reach market. Effective legislation and enforcement of this technology will be critical in this respect."

It was recognized that there is also a risk of letting conventional proven harmful tickler chain beam trawling continue and shifting a promising alternative on the side!

"Earlier experiments demonstrated significantly higher catch rates of target species, in some cases catches increased by over 50% in comparison to conventional tickler beam trawls. The results from these experiments show that the changes in efficiency (either positive or negative) are species and in some cases size dependent. In many cases, the systems tested on commercial beam trawlers used high power pulse generators some of which were delivering up to 2000V. More recent (post 2000) work undertaken using reduced power (<100V) on both commercial and research vessels showed comparable sole catches, but reduced plaice catches."

It was remarked that many of the earlier systems (developed in The Netherlands in the 1980s) were heavily powered, and the existing systems went back in power considerably. Also those experiments on FRVs suffer from non-optimal towing speeds for either the pulse or the conventional gear. The catch comparison of 2011 provided the most up-to-date values.

"From the spatial and temporal data presented the experiments were not conducted using the parallel haul technique (Anon, 1996), but fished independently of the other vessels in approximately the same area and time. This approach is sufficient to provide a broad overview of the likely gross effects at a trip or fleet level, but insufficient to provide adequate length dependent differences between the three systems."

With different towing speeds a full parallel haul technique is simply not possible! It was tried to keep the three vessels together as most as possible. More data are of course welcomed.

"However, there appears to be some disagreement between the LPUE estimates derived from landings and raised trip cpue data and with the modelled cpue estimates derived from sampled data. It is unclear why or indeed how these differences occur, particularly contrasting the raised and sampled only estimates, but the authors note that sampling levels did not produce reliable results in all cases, particularly for more rarely caught species such as turbot and brill. Therefore care should be taken not to over interpret the results shown in tables 6.3 and 6.4. For example, using the LPUE estimate from the auction data (table 6.3), plaice landings associated with the pulse system are ~70% that of the conventional vessel, whereas the modelled estimates (table 6.4) indicate that plaice LPUE of the pulse trawl is 45% that of the conventional vessel. It is not possible to reconcile these differences."

It was recognized that sampling has its limitations. The Dutch researchers stated that auction data is usually concerning landings quite reliable, and discards were sampled to a much larger extent than landings. New analyses carried out on the catch comparison data recently confirmed the trend of lower landings, also taken by unit of area fished. Also here more data is of course welcomed.

"Due to the uncertainties in the length estimates (and lack of numerical data) and the somewhat variable results presented in tables 6.4–6.6, it is no possible to provide a forecast as to the likely impact that the wider introduction that such systems would have on stock development."

The Dutch researchers have made a plea for more data and larger samples! The study with the Model of Piet *et al.*, 2009 shows potential in reducing discards in five major target species in the North Sea.

"Second, the systems presented offer an alternative stimulus method for beam trawls fitted with tickler chains, normally deployed on finer substrate and are not proposed as an alternative to the chain mat matrix used in rougher substrate. It is unclear what degree of uptake could be expected or how much transfer would occur between chain mat beam trawls to tickler chains."

It was commented that fishers in the Southern parts of The Netherlands showed interest and some step over into pulse trawling with a modified Pulse Wing. More data are needed from this group.

"However, given the levels of reductions in both landings and discards, it can be concluded that the impacts would be positive in reducing the fishing mortality associated with the tickler beam trawl fleet, provided the introduction of the system does not introduce higher levels of avoidance (unaccounted) mortality."

As stated before, the model results of Piet *et al.*, 2009 in various scenarios underline the potential for discard reduction.

"Lindeboom and de Groot (1998) estimate that for a 12m beam trawl, fitted with tickler chains, the catch efficiency for invertebrates is less than 10% and for almost half the species encountered much less than 5%. Despite this, the catch of invertebrates can be several times larger than the catch of target species. It is unclear what the level of avoidance mortality is associated with the conventional tickler beam trawls but it would be fair to assume that the removal of the tickler chains and replacement with a pulse system will have significant and positive effect, first in terms of reducing the catch of non-target benthos and also in terms of the likely reduction in avoidance mortality."

The effect of avoidance mortality was questioned, as many of these species are not very mobile. The trials in project REDUCE in 2000 showed a lower direct mortality in the 7m (Verburg-DELMECO) variant of 15 taxa of benthos, the median went down from 36% to 24% ($p = 0.09$). There is reason to believe this might be lower in the 12m gears especially because electrode spacing has been increased!

"It is evident that in its current form, the existing EU derogation allows a range of pulse equipment to be developed for testing under normal fishing conditions. However, the absence of control on other pulse characteristics means that it is possible to deploy electric fishing techniques with negative ecological consequences within the specification in the current derogation. Yu et al. (2007) notes that the ability of operators to increase the power output and improper setting of pulse characteristics resulted is injury to both shrimp and other marine life in the eastern China Sea. The authors further note that the desire to increase catching

efficiency of the pulse system effectively let to a system that developed to a killing apparatus rather than the intended stimulus device."

This is in line with the findings of SGELECTRA reported in 2011, and the Dutch are currently exploring a proper Control and Enforcement Procedure. The Chinese case provides a warning, but in our setting there are many other limits to uncontrolled growth in capture efficiency, *i.e.* the TACs, DAS, gear restrictions, etc..

´It is necessary to expand the current understanding of electric trawling in general with the aim to determine further and appropriate threshold levels. However, it may be necessary to maintain broad regulatory limits so as to allow engineers to develop and optimize their pulse trawl designs. Due to the potential benefits of reduced fuel consumption, swept are and reduced catch rates while maintaining profit levels, there is a need to facilitate technical advancement in the field of pulse trawl technology while avoiding unnecessarily complex and potentially stifling technical legislation, while simultaneously servicing conservation, environmental and fisheries management requirements. This need becomes more acute as industry demand for such technology exceeds the current EU 5% limitations (as has become the case now). Future developments should continue to undertake extensive ecological impact assessments. As requests to expand the user base of the pulse trawl technology beyond the current 5% derogation limit are considered, new legislation will need to be drafted."

It was welcomed that the report also recognized that the pulse technique has many positive effects. From a conservation point of view no fishing at all would perhaps be the best, but we need to produce food as well! The work will be continued in EU-project BENTHIS.

"Even with a broader understanding of all pulse characteristics, it will be difficult to define effective and detailed technical legislation needed to ensure safe and responsible environmental practice. Such prescriptive legislation will need to encapsulate all the critical technical parameters, thresholds, pulse fields parameters and equipment specifications for a range of pulse trawls. Such legislation will be technically very complex and will require a matrix of pulse characteristics benchmarked against a range of specified ecological indicators. Defining appropriate thresholds will require extensive field and laboratory testing to explore and quantify the impacts of the critical pulse characteristics and selection threshold boundaries."

SGELECTRA acknowledges this view. Knowing all what need to be known may take another many years of study and considerable funding.

"It may be more appropriate to identify whether a specific gear with fully documented pulse characteristics and output range is tested against a range of agreed criteria and if successful, the gear becomes an 'approved design' and allowing the full use of these systems outside the 5% effort restriction. To obtain such approval the manufacturers must provide the appropriate authority with a credible & robust environmental impact assessment (EIA) on their technology. This reverses the burden of proof onto the manufacturers and encourages the development of electric pulse systems that operate within safe ecological boundaries."

One may wonder whether producers really have got the expertise, time and money needed to carry out such an assessment especially in the difficult economic times of the present.

"This should include a clear identification of the technical parameters of the pulse fields which are generated and the identification of where the potential harmful effects can be generated and where thresholds for harm lay."

The Dutch researchers asked for technical data from 1998, got it only completely since 2006, and can use in the debate since 2009.

"There are also a number of control issues that need to be adequately addressed. This should include provisions to prevent tampering of the technology to produce or alteration harmful pulse effects and tamper proof recording systems that can be used to determine if the pulse characteristics being generated match those demonstrated in field and aquarium experiments."

The idea of a 'type certification' scheme was brought up. Also it is intended to add field strength measurements in case of doubt.

7 Conclusions and recommendations

The group felt that given the list of ongoing research and development in various nations, SGELECTRA should be continued. As results can be expected towards the end of next year (*e.g.* results of German Hovercran trials, half-time results of Belgium PhD-studies), it is proposed to meet in autumn 2013. Work will be continued on the topics given in Annex 3.

Discussion

In the discussion the following items were mentioned:

- It was acknowledged that as a result of the studies for ICES more information on the effects is now available than 6 years ago, *e.g.* real numbers on damages in cod in the catches, also dependence of damages on size classes, the effect on sharks, and invertebrates.
- It should also be kept in mind that the conventional beam trawl has a bad reputation, and even in the industry voices are expressed that it has no long-time future.
- The pros and cons of each system should be balanced. It is also necessary to separate the different pulse-systems in discussions and public awareness, since all systems have significant differences (also in potential positive and negative effects).
- The need was expressed for further long-term investigations.
- It should also be noted that we might never be able to clear out all doubts!
- There are a number of advantages of pulse trawling, but also still problematic issues. The views of SGELECTRA on pulse trawling are still under development.

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Annex 2: Terms of Reference (ToRs) 2011 (for meeting in 2012)

2011/2/SSGESST06 The **Study Group on Electrical Trawling** (SGELECTRA), chaired by Bob van Marlen, the Netherlands and Bart Verschueren, Belgium, will meet in Lorient, France, 21–22 April 2012 to:

a) Improve knowledge of the effects of Electrical Fishing on the marine environment (reduction of bycatch, impact on bottom habitat, impact on marine fauna, energy saving and climate related issues), in view of current technical developments on electrical fishing and emphasis on the relationship of pulse characteristics (power, voltage, pulse shape) and thresholds in terms of effects on fish and other organisms (mortality, injury, behavioural changes);

b) Evaluate the effect of a wide introduction of electric fishing, with respect to the economic impact, the ecosystem impact, the energy consumption and the population dynamics of selected species;

c) Consider whether limits can be set on these characteristics to avoid unwanted effects (e.g. unwanted and uncontrolled growth on catch efficiency, unwanted ecosystem effects) once such systems are allowed and used at wider scale.

SGELECTRA will report by 30 June 2012 (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 ecosystem effects of fisheries, especially with regard to the application of the Precautionary Approach. Consequently, these activities are considered to have a very high priority.
Scientific justification	Term of Reference The use of electricity in fishing is currently banned in EU regulations due to concerns on the impact and efficiency. Several countries, however, notably the Netherlands and Belgium have been testing the potential for electrical pulse trawl systems to replace conventional beam trawls, which are classified as having high environmental impacts. Such systems are currently being tested under derogation on commercial vessels and the results of the Dutch trials have been reviewed by ICES and STECF. A number of 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. There is a lack of data on the response thresholds for various species and length classes, describing the power limits for survival and reproduction of fish. Pulse trawling is currently being developed for other species than flatfish i.e. brown shrimp (Crangon crangon L.). Consequently a growing number of (European) fishing vessels is potentially involved, with a considerable value in terms of landings. There is a need for clearer identification of workable and enforceable limits in defining regulation than the two (power per unit of length and maximum voltage) currently in use in the present EU-derogation for use of electrical fishing in The Netherlands, that will aid to a sustainable development of electric fishing. There is interest in fishing with electrical stimuli on other

	species, e.g. Atlantic razor clams (Ensis directus L.).
Resource requirements	The research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants	The Study Group will be attended by some 10–12 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	This work is of direct relevance to the Working Group of Fishing Technology and Fish Behaviour, WGCRAN, WGECO and WGNSSK.
Linkages to other organizations	There is a very close working relationship with all groups of SSGESST.

Annex 3: Agenda

Saturday 21/04/2012

09:30	Welcome and opening
09:30–09:45	Short intro of participants
09:45–12:30	Presentations and discussions TOR a)
	Report on catch comparison and reference measurements 2011 (Bob van Marlen)
13:00–14:30	*Lunch break*
14:30–18:00	Presentations and discussions TOR a)
	Report on catch comparison and reference measurements 2011 (Bob van Marlen)
	Presentations and discussions TOR b)
	Extension of study LOT3 with new scenarios – effect of introducing pulse trawling in North Sea fisheries on discarding of five major fish species (Bob van Marlen)
	Presentations and discussions TOR c)
	Discussions in the Netherlands Control & Enforcement Group and draft Procedure for Control and Enforcement (Bob van Marlen)

Sunday 21/04/2012

09:00–12:30	Presentations and discussions TOR a)
	Report on further development of the "Hovercran" (Maarten Soetaert)
	A short introduction to the German "Hovercran" project (Daniel Stepputtis)
	Work on effects of electric fishing on various marine organisms (Marieke Desender and Maarten Soetaert)
	Electrical fishing for Ensis – Description of equipment development and trial results (Phil Copland).
13:30–14:30	*Lunch break*
14:30–18:00	Presentations and discussions TOR c)
	Discussions in the Netherlands Control & Enforcement Group and draft Procedure for Control and Enforcement (Bob van Marlen)
	Discussion of the report recommendations for further work en new TORs

Annex 4: Recommendations

- This section contains a summary of recommendations.

Recommendation	Addressed to
1. Carry out further analysis of the catch comparison data of May 2011, and prognosis of effects on major target species using the Piet *et al*., 2009 model.	IMARES
2. Investigate the effect of pulses on the electro-receptor organs of elasmobranchs (catshark and thornback ray), and determine the catch rates of these fish in beam trawls using the Hovercran pulse	ILVO & UGent
3. Report on the trials on the Hovercran developed in the Dutch fleet.	IMARES & ILVO
4. Investigate the effect of the electrical stimulation on eggs, larvae and juveniles of sandworm, shrimp, cod and sole, using the Hovercran and the flatfish type of pulse.	ILVO & UGent, IMARES
5. Carry out research on pulse suitable to generate the startle response in sole.	ILVO & UGent
6. Investigate aspects of control and enforcement and develop acceptable limits to be set in any future regulation, and consider a wider coverage in Europe, e.g. participation by UK, France, and Germany.	IMARES & ILVO researches in collaboration with fisheries managers
7. Harmonize sampling and data collection methods.	IMARES, ILVO, VTI
8. Trials and data collection and analyses on the Hovercran type of Crangon pulse gears.	VTI
9. Continue monitoring catches onboard commercial pulse trawl vessels in 2012.	IMARES
10. Further consider the development of Ensis fishery in the UK. IMARES & ILVO researchers in collaboration with fisheries managers	MSS, SEAFISH?

Annex 5: Proposed ToRs for 2013

The **Study Group on Electrical Trawling** (SGELECTRA), chaired by Bob van Marlen, the Netherlands and Bart Verschueren, Belgium, will meet in October 2013, at a venue still to be decided to:

a) Improve knowledge of the effects of Electrical Fishing on the marine environment (reduction of bycatch, impact on bottom habitat, impact on marine fauna, energy saving and climate related issues), in view of current technical developments and recent studies carried out in The Netherlands, Belgium and Germany on electrical fishing and emphasis on the relationship of pulse characteristics (power, voltage, pulse shape) and thresholds in terms of effects on fish and other organisms, also in the egg, larval and juvenile stages (mortality, injury, behavioural changes);

b) Further evaluate the effect of a wide introduction of electric fishing, with respect to the economic impact, the ecosystem impact, the energy consumption and the population dynamics of selected species;

c) Consider the current activities to ensure a proper control and enforcement procedure with limits set on pulse characteristics to avoid unwanted effects (e.g. unwanted and uncontrolled growth on catch efficiency, unwanted ecosystem effects) once such systems are allowed and used at wider scale.

SGELECTRA will report by 30 June 2014 (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 ecosystem effects of fisheries, especially with regard to the application of the Precautionary Approach. Consequently, these activities are considered to have a very high priority.
Scientific justification	Term of Reference The use of electricity in fishing is currently banned in EU regulations due to concerns on the impact and efficiency. Several countries, however, notably the Netherlands and Belgium, and in the near future also Germany are involved in testing the potential for electrical pulse trawl systems to replace conventional beam trawls, which are classified as having high environmental impacts. Such systems are currently being tested under derogation on commercial vessels and the results of the Dutch trials have been reviewed by ICES and STECF. A number of this involves substantial investments that are stimulated by the Dutch Ministry EL&I. 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, and STECF in 2012. There is a lack of data on the response thresholds for various species and length classes, describing the power limits for survival and reproduction of fish. Pulse trawling is currently being developed for other species than flatfish i.e. brown shrimp (Crangon crangon L.). Consequently a growing number of (European) fishing vessels is involved, with a considerable value in terms of landings. There is a need for clearer identification of workable and enforceable limits in defining regulation than the two (power per unit of length and maximum voltage) currently in use in the present EU-derogation for use of electrical fishing in The Netherlands, that will aid to a sustainable development of

	electric fishing. There is interest in fishing with electrical stimuli on other species, e.g. Atlantic razor clams (Ensis directus L.) in the UK.
Resource requirements	The research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants	The Study Group will be attended by some 10–12 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	This work is of direct relevance to the Working Group of Fishing Technology and Fish Behaviour, WGCRAN, WGECO and WGNSSK.
Linkages to other organizations	There is a very close working relationship with all groups of SSGESST.

Annex 6: Procedure Control and Enforcement in Pulse Fishery – Draft EN 2 – April 2012

Objectives

The objectives of this document are:

1) To ensure that work on-board fishing vessels with pulse trawl systems is safe for the operators.

2) To ensure that using pulse trawl systems meet requirements of ecosystem sustainability. Although such requirements are not yet formally defined, elements should include:

   a) Maintaining catches within international regulations (TACs).

   b) Reduction of fish and benthos discards to agreed levels.

   c) Reduction of impact on marine habitats.

   d) Avoidance of any unforeseen hazard on the marine ecosystem (e.g. spinal damage in cod).

Advice

Definition of documents.

Type manual. This document is issued by the system manufacturer on delivery of system. It describes in detail the pulse system in terms of physical components and electrical performance. The document also describes the protocol for measuring the physical dimensions and electrical performance which are the basis for issuing of the type approval certificate.

Type approval certificate. This will be issued by a certifying agency and will confirm that the pulse system, as inspected on the vessel, meets the physical and performance criteria as described in the type manual.

Concerning legislation

Fishing with electrical pulse beam trawls is allowed under the following conditions:

1) A pulsating electrical field may be generated on, at maximum, two towed fishing gears on any vessel. Energy transfer is by use of an array of electrodes towed parallel with the direction of fishing. An electrode may consist of a linear combination of electrically isolated connecting parts and conductors. An electrode and isolating connectors are defined as cylinders of diameter and material as specified in the type manual.

2) Fishing with pulse trawls is permitted in the North Sea, Skagerrak and Kattegat, the British Channel, Irish Sea and Bay of Biscay (ICES areas IV, ……)

3) A type approval certificate is required for each system. The certificate is to be issued by an accredited certifying agency. The certificate should describe the components and performance of the system in detail including:

   a) A unique description of each pulse system as identified in the type manual (e.g. DELMECO pulse trawl, type X; HFK Pulse Wing, type Y).

b) Type manual information must define physical and performance parameters of the pulse trawl.

c) System parameters to include: product name, serial numbers and type of data storage medium monitoring the electrical output of the system.

d) Physical parameters. To include number, length, conductor and connector diameters and materials. Electrode spacing must also be specified. In addition the quantity and identifying type numbers of pulse modules, where applicable.

e) Performance. To include pulse shape, amplitude and frequency, power output and field strength as defined below.

f) The field strength is to be defined as: The measurement of the potential difference between adjacent electrodes divided by the electrode spacing in meters. Voltage measurements are to me made as described in the type manual with gear hanging in seawater. Salinity and temperature must be measured in situ and used in calculation of field strength. NB if electrode spacing's are to be asymmetrical then this must be defined specifically in the type manual with spacing and individual field strength values included for each electrode pair.

g) The type manual must define the protocol to allow the annual safety and performance certification to be carried out as required in 4 below.

4) Safety protocols. Within the type manual the manufacturer should provide a safety inspection protocol for the system. This must detail recommended inspection procedure at daily, monthly and annual intervals as appropriate. It should include a description of the safe handling procedure for system use. A certifying safety and performance inspection of the pulse gear system is to be carried out annually as per the type manual and a type approval certificate issued. A current type approval certificate must be available for inspection on the vessel during fishing operations by compliance agency personnel when the pulse trawl is on board. A copy of the type approval certificate must be lodged with the relevant compliance agency by the certifying agency before fishing operations may commence.

5) The electrical power, as measured at the generator output, before feeding through cables of any single pulse gear may not exceed 1.0 kW (instead of the former 1.25 kW) per meter of beam length or width of the electrode array as detailed in the type manual.

6) The width of the electrode array is to be defined as the horizontal distance between first and last electrodes. This may not exceed the width of the beam trawl and should not exceed 12 meters

7) The electrical power, at the generator output, must by logged automatically and continuously and the records stored in a secure medium. Access to this data logger should be available only to authorized compliance and certification persons. Adequate storage capacity for previous 3 months data must be available. Data records should include input from navigation system of date, time and position. In addition electrical power information is to be collected from the output of each pulse generator control unit on the vessel. Recordings should be made at 1 minute intervals.

8) Apart from active electrodes, the addition of tickler chains, net ticklers or any other device contacting the seabed which could provide mechanical stimulation, whether perpendicular or parallel with the direction of motion of the fishing gear, is prohibited.

9) One cross chain or other weight attached on the electrodes in front of the first conductors, aimed at forcing the electrodes to the seabed is allowed as an exception to 8 above. The weight of the cross chain should not exceed xx kg/m (still to be decided). Chain length may not differ from the certified array width by more than 10%.

Explanation of section 3:

The certificate can be issued by an accredited certifier, such as a Classification Bureau or Agency. This is sometimes called "Third-party certification" and involves an independent assessment declaring that specified requirements pertaining to a product, person, process, or management system have been met. When a producer offers a standardized system, a type-certificate might be sufficient. This would be a "first-party certification", for which an individual or organization providing the good or service offers assurance that it meets certain claims. An intermediate form is the "second-party certification", an association to which the individual, manufacturer or user i.e. fishermen's or manufacturers trade organization provides the assurance (source: http://en.wikipedia.org/wiki/Certification).

Concerning inspection and control

Inspection activities are to be distinguished at three levels:

Level 1: To be carried out by compliance staff. Routine inspections aimed at checking physical characteristics such as: beam length, availability of a certificate, array width, dimensions of electrodes and conductors and integrity of data storage medium. This level does not require electro-technical expertise.

Level 2: To be carried out by compliance staff or authorized personnel. Accessing and reading data from the data storage medium as a routine inspection. This need not include a physical inspection of the whole system but should note if the integrity of the secure data storage medium is suspected to have been compromised.

Level 3: To be carried out by certifying agency. Conducting a field strength measurement and power output check at sea if Level 1 and Level 2 inspections call for further inspection. These measurements are to be carried out as per the protocol defined in the type manual for the system and will require electro-technical expertise.

Concerning enforcement and sanctioning

Modification of the pulse system will be regarded as a breach of the certifying regulations.

Concerning implementation

At any adaption of the regulations pulse fishers should comply as per date of change.

Meeting the new rules may call for investments and adaptations in the existing pulse systems for the fishers already working under the current derogation, possibly linked to type-certification.

One may opt for a transition period during which existing pulse systems can be depreciated and gradually adapted to the new rules. Such a period might be restricted at 6 to 12 months.

Annex 7: Physical background of electricity (Bob van Marlen)

Electric currents occur by the flow of electrically charged subatomic particles, *e.g.* electrons through a conductor such as a metal or charged ions through a liquid (electrolysis). Ohm's Law states that V = I x R, with electric potential V in Volt, current I in Amperes and resistance R in Ohms. There are many types of currents: constant and fluctuating over time. Basic types DC (Direct Current, the unidirectional flow from the positive part of a circuit to the negative), and AC (Alternating Current, *i.e.* any current that reverses direction repeatedly). These and mixed characteristics are given in Figure 1, while basic pulse shapes used in electric fishing can be found in Figure A7.1.

Electric fields are generated between charged particles and exert forces on any other particle in the space that surrounds them. These fields extend towards infinity and their strength shows an inverse square relationship with distance. Contrary to gravitation, electric fields can result in either attraction or repulsion depending on whether particles have a positive or negative charge. A positive charge occurs when there is a shortage of electrons, a negative charge when there is a surplus of electrons. Any charge in an electric field feels a force working on it, and as forces have both magnitude and direction, these fields are vector fields. When moving a charged particle through an electric fieldwork has to be done against the force exerted by the electric field. The energy or electric potential (work per unit of time, measured in Volts) required to move a unit charge between two specified points is irrespective of the path between these particles. Electric potential is thus a scalar quantity.

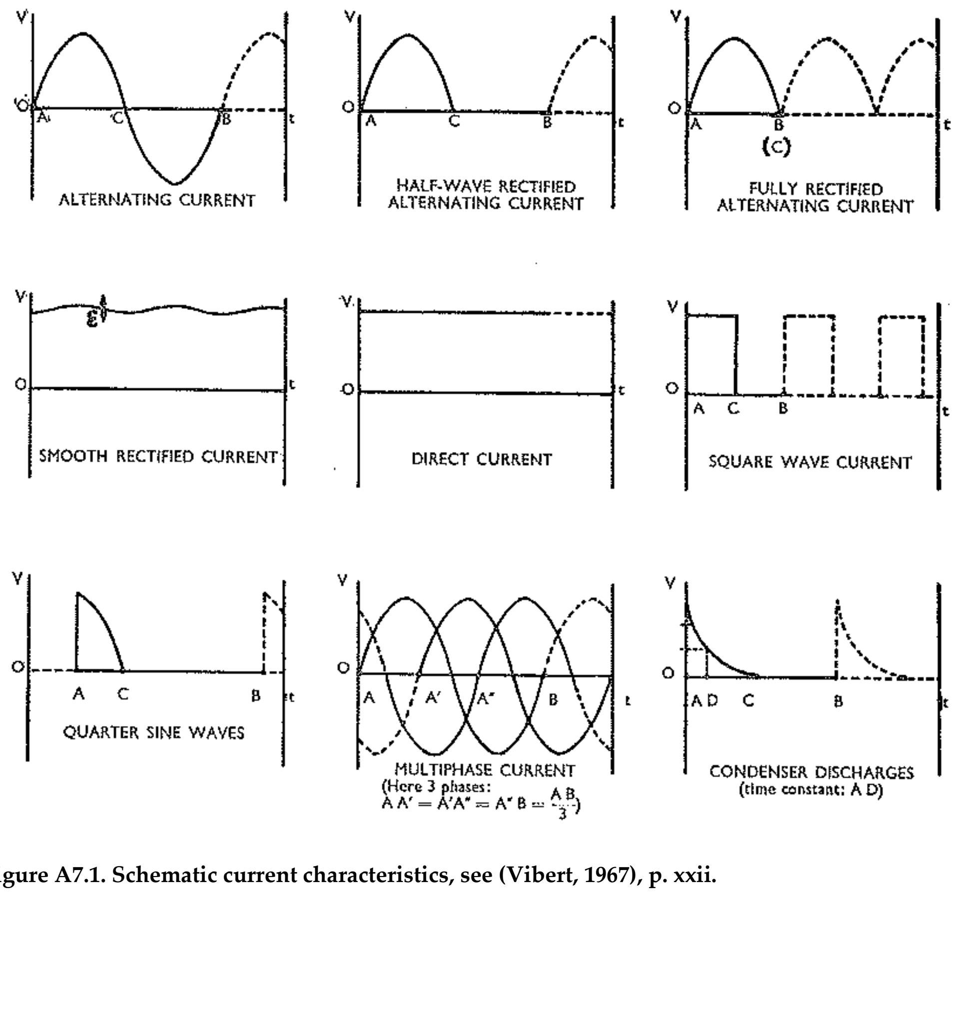

Figure A7.1. Schematic current characteristics, see (Vibert, 1967), p. xxii.

An electrical field is a vector field with SI units of Newton per coulomb ($N.C^{-1}$) or, equivalently, volts per meter ($V.m^{-1}$). The coulomb (symbol: C) is the SI derived unit of electric charge. It is defined as the charge transported by a steady current of one ampere in one second, thus 1C = 1A*1s. The SI base units of the electric field are $kg.m.s^{-3}.A^{-1}$. The strength or magnitude of the field at a given point is defined as the force that would be exerted on a positive test charge of 1 coulomb placed at that point; the direction of the field is given by the direction of that force. Electric fields contain electrical energy with energy density proportional to the square of the field amplitude. The electric field is to charge as gravitational acceleration is to mass and force density is to volume (see http://en.wikipedia.org/wiki/Electric_field).

The RMS for a function f(t) over all time is

(see: http://en.wikipedia.org/wiki/Root_mean_square):

$$f_{\mathrm{rms}} = \lim_{T\to\infty} \sqrt{\frac{1}{T}\int_0^T [f(t)]^2\,dt}.$$

Below RMS-values are given for some wave forms (see also Figure A7.2):

Waveform	Equation	RMS
DC, constant	$y = a$	a
Sine wave	$y = a\sin(2\pi f t)$	$\frac{a}{\sqrt{2}}$
Square wave	$y = \begin{cases} a & \{ft\} < 0.5 \\ -a & \{ft\} > 0.5 \end{cases}$	a

A numerical example is given here. Assume one uses pulses at 10 Hz (= 10 pulses per second) with pulsewidth of 0.5 ms and a field strength of 200 V/m. This would result in an RMS field strength of $10s^{-1}$ * 0.0005s * 200V/m = 1 V/m.

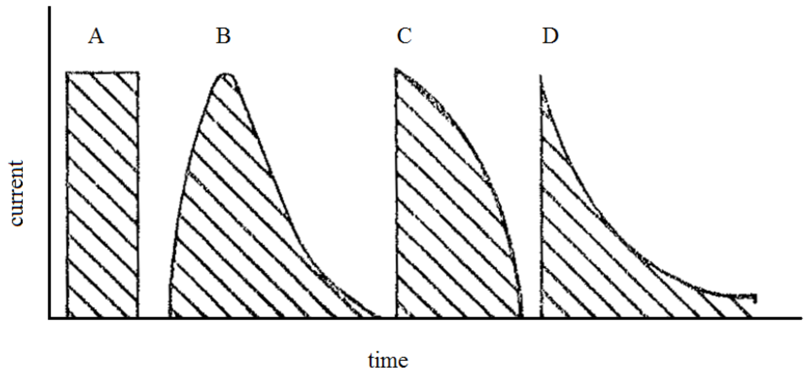

Figure A7.2. Principle type of pulses used in electric fishing, see (Vibert, 1967), p. 61.