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22–24 October 2013

Ostend, Belgium

International Council for the Exploration of the Sea

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Executive summary

The Study Group on Electrical Trawling (SGELECTRA), chaired by Bob van Marlen, the Netherlands and Bart Verschueren, Belgium, met in Ostend, Belgium, 22–24 October 2013. A total of 10 participants attended from Netherlands, Belgium, Germany, Scotland, and France.

The meeting began with a short review on the history of research of pulse trawling (on flatfish), and the ICES Advice on Pulse Trawling on flatfish of 2006 and 2009, and the following tank experiments carried out by IMARES.

Further data analyses by IMARES, IJmuiden, The Netherlands, were presented and discussed, on the catch comparison of May 2011 on the two pulse trawl vessels TX36 and TX68 and the conventional tickler chain beam trawl vessel GO4, and new reference measurements of field strength *in situ* in 2013 on the TH7.

An updated presentation was also given about the development of the pulse trawl 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 Marelec-Crangon-pulse-beam-trawl in Germany on a commercial boat has recently finished the practical phase.

In addition, an update was given on the razor clam (*Ensis*) fishery in Scotland in which electrical stimulation is used.

The documents produced by the Netherlands Control and Enforcement Group and draft Procedure for Control and Enforcement were presented and discussed.

The reviewing experts concluded that:

SGELECTRA recommended continuing work with Terms of Reference given in Annex 5.

1 Opening of the meeting

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

Then members shortly introduced one another:

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 Thuenen-Institute of Baltic Sea Fisheries, and is head of the Technology Group since 2009. Work topics are Baltic Sea fisheries and shrimp trawls, now also involved in Crangon-pulse-fishery evaluation in Germany. MFV SD-33 was fitted out with the Marelec system. The practical phase of the project was from June 2012 to August 2013.

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 fishermen 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, where he plays a key role in development and test of pulse fishery system targeting Crangon.

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.

Dick de Haan started to work at RIVO (now IMARES) in 1973, with expertise on remote sensing/data acquisition techniques, underwater gear observation robotics, the effects of pulse fishing to marine fauna and remote sensing and data acquisition techniques. Contributed to reduction of bycatch of mega fauna in the pelagic fisheries; development of a Large Animal reduction Device (LARD); the effects of pingers on fish and marine mammals; Bio-sonar studies on harbour porpoises and bottlenose dolphins. Auditory studies on harbour porpoises, harbour seals, walrus and lion seals. At present underwater acoustic noise of wind farm construction and operation.

Petr Zajicek has a background in Fishery Science & Aquaculture and in Geography and started working in the Pulse-Beam-Trawl-Project in Germany in February 2013.

2 Adoption of the agenda

The agenda was adopted with a minor change (See Annex 3).

3 Review of earlier work and recommendations at WKPULSE

3.1 Short history and background presented by Bob van Marlen

3.1.1 Background and state-of-the-art

BvM gave a short review 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
- Tank experiments related to ICES requests – IJmuiden-Yerseke 2007–2011
- Catch comparison of two pulse trawlers with conventional beam trawler in 2011
- Reference measurements of *in situ* pulse characteristics on-board fishing vessels
- Further analyses of these catch comparison data for a publication in 2012
- Drafting Control and Enforcement documents in 2012
- Monitoring of pulse trawl vessels in 2012–2013

The current EU ban (Council Regulation (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 reviewed with 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, 22–24/10/2013

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.
- Catshark (*Scyliorhinus canicula* L.) trials in tanks in 2007 at IMARES
- X-ray tests on cod in 2007 (*Gadus morhua* L.)
- Further catshark tests 2009
- Cod tests 2008
- Benthos tests 2009

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
- Reference measurements at sea, 2011
- Catch comparison trials in May 2011 (08/05/2011–13/05/2011)
- Monitoring on pulse trawlers 2012–2013

3.1.4 Work planned by IMARES in 2013

Further work to be undertaken by IMARES will involve:

Reference measurements at sea, 2013

Not done yet.

Discussion

Sole catches are also important in Belgian shrimp trawling. International approach needed, support by many participants. Through North Sea RAC? Involve other groups, e.g. Italy. Often general terms are used in the RAC.

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 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)

4.1 Report on catch comparison and further analyses from the Dutch flatfish fishery (Bob van Marlen)

4.1.1 Comparative fishing experiments

Pulse trawling is used to a growing extent in the Dutch flatfish beam trawl fleet, and deemed as a promising alternative for tickler chain beam trawling. A comparative fishing experiment was carried out with three Dutch vessels fished side-by-side for a week in May 2011 (van Marlen, *et al.*, *in press*), one using conventional beam trawls, and the other two vessels using flatfish pulse trawls supplied by two different companies.

Pulse trawl landings were lower both expressed in kg.h-1 (ratio 67% based on auction data) or baskets per hectare (ratio 81%). The pulse trawls caught also fewer fish discards (ratio 57%, s), of which undersized plaice (*Pleuronectes platessa* L.) ratio 62% (s) and sole (*Solea vulgaris* L.) ratio 46% (ns), and fewer benthic invertebrates (ratio 80%, s) per hectare.

The length frequency distributions of sampled fish also show that fewer undersized plaice and sole are caught, and GLMM-analysis (method by Holst and Revill, 2009) confirmed this, both when comparing cpue per hectare and by hour fished.

The pulse fishing technique reduces fuel consumption by 50% or more, and consequently despite lower landings (67%) net revenues were higher. A down-side is that particularly marketable cod (*Gadus morhua* L.) can suffer spinal damage, but catches in the pulse trawl were lower, and total cod landings in beam trawling are small (4–5%), so the implication will be limited. This effect was not found in whiting (*Merlangius merlangus* L.).

As overall conclusions we can state that:

- Fuel consumption is lower (ratio 40–50%)
- Net earnings are higher (ratio 150%)
- Fewer landings (ratio 60–80%)
- Fewer discards (ratio 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

Tabel 1. Pros and cons of pulse trawling.

PRO	CON	UNKNOWN
Less fuel & CO2 (50%), higher net earnings (150%)	Less plaice, sole per area same or higher	Thresholds pulse characteristics on all species in contact with net
Less cod (~20%)	Spinal damage in 9% cod	Avoidable with changes in pulse or net
Less benthos (20–40%). Little or no effect on benthos		Indirect effect on reproduction?
Lower direct mortality		Indirect effect on growth?
Less discard fish (30–40%)		Deformations in other fish?
Little or no effect on catsharks		Effect on electro-receptor system of elasmobranch fish?

Discussion

A reference measurement on the DELMECO-system was done on a 7m trawl; the result will be extrapolated to 12m. The HFK-system still needs to be done in 2013 (dH). Measurements of power and voltage are needed to improve the control and enforcement limits. Field strength measurements were done before. Isolators create hot spots along the length of electrodes, how to legislate this? (PC). This is done by type specification with detailed technical data. The industry plays around with conductors and isolators.

Sole landings were monitored for a range of euro-cutters along the Dutch coast. Landings increased largely from 1000 to 3500–4000 kg per week when pulse trawling was started (BV). Is there a seasonal effect in this (DS, BvM)? Is this really a problem when they stay within their quota (HP)? We should also look at the impact on the fish stocks, not only on non-target species (AV). This could be a sensitive message within the EU, as EC Reg. 850/98 was set to avoid this (BvM).

4.2 Electrofishing for *Crangon* in The Netherlands (Bart Verschueren)

The brown shrimp (*Crangon crangon* L.) fishery is a widespread human activity in the coastal-zones of the North Sea. The fishery itself is carried out by an international fishing fleet of approximately 600 vessels operating mainly off the coasts of Denmark, Germany, The Netherlands, Belgium and the east of England. Total landings can mount up to 35,000 tons a year.

The discarding practices associated with the brown shrimp fishery have been regarded as a problem for many years. The poor selectivity of the small-meshed nets produces very high amounts of unwanted bycatch. The fact that the fishery itself is carried out in vulnerable areas like coastal zones and estuaries, often important nurseries for a wide range of marine species, intensifies this problem. Especially the bycatch of young flatfish, like sole and plaice has a significant influence on the commercial fish stocks. An additional problem facing the fishery is the seabed contact caused by the heavy bobbin rope used to startle the shrimp.

Current technical modifications for bycatch reduction in the *Crangon* fishery, like sieve nets, focus on catch separation or filtering after species have entered the trawl. Damage incurred by contact, or stress caused during the capture and escape process may lead to higher discard and escapee mortality. Sieve nets are satisfactory effective at reducing bycatch of relatively large fish of all species, but less so at reducing 0 group plaice and sole, which make up a large fraction of the bycatch. Because of these drawbacks alternative measures are needed.

The "HOVERCRAN", a modified shrimp beam trawl, aims at stricter selectivity and reduced seabed contact. The fundamental idea is to replace the heavy bobbin rope with 12 lightweight electrodes, in order to use electrical pulsation as a stimulation alternative. Prior research by ILVO showed that the use of a specific electric field close to the seabed induces a startle response in shrimp, meanwhile not affecting most of the other benthic species. The elevated footrope lets non-target species escape underneath the trawl and collects the shrimp that jumps up into the water column. Herein lays the selective fishing potential of this alternative technique.

Currently several prototypes of the gear have been or are being tested on different commercial shrimp vessels. Meanwhile the optimal *Crangon* pulse is pretty well defined, there seems to be no need to vary pulse settings. Only two prototype Marelec™ generators with minor differences have been used on the vessels. The basic trawl concept, an elevated groundrope without bobbin rope was first tested on O191 in a scientific setup (2008 – 2011). Recently customized versions are being used in commercial circumstances on TX25, HA31, WR40 and SD33 (with Marelec systems), and TH10 (with the DELMECO system). Together with the Dutch sector a lot of flume tank research was done to facilitate bobbin rope design in relation to pulse fishing. Currently all vessels work with different bobbin rope designs and as a consequence all these ships have different outcome in relation to catch efficiency, discard reduction and reduction of seabed contact.

A combined gear with a classical round bobbin rope (36 bobbins) and 12 lightweight electrodes was experimentally tested on TX25. Logically no discard reduction was observed. However, commercial catch increase unexpectedly rose to 50%. Pulse amplitude was found to be optimal at 90% of the maximum generator output. In other words, increase of the pulse generator output (higher energy output) beyond a certain threshold did not lead to higher shrimp catches. No conclusive explanation for this was found. It is plausible that very efficient shrimp stimulation at higher amplitudes leads to the escape of shrimp out of the gear. Commercial gears on TX25 had 10 bobbins in a straight configuration (square net design) with significant spacing in between bobbins, resulting in less discards (50% less small plaice), but increase in shrimp catch compared with traditional gear with 36 bobbins. This was tested in a one-week comparison with the two gears fished simultaneously.

The WR40 switched to electric fishing (Marelec system) in spring 2012. This vessel was not followed up in a scientific project. The makeover was completely financed by the company itself apart from any project subsidy. As a consequence crew focuses on catch quantity (short return of investment) and less on catch selectivity. Accordingly the preferred bobbin rope was constructed rather heavily. Bobbin ropes with dumbbell-shaped bobbins were produced in Poland in a way that spacing between bobbins was filled up as much as possible. Nevertheless the reduced number of bobbins used in the new bobbin ropes (*i.e.* 24) is still a considerable step forward compared to the old (traditional) round bobbin rope with 36 bobbins.

The HA31 followed a different approach with a very lightweight bobbin rope, with 11 bobbins connected by a steel wire, with a total 95 kg weight on the rope (see picture below). Bottom contact is estimated to be very low (a reduction of 75% compared to the conventional setup). Catch comparison with a conventional gear showed a commercial catch increase of 23% and 67% less discards in volume, with both gears having sieve nets in (preliminary results). Unwanted bycatch of small sole, whiting and plaice decreased dramatically.

Figure 1. Shrimp pulse trawl with lightweight bobbin rope design (11 bobbins) tested on board of HA31 (Marelec pulse system).

In contrast to the vessels mentioned above, TH10 uses a completely different shrimp pulse system. The "Combi-pulse" system developed by DELMECO, with 19 electrodes and heavyweight gears is customized to bigger and more powerful vessels, the so called eurocutters. These vessels often change type of fishery throughout the year. Choice of target species (sole, shrimp, …) and thus fishery method depends on available quota, market prices etc. Therefore there's a strong commercial need for a pulse fishing system that allows targeting different target species. By using a DEL-MECO system, fishermen can now switch between gears and generate different pulse fields with the same equipment. In practice the switch from shrimp to sole gears and vice versa takes more time than is desirable.

In a small experiment, followed up by ILVO, different groundrope designs were tested on-board TH10 (see figure below). Various types of straight bobbin ropes and a groundrope design with rubber discs were compared mutually and with a conventional (round) bobbin rope type. Strongly varying results were shown. Catch efficiency (commercial shrimp catches) and bycatch levels were different for each design. Apparently the bobbin rope design has a large effect on the outcome in pulse trawling. In all experiments it was found that bycatch reduction increases with the size of the escape opening between the seabed and the groundrope. Consequently a lightweight bobbin rope design with significant spacing between adjacent bobbins delivers the best results in terms of bycatch reduction.

Figure 2. Different groundrope designs tested on board of TH10 with the DELMECO COMBIP-ULSE system.

Discussion

Bobbin rope (and groundrope) design has a large effect on the outcome in pulse trawling. In all discussed experiments it was found that bycatch reduction increases with the size of the escape opening between the seabed and the groundrope of the gear. Fishermen will logically choose for the type of rigging that delivers the biggest catch with secondary attention to bycatch and seabed impact related aspects. In other words pulse fishing techniques can be used in different ways, depending on the motives of the user.

Consequently someone (i.e. fisheries management) will have to give direction to the practical implementation of the pulse gears (sole and shrimp systems). Detailed technical descriptions in Control & Enforcement documents are needed, but the trend is to step away from very detailed regulations in the EU (BvM). Science and compliance people can be put together and create more power to affect the industry (PC). Combining different target species with the same pulse fishing system (*i.e.* shrimp and flatfish) may not be a good thing. It might strengthen the groundrope issue and might complicate the legislation, control and enforcement (dH). Allowing for certain bycatches, *e.g.* sole will hamper the use of selective devices, such as sieve nets for example (dH, BvM).

4.3 Update on the development of the German shrimp pulse trawl (Petr Zajicek and Daniel Stepputtis)

To test a pulse beam trawl in the German shrimp fishery under commercial conditions and over the course of a year (to consider a seasonal effect), a commercial vessel was equipped with a pulse beam system (Marelec, Belgium). To allow for a direct comparison, the pulse-system was used on starboard and a traditional shrimp-beam trawl was used on portside. The groundrope of the pulse beam trawl consisted of 11 bobbins with a diameter of 220 mm which were installed on an iron cable. The shape of this groundrope was straight which is in contrast to the traditional U-shaped groundrope consisting of 36 bobbins. In the pulse beam trawl, bobbins can therefore rotate in towing direction which is limited in the traditional beam trawl.

In total, more than 750 hauls were conducted over the course of 13 months (Method 01, main experiment) and used for analyses. Additional tests were conducted to prove the functionality of the pulse beam trawl and to elucidate the effect of different groundropes designs of the pulse beam trawl on catches.

Catches ("Total Catch", "Uncooked Shrimps", "Cooked Shrimps" and "Bycatch") were monitored under periodical supervision of scientists via self-sampling by the fisherman for all tests. Bycatch subsamples were taken periodically and presented for the main experiment considering fish-categories ("flatfish", "benthic fish", "pelagic fish" and "other" [e.g. swimming crabs, trash]), and considering fish species (number of individuals, weight, length).

Data were analysed per unit fishing time (l/h) and relations of the catch at starboard side (main experiment: pulse trawl) were given in percent compared with the catch at portside (main experiment: traditional trawl). An overview of the results was presented for all tests for each catch-fraction, also showing the amount of landed bycatch per litre cooked shrimps. For the main experiment, an overview was presented per months and per daytimes to elucidate a seasonal and a daytime effect, respectively. Statistical tests were preliminary (mostly linear mixed effects models and binomial general additive models with transformed response variables).

Total catch (+ 23%), uncooked (+ 8%) and cooked shrimps (+ 9%) were significantly higher and bycatch (- 9%) was significantly lower with the pulse beam trawl compared to the standard trawl, albeit absolute differences were only little. Further, there was a pronounced variability for all catch fractions over the course over the whole year and over the course of daytimes, indicating a clear seasonal effect and a clear daytime-effect on catches. The pulse beam trawl was thereby beneficial over the standard trawl considering all catch fractions in most cases. The amount of caught bycatch per litre cooked shrimps was reduced by 14% with the pulse beam trawl on average.

Flatfish and benthic fish were significantly reduced in numbers of individuals with the pulse beam trawl (-13%, -29%, respectively) and in weight of individuals (-15%, -23%, respectively). There were no significant differences for pelagic fish in numbers and weight and no significant differences for the length of all fish categories. Statistics for individual species have not been conducted yet but figures were presented.

To verify the effect of the electric field, the pulses of the pulse beam were switched off. Though very small sample sizes (n=6–8), all catch fractions were significantly lower with the pulse beam trawl-rigging without pulses compared to the standard trawl. Taking into account results from the main experiment, high efficiency of the electric field was indicated. However, a lowered bycatch of 45% on starboard side (pulse trawl rigging without pulses) indicates an effect of the electric field also on bycatch-species.

To proof same catch efficiency of similar pulse beam trawls and to exclude a side effect of portside vs. starboard, two identical pulse beams (11 bobbins, 220 mm; as used in the main experiment) were tested against each other. Though relative differences were relatively high for all catch fractions, no significant differences were detected comparing absolute values (n=15 for each fraction) indicating similar catch amounts at starboard side and at portside when similar pulse beam trawls are used. Consequently, no side effect was indicated.

In a first setup of groundrope modification, larger bobbins (Figure 3) were used with the pulse beam trawl at portside (9 bobbins with a diameter of 305 mm). At starboard, a pulse beam trawl with 11 bobbins (220 mm) was used. Catches at with 220 mm bobbins were significantly higher for all catch fractions than with 305 mm bobbins. Bycatch was 47% higher with 220 mm bobbins compared to 305 mm bobbins.

In a second setup of groundrope modification, the diameter of the bobbins (Figure 3) was further increased at the pulse beam trawl at portside (9 bobbins with a diameter of 405 mm). At starboard, a standard trawl with 36 bobbins (220 mm) was used (A comparison to the "standard" pulse trawl with 11 bobbins 220mm was not possible due to technical defects at the time of this test). Data of this test were not analysed yet. According to observations of the fisherman, catches seemed to be very promising, i.e. comparable shrimp catches and highly reduced bycatches with the pulse trawl with 405 mm bobbins compared to the standard trawl with 220 mm bobbins.

In a third setup of groundrope modification, an iron chain was tested vs. an iron cable as carriers of bobbins in two identical pulse beam trawls (11 bobbins, 220 mm). The aim of this test was to exclude an effect of the iron cable used in our tests as in traditional beam trawls iron chains are usually deployed. No significant differences were detected for any catch fraction besides total catch; also relative differences were comparable indicating no effect of the iron chain used in our tests on catches

During our tests, some challenges arose from unexpected deterioration of the gear. These embrace a) a deformation of the iron cable which was used as carrier of bobbins (Figure 4), b) breaking down of "banana"-connections between groundrope and relief-strains (Figure 5), c) cutting of banana-connections into the mounting device of bobbins (Figure 6), d) appearance of splines in electrodes (Figure 7) and e) shaking of bobbins larger 220 mm at the groundrope resulting in their fast and heavy deterioration (Figure 8) and also resulting in limited control of the vessel during trawls. Challenge a) is not solved yet and further research is needed. Bananas (challenge b) have been replaced by thicker material (10 mm instead of 8 mm) and seem to work well. Challenge c) might be inevitable or require thicker mounting devices for bobbins. Challenge d) might be inevitable erosion of electrodes. Challenge e) is due to a very large diameter of the inner hole of the bobbins which is used to thread the bobbins on the iron chain of the groundrope. Bobbins with a smaller inner diameter would be needed but manufacturer of such bobbins are not found yet.

Conclusions:

The comparison of a pulse beam trawl and a standard trawl revealed little differences in catches in favour of the pulse beam trawl. All catches were highly variable between seasons and daytimes. The potential for preservation was indicated to be highest for flatfish and other benthic living fish species when using the pulse beam trawl. Additional tests revealed the efficiency of the electric field on targeted (shrimp) and also on not-targeted species (bycatch) and negligibility of a side effect of the trawls. Further tests revealed variable results when using modified groundropes and also revealed new challenges with the gear itself, requiring further investigations of the design of the groundrope and its devices.

Discussion

How to analyse paired statistics or not (DS)? Paired seems better. Swapping gears or not? Swapping gives two days lost was not done. Keeping the gear the same? Yes we did so in the year-long trial in Method 1 to be able to investigate the seasonal effects. Both, the standard gear and the pulse trawl are fished with the same speed. Some experiments were done with differing towing speed, but still need to be analysed (DS). Shrimp react very fast, we may be able to use a shorter electrode (DS) to decrease the reaction time for bycatch species (react slower than shrimp) and therefore to further reduce the amount of bycatch. Good idea, but the generator may be the limiting factor, we thought of getting down from 3 to 1.5m, but the manufacturer saw problems to get rid of the energy (BV). Laboratory tests should help to find reaction times, and field studies may not deliver such knowledge because they are statistically poor. Should we measure turbidity, light, flow speed, etc.? This can be on the wish list for future work. CTD logger was placed on both beams, but the data still needs to be analysed (DS). We do not know whether differences are in gears due to tide, or how they shoot, with or against tide, etc. In similar seasons the results were similar as the Belgian results. Outside this range there are differences, therefore we need more seasons. Technical solutions for the technical problems mentioned can be found and suggestions were given. It seems interesting to me to try to implement the optimal German gear in the ILVO experiments planned for 2014. This way a comparison can be made and hopefully the reason for the less optimistic outcome can be found and overcome (MD).

Figure 3. Size relations of bobbins used in our tests: 220 mm, 305 mm and 405 mm.

Figure 4. New challenge: deformation of the groundrope.

Figure 5. New challenge: weak material, breaking down of "banana"-connections.

Figure 6. New challenge: cutting in of banana-connections into the device used to mount bobbins.

Figure 7. New challenge: Splines in electrodes.

Figure 8. New challenge: deterioration of large bobbins.

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

4.4.1 The effect of different pulse parameters on marine organisms (Maarten Soetaert)

The goal of the research that was done the past year was to determine the safe zone of pulse parameters that can be used by pulse gears without the risk of harming marine organisms. Therefore, two vertebrates, sole and cod, and two invertebrates, shrimp and sandworm, were exposed to a wide range of pulse parameter combinations (pulse frequency 5–200 Hz, field strength 50- 200 V/m, pulse duration 0.1–1 m/s, exposure time 1–5 s, pulse shapes: square, sinusoidal and exponential wave form and 3 pulse types, namely pulsed direct current and two types of alternating pulse). They were kept for 14 days, euthanized and autopsied. During and after the autopsy the animals were examined on external and internal injuries, histological samples were taken and X-rays were made of the fish. The pulse parameters that were varied during the research were frequency, amplitude, pulse type, pulse form, pulse duration and exposure time. The nominal exposure happened homogenously between two plate electrodes.

In total, more than 400 sandworms were exposed to 12 different combinations, and all except 1 died. None of the 40 control animals died. All other animals survived well and showed normal behaviour. The histological samples were examined on abnormalities in the epidermis (cuticulum and epidermis), parapodia (epidermis and ganglia), ganglion, gut (epidermis, muscle) and the muscles (circular, parapodial, ventral and dorsal) but no injuries were observed, indicating that the exposure had not affected the animal. Additionally, 600 brown shrimps were used, in 5 different exposures and each exposure of a group of 30–50 animals was repeated 3 times. No huge differences in mortality were observed, although exposure to pulses with long duration and bipolar shape show a tendency of greater mortality. However, statistical analysis and extra experiments with other parameter combinations will have to be performed to proof this. Also the histological examination still has to be done. In the coming month another 1000 shrimps will be used to test other parameter combination, and they will be screened in the same way.

Besides, 120 sole have been exposed in perpendicular orientation to the electrode using a wide range of 40 different parameter combinations without any mortality, macroscopic or microscopic injuries. The behaviour of this species during the pulse was either a flight (<25Hz), either a cramp (>25Hz), with very short epileptic seizures if frequencies above 150 Hz were combined with long pulse durations or high field strengths. However none of these had an effect on the fish longer than a few seconds after the exposure. None of the fish died during the 2 weeks follow-up, nor new induced spinal injuries were found on the X-rays. Also the histological examination of gills, heart, muscle of the back, spleen, liver, kidney and mid gut did not reveal any abnormalities. In the coming months some extra fish will be used to make sure that a parallel orientation to the electrodes is safe as well.

Last but not least, many experiments were done with cod. 40 wild cod were exposed in different set ups, but only 1 injury was observed. As the supply of wild cod to the lab was a very time consuming and hardly consistent method, we decided to move to the cod breeding centre in Tromsø, Norway, to perform these experiments. Although, 150 animals of different sizes were used, we were not able to reproduce the results obtained by Dick de Haan in 2008 and 2010. Hoping to reveal the critical parameters and to exclude a parameter effect, both scientists went together to the IMR in Austevoll were Dick's previous experiments were done. Both generators (the Laboratory Pulse Generator of ILVO and the dummy Delmeco generator of IMARES used in in the experiments of 2008/2010) were shown to produce the same electrical fields. However, this time only 1 cod out of 40 was injured, whereas in the past 50–70% of the cod had spinal injuries under this experimental set up (very close to the electrode, 60V, 40 Hz bipolar current). These results seem to indicate that there may be a fish-related parameter that is far more critical than the electrical ones, but unfortunately we don't have a clue at this moment.

Discussion

The same pulse simulator was used as in the earlier trials; there is no more secrecy about the detailed pulse characteristics (dH). Evgeny commented later by correspondence that a substantial decrease in spinal injury in the cod exposed to the strong electric field in the last tests is an intriguing effect. Such a long-term variability may complicate the standardization of safe levels for electric impacts. As for a possible mechanism of this difference, the seasonal changes of fish physiological state could influence their response thresholds and reactivity to an electric current (if there was a time shift between the different series of the test). Such seasonal variations are documented in some papers (see the doc-file attached for a review).

4.4.2 Experiments on cod in Norway (Dick de Haan, Maarten Soetaert)

A joint experiment in 2013 with IMARES and ILVO was presented. A diagram was shown of the fish positions used and compared to the 2008, and 2010 experiments. In 2008: 9 out of 20, i.e. 45% in the nearfield range got damaged, in 2010 we were more precise with positioning and 60–70% of the fish suffered injuries. In the 2013 experiment a total of 83 adult cod were exposed, 53 specimens were exposed at 60 V and 30 specimens far outside the commercially applied amplitude range (120 V). In 5 cases vertebral injuries occurred of which 4 at 120 V and a single one at 60 V. When the type of stimulus is taken in account this single injury at 60 V amplitude represents an injury rate of 4.4% of 23 exposed fish and 13% at 120 V (4 out 30 specimens). All injuries occurred using the Delmeco TX68 pulse shape.

The post exposure reaction of the fish exposed at 60 V amplitude seemed less strong than in the IMARES study of 2010. In this study some of the fish accelerated out the holding cage into the main tank, while this did not occur in the present study. A second observation was that tail marks indicating vertebral injury were weaker, while the fish of 2010 with similar injuries had very strong and large tail marks. The post exposure reaction of the fish exposed at 120 V included electro-narcosis and some became stunned. After dissection parts of the fish were taken to the University of Ghent for detailed analysis on the morphology of the dissected fish.

The present results confirmed the recent outcome of 2013 made by ILVO and Ghent University and showed that the origin of the conflicting outcome must have been related to differences in morphology of the fish. Vertebral injuries could have been related to deviations in the vertebrae related to unknown changes in the methods of the culture, which could have caused differences in the muscular system, or mineral content of the vertebrae. Seasonal effects in the cultured fish could be excluded as the present study was executed in the same period as in the 2008 study and a month earlier than the study of 2010. The rearing history of the fish was also not the background of the differences in results. All fish used in the experiments between 2008 and 2013 from the Austevoll hatchery were cultured according the exclusively reared method, in which larvae are fed with zooplankton in the first stages of the culture.

The conditions during these experiments, among which seawater temperature and salinity, were quite similar. The electrode current was a bit higher in 2013. The field strength to inhibit injury was 103 V/m in the earlier experiments, now found to be 248–265 V/m, and a factor 2.5 above the conditions applied in the 2010 study and a factor 6 times higher than the field strength measured under the commercially fished nominal condition (59 V/m).

The length weight relationships of fish in 2010 and 2013 were compared, but the differences were small. Could results be caused by having hatched fish, how does our result relate to wild cod? Morphology might have been changed, but the feeding scheme was not altered since. The mineral status of vertebrae might be important and can differ between the different methods of hatching fish and the wild fish. We did not find a flaw in the equipment. Literature references used were presented. The ILVO stimulus has a delay time of 2 s after triggering. The present results show that additional research may be required in particular using wild cod.

As first step to investigate the background of this result we did check the rearing history of the Austevoll hatchery used between 2008–2013. IMR-scientists confirmed that larvae were reared according the exclusive method so exclusively fed with zooplankton. Further research may be required; research on dissected fish will be continued at the University of Ghent.

4.4.3 Electrical trawling for brown shrimp: Consequences for young life stages in spawning areas? (Marieke Desender)

Previous exposure and survival experiments carried out in 2012 indicated that the use of electrical pulses for catching brown shrimp has no immediate harmful effects on different adult fish (plaice, armed bullhead, bull-rout, dragonet, fivebeard rockling, cod and sole) after exposure in a heterogeneous field for five seconds. After 24 hours the organisms were euthanized. Minor and brief fright reactions were observed but no mortality or macroscopic and spinal injuries could be established. Unfortunately microscopic analyses are still ongoing.

However the impact on other marine life stages is still unknown. As brown shrimp are often caught in coastal zones and estuaries, important nurseries and spawning areas for a wide range of marine species, electro fishing could therefore harm embryos, larvae and juveniles if exposed during their most sensitive stages.

As cod (*Gadus morhua*) was already considered to be a vulnerable species to electrical pulses, due to the spinal injury observed in former experiments performed by De Haan *et al.* 2009, experiments were carried out on this round fish species in cooperation with the cod breeding centre of Nofima in Tromso, Norway. Different developmental stages (Figure 9) of embryonated cod eggs (3 stages), larvae (4 stages) and juveniles (1 stage) were exposed in a homogeneous electrical field of 150V/m during 5 seconds. Survival, injury and development were macro- and microscopically inspected until 2 weeks after metamorphosis.

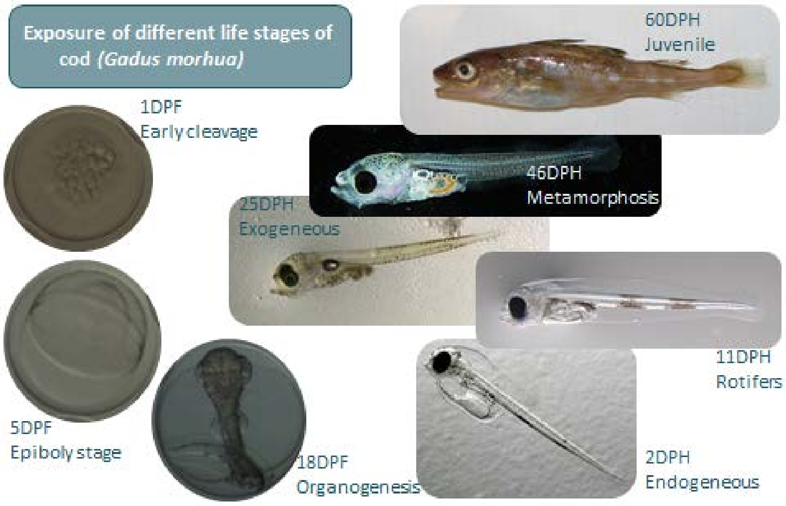

Figure 9. Exposure of the different life stages of cod (3 egg stages, 4 larval stages and 1 juvenile stage). DPF= days post fertilization, DPH=days post-hatching.

After exposure 20 000 eggs were incubated in a cilindroconical tank wherefrom the upper part of the tank density measurements were taken until 2 days after hatching and the amount of hatched eggs during the hatching process was also counted. From the bottom part, the volume of dead eggs was measured. During the further development, samples were taken for following up growth, yolk resorption, malformations, and changes in pigmentation and for histological examination. In the larval stages the amount of experimental units could be doubled. This means an extra cilindroconical tank was included with 200 larvae for measuring more accurate short time mortality as density measurements are not possible in larval stages due to differences in buoyancy. The other tank was used for sampling during further development wherein initially +/- 3500 larvae where included. In the juvenile stages the accommodation was more limited. In each tank 200 juveniles were included, again samples were taken to follow up several parameters during further development and after two weeks the amount of alive juveniles were counted from the same tanks. On all sampled larvae a morphometrical analysis will be performed by taking pictures and measuring parameters like length, yolk resorption and shape. All experiments were performed in triplicate and appropriate controls were included.

As a result no significant density or hatching differences could be established between control and exposed groups in the different egg stages. Also in the juvenile stage no difference in mortality was observed. In the larval stages there was no significant effect in the stages right after hatching, the rotifer stage and the stage that was in metamorphosis. However in the exogenous larval stage, starting to eat artemia, there was a significant difference ($p<0.0014$ and odds ratio 1.94; Figure 10). Maybe the morphological analysis will reveal what is happening in this stage, but unfortunately these analyses are still ongoing.

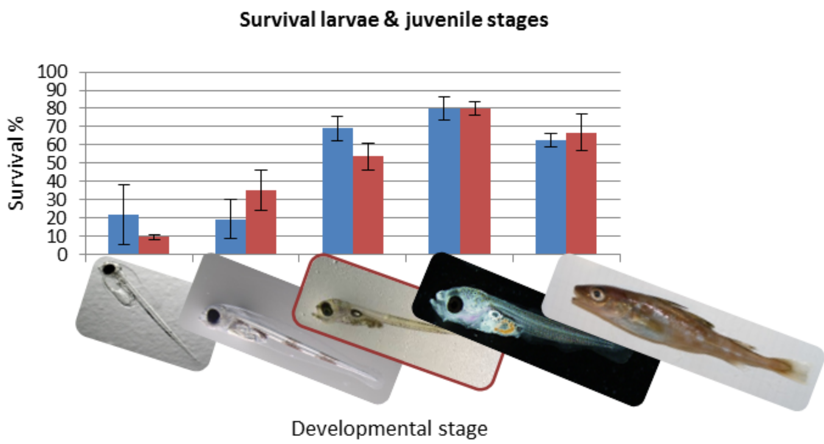

Figure 10. Survival of 4 larval stages and one juvenile stage. In the third larval stage, the artemia feeding stage, a significant difference was observed between control and exposed groups.

In all experiments a worst case scenario was performed. At sea 150V/m is only a small part of the electrical field very close to the electrode. Besides, cod eggs and larvae are floating which makes the chances of getting in contact with such high field strengths small which put the results in perspective

For the future comparable experiments will be performed starting in January on sole (*Solea solea*). We will focus on more replicates and more accurate short and long-term mortality in the egg stages, instead of density measurements. Culturing of this species worked out well in January 2013.

Towards the end of 2014 long-term experiments on Dogfish and Thornback ray will be done. So far no short term effects were observed on these species but microscopic and blood plasma analysis are on the way. To establish the effect on AoL (Ampullae of Lorenzini) a morphological study will be done (scanning and transmission electron microscopy) where we will focus on the kinocillium. But also a functional analysis will be performed. Different options are available for this last part of research. The best one would be: simulating prey with electrodes (Kalmijn, 1971) but it is very difficult to produce and measure such small voltages. Another option could be by isolating alive prey (shrimp or small flatfish) in an agarbox and check if an attack is still possible after exposure. Suggestions?

References:

De Haan D., van Marlen B., Kristiansen TS., Fosseidengen JE. 2009. The effect of pulse stimulation on biota – Research in relation to ICES advice – Progress report on the effects on cod. IMARES report C098/08: 25 pp.

Kalmijn A.J. 1971. The electric sense of sharks and rays. Journal of experimental biology, 55: 371–383.

Discussion

Kalmijn is in San Diego and can be contacted. There is a shark and cetacean centre in Hawaii (dH). The background field should be measured, and very a sensitive amplifier is needed, or shield a tank in a Faraday cage (dH).

The tanks were monitored for temp and salinity, and no differences were found. The cod larval stadia are pelagic, but shrimp trawl may affect sole larvae. One stadium of cod showed differences, should this be looked at again? There are no possibilities to repeat it, but there was high variability. There are more opportunities in the sole experiments. Sole eggs develop much faster.

4.5 Electrical fishing for *Ensis* – Update on developments in Scotland (Phil Copland)

Phil Copland of Marine Scotland- Science, Marine Laboratory, Aberdeen described a project looking at the *Ensis* fishery in Scotland.

The project is being conducted with funding from the Scottish government using the FISA scheme. This scheme encourages the fishing industry to work with scientific institutes to address current problems in various fisheries.

The project was set up to evaluate the impact of an illegal fishing activity, *Ensis* fishing using electrical equipment, on the various species which encounter the field and on the benthos. The project will look at one specific set of equipment currently being widely used in the fishery for commercial purposes.

The project, which started in October, has collected video information on the behaviour of target and non-target species which encounter the fishing equipment in locations on the East and West coast of Scotland.

Tank trials will be conducted to establish the survivability of *Ensis* and non-target species which have been in contact with the electric field. It is expected that this project will be completed by March 2014 unless additional funding is committed.

Short summary of Ensis electrical fishing:

- is illegal
- estimated to around 2.4 M BP
- Divers collect the Ensis.
- requires live animals
- Speeds are very low at 3m/min
- Fishermen want to have it legalised

Discussion

Are higher frequencies used more (dH)? Not really, but the rig is smaller with higher frequency. The fishermen take what is available on the shelf, not any optimum (PC). Amplitude of 30 V (dH)? Not entirely found by accident, chosen to avoid hazards (PC). In Zoo’s 42 V is the level used. Could DC be used with anodic attraction (dH)? Maybe, but mostly existing equipment is taken. Why is survival of *Ensis* an issue when all are collected? (DS). Concern was what happens to animals divers do not pick up (e.g. size selection); these are going back into the ecosystem (PC). If studies on larger animals give results, it may not be enough, one may ask about other species not investigated yet. Just like in other pulse/electrical fisheries. This fishery is quite largely spread out, inspection vessels use considerable amount of time on this (PC). Is there *Ensis* fishery in France (DS)? Yes, but not caught by electric device (AV). With such a low speed (vessel is typically anchored and pulls slowly) is the effect not very small given the large area on the Scottish coast (DS)? Yes, but the energy input is quite large, but proof of no effect is needed (PC). Exposure time is larger than in pulse beam trawling on the other hand (MD). With the current information MSS is contacted more (PC). Divers are at a depth range of 4–7 m, about 10 m behind the boat. Areas are detected by experience. Rig needs to be strong enough not to flex, but then it will be too heavy for small boats. *Ensis* can also be hit by the collector before they are buried, then they suffer real damage. One needs about 40–60s to allow the animal to come out of the seabed. Once on the surface the behaviour does not matter, one can just pick them up. Constant DC will dissolve an anode quite quickly (PC). When the technique is legalised then improvements will be made and costs reduction found. With lower energy inputs the question is whether the *Ensis* would come out of the seabed. There is no cooperation with SEAFISH at present. Fish are not seen at all in these trials because of the low speed, but ducks love *Ensis* and are often competitors (PC).

5 ToR b) Further evaluate the effect of a wide introduction of electric fishing, with respect to the economic impact, the eco-system impact, the energy consumption and the population dy-namics of selected species

5.1 Estimating effects on major fish species on North Sea level

The scenario study undertaken as a follow-up of the EU-tender project FISH 2007/07 LOT3 (Polet *et al.*, 2010), presented last year was reviewed. 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 flatfish beam trawling in the fleet segments with a vessel length of 24–40m, and larger than 40m.

The 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; ICES, 2012; Piet *et al*., 2009).

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 and COD (roundF): 1.0 → 0.30
- Towing speed in pulse trawls reduced from 6.5 to 5.0 kts

This scenario gave the results of Table 9 and Table 10.

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.

Table 1. Results of the model study in terms of percentage landings (LAN) and discards (DIS) for five major fish species in the North Sea demersal fleets. Scenario 2e. TBB = Beam trawls.

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

Table 2. Results of the model study in terms of percentage landings (LAN) and discards (DIS) for five major fish species in the North Sea demersal fleets. Scenario 2e. All = all gears.

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

5.2 Reduction in fuel consumption, fuel costs, and CO_2 emission

The number of vessels using pulse gear increased during the last year, not only in the Netherlands, but also in other European member states, *e.g.* Belgium, Germany, and the UK (Table 3). The systems are specialised for catching flatfish (sole and plaice) or brown shrimps (*Crangon crangon* L.). However, one Dutch vessel uses a combination system.

Table 3. Number of pulse trawlers in European member states, dated 01/01/2013 (source: K. Taal, LEI, The Hague, the Netherlands).

Country	Vessel class [hp]	Flatfish	Flatfish + shrimps	Shrimps	Total
Netherlands	> 300	25			
	≤ 300	13	1	3	42
Germany	> 300	3			
	≤ 300	1	0	1	5
UK	> 300	3			
	≤ 300	0	0	0	3
Belgium	> 300	0			
	≤ 300	0	0	1	1

A conventional flatfish beam trawler in the class > 300 hp uses about 30,000 litres of fuel per week. When taking 40 fishing weeks a year this means 1.2 M litres of fuel annually.

Based on the flatfish-fleet and on values for variables as given in Table 4 below, we estimated the total fuel and costs savings, and the reduction in CO_2 emissions per year.

Table 4. Variables used in the calculation.

Variable	Value	Dimension
Fuel saving large	50	%
Fuel saving small	35	%
Fishing weeks large	40	weeks
Fishing weeks small	35	weeks
kg CO^2 per litre	2.6	kg/litre
Fuel consumption large	30000	litre/week
Fuel consumption small	15000	litre/week
Fuel costs per litre	0.65	€/litre

The 51 vessels in this fleet consume 47.7 M litres of fuel annually. Using pulse trawls and assuming a fuel reduction of 50% (> 300 hp class), and 35% (≤ 300 hp class) this would be 22.3 M litres of fuel per year less. With a price of 0.65 €/litre this results in a saving of 14.5 M € per year. Taking the CO_2 emission at 2.6 kg CO_2/litre fuel used, the total reduction of CO_2 emissions in this group is 57.9 M kg CO_2/year (Table 5).

Table 5. Total fuel consumption, fuel costs, savings and reduction in CO_2 emissions by European pulse trawling fleet.

Country	Vessel class [hp]	Sum	Total by nation	Fuel consump sumption [M litre /year]	Fuel cost [M €/ year]	Fuel saving [M litre /year]	Fuel cost reduction [M €/year]	CO2 reduction [M kg /year]
Netherlands	> 300	**25**		30.0	19.5	15.0	9.8	39.0
	≤ 300	**17**	**42**	8.9	5.8	3.1	2.0	8.1
Germany	> 300	**3**		3.6	2.3	1.8	1.2	4.7
	≤ 300	**2**	**5**	1.1	0.7	0.4	0.2	1.0
UK	> 300	**3**		3.6	2.3	1.8	1.2	4.7
	≤ 300	**0**	**3**	0.0	0.0	0.0	0.0	0.0
Belgium	> 300	**0**		0.0	0.0	0.0	0.0	0.0
	≤ 300	**1**	**1**	0.5	0.3	0.2	0.1	0.5
Total	> 300	**31**		**37.2**	**24.2**	18.6	**12.1**	48.4
	≤ 300	**20**	**51**	**10.5**	**6.8**	3.7	**2.4**	9.6
			Totals	**47.7**	**31.0**	**22.3**	**14.5**	**57.9**

5.2.1 Influence of a discard ban on the transition towards more selective fishing gear (Jurgen Batsleer presented by Bob van Marlen)

A large part of demersal fisheries catches constitute of undersized target species. Currently, minimum landing size (MLS) regulations force a fisher to discard this part of the catch, causing additional mortality and hence reducing future yield of a fishery that is already in a fragile economic situation. Discard reduction is high on the agenda of EU fisheries managers wherein modifying current fishing technologies (pulse trawling) are among the possible adaptive strategies of fishers to cope with the changes in management (*e.g.* discard ban). A dynamic state variable model (DSVM) is used to explore the economic and ecological implications of a discard ban for mixed fisheries, comparing two gear types that differ in their selectivity for the target species. Results show that a discard ban and catch quota force a fisher to reduce his fishing effort and restrict fishing to the fishing grounds and weeks where a maximum revenue can be realized by catching other species while exploiting the individual quota of the restricted species. In addition, a discard ban provides an economic incentive towards the implementation of more selective fishing gears that catch fewer undersized plaice and are more fuel efficient (pulse trawl).

Discussion

A catch rate of 83% was used for sole, but information is lacking about the real catches and landings, discards (MD, MS). Monitoring is done but report not out yet, more data are needed. Sensitivity analysis in these models would be recommended (DS, BvM). If not, such models can be outdated in a short time (DS). We also do not know how pulse systems are really used in actual fishing, and whether the pulse settings are recorded in monitoring programmes. For instance the HFK-system is a black box for us (dH).

Pulse techniques are also suggested for other gears, e.g. the twin-rig. A scale model was shown in the Schiphol Van de Valk A4 meeting on 28/09/2013 of "Stichting Masterplan Duurzame Visserij" (MS). Pulse chains were only in a 12m width of the net. This gear is in development. The licence should come from a beam trawl pulse fisher.

5.3 Ecosystem effects of pulse trawling

In EU project BENTHIS (www.benthis.eu) the case study on the North Sea will deal with the effect of flatfish fisheries for flatfish and brown shrimps on the benthic ecosystem. Alternative gears developed by the fishing industry to reduce the fuel consumption and mitigate the impact on the seabed will be studied among which pulse trawling.

BENTHIS will provide the knowledge to further develop the ecosystem approach to fisheries management as required in the Common Fisheries Policy and the Marine Strategy Framework Directive. It will study the diversity of benthic ecosystem in European waters and the role of benthic species in the ecosystem functioning. Fisheries impacts will be studied on benthic organisms and on the geo-chemistry. The newly acquired knowledge will be synthesized in a number of generic tools that will be combined into a fishing/seabed habitat risk assessment method that will be applied to fisheries in the Baltic, North Sea, Western waters, Mediterranean and Black Sea. Fisheries will be selected with the fishing industry based on the impact on the benthic ecosystem.

BENTHIS follows a multidisciplinary approach with strong stakeholder involvement. Together with fishermen, researchers will conduct trials with innovative fishing gears such as pulse trawls. Generic tools will be developed to assess the impact of fishing gears based on physical characteristics of the gear and the morphological and life-history characteristics of benthic organisms. Also bioeconomic models will be developed to quantify the effect of mitigation measures on the socio-economy of the fishing sector. The models will allow an integrated assessment of both the ecology and the socio-economic consequences.

6 ToR 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

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

Recently IMARES finished the Control and Enforcement project for the Dutch Ministry EZ (former EL&I) aimed at preparing documents on Control and Enforcement of Pulse trawling. A special task-force was established in the Netherlands to look at these issues with representation from the fishing industry, pulse trawl producers, policy makers, inspection agencies, and scientists.

A set of specific procedures was developed with upper limits for relevant pulse characteristics such as delivered power to the system and pulse amplitude, together with a certification scheme, and ideas to log and monitor the electric performance of pulse trawls. The 2009 derogation worked on the basis of a maximum electrical power per unit beam length (1.25 kW/m), and a maximum effective voltage of 15 V on the electrodes. A total of 5% of the fleet was allowed to use pulse beam trawls (EU, 2009). In the new rules it is suggested to reduce the power to **1.00 kW_{rms}/m** gear width and the amplitude limit into a maximum field strength of **0.25 V_{rms}/cm**.

In addition it is suggested that each vessel would carry a **Type Approval Certificate** and a **Technical File** describing the pulse system and **an on-board system** to log and store data on the electrical performance of the gears available for inspections.

Inspections can be done at two levels: routine inspections on-board aimed at checking the availability of required documents and the physical characteristics of the fishing vessel and the pulse fishing gears, and accessing and reading data from the data storage medium as a routine inspection or when suspicion may have risen of a breach with these regulations.

Two drafts were presented by Bob van Marlen at SGELECTRA for further consideration (Annex 6 and Annex 7). Dick de Haan presented a document on a Monitoring and control system for the Pulse Fishery (Annex8).

Reference

EU. 2009. Council Regulation (EC) No 43/2009 of 16 January 2009 fixing for 2009 the fishing opportunities and associated conditions for certain fish stocks and groups of fish stocks, applicable in Community waters and, for Community vessels, in waters where catch limitations are required. (OJ L22, 26.1.2009). p. 205.

Discussion

The limit of 1.00 kW/m is higher than the current level used in any of the pulse systems. This will give quite much room for developers of future systems (which could also be seen as downside of this approach, but better than the current regulation) (DS). The number and dimensions of isolators and conductors is not given (PC). This is given in the Technical File and can be checked by inspectors (BV, BvM, dH). What in case of changes in the electrical system (this includes also the question on whether it is necessary to conduct all the investigations for each new development, especially since the causes for effects on species are not fully understood; DS)? Any new system needs to get a new certificate (BV). New modules will need a new certificate (dH). Can producers alter something in the pulse module while keeping the outlook the same, and will this be detected by the inspection services (DS)? Or have more power on a shorter length of the beam? There are physical dimensions in the system that hampers this (dH). Dick explains the system suggested, which was developed with the experience in controlling engine power in fishing vessels. None of the producers indicated that this could not be integrated in their pulse fishing gear. Some manufactures have pairs of conductors in the feeding cable that can be used to transfer these signals, in other cases the feeding cable itself might be used (dH). Were these discussed by other inspection services than the Dutch (DS)? This still needs to be checked and worked out, there has been some contacts from the Dutch Ministry (BvM). The limit of 1 kW/m gear width could be a problem in the *Ensis* fishery, where 5 kW/m is used, but this system may be wind down (PC). The 1 kW/m gear width is high for shrimp pulse trawls, which only use 1 kW per 9m width (BV). This means that different limits should be set per target species (flatfish, shrimp). Allowing the bycatch of flatfish (e.g. sole) in shrimp fisheries might not be the right approach (dH). Such bycatches are limited as a function of mesh size (BV). In many areas there are rules for bycatch levels, e.g. *Nephrops* and roundfish (PC). Twin-trawling with electricity will add more complexity as many new target species come into the picture (BvM). For lower power, e.g. 1 kW per 9m, 0.11 kW/m, accuracy of the measurement may be an issue, we may need another specification for shrimp fisheries (dH). There are no practical constraints in making rules for each target species (PC). Our reports on the tank trials were based on peak voltages, not rms, the peak of 60 V we used will give 7–8 V_{rms}. We indicated this by stating that: *"Ranges above nominal are apparently allowed in the derogation, which allows settings for electric power and electrode voltage amplitude above the ranges tested on marine biota. As the effects on marine biota are not known, application above the nominal range will demand additional tests on the effects"* (dH). Then we need to define both peak V and V_{rms}. Limits of 60 V for flatfish and 70 V for shrimps is a better approach (dH). The 12 m gear width definition needs to be investigated again when stepping into pulse twin trawling (DS). Should we limit the procedures presented here into BEAM (or WING) pulse fishing gear only (PC)? Twin-trawls have the problem of non-fixed spread, and the gear spread should then also be measured (DS). Is there any form of control in the existing pulse vessels (AV)? The manufactures contributed to these procedures, but we do not know exactly what control are set in place, other than TACs, etc. (dH, BvM).

Conclusions

There needs to be a distinction in target species (flatfish, shrimps, *Ensis*) in defining limits to pulse trawl systems.

The new developments in applying pulse stimulation in other gears than beam trawls (*e.g.* twin-trawls that have a non-fixed spread) will make control and enforcement much more complex.

In shrimp trawling the performance of pulse trawls depends very much on the way the groundrope is rigged.

Limits should be set on peak voltages in combination with V_{rms}.

A pilot study with control and enforcement procedures and equipment needs to be done in practical commercial fishing.

The discussion held in The Netherlands needs to be expanded to other MS or on European level to also integrate additional views and opinions.

7 Conclusions and recommendations

The group felt that given the list of ongoing research and development in various nations and gaps in knowledge, SGELECTRA should be continued at least for three years. It is proposed to meet for 2 days in 2014 in IJmuiden/Aberdeen/Rostock. Work will be continued on the topics given in Annex 3.

Discussion

Work is continuing, and we should continue (PC). The list produced by Martin Pastoors was presented and discussed (See Annex 6). Stakeholder analysis has been suggested in the IMARES inventory. There may not be an official view on electrical fishing in the UK (PC). The wish list of Annex 6 shows many items under high priority (DS). Prioritization on the other hand may not work well. Financers will decide what to support (BvM). Other items we did not address: effects on sediments. Fisheries management should say what they need in terms of information (DS). We do not fully know what species might play a role in the ecosystem that are not addressed yet, and management will ask ecosystem researchers what they think is important. Research into effect on sediments of electric pulses, and research into dissolution of chlorine compounds by electric pulses are actually two different subjects and can be split out (MS). Electrolysis and production of chlorine gases may not be a problem with the AC stimulus, but if DC is used it will be a problem (PC, MS).

Ongoing activities

ACTIVITY	TIMING
PhD work ILVO-Uni Ghent - research on effects of the Hovercran pulses on elasmobranchi and egg, larval and juvenile lifestages of cod and sole (contact: Marieke Desender University Ghent) .	2013, 2014, 2015
PhD work ILVO-Uni Ghent - research on effects of electrical pulse parameters on various marine species (contact: Maarten Soetaert University Ghent)	2013, 2014, 2015
Study on effects on electric fishing for *Ensis* by Marine Scotland Science (contact: Philip Copland MSS)	2013, mid 2014
Electrical shrimp fishing in Germany by Thuenen Institute (contact: Daniel Stepputtis TI)	2013, Mar 2014
Effects of pulse beam trawling on benthic invertebrates in BENTHIS-project IMARES (contact: Bart Verschueren ILVO, Adriaan Rijnsdorp IMARES)	2013–2018
Monitoring economic performance of more vessels by LEI in BENTHIS. (contact: Hans van Oostenbrugge or Kees Taal LEI)	2013–2018
Inventory of research topics pulse fishing by IMARES (contact: Martin Pastoors IMARES))	2013
Ongoing experiments with electrical shrimp fishing in Belgium and the Netherlands by ILVO (contact: Bart Verschueren ILVO)	2013–2016

Reference measurements on HFK-system on a commercial fishing vessel with 7m beams (TH7; contact: Dick de Haan IMARES)	2013
Development of an electrical twin-trawl system as part of "Masterplan Duurzame Visserij" (contact: Mascha Rasenberg IMARES)	2013-xxxx?

Recommended activities

Activity	Target Species	Organization	Timing
Using other, lower energy pulse systems for fishing *Ensis* than currently used.	Ensis	MSS	2014
Pilot study using the defined control and enforcement documents with physical implementation of monitoring technology.	flatfish	IMARES, ILVO	2014
Further tank experiments on wild-caught cod, using pulse simulators.	flatfish	IMARES, ILVO	2014
Create control and enforcement documents for the shrimp pulse fishery in which other aspects than the electrical stimulus (e.g. the groundrope used) are also taken into account.	shrimps	IMARES, ILVO	2014–2015
Extra catch comparisons and monitoring on a broader range of vessels, fishing grounds and seasons for flatfish and shrimp pulse fishing.	flatfish, shrimps	IMARES, ILVO	2014–2016
Study to optimize the front part of the shrimp-pulse-trawl to make optimal use including a) maintaining commercial catch rates; b) reducing unwanted bycatch; c) reducing energy consumption by using the opportunity the electrical startle pulse offers. The main part of the work will focus on the rigging of the groundrope, including design studies in the flume tank and the field, as well as catch comparison studies.	shrimps	TI	2014–2015
Further monitor pulse fishing technology development beyond the current status and the beam trawl applications.	all	All	2014–2015

In the discussion the following remark was made: The groundrope effect on catch and bycatch is large, research and regulations should take this into account. Discard ban might stimulate the use of more selective nets in the shrimp fishery.

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Annex 2: Terms of Reference (ToR's) 2012

2012/2/SSGESST10 The **Study Group on Electrical Trawling** (SGELECTRA), chaired by Bob van Marlen, the Netherlands and Bart Verschueren, Belgium, will meet in Ostend, Belgium, 22–24 October 2013 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 November 2013 (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 3: Agenda

Wednesday 23/10/2013

09:00 Welcome, opening and practical arrangements (Bart Verschueren)

09:00–09:15 Short intro of participants

09:15–12:30 Presentations and discussions TOR a)

Short review of SGELECTRA 2011 and 2012 (Bob van Marlen)

Update on catch comparison 2011 and reference measurements 2011 (Bob van Marlen, Dick de Haan)

Experiments on pulse fishing for shrimp in the Netherlands (Bart Verschueren)

Update on the development of the German "Hovercran" (Petr Zajicek and Daniel Stepputtis)

12:30–13:30 Lunch break

13:30–16:30 Presentations and discussions TOR a)

The effect of different pulse parameters on marine organisms (Maarten Soetaert)

Recent experiments on cod in Norway – comparison between Belgium and Dutch results (Dick de Haan, Maarten Soetaert)

Pulse trawling for brown shrimp: Consequences for young life stages in spawning areas? (Marieke Desender)

Electrical fishing for Ensis – Update on developments (Phil Copland).

Presentations and discussions TOR b)

Influence of a discard ban on the transition towards more selective fishing gear (Jurgen Batsleer presented by Bob van Marlen).

Thursday 24/10/2013

09:00–12:30 Presentations and discussions TOR c)

Update on Control and Enforcement documents produced in The Netherlands (Bob van Marlen).

12:30–13:30 Lunch break

13:30–16:30 Discussion of the report recommendations for further work en new TORs – future of SGELECTRA

Writing report SGELECTRA – 2013.

Annex 4: Suggestions for further work

- This section contains a summary of recommended work.

Recommendation	For follow up by:
1. Longer and more elaborate catch comparisons on the recent gear types, in order to get a beter insight in abundancy of injuries, the role of certain pulse parameters and a good estimation of the landings.	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 and UGhent
3. Report on the trials on the Hovercran developed in the Dutch fleet.	IMARES and ILVO
4. Continue the investigation of the effect of the electrical stimulation on eggs, larvae and juveniles of cod and sole, using the Hovercran and the flatfish type of pulse.	ILVO and UGhent IMARES
5. Carry out research on pulse suitable to generate the startle response in sole	ILVO and UGhent and TI
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 and ILVO and TI researchers in collaboration with fisheries managers
7. Harmonize sampling and data collection methods	
8. Continue monitoring catches onboard commercial pulse trawl vessels in 2014.	IMARES, ILVO, TI IMARES
9. Further consider the development of *Ensis* fishery in the UK.	MSS, SEAFISH?

Activity	Target Species	Organization	Timing
Using other, lower energy pulse systems for fishing *Ensis* than currently used.	Ensis	MSS	2014
Pilot study using the defined control and enforcement documents with physical implementation of monitoring technology.	flatfish	IMARES, ILVO	2014
Further tank experiments on wild-caught cod, using pulse simulators.	flatfish	IMARES, ILVO	2014
Create control and enforcement documents for the shrimp pulse fishery in which other aspects than the electrical stimulus (e.g. the groundrope used) are also taken into account.	shrimps	IMARES, ILVO	2014–2015
Extra catch comparisons and monitoring on a broader range of vessels, fishing grounds and seasons for flatfish and shrimp pulse fishing.	flatfish, shrimps	IMARES, ILVO	2014–2016
Study to optimize the front part of the shrimp-pulse-trawl to make optimal use including a) maintaining commercial catch rates; b) reducing unwanted bycatch; c) reducing energy consumption). By using the opportunity the electrical startle pulse offers. The main part of the work will focus on the rigging of the groundrope, including design studies in the flume tank and the field, as well as catch comparison studies.	shrimps	TI	2014–2015
Further monitor pulse fishing technology development beyond the current status and the beam trawl applications.	all	All	2014–2015

Annex 5: Proposed Multi-annual TORs for 2014–2016

The **Study Group on Electrical Trawling** (SGELECTRA) **will be renamed** as the **Working Group on Electrical Trawling** (WGELECTRA), chaired by Bob van Marlen*, The Netherlands and Bart Verschueren*, Belgium, and will meet in IJmuiden/Aberdeen/Rostock, Netherlands/Scotland/Germany, 22–24 October 2014, to work on ToRs and generate deliverables as listed in the Table below.

WGELECTRA will report on the activities of 2014 (the first year) by 30 November 2014 to SSGESST.

ToR descriptors

ToR	Description	Background	Science Plan topics addressed	Duration	Expected Deliverables
a	Review 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, Scotland, Belgium and Germany.	a) Science Requirements Need for better understanding of short-term and long-term effects on various species and life stages. b) Advisory Requirements Need for better understanding of thresholds of pulse characteristics and effects. c) Requirements from other EGs	211, 214	year 1, 2, 3	Scientific paper(s) by year 3 to WGFTFB, WGCRAN, WGECO
b	Evaluate the effect of a wide introduction of electric fishing, with respect to the economic impact, the ecosystem impact, fleet dynamics, the energy consumption, and the population dynamics of selected species.	a) Science Requirements Need for appraisal of effects of large-scale use. b) Advisory Requirements c) Requirements from other EGs	211, 214	year 1, 2, 3	Scientific paper(s) by year 3 to WGFTFB, WGCRAN, WGECO
c	Conduct a pilot study on defined control and enforcement procedures for flatfish pulse trawling.	a) Science Requirements b) Advisory Requirements Need for an adeqaute control of fishing capacity in view of ecosystem effects. c) Requirements from other EGs	214	year 1 and 2	Pilot study report by year 2 to ACOM

d	Define control and enforcement procedures for shrimp pulse trawling, including technical aspects of pulse stimulation and rigging of the groundrope.	a) Science Requirements b) Advisory Requirements Need for an adeqaute control of fishing capacity in view of ecosystem effects c) Requirements from other EGs	214	year 1 and 2	Control and enforcement documents for shrimp trawling by year 2 to ACOM
e	Further monitor pulse fishing technology development beyond the current status and the beam trawl applications.	a) Science Requirements Need for appraisal of ecosystem effects when pulse stimulation is used in other gear than beam trawls. b) Advisory Requirements Need for an adeqaute control of fishing capacity in view of ecosystem effects c) Requirements from other EGs	214	year 1, 2, 3	Review paper(s) by year 1, 2, 3 to WGFTFB, WGCRAN, WGECO
f	Make an inventory of views on pulse fishing among various stake-holders in European member states.	a) Science Requirements Need for understanding views and attitudes b) Advisory Requirements Need for understanding management implications and policy issues. c) Requirements from other EGs	214	year 1 and 2	Stakeholder views inventory report by year 2 to WGECO

Summary of the Work Plan

Year 1	Fundamental research on the effect on pulse stimulation on xx, both juvenile and adults stages by PhD workers under guidance of ILVO and University Ghent, Belgium. Pilot study on defined control and enforcement procedures for flatfish pulse trawling by IMARES, Netherlands. Further tank experiments on wild-caught cod, using pulse simulators by IMARES, Netherlands, and ILVO, Belgium. Study effects of pulse beam trawling on benthic invertebrates in EU-project BENTHIS by IMARES, Netherlands, and ILVO, Belgium. Monitor economic performance of more vessels in EU-project BENTHIS by LEI, Netherlands. Ongoing experiments with electrical shrimp fishing in Belgium and the Netherlands by ILVO Fishery, Belgium. Study on effects on electric fishing for *ensis* by Marine Scotland Science, and the possibilities of using other, lower energy pulse systems than currently used. Study to optimize the front part (particularly the groundrope) of shrimp-pulse-trawls with respect to a) maintaining commercial catch rates; b) reducing unwanted bycatch; c) reducing energy consumption in Germany by Thuenen Institute. Comment on the technical development of an electrical twin-trawl system as part of the Dutch "Masterplan Duurzame Visserij" by IMARES IJmuiden, The Netherlands. Make an inventory of views on pulse fishing among various stakeholders in European member states.
Year 2	Fundamental research on the effect on pulse stimulation on xx, both juvenile and adults stages by PhD workers under guidance of ILVO and University Ghent, Belgium. Study effects of pulse beam trawling on benthic invertebrates in EU-project BENTHIS by IMARES, Netherlands, and ILVO, Belgium. Monitor economic performance of more vessels in EU-project BENTHIS by LEI, Netherlands. Ongoing experiments with electrical shrimp fishing in Belgium and the Netherlands by ILVO Fishery, Belgium. Study on effects on electric fishing for ensis by Marine Scotland Science, and the possibilities of using other, lower energy pulse systems than currently used. Study to optimize the front part (particularly the groundrope) of shrimp-pulse-trawls with respect to a) maintaining commercial catch rates; b) reducing unwanted bycatch; c) reducing energy consumption in Germany by Thuenen Institute. Comment on the technical development of an electrical twin-trawl system as part of the Dutch "Masterplan Duurzame Visserij" by IMARES IJmuiden, The Netherlands. Define control and enforcement documents for the shrimp pulse fishery in which other aspects than the electrical stimulus (e.g. the groundrope used) are also taken into account by IMARES, Netherlands, Thuenen Institute Germany, and ILVO, Belgium. Comment on the technical development of an electrical twin-trawl system as part of the Dutch "Masterplan Duurzame Visserij" by IMARES IJmuiden, The Netherlands. Make an inventory of views on pulse fishing among various stakeholders in European member states.

Year 3	Fundamental research on the effect on pulse stimulation on xx, both juvenile and adults stages by PhD workers under guidance of ILVO and University Ghent, Belgium. Study effects of pulse beam trawling on benthic invertebrates in EU-project BENTHIS by IMARES, Netherlands, and ILVO, Belgium. Monitor economic performance of more vessels in EU-project BENTHIS by LEI, Netherlands. Ongoing experiments with electrical shrimp fishing in Belgium and the Netherlands by ILVO Fishery, Belgium. Study on effects on electric fishing for ensis by Marine Scotland Science, and the possibilities of using other, lower energy pulse systems than currently used. Study to optimize the front part (particularly the groundrope) of shrimp-pulse-trawls with respect to a) maintaining commercial catch rates; b) reducing unwanted bycatch; c) reducing energy consumption in Germany by Thuenen Institute. Comment on the technical development of an electrical twin-trawl system as part of the Dutch "Masterplan Duurzame Visserij" by IMARES IJmuiden, The Netherlands. Define control and enforcement documents for the shrimp pulse fishery in which other aspects than the electrical stimulus (e.g. the groundrope used) are also taken into account by IMARES, Netherlands, Thuenen Institute Germany, and ILVO, Belgium. Comment on the technical development of an electrical twin-trawl system as part of the Dutch "Masterplan Duurzame Visserij" by IMARES IJmuiden, The Netherlands. Make an inventory of views on pulse fishing among various stakeholders in European member states.

"Supporting information

Priority	Pulse trawling is used under national derogation on commercial vessels in growing extent in various ICES member states, *e.g.* The Netherlands, Belgium, UK, and Germany. Per 01/01/2013 a total of 51 licences to use this technique were issued in The Nethrelands, , Belgium, UK, and Germany. ICES gave advice on the effects on the ecosystem of the implementation of this technique in fishing fleets in 2006, which was updated in 2009. The current activities of this Working 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.
Resource requirements	The research programmes which provide the main input to this group are already underway, and many of the resources are already committed, but for some tasks new resources ought to be found.
Participants	The Group is normally attended by some 10–15 members and guests.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	There are no obvious direct linkages.
Linkages to other committees or groups	There is a very close working relationship with all the groups of SSGESST. It is very relevant to the Working Group on Fishing Technology and Fish Behaviour (WGFTFB) , WGCRAN, WGECO and WGNSSK.
Linkages to other organizations	

Annex 6: Table of pulse research topics 24/09/2013 (IMARES, Martin Pastoors)

Theme	Issue	Need expressed	Existing knowledge status	Knowledge gaps	Proposed research	Need
Ecology	Claims of damaged or dead fish and additional fish mortality from the industry.	Stakeholder analysis	Very little active monitoring of stakeholder claims	Claims are being presented of adverse effects due to pulse trawling without real evidence.	Collect and log the 'anecdotes', discuss them with pulse fishers and others (if possible), try to understand a pattern if possible.	H
Ecology	Current research only focuses on limited number of species. More species come into contact with pulse trawl that are not captured. This relates to the issue of dead fish reported by fishermen.	STECF	Catsharks, cod, six benthic species studied. Effect on cod can be prominent, other effects were limited.	Why did Dutch find spinal damage in cod, and Belgians not? Potential impacts on non-researched species	Compare Dutch and Belgian studies in a repeated experiment. Develop monitoring approach for unaccounted mortality (e.g. by sampling on board of non-pulse vessels?)	H
Ecology	Thresholds of short and long-term effects of pulse characteristics are not known. Pulse used in flatfish gears may be too strong	STECF, ICES	Optimal pulse for shrimps and sole developed	Can settings be reduced to decrease effects?	Fundamental research on various species under pulse stimulation with varying pulse characteristics.	H

Theme	Issue	Need expressed	Existing knowledge status	Knowledge gaps	Proposed research	Need
Ecology	Effect on electro-receptor organs of elasmobranchs fish is not known. Stocks of these fish are in decline, and special conservation measures might be required.	ICES	Such organs are very sensitive to electric currents, and may get disturbed. Only catsharks as indicator species studied.	Fish may not be able to detect prey after exposure to electric fields of pulse trawls. What about rays?	Study elasmobranch prey detecting capabilities after exposure. Include rays.	M
Ecology	Long-term effects on populations (including mortality over longer time, reproduction, juvenile stadia and growth).	ICES/ Soetaert	Only short-term effects studied with limited pulse settings, and limited on direct mortality and larger sizes, only some indicator species.	Long-term effects (including mortality over longer time, reproduction, juvenile stadia and growth) on populations are not known.	Studies on target and non-target biota in contact with gears: indirect mortality, growth, reproduction, of adult and juvenile stadia on longer term.	M
Ecology	Effect on substrate (habitats) and chemical composition in water column from electrolysis.	Soetaert *et al*.	Some claims of potential effects were given (e.g. Mike Breen on chlorine production).	Effect on substrate (habitats) and chemical composition in water column not known.	Research into effect on sediments of electric pulses. Research into dissolution of chlorine compounds by electric pulses.	M
Economy	Economy of pulse trawling applications, and socio-economic aspects are not all known.	STECF?	Some existing systems are evaluated. This shows economic potential. NL industry invests in the method as the best alternative to tickler chain.	Does this apply to all systems? Can this be extended to new technical developments?	Monitor economic performance of more vessels (BENTHIS).	M

Theme	Issue	Need expressed	Existing knowledge status	Knowledge gaps	Proposed research	Need
Management	Resistance to allow pulse trawling within other European member states (BE, DE, FR, UK). Problem perceived as a Dutch problem only. Stakeholder perceptions of risks associated with electricity and fishing.	Dutch government	Some EU member states oppose the implementation of pulse trawling on a wider scale.	Perceptions? Interests? Fears? Hidden agendas?	Stakeholder analysis, interviews. Research on political aspects.	H
Management	Control and enforcement needs to be assured.	STECF, ICES	Control and enforcement documents and technology defined.	Practical experience with the suggested rules and technology.	Do pilot study with newly suggested regulations and performance monitoring technology with inspection agencies.	H
Management	Decision framework and models are not fully developed.	IMARES	Crude models exist (e.g. Piet *et al.*, 2009) and show potential in reducing discards in five target species.	Effects of new effort allocations, fishermen's response, effects on benthic species, definite ecosystem indicators.	Extend ecosystem research and models.	M
Management	Most reports only in grey literature.	ICES, STECF	Papers in preparation, 1 submitted (van Marlen)		Several papers in progress.	H
Management	Insufficient visibility of international research	IMARES workshop	SGELECTRA platform for research	Need for more comprehensive expert groups on effects of electricity in marine environment	Expand scope and outreach of SGELECTRA	H

Theme	Issue	Need expressed	Existing knowledge status	Knowledge gaps	Proposed research	Need
Technology	Technology progresses beyond the current status. Pulse characteristics for shrimps and flatfish will be combined in one system. Pulse trawling will be developed for other gears than beam trawls, e.g. twin-trawls, dredges,...	ICES	DELMECO integrates shrimp and flatfish pulse.	What are the new pulse settings, what are effects?	Monitor pulse technology development beyond the current status and the beam trawl applications.	H
Technology	Monitoring of spatial deployment of pulse gears	Stakeholder analysis	VMS data available	Do pulse vessels explore different grounds?	Monitor spatial deployment of pulse gears	M

Annex 7: Procedure Control and Enforcement in Pulse Fishery – Version sent to the EU – 30/08/2012

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

Definitions

A. Pulse fishing gear

A towed fishing gear meant to stimulate marine organisms (such as: flatfish, shrimps, razor clams) out of the seabed by means of a pulsating electrical field.

(Explanation: Towed fishing gears are trawls, including scallop dredges. Purse-seines, Danish seines and fly-shoot gear are excluded, as well as all sorts of static and passive gears.)

B. Electrode

A combination of electrically isolated connecting parts and conductors.

C. Pulse module

A self-contained pulse generator to be controlled from the fishing vessel, and placed in, or on a pulse fishing gear that converts the electrical energy supplied by the ship's generator in electrical pulse stimuli.

D. Stimulation field

An electric field generated by a composition of at least two or more electrodes, towed parallel with the direction of motion.

E. Field strength

The potential difference (expressed in V_{rms}, 'root mean square') per m. The unit is thus: V_{rms}/m.

F. User guidelines

Guidelines for the users giving instructions for a safe and effective operation of the pulse fishing gear.

G. Technical file

A unique document issued by the system manufacturer on delivery of the pulse fishing gear. This document describes at least:

1. The on-board components (generators, winches, computers, data storage medium), and wet components (feeding cables, stimulation field, etc.) of the Pulse fishing gear;
2. System information of components, among which: product name, serial number(s) of products,
3. The type of data storage medium for recording the events of exceeding the prescribed limits of the pulse fishing gear.
4. Details of physical components of the Pulse fishing gear, such as:
    a. The number, of electrodes, with a description of isolators, conductors and connectors with their minimum and maximum length, minimum and maximum diameter, average spacing and material used.
    b. The number of Pulse modules and their serial numbers, if applied.
5. Characteristics of the pulse stimulation, including pulse shape, amplitude and pulse frequencies.
6. The result of the measurements of pulse amplitude in true rms in an unloaded circuit (no impedance) and the peak amplitudes in a laboratory and/or on-board the vessel, carried out by a certified organization or using certified measuring equipment, with a known and constant accuracy within 2%.

(Explanation: The aim is to measure the unloaded clamp voltage, giving the maximum the pulse fishing gear can attain, which is always lower in situ in seawater.)

7. A protocol describing the method and timing of safety inspections on the components of the pulse fishing gear.

H. Type Approval Certificate.

This is a certified document issued by an accredited certifying agency to confirm that the pulse fishing gear, on board of the vessel indicated in the document, meets the criteria as described in the **User guidelines**. The certificate will be issued for a period of at least one year. A logbook documenting the results of the inspections as required in the **Technical file** will be part of this certificate.

Concerning legislation

In exemption of Article 31, Item 1 of (EC) Reg. no. 850/98 it is allowed to fish with maximum two pulse fishing gears in ICES-areas IIIa, IV, VIIa,e,d,f,g,h and VIIIa,b,c,d.

(Explanation: this is depending views in EU STECF and the EU Commission.)

The following conditions and restrictions do herewith apply:

1. On-board the vessel the following documents must be available:
    a. An original and marked **Type Approval Certificate** (H) proving that the pulse fishing gears belong to the vessel, and safety inspections have been carried out;
    b. The **Technical file** (G) describing the composition of the pulse fishing gears;
    c. The User guidelines for a safe and effective operation (F);
2. Prior to the first fishing trip using the pulse fishing gears a copy of the **Type Approval Certificate** must have been submitted and received by the inspection agency (e.g. NVWA, or ILandT in the Netherlands).
3. The composition of the pulse fishing gears conforms to the description in the **Technical file.**
4. The width of the Stimulation field, defined as the horizontal distance between the first and last electrodes at the outside, and measured across the Stimulation field perpendicular to the electrodes may not exceed the width of the fishing gear and in any case should not exceed 12 m per pulse fishing gear.

(Explanation: It should be avoided that the catch efficiency is raised beyond current levels. The maximum width is also important to avoid that pulse stimulation in e.g. a twin-rig, may render this gear as more efficient on sole, which was restricted by the beam length limitation in beam trawling to 12 m.)

5. The amplitude in true rms measured as given in the Technical file (G4) on the first conductors of an electrode must not exceed 0.25 V_{rms}/cm.
6. The supplied electrical power, as measured at the ship's generator output, before the feeding cables of any single pulse gear may not exceed 1.0 kW_{rms} per meter of beam length or width of the stimulation field.

(Explanation: Some fishermen asked to maintain 1.25 kW/m. The producers have indicated that in actual practice the input need not exceed 1 kW/m, which implies a reduction obtained of 20% compared to the current limit in the derogation.

The application of pulse stimulation in shrimp trawling is still under development, and optimal characteristics on the pulse setting to be used cannot be given at this moment. The research so far indicates that settings will actually be lower than the 1.0 kW_{rms}/m beam width and 0.25 V_{rms}/cm suggested here on the basis of research and development in flatfish pulse trawling. These developments will be closely monitored and further studies be carried out.)

7. The excess of set values as given in the Technical file (G5,6) must be recorded automatically and continuously without the possibility of manipulation for each pulse fishing gear and the records stored in the data storage medium.
8. The data storage medium must provide adequate data storage capacity for at least the previous 3 months, and be secured against unintended access, ensuring that data stored cannot be changed. Access to the data storage medium should be restricted to authorized compliance and certification persons, while reading permission should be allowed to the skipper or one of the crew members of the fish-

ing vessel. The skipper should announce any excess of prescribed limits without delay to the inspection authorities.

9. Except the groundrope, the use of tickler chains, net ticklers or any other form of mechanical stimulation, whether perpendicular or parallel with the direction of motion of the fishing gear, is prohibited in pulse fishing gear.

Concerning inspection and control

Inspection activities at sea can be distinguished at two levels:

Level 1: Routine inspections on-board aimed at checking the availability of required documents and the physical characteristics of the fishing vessel and the pulse fishing gears with the **Type Approval Certificate** (H), and **Technical file** (G). Such inspections do not require technical expertise.

Level 2: Accessing and reading data from the data storage medium mentioned in Article 8 above as a routine inspection or when suspicion may have risen of a breach with these regulations. Several options can be considered here: replacing the data storage medium and having its data read out, sending the data along with VMS-data, or attaching the data to the electronic logbook and sending it this way.

Concerning enforcement and sanctioning

Infringement of these rules allowing use of Pulse fishing gear will be regarded as a breach of the certifying regulations, and as serious an offence as using prohibited net attachments (such as liners, restricting ropes, too small mesh sizes) or fishing in positions that are not allowed, with sanctions according to such an offence.

Concerning implementation

At any adaption of the regulations, preferably as given in this document, pulse fishers should comply immediately (as per date of change).

For vessels fishing under licence conforming the current derogation it may be necessary in order to comply with the new rules to adapt their systems partly or completely. They need full compliance with these regulations after a transition period of maximum 12 months.

Annex 8: Inspection Report Pulse Fishery – 30/08/2012

Netherlands Food and Consumer Product Safety Authority
Consumer and Safety Division, Department of Sustainability.

INSPECTION REPORT **PULSE FISHERY**

Data fishing vessel:	
Vessel ID and number	
Name	
Nationality	
Name of skipper	
Name, mailing address and city of fishing company	… … …
Producer, brand, type of pulse fishing gear	
Installed engine power (kW)	
Fishing method	
Data on inspection :	
Date of inspection	
Place of inspection	

• Port			
• If at sea : position and ICES-area	… …		
Questions concerning fishing gears:			
Check on availability and validity of documents	Answer/Comment	meets criteria	does not meet criteria
Type Approval Certificate available on-board?			
Certificate issued on which date?			
Certificate valid on which date?			
Certificate marked by organization (date/place/stamp)?			
Name, mailing address and city of data certifying organization?	... ...		
Logbook part of certificate: Safety inspections carried out on which date?			
Safety inspections carried out by …?			
Result of latest safety inspection?			
Technical File available on-board?			
Technical File issued on which date?			
Technical File valid on which date?			
Technical File marked by produc-			

er?			
Technical File describes at least?: • Number of electrodes • Length of electrodes (m) • Spacing of electrodes (mm) • Number of conductors per electrode • Number of isolated parts per electrode • Thickness of conductors (mm) • Characteristics of the pulse stimulation • Description of Pulse Modules • Storage medium and access • Electrode peak voltage and V_{rms} under laboratory conditions	… … … … … … … … … …	… … … … … … … … … …	… … … … … … … … … …
Check on physical dimensions in documents, do actual values match those given in documents?	Answer/Comment	match	no match
Beam or wing length (m)			
Width of stimulation field (m)			
No tickler chains used			
Criteria met by technical variables: • Number of electrodes • Length of electrodes • Spacing of electrodes • Number of conductors per electrode • Number of isolated parts per electrode • Thickness of conductors	… … … … … …	… … … … … …	… … … … … …

• Characteristics of type description • Description of Pulse Modules • Storage medium and access • Electrode peak voltage and V_{rms} under laboratory conditions	… … … …	… … … …	… … … …
Width of stimulation field is equal or less than beam or wing length (max 12 m)			

Comment: Further detailed questions can be required on the data-storage medium. If needed this will be defined at a later stage. Lay-out still to be optimized.

Annex 9: Monitoring and control system Pulse Fishery - Rev 4 EN 2012-08-31

Author:	D. de Haan
Date:	31 August 2012
Revision nr:	4
Revisions	Addition of laboratory measurement as guideline to the reference values for supplied electrical power and electric field strength Electrode Voltage is not arithmetically determined from pulse settings, but based on a real measurement Generic Model (Figure 1)

Objective

An effective control and enforcement of pulse fishery requires that the performance in terms of electrical power supplied to the system and the pulse stimulus does not exceed defined limits. The objective for a monitoring and control system is to guard certified settings of the pulse fishing gear and record the events where these references are exceeded, or attempts are made to manipulate the operation or outcome.

Introduction

The values of the supplied electric power and the voltage across the conductors of electrodes (≈pulse voltage amplitude) are the main references for controlling the certified ratings for pulse fishing. The present derogation for supplied electric power is 1.25 kW per meter beam length and a step back to 1 kW/m appeared feasible. The electrode pulse amplitude 15 V, unspecified as such, but interpreted as the RMS (Root Means Square) value 15 V_{rms}.

The present commercial pulse systems differ in pulse shapes and so in terms of supplied electric power and electrode voltage amplitudes, with values between 0.58 kW/m and 0.7 kW/m and the pulse voltage amplitude, ranging from 6.5 to 11 V_{rms} (the upper limit 11 V_{rms} is an estimate and will have to be validated). The final measure will be referred to field strength per cm electrode spacing as than the electrode spacing is decoupled from the measure and can be kept as variable in future electrode arrangements. A field strength of 0.25 V_{rms}/cm is the arithmetic result of 10 V_{rms} electrode voltage amplitude and 40 cm electrode spacing (practical range).

The effects of the nominal pulse ratings were tested in the laboratory on cod (de Haan *et al*., 2008 and 2011) and dogfish (de Haan *et al*., 2008) and on benthic invertebrates (Van Marlen *et al*., 2009).

Ranges above nominal are apparently allowed in the derogation, which allows settings for electric power and electrode voltage amplitude above the ranges tested on marine biota. As the effects on marine biota are not known, application above the nominal range will demand additional tests on the effects.

Efficient guarding of pulse references relies on a high overall accuracy, within 2% overall. This allows a low offset between settings of pulse parameters to be certified, and their defined threshold levels marked as an event of excess. In this approach a threshold level of 10% above certified ratings is proposed. The certified ratings are defined as the maximum possible rating applied which will include seasonal changes.

For both limits (electrical supplied RMS power per meter beam (or wing) length, and electric field strength), it should be defined which sanctions will be imposed at which levels of excess.

The maximum controllable pulse limits differ per pulse design. The procedure for Control and Enforcement of Pulse Fishery and the Technical File of the pulse fishing gear give maximum values for electrical RMS power (thus in kW_{rms}/m) supplied to the system and maximum electric field strength in V_{rms}/cm, based on the voltage amplitude of the pulse measured at the most frontal conductors of the electrodes and the distance between the conductors. Although the peak voltage amplitude is not a reference parameter, it is stored in the certification list of the manufacturer. The position of these conductors is closest to the pulse discharge module. Within the boundaries of certified levels, the user can choose operational settings for the pulse characteristics (pulse amplitude, pulse frequency, and pulse duration). A problem is, that the electrode voltage is not easily measured real-time *in situ* unless the measured data can be coupled over the existing electric cables between the deck unit and underwater system and connections of measurement probes to the electrodes can be avoided. In our Procedure Control and Enforcement in Pulse fishery we propose a certified laboratory measurement in air with a fixed load as reference for the highest possible RMS voltage amplitude. As this control instrument relies on an accurate measurement the procedure of this laboratory exercise is described in detail in this document.

Another concern is that the laboratory certification exercise will not produce the nominal rating of supplied electric power in the fishing condition at sea, and that there are no measured data records available, other than estimates from the manufacturer. This called for additional measurements, which were executed in a laboratory for all present operational stimuli and will be continued at sea on full discharge systems. The laboratory measurements were limited to a pair of discharge modules and as a 12 m pulse gear contains 25 to 27 modules the extrapolation of the results of a pair of modules could contain errors.

To reduce this uncertainty measurements in the field are foreseen on fishing vessels with at least 10 modules.

Access to the control instrument is restricted to the manufacturer of the pulse fishing gear, his authorized representative(s), and staff of authorized inspection organizations. Experience in the design of a measuring and registration system of shaft horse power of fishing vessels for control of 221 and 1471 kW licences is used in our design for pulse fishing gear.

Definition of Limits

Supplied Electric Power

The present derogation for supplied electric power is 1.25 kW per meter beam length, while manufacturers proposed a decrease to 1 kW/m. The maximum nominal range of supplied electric RMS power depends on the applied pulse concept. At present there are a number of concepts operated on the Dutch market all these with different values for electric supplied power and RMS pulse voltage amplitudes (Table 1). The current available pulse systems use different methods of pulse generation and control of the pulse settings. Pulse settings can either be fixed in the hardware of the pulse fishing gear, or real-time controllable on a bridge control module in a range ±10% around the nominal value.

The supplied electric power ratings based on single discharge modules under laboratory conditions (Appendix 1, Table 1) are in the range of 0.47 and 0.90 kW_{rms}/m. The proposed threshold level, which triggers the recording of an excess, is +10% above the highest value of the measured result, and thus 1 kW_{rms}/m. The observed differences between the two commercial pulse concepts demand a validation with full discharge systems under normal fishing practice at sea.

Voltage amplitude across the conductors

The second pulse parameter to monitor and control is the RMS voltage amplitude measured across the two conductors of an electrode closest to the pulse discharge module (defined in the document: Procedure Control and Enforcement in Pulse fishery). As an external measurement across these conductors under fishing practice is practically difficult to maintain, the voltage will be measured in the interior of a discharge module at the junction of the electrodes. In practice the isolated electrode length between this junction and the first conductors is in the range of 3 to 4 m and the voltage drop across the isolated electrode leads over this length can be determined in the laboratory and the result of the electrode voltage reading will be compensated in software with this drop. The voltage across the conductors measured under laboratory conditions (Appendix 1, Table 1) is in the range of 6.19 V_{rms} and 9.75 V_{rms}. The proposed threshold level, which triggers the recording of an excess, is +10% above the highest value of the measured result. Based on the conductor distance and highest measured result the proposed threshold level is 0.25 V_{rms}/cm.

The first step for a pulse system is to derive a certification, and the discharge characteristics over the conducting elements of the electrodes are measured in a certified laboratory with certified equipment.

Laboratory certification and reference measurements

To certify the pulse characteristics any new pulse development has to pass this stage first. The voltage across the front and aft conductors of a pair of electrodes is measured in air with certified equipment using a pair of certified fixed metal film resistors of equivalent value in the range of 0.8 to 1.2 Ω (certified in terms of temperature stability and resistor tolerance). The front conductors are in the position closest to the pulse discharge unit, the aft conductor pair at the far end of the electrode pair. This load condition is far below the nominal range used *in situ* underwater during fishing and will produce the highest possible electrode amplitude voltage presenting the worst case condition of the pulse amplitude range. The fore and aft position of the resistors will show the discharge characteristics over the complete electrode length. The RMS and peak values of the voltage across the front and aft conductor sections will be measured as well as pulsewidth and frequency and the pulse shape, which will be saved as a picture together with the other data in a library. The measurements are conducted by a certified laboratory and the load conditions and equipment will be used as standard for all commercial pulse systems.

Amplitude Voltage limitations

The present derogation uses a limit of 15 V, here interpreted as 15 V_{rms} and this value was adopted before effect studies were conducted. The measurements in the laboratory showed the maximum electrode voltage present systems can produce is 9.75 V_{rms} (Appendix 1, Table 1). As a measurement at sea will not lead to a higher result, this outcome can be taken as reference for the actual threshold. The highest electrode voltage for which the effects were studied (de Haan *et al*., 2008, 2011, van Marlen *et al*., 2009) is 6.3 V_{rms}. A reduction from 15 to 10 V_{rms} is justified by the laboratory measurements, and this reduction ensures that the threshold value chosen is closer to the range of values used during the tests. We suggest to convert this threshold value to field strength per cm electrode spacing as electrode spacing is an important variable determining effects, and not prescribed in our Procedure Control and Enforcement in Pulse fishery. A value of 0.25 V_{rms} /cm and 0.4 m electrode spacing (practical range) will be the result of setting the threshold to 10 V_{rms} electrode voltage.

Bridge monitor

The peak and RMS voltage amplitude, pulsewidth and pulse frequency are displayed on a bridge monitor. Excess event will generate an alarm indicator on the bridge monitor. The latest data of fished pulse parameters will be kept displayed after completion of a fishing haul and refreshed when a new haul starts.

Description and generic model of the system

The Monitoring and Control System for Pulse Fishery is given in the generic model of Figure 1. Data from the electric power converter and pulse circuitry are processed in a processing module where the analogue signal from the power converter is digitized and the moving average determined over a fixed period of 5 minutes to balance out the dynamics of the variance of discharges driven by the towed operation and fluctuation of conductance (salinity and conductor distance). Each sample is compared to the reference threshold marked as an exceeding and the integrator is triggered as soon as the level of a sample exceeds the threshold. When the averaged result exceeds the threshold the exceeded value is stored in memory with the date and time reference of the first exceeding. When the first sample after the completion of a moving averaging cycle still exceeds the threshold limit the integrator will restart without delay.

Data processing module

The signals representing the supplied electric power and electrode voltage will be conditioned (electrically filtered) and digitized with at least12 bit accuracy and resolution of 1 in 10000. The summation of all system errors should not exceed 2% of the nominal range.

The voltage loss over the electrode leads between the connection and first conductors (3 to 4 m) is determined in the laboratory and will be implemented as fixed in software as compensation for the final result.

The values for the peak voltage amplitude, pulsewidth and pulse frequency are displayed on the bridge monitor. The latest data will be kept displayed after completion of a fishing haul and refreshed when a new haul starts. The Monitoring and Control System will regularly perform self-tests (e.g. once per 24 h), results of which will also be stored with a date and time reference.

The real-time electrode voltage measurement will be processed as a second DAQ channel similar to the specification of the electric power channel (12 bit resolution, 1% accuracy). The sample rate should be not lower than a factor 20 times the highest pulse frequency (not lower than 1 kHz).

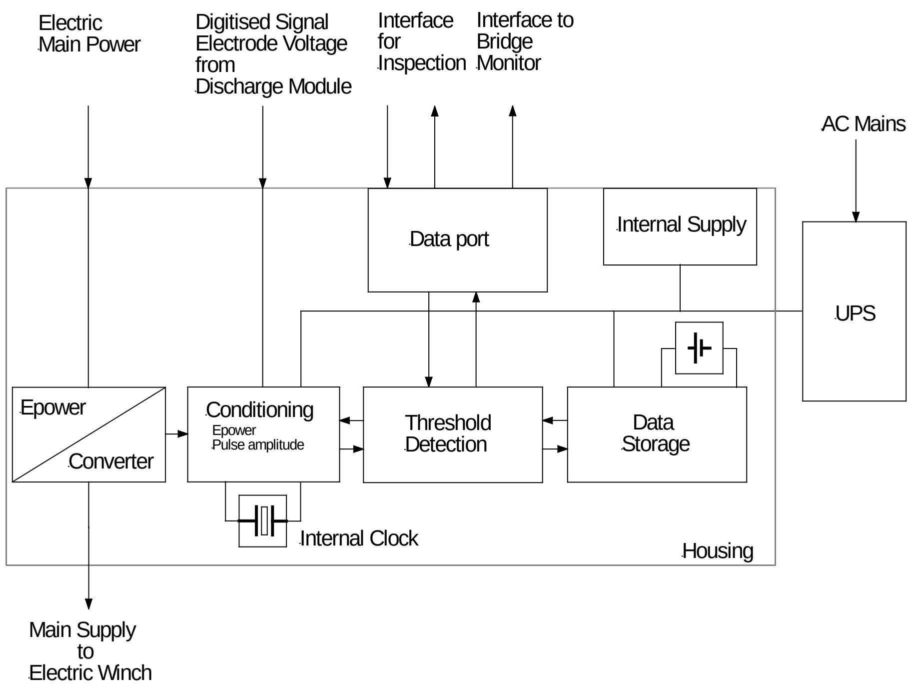

Figure 1. Generic model of the Monitoring and Control System for Pulse Fishery.

Conditions underlying recordings and the action generated:

1) When levels of certified pulse variables are exceeded;
   a. The average value of the variables.
   b. Date and time reference of the event.
2) When levels of certified pulse settings are changed by the producer;
   a. Old and new pulse setting.
   b. Date and time reference of the event.
2) Unauthorized access and defects (including battery failure);
   a. Date and time reference of the event.
4) Self-test values of pulse parameters once per 24 h;
   a. Date and time reference of the self-test.
5) Authorized access for reading data;
   a. Date and time and the ID code of the authorized person.

Data storage and formats

The data storage will be executed according a first-in first-out mode, which means when data memory is completely filled the first recording address is overwritten with the latest data and these data are lost.

The memory size will be adapted to the stored amount data, the number of ships and the capacity of authorized inspectors. Preferably inspections should be carried out within time intervals not exceeding 3 months. The memory will support storage of a period of 4 to 5 months.

Data transfer from memory will include:

1) Vessel identification (EU-Casco number, 14 positions format XXX CCYY xxxxx, EC Reg. 109–94)

2) Instrument code (Model type nr., certificate nr., and positions to be defined)

3) Person code (Inspection organization, ID xx positions)

4) Date and time reading data (CCYY-MM-DDTHH:MM)

5) Motive (inspection, maintenance; Positions to be defined)

Accuracy of the measurement and other conditions

The overall accuracy is the summation of the square root of all system errors involved and should be kept as low as possible.

- The module converting the supplied electrical power to an analogue voltage reading is defined as a class 0.5 instrument, which allows an accuracy of +/-0.5%.
- Measured values of the supplied electrical power and the simulated RMS voltage amplitude have are digitized with at least 12 bits resolution, and an overall accuracy 2%. The pulse duration is fully identical with the value set.
- The simulated pulse characteristics, with which the virtual effective amplitude on the electrodes is calculated, should also have an accuracy ≤1%.
- The Monitoring and Control System has an internal system clock with a drift lower than 1 minute over a duration of 3 months. The clock is set on UTC, and can be adjusted by authorized persons only.
- Interruptions of feeding power of the Monitoring and Control System will be overcome by an internal back-up battery of high quality and a lifespan of at least 10 years. The UPS battery capacity should support AC mains interruptions of at least 2 h.
- The accuracy of the internal clock should not deviate more than 1 minute/month.

Access to the data storage memory

The access to the data storage memory is safeguarded and limited to the manufacturer of the pulse fishing gear, and staff of certified inspection organizations by using a ciphered (encrypted) code (for the shaft power control unit a DES-algorithm or comparable code was used). This was a high specification, and the final algorithm will be adapted to the latest developments. Date and time of access are also stored in memory using a predefined format.

Bridge monitor

The registration part of the system is connected to a read-only monitoring port on the bridge of the vessel, allowing data transfer only in one direction, and through which the data storage memory cannot be accessed. The bridge monitor indicates when limits are exceeded or system-defects occur, and also displays the status of the battery. The bridge monitor is supplied through the ship's power supply system, and interruptions of this will not affect its proper functioning. Exceeding of certified levels or malfunctioning observed on the bridge monitor will have to be reported to the inspection authorities without delay.

Implementation

The measurement of the electrode voltage amplitude at the connection of the electrodes in the discharge module and the use of the serial bus of the pulse system will demand security measures against manipulation. As the electrode voltage amplitude is measured, the other pulse parameters, such as pulsewidth and pulse frequency can be derived from the analogue signal and there is no direct need to input pulse settings from the pulse control circuitry. Any input to the Monitoring and Control System will raise the risk of manipulation. The only input connections to the outside are the input of the electric supplied power and the electric voltage amplitude across the conductor, which is measured at the discharge module. Measures will have to be taken to secure the data against manipulation. Preferably the Monitoring and Control system is implemented as a separate unit with its own guarding against manipulation or access. Unauthorized access to the interior will have to be guarded and the access will cause a date/time record.

Functional requirements and environmental conditions

The housing of the Monitoring and Control System can withstand environmental conditions comparable to those of machinery rooms (defined in norm 6K3) and electromagnetic disturbances (defined in norm EN 50081-2). The housing is robust and should withstand normal working conditions on-board sea-going vessels.

For climate classification 6k3 (appliances in machinery rooms) the following norms apply:

Temperature (working)	+5 ˚C to 55 ˚C;
Temperature (storage)	-25 ˚C to 70 ˚C;
Rate of change in temperature	-25/+40 ˚C; 3 ˚C/min;
Humidity	+35 ˚C/95% rh;
Heat radiation	1200 W/m^2

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Appendix 1 Results of Laboratory measurements

Table 1a and b overview of commercial pulse systems and the nominal (a) and max (b) ratings of electric pulse parameters based on laboratory conditions with a single discharge module (this table will further develop to an overview including measurements at sea with a full discharge system). The measurements involved a single commercially representative electrode pair of two different Dutch commercial fishing systems, manufactured by Delmeco Group BV, Goes, NL and HFK Engineering BV, Soest, NL. The Delmeco electrodes contained 6 conductors, the HFK-electrodes 10. The HFK 12 m pulse wing incorporates 27 modules, the 12 m Delmeco equivalent 25. The current Delmeco electrode spacing is 42.5 cm, the HFK electrode spacing is 41.5 cm. The measurements are the result of the walking averages measured over 10 pulse cycles, measured with a 200 MHz LeCroy WaveSurfer 24XS oscilloscope with two types of differential probes, a high voltage type ADP 305 (SN5069) and a AP015 30 A probe for supply current measurements and a CWT Rogowski 60B current probe (0.5 mV/A) to measure the electrode current (not listed in this overview).

Table 1a. Nominal ratings of the controllable range.

Type of pulse system	Electric Power Supplied (kWrms)	Electric Power Supplied (kWrms/m)	Pulse Voltage (Vpeak)	Pulse Voltage (Vrms)	Electric Field strength (V/cm)	Freq (Hz)	Pulse Width (µs)
Delmeco TX-68 alternating	0.169	0.35	51	6.19	0.15	40	200
Delmeco TX19 bipolar	Implemented but not operational at present						
HFK TX-36 alternating	0.352	0.79	53.2	6.46	0.16	40	230
HFK OD-17 bipolar	Not measured						
HFK OD-17 bipolar	0.366	0.82	54.2	6.48	0.16	45	400

Table 1b. Upper limits of the controllable range.

Type of pulse system	Electric Power Supplied (kWrms)	Electric Power Supplied (kWrms/m)	Pulse Voltage (Vpeak)	Pulse Voltage nominal (Vrms)	Electric Field strength (V/cm)	Freq (Hz) nominal	Pulse Width nominal (µs)
Delmeco TX-68 alternating	0.226	0.47	63.8	9.75	0.23	40	200
Delmeco TX19 bipolar	Implemented but not operational at present						
HFK TX-36 alternating	0.388	0.87	53.2	6.96	0.17	40	260
HFK OD-17 bipolar	0.364	0.81	52.8	6.64	0.16	80	260
HFK OD-17 bipolar	0.401	0.902	53.2	7.03	0.17	45	470

Annex 10: Comments on contents by Evgeny Izvekov

I have read the SGELECTRA-2013 draft report (of 19/11/2013) curiously and found many new points of great importance. I'm glad to see the work marches on and sorry that I could not be present in person this year.

A substantial decrease in spinal injuries incidence in the code exposed to a strong electric field in the last tests is an intriguing effect. Such a long-term variability may complicate the standardization of safe levels for electric impacts. As for a possible mechanism of this difference, the seasonal changes of fish physiological state could influence their response thresholds and reactivity to an electric current (if there was a time shift between the different series of the test). Such variations are documented in some papers presented here. Lower individual threshold of the first reaction implies that during the exposure to a stronger field this fish would exhibit forced swimming activity and more powerful muscular contractions fraught with spinal injury.

For example, the thresholds of fish response to electric fields may vary following the seasonal changes in their physiological state. Thus, Caspian kilka (*Clupeonella cultriventris*) appears to be most sensitive to electric current in autumn (Nikonorov, 1956). Similarly, it was shown that threshold voltage in European anchovy (*Engraulis encrasicolus*) tends to decline from January (3.0 V) to October (1.6 V; Balaev, 1967). The same was true for the Black Sea horse mackerel (*Trachurus mediterraneus*): in autumn its sensitivity thresholds were 1.5 times lower compared to spring and summer values (Balaev, 1969). In bream (*Abramis brama*), roach (*Rutilus rutilus*) and pike-perch (*Sander lucioperca*), the head-to-tail voltages required for electrotaxis and electronarcosis were also lower when measured in autumn and winter than during the summer period (Lukashov, Usachyov, 1963). At the same time, in some other species, such as rainbow trout (*Oncorhynchus mykiss*) and carp (*Cyprinus carpio*; Vosilene, Berdysheva, 1981) or pike (*Esox licius*) and goldfish (*Carassius auratus*; Berdysheva *et al*., 1982) no pronounced seasonal variations in electric sensitivity were found. The authors could only observe a slight decrease in threshold values during the summer-winter period against the autumn-summer period, which was seen in carp (0.12 V/cm in winter vs. 0.07 V/cm in summer) and pike (1.08 V/cm in winter vs. 0.92 V/cm in summer).

This problem is also discussed in the book by D.E. Snyder (2003). Here is the large citation from this book touching upon these issues:

"*The physical condition of fish subjected to electric fields can affect their susceptibility to electrofishing injury and mortality, but assessment of this factor is based mostly on suppositions and casual observations rather than specific experiments and data. It is logical to expect that fish in poor health, or an otherwise highly stressed condition (as when habitat approaches upper limit temperature or lower limit oxygen conditions), might be less alert and sensitive to electric fields, thereby responding less strongly and reducing chances for spinal injury, but they also would be less able to withstand the stresses of tetany and apnea during narcosis, thereby increasing probability of death. Thompson et al. (1997a) observed higher incidences of injury among populations of rainbow trout with generally higher condition factors and suggested that better-condition wild fish may be more likely to be injured because of more powerful muscular contractions. However, whether in poor condition or otherwise normal, fish with weakened or brittle bones, particularly vertebrae, may be especially susceptible to spinal injuries. Stewart (1967, as cited by Lamarque, 1990) suggested that spawning fish, particularly salmon, may be especially susceptible to spinal injuries due to skeletal decalcification; likewise for fish with diets deficient in magnesium and calcium (Lamarque, 1990). Over-wintering fish may be less likely to suffer either spinal injuries or mortality due to thermally reduced metabo-*

lism and slowed responses, but like most of the above, this hypothesis has not been experimentally tested."

I hope these references are valuable for explanation of the situation with cod injury rates. By the way, different reactivity of the wild and artificially raised cod also could be a possible reason for observed variations in fish trauma-resistance across the test series.

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