

ICES WGELECTRA REPORT 2015

STEERING GROUP ON INTEGRATED ECOSYSTEM OBSERVATION
AND MONITORING

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Second Interim Report of the Working Group on Electrical Trawling (WGELECTRA)

10–12 November 2015

IJmuiden, the Netherlands



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Executive summary

WGELECTRA met in IJmuiden, the Netherlands from 10-12 November 2015 to review knowledge of the effects of electrical fishing on the marine environment (a), evaluate the effect of a wide introduction of electric fishing (b), conduct a pilot study on control and enforcement procedures for flatfish pulse trawling (c), evaluate the impacts of restrictions on pulse characteristics for shrimp pulse trawling and groundrope configurations (d), to make an inventory of views on pulse fishing among various stakeholders in European member states (e), and respond to a request by France for ICES to review the work of the Study Group on Electrical Trawling (SGELECTRA) and IMARES and to provide an updated advice on the ecosystem effects of the pulse trawl, and especially on the lesions associated and mortality for targeted and non-targeted species that contact or are exposed to the gear but are not retained on board, and with special reference to those species covered by the on Natura 2000 species and habitats Directives (f).

1 Administrative details

Working Group name

Working Group on Electrical Trawling (WGELECTRA)

Year of Appointment

2014

Reporting year within current cycle (1, 2 or 3)

2

Chair(s)

Bob van Marlen, the Netherlands

Bart Verschueren, Belgium

Meeting venue

IMARES, IJmuiden, the Netherlands

Meeting dates

10-12 November 2015

2 Terms of Reference a) – z)

ToR a

Review knowledge of the effects of Electrical Fishing on the marine environment (changes to bycatch, impact on bottom habitat, impact on marine fauna, energy and climate related issues), in view of current technical developments and recent studies carried out in The Netherlands, Scotland, Belgium, and Germany.

ToR 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.

ToR c

Conduct a pilot study on control and enforcement procedures for flatfish pulse trawling.

ToR d

Evaluate the impacts of restrictions on pulse characteristics for shrimp pulse trawling and groundrope configurations.

ToR e

Make an inventory of views on pulse fishing among various stake-holders in European member states.

ToR f

Respond to a request by France for ICES to review the work of SGELECTRA and IMARES and to provide an updated advice on the ecosystem effects of the pulse trawl, and especially on the lesions associated and mortality for targeted and non-targeted species that contact or are exposed to the gear but are not retained on board, and with special reference to those species covered by the on Natura 2000 species and habitats Directives.

3 Summary of Work plan

Year 1	<p>Fundamental research on the effect of pulse stimulation on a range of species, both juvenile and adults stages by PhD workers under guidance of ILVO and University Ghent, Belgium.</p> <p>Pilot study on defined control and enforcement procedures for flatfish pulse trawling by IMARES, Netherlands.</p> <p>Further tank experiments on wild-caught cod, using pulse simulators by IMARES, Netherlands, and ILVO, Belgium.</p> <p>Study effects of pulse beam trawling on benthic invertebrates in EU-project BENTHIS by IMARES, Netherlands, and ILVO, Belgium.</p> <p>Monitor economic performance of more vessels in EU-project BENTHIS by LEI, Netherlands.</p> <p>Ongoing experiments with electrical shrimp fishing in Belgium and the Netherlands by ILVO Fishery, Belgium.</p> <p>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.</p> <p>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.</p> <p>Comment on the technical development of an electrical twin-trawl system as part of the Dutch "Masterplan Duurzame Visserij" by IMARES IJmuiden, The Netherlands.</p> <p>Make an inventory of views on pulse fishing among various stakeholders in European member states.</p>
Year 2	<p>Fundamental research on the effect of pulse stimulation on a range of species, both juvenile and adults stages by PhD workers under guidance of ILVO and University Ghent, Belgium.</p> <p>Study effects of pulse beam trawling on benthic invertebrates in EU-project BENTHIS by IMARES, Netherlands, and ILVO, Belgium.</p> <p>Monitor economic performance of more vessels in EU-project BENTHIS by LEI, Netherlands.</p> <p>Ongoing experiments with electrical shrimp fishing in Belgium and the Netherlands by ILVO Fishery, Belgium.</p> <p>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.</p> <p>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 Thünen-Institute.</p> <p>Comment on the technical development of an electrical twin-trawl system as part of the Dutch "Masterplan Duurzame Visserij" by IMARES IJmuiden, The Netherlands.</p> <p>Evaluate the impacts of restrictions on pulse characteristics for the shrimp pulse fishery and consider recommendations for groundrope configurations by IMARES, Netherlands, Thünen-Institute Germany, and ILVO, Belgium.</p> <p>Comment on the technical development of an electrical twin-trawl system as part of the Dutch "Masterplan Duurzame Visserij" by IMARES IJmuiden, The Netherlands.</p> <p>Make an inventory of views on pulse fishing among various stakeholders in European member states.</p> <p>Respond to a request by France for ICES to review the work of SGELECTRA and IMARES and to provide an updated advice on the ecosystem effects of the pulse trawl, and especially on the lesions associated and mortality for targeted and non-targeted species that contact or are exposed to the gear but are not retained on board, and with special reference to those species covered by the on Natura 2000 species and habitats Directives by December 2015.</p>

Year 3	<p>Fundamental research on the effect of pulse stimulation on a range of species, both juvenile and adults stages by PhD workers under guidance of ILVO and University Ghent, Belgium.</p> <p>Study effects of pulse beam trawling on benthic invertebrates in EU-project BENTHIS by IMARES, Netherlands, and ILVO, Belgium.</p> <p>Monitor economic performance of more vessels in EU-project BENTHIS by LEI, Netherlands.</p> <p>Ongoing experiments with electrical shrimp fishing in Belgium and the Netherlands by ILVO Fishery, Belgium.</p> <p>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.</p> <p>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 Thünen-Institute.</p> <p>Comment on the technical development of an electrical twin-trawl system as part of the Dutch "Masterplan Duurzame Visserij" by IMARES IJmuiden, The Netherlands.</p> <p>Evaluate the impacts of restrictions on pulse characteristics for the shrimp pulse fishery and consider recommendations for groundrope configurations by IMARES, Netherlands, Thünen-Institute Germany, and ILVO, Belgium.</p> <p>Comment on the technical development of an electrical twin-trawl system as part of the Dutch "Masterplan Duurzame Visserij" by IMARES IJmuiden, The Netherlands.</p> <p>Make an inventory of views on pulse fishing among various stakeholders in European member states.</p>
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4 List of Outcomes and Achievements of the WG in this delivery period

Intermediate results were presented. Publications are foreseen in later years.

5 Progress report on ToRs and workplan

Year	ToR	Planned work	Status
1	a	Fundamental research on the effect on pulse stimulation on various species, both juvenile and adults stages by PhD workers under guidance of ILVO and University Ghent, Belgium.	<p>Desender presented a study into the effect of pulse stimulation on the electro-response organ (Ampullae of Lorenzini (AoL)) of small-spotted catsharks <i>Scyliorhinus canicula</i>, showing that there was no effect on the bite response, but the impact on the complex behaviour of sharks towards pulse trawls, or anthropogenic E-fields in general merits further investigation.</p> <p>Soetaert presented a quick overview of his PhD work done over the past 4-year period. He summarized the exposure studies carried out with sandworm, brown shrimp, sole and cod. In general his research revealed no significant adverse effects, apart from the vertebral injuries in cod, which have already been demonstrated in earlier years. The un-predictability and the varying degree of injury remain however complex and is still not fully understood.</p>
	a	Study on effect of electrical stimulation on dab (<i>Limanda limanda</i> L.)	De Haan presented a study on the relationship between pulse exposure and skin lesions in dab (De Haan <i>et al.</i> , 2014 paper <i>in prep.</i>). Lesions were found, but no clear differences between treated fish and reference fish could be distinguished. The outcome showed that no direct relation could be concluded.

a	Ongoing experiments with electrical shrimp fishing in Belgium and the Netherlands by ILVO Fishery, Belgium.	A series of trials is planned in Natura 2000 areas in 2015 on the cable-less 'Jack Wing' pulse gear for shrimps. The idea is to generate the electrical energy underwater on the gear during towing. This would make an electrical supply cable redundant. A complete new modular shrimp pulse system with 12 electrodes, and all electronics (11 modules) built inside a wing has been tested for the first time on RV 'Simon Stevin' in November 2015. During 2016 new trials on RV's and commercial shrimp cutters will be carried out. Soetaert also presented recent experimental work with an electrified benthos release panel (eBRP) in flatfish beam trawls. The combination of a BRP with pulse stimulation in the belly of the trawl allows efficient release of debris, benthos and undersized fish, without losing large quantities of marketable sole. The latter used to be a drawback in the use of a traditional BRP without electrical stimulation. Results are promising and further fine-tuning will be done.
a	Study on effects on electric fishing for <i>ensis</i> by Marine Scotland Science, and the possibilities of using other, lower energy pulse systems than currently used.	The work on the effects of fishing for <i>ensis</i> with electricity was published as an internal report and as a paper in Fisheries Research. The Scottish government is beginning a six week consultation exercise with stakeholders. The fisheries minister will then decide whether or not to approach the EU for obtaining a derogation for this fishery. At present there are no plans to investigate alternative stimuli for the <i>Ensis</i> spp. fishery.
b	Study effects of pulse beam trawling on benthic invertebrates in EU-project BENTHIS by IMARES, Netherlands, and ILVO, Belgium.	Work from BENTHIS is still ongoing and was presented at this meeting. A 300 hp pulse eurocutter and a Pulsewing (2000 hp) were compared with standard gears. Much less benthos was caught. The penetration depth of the pulse trawl was less than the tickler chain beam trawl. There was not difference in sediment resuspension. No difference in direct mortality of benthic invertebrates was found between control, tickler and pulse trawl.
b	Monitor economic performance of more vessels in EU-project BENTHIS by LEI, the Netherlands.	Work from BENTHIS is still ongoing but progress on this topic was not presented at this meeting.

c	Pilot study on defined control and enforcement procedures for flatfish pulse trawling by IMARES, the Netherlands.	Two projects for a pilot study for the Ministry of Economic Affairs run in 2015 both for the flatfish and shrimp pulse fishery.
		A new set of regulations with better limits to control was defined, based on the earlier suggestions and discussed at this meeting. The Dutch Ministry with its Inspection Agency take the lead. These projects are expected to be continued in 2016.
d	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.	No further scientific work was done in Germany, and the vessel (SD 33) working with pulse shrimp trawls was sold. There is a chance that further experiments will be taken up. At present two new commercial cutters have shifted to electrotrawling for shrimp with equipment from company Marelec. Opinions in the industry on the use of pulse stimulation are mixed.
		A research agenda on pulse fishing on brown shrimps was drafted in the Netherlands with input from various stakeholders. A programme will be made for the four Dutch shrimps vessels fishing with pulse. The idea is to minimize bycatches and bottom impact.
e	Comment on the technical development of an electrical twin-trawl system as part of the Dutch "Masterplan Duurzame Visserij" by IMARES IJmuiden, the Netherlands.	An electrified twin-rig using pulse stimulation for catching plaice and sole is still being developed under the Dutch "Masterplan Duurzame Visserij". There was no additional information since the report of 2014.
e	Make an inventory of views	An International Pulse Dialogue Meeting has been held in Scheveningen, the Netherlands in July 2015, chaired by M. Kaiser of Bangor University. 63 stakeholders participated from industry, fisheries management, science, NGOs, etc.. An inventory of topics for further study was made resulting in a wide range of suggestions related to e.g. ecosystem effects, technology and governance. This was taken onboard in defining a Dutch Pulse Trawl Impact Assessment Study for the years 2016–2019. In addition a research agenda was written with stakeholder input for pulse fishing on shrimps, and discussed during the meeting.

f	Respond to a request by France for ICES to review the work of SGELECTRA and IMARES and to provide an updated advice on the ecosystem effects of the pulse trawl, and especially on the lesions associated and mortality for targeted and non-targeted species that contact or are exposed to the gear but are not retained on board, and with special reference to those species covered by the on Natura 2000 species and habitats Directives.	A text was drafted and discussed during the meeting, see section 8. Essentials are: characteristics of the electrical stimuli from commercial pulse trawls, influence of habitat characteristics on the electrical stimuli, proportion of the population and the intensity at which the organisms are exposed, and the response of marine organisms to these electrical stimuli. A review of current work by IMARES and ILVO was added.
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6 Revisions to the work plan and justification

ToR f was added by request from ICES in October 2015.

7 Next meetings (Interim reports only)

Time: Second week of October 2016

Venue: IMARES IJmuiden, the Netherlands or ILVO Fishery Ostend, Belgium as second choice.

Duration 3 days.

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9 Annexes

Annex 1: List of participants

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Annex 2: Recommendations

Recommendation	Adressed to
Meet again in October 2016 for 3 days, venue to be decided later.	ICES Secretariat, SCICOM

Annex 3: ToR f–Respond to a request by France for ICES to review the work of SGELECTRA and IMARES and to provide an updated advice on the ecosystem effects of the pulse trawl, and especially on the lesions associated and mortality for targeted and non-targeted species that contact or are exposed to the gear but are not retained on board, and with special reference to those species covered by the on Natura 2000 species and habitats Directives.

The question about the ecosystem effects of the pulse trawl is not easy to answer because a wide variety of marine organisms and seabed habitats will come into contact with the gear during commercial operations. In order to assess the impact of pulse trawls on marine organisms and habitats, quantitative knowledge is required on the electrical properties of the pulse stimulation and on the response of marine organisms to the stimuli. The ecological impact will further be dependent on the proportion of the population that will come into contact with the pulse trawl, and the strength of the stimuli. In order to assess the ecosystem effects, it is important to make a distinction between the organisms that are retained in the net and those that escape underneath the groundrope or escape through the meshes of the codend. In the following sections the different topics will be described.

A. Characteristics of electrical stimuli of pulse trawls:

Pulse trawl systems used in the flatfish fisheries (sole) use bipolar stimuli (alternating current) with a pulsewidth of 100–270 μ s and the electric current flows during about 2% of the time (duty cycle). The peak voltage over the electrode pairs is between 45–60V and the power is 0.7 kW per meter beam width (de Haan *et al.*, submitted).

Pulse trawls generate a heterogeneous electrical field, both in the horizontal plane and vertical plane (Figure 1). Figure 1a shows the maximum field strength of a Delmeco pulse system with 32.5 cm electrode distance, a 60 V conductor voltage. Maximum field strength is highest close to the conductor elements and decreases with increasing distance from the electrode. The decrease in field strength is steeper outside the electrode pairs. The maximum field strength outside the fishing net, at a minimum distance of 40 cm outside the array of electrodes, is estimated to be less than 17 V.m⁻¹ (de Haan *et al.*, submitted). The strength of the pulse stimulus experienced by an animal in the path of the trawl thus depends on the position of the animal relative to the electrodes.

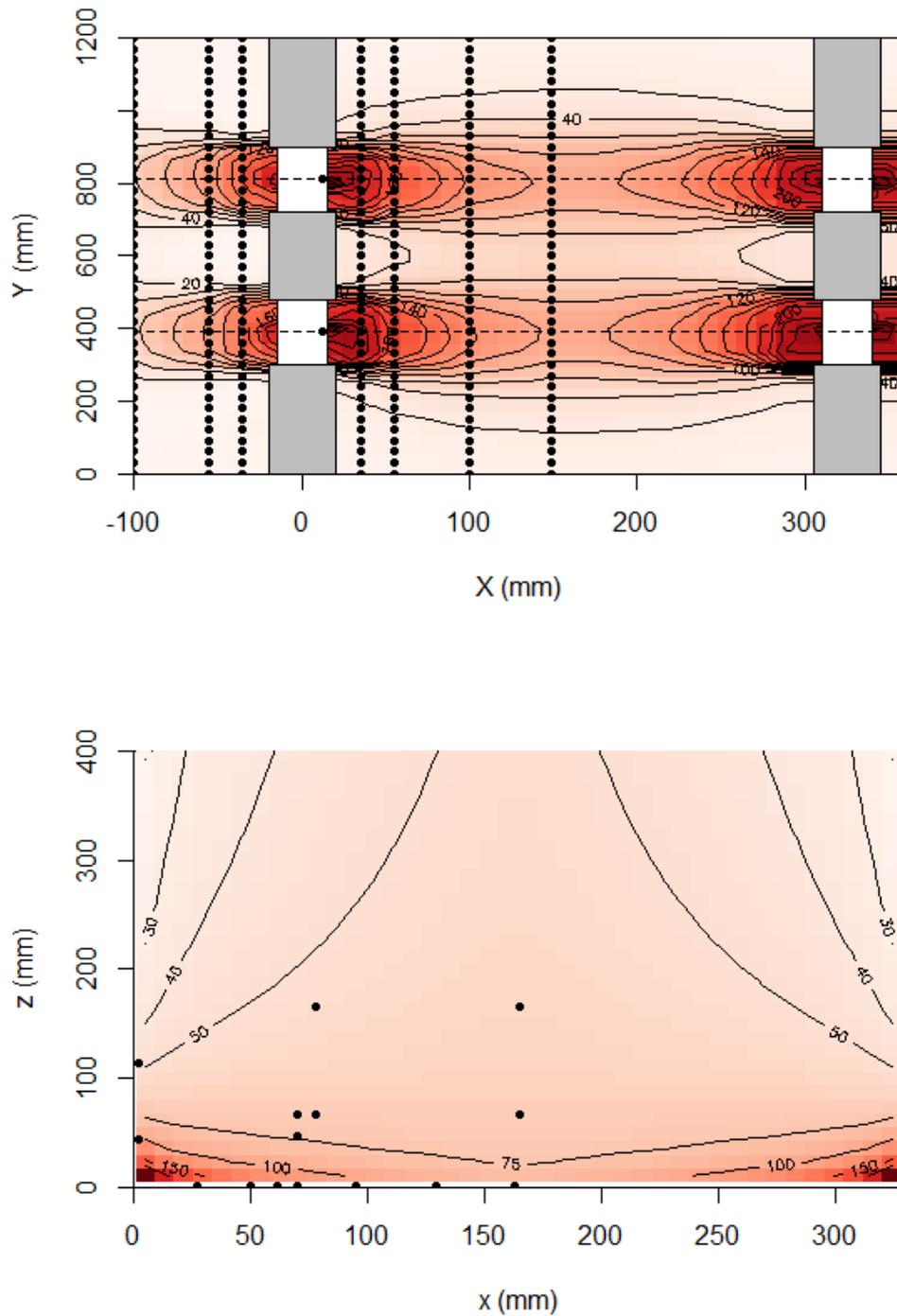


Figure 1. Field strength ($\text{V}\cdot\text{m}^{-1}$) contours around a pair of Delmeco electrodes positioned at $X=0$ mm and $X=325$ mm. Top panel shows the contours in the horizontal plane. The white parts show the conductors, grey parts show the isolators. The pattern on the left side of the electrode shows the decline in field strength outside the pair of electrodes. Bottom panel shows the contours in the vertical plane with the headrope located at $Z=430$ mm. The dashed lines in the top panel show the location of the vertical plane. Locations of the field measurements are indicated by black dots (de Haan *et al.*, submitted).

The main driver behind the development of the pulse fishing technique for brown shrimp is to avoid non-target species from entering the net by applying a stimulus that only startles the target species in the net mouth and thus reduces unwanted bycatch. Quite a lot of research has been conducted on the selective potential. Verschueren and Polet (2009) found that unwanted bycatch could be reduced by 35% when using a pulse trawl (pulse frequency 4.5 Hz, pulse duration 0.5 ms, minimal electrical field strength between the electrodes of 30 V.m^{-1}), while commercial catch levels remained more or less constant. At a towing speed of 3 knots, an animal in the trawl path is exposed for about 1 s to the electrical field and hereby experiences a maximum of 5 pulses of 0,5 ms. This is enough for the shrimp to leave the seabed vertically up to 50 cm high in the water column (Polet *et al.*, 2005b). The electrical field intensity varies however with the distance and orientation in relation to the electrodes. The startle response is minimal when the shrimp is laying parallel, and maximal when perpendicular to the field (Polet *et al.*, 2005a). Smaller shrimp need a slightly stronger pulse than larger shrimp to elicit the same tail flipping response. A pulse of around 30 V.m^{-1} was found to be sufficient to have 100% of the shrimp (large and small, parallel and perpendicular) tail flipping in laboratory conditions (Polet *et al.*, 2005b).

B. The influence of habitat characteristics on the electrical stimuli.

The electric field generated by a pulse trawl will be influenced by the conductivity of the seawater. Hence the field strength generated will decrease with increasing salinity, which can be compensated by increasing the electrical power supplied. The penetration of the electric field in the seabed will be influenced by the sediment structure and its conductivity. No research has been done to quantify how these factors affect the strength of the exposure experienced by benthic invertebrates living in the seabed.

C. Proportion of the population and the intensity at which the organisms are exposed.

The proportion of the population that will be exposed to the pulse stimuli is a function of the overlap between the areas fished by the pulse trawlers and the distribution area of the population. We can distinguish between four different parts of the population:

- Fish that occur in areas that are not captured.
- Fish that are exposed to electrical stimuli, occur within the trawl path and are retained in the net.
 - Landings.
 - Discards.
- Fish that are exposed to electrical stimuli, occur within the trawl path but escape through the meshes.
- Fish that are exposed to electrical stimuli, but are outside the net.

To evaluate the ecological impact of the pulse trawl fishery, the last two categories and the discarded fraction of the catch are relevant to evaluate. The effect of electricity on the landed fraction of the catch is from an ecological perspective irrelevant but may be relevant from an ethical perspective.

D. Response of marine organisms to these electrical stimuli

D.1 Effect on adult species

The most important side effect of electric stimulation is that it may induce spinal injuries in fish. Salmonids and cod are very sensitive to this, whereas other fish species such as bass or flatfish have not been observed with injuries so far (Soetaert *et al.*, 2015a). Fractures occur when fish experience a muscular “cramp” and the forces imposed by the muscle contraction cause a dislocation or fusion of the vertebrae. It has been hypothesized that the probability of a vertebral fracture occurring is due to the biomechanical relationship between the animals musculature and its vertebral column. The higher sensitivity of cod and salmonids to vertebral damage might be explained by their large number of relatively small vertebrae whereas the absence of fractures in flatfish may be related to the relatively light body musculature. In addition the electrical properties of the skin may play a role as this may influence the isolation of the body from the surrounding water.

When electro-trawling has been assessed, no major side effects have been observed in commercial fishing conditions except for spinal injuries in cod and whiting. Experimental studies have therefore focused particularly on spinal injuries in Gadoid species. Studies on benthic animals commonly found in bottom-trawl catches were carried out using a model based their anatomical and physiological characteristics. This showed that the electrical fields produced in commercial pulse trawls should have no effect on them. Laboratory experiments have also been performed using Atlantic cod (gadoid roundfish), European sea bass (non-gadoid roundfish), sole (flatfish), dab (ulceration sensitive flatfish), dogfish (elasmobranch/electro-sensitive species), non-commercial species encountered in shrimp fishery bycatch) and a variety of invertebrate species. The studies on cod confirmed that spinal injuries may be induced in cod exposed close to the conductor. However, no mortality or significant injuries were observed in any other adult species examined. A more detailed overview of the results is listed below.

De Haan *et al.* (2015b) exposed farmed cod to three different pulse types, for a range of field strength, frequency and duty cycle settings. Two size classes were tested representing cod that might escape through the meshes (11–17 cm) and marketable sized cod that are retained in the net (34–56 cm). Cod exposed to a field strength of $\geq 37 \text{ V.m}^{-1}$ responded by moderate to strong muscular contractions and developed injuries. Some of the large cod ($n=260$) exposed developed haemorrhages and fractures in the spinal cord and haemal and neural arches in the tail part of the body. This number could increase to 70% if cod was exposed near the electrodes (within 10–20 cm). It was observed that the probability of injuries increased with field strength and decreased when frequency was increased from 100 Hz to 180 Hz. None of small cod ($n=132$) were injured and all survived. The field strength at the lateral boundaries of the trawl was 4 V.m^{-1} . Cod exposed in the lateral boundary area did not produce muscular contraction and injuries were not observed. These results could not be reproduced by Soetaert *et al.* (2015c) who exposed farmed cod in identical set-up and conditions. In wild cod and 2 groups of intensively reared cod, 5%, 2% and 0% injuries were found respectively, demonstrating a fish-effect rather than a pulse (setting) effect. Therefore, size, somatic weight, muscularity, number of vertebral bodies and vertebral mineral contents of animals of these groups were examined. Despite offering clues for further research, no physiological or morphological parameters could be identified as being responsible for influencing vulnerability to electric pulses, although it is suspected that rearing conditions may play a decisive role.

In conclusion it can be summarized that cod is vulnerable to damage when cramp stimuli can be induced, and may develop spinal injuries when exposed near the electrodes to field strengths $\geq 37 \text{ V.m}^{-1}$. The $\pm 10\%$ injury rate observed in the field indicates that this exposure happens for a number of fish in reality. This injury rate can to some extent be affected by the pulse settings. However, the injury rate may vary between 0 and 70% depending on the origin of the cod, indicating a large fishing-effect.

In order to determine if the observed sensitivity in gadoid species can be generalized for all roundfish, or is restricted only to gadoid roundfish, experiments were performed with sea bass (*Dicentrarchus labrax* L.). Two groups of different size classes, 29 smaller sea bass ($31.3 \pm 2.2 \text{ cm}$) and 15 larger sea bass ($42.1 \pm 2.5 \text{ cm}$), were exposed, monitored and examined identically in the same way as had been done for cod in previous research. However no (spinal) injuries were observed (Soetaert *et al.*, 2015e). This suggests that sea bass is less vulnerable than gadoid roundfish such as cod and further suggests that other parameters such as the size and number of vertebrae may be more decisive than the anatomy of the musculature.

Although no effects on caught flatfish have been observed or reported by fishers or scientists, elaborate experiments were performed with sole (*Solea vulgaris* L.), the most important target species (Soetaert *et al.*, 2015b). The animals were exposed to homogeneously distributed electric fields with varying values of the following parameters: frequency (5–200 Hz), electric field strength (100–200 V.m^{-1}), pulse duration (0.25–1 ms) and exposure time (1–5 s). Pulse polarity and pulse shape were also altered. The goal was to determine the range of pulse parameters which could be regarded as safe as well as evaluating the effect of the stimuli already being used in commercial electrotrawls. Fish behaviour during and shortly after exposure, 14-d post exposure mortality rates, as well as gross and histological examination were used to evaluate possible effects. During exposure, sole showed an escape response below a frequency of 20 Hz and a cramp reaction above 40 Hz. These reactions were followed by an immediate post-exposure escape behaviour as soon as the electrical stimulus was stopped. No mortality was observed and histological examination did not reveal any abnormalities. So although various worst-case scenarios were tested by greatly exceeding the intensities and exposures to electrical stimuli encountered during fishing practice, no irreversible lesions were found in sole as a direct consequence of exposure to electric pulses. These results confirm the field findings and indicate that no irreversible side effects of the electrical stimulation are to be expected in sole and other flatfish species.

To study the relation between skin lesions and pulse exposure in dab, de Haan *et al.* (2015a) exposed 102 wild-caught fish to two types of commercially used pulse stimuli and tested in two groups of 51, while a third group was used as a “control” group being treated identically to the experimental group but without being exposed to the electrical stimulus. The pulse stimuli applied was equivalent to the field strengths found adjacent to the conductor with and the exposure period of exceeded that normally encountered in commercial gears. The results showed that lesions primarily related to pulse exposure were neither observed in the fish analysed directly after the treatment, nor in the fish that were kept in observation for a period of five days after the treatment. Of the electrically exposed dab, two fish died after the treatment with but it was unclear if this was due to electrical exposure. External and internal anomalies occurred in all groups including the control group. Statistically there was no clear difference between the exposed and control groups. Approximately 12 % of the fish contained a *Glugea* infection in their gut, and only in two cases, a bacterial disease was found. In the control group a fish gut contained *Vibrio fortis* and in a single case a primary fish disease *Vibrio anguillarum* was found.

De Haan *et al.* (2009) exposed small-spotted catshark formerly named lesser-spotted dogfish (*Scyliorhinus canicula* L.) representing elasmobranch species to the flatfish pulse under laboratory conditions. Lesser spotted dogfish were caught in the wild and exposed them, in three groups of 16 individuals, to a commercially applied electric pulse stimulus, while a fourth group of similar number was confined in the same way, but not exposed to the electrical stimulus. The fish were exposed at three different field strength levels, 162, 99.6, and 8 V.m⁻¹, the lowest level representing the field strength just outside the horizontal boundaries of the trawl. Behavioural responses (in particular contractions, swimming patterns) were monitored during exposure and in the 14 days period following stimulation. The dogfish were kept in husbandry for another 9 months to observe long-term effects and other behaviour, such as egg production. No evidence was found of differences in feeding response or likelihood of injury or death between the exposure and control groups. There was no visual evidence that fish sustained injuries as a result of the exposures. Behavioural responses involved muscle contractions on exposure to the stimulus with rapid body reverse, short-curved body rotations and rapid swimming on removal of the stimulus. There were some distinct differences observed in the responses to the three field strength levels. The responses of the fish exposed to the lowest field strength (8 V.m⁻¹) were minor and ignorable. However, the responses of the fish exposed in the “above field” range were more pronounced with contractions, rapid body reverses, short-curved body rotations and acceleration towards the water surface occurring. The responses of the fish exposed in the shortest possible range, the “nearfield” range, were the strongest with increased incidence of contractions and rapid body reverses, short-curved body rotations and acceleration towards the water surface. During the 14 days observation period no aberrant feeding behaviour could be distinguished. All dogfish started normal feeding directly after exposure. In the period of 9 months after the exposures all exposed groups produced eggs in numbers varying between 5 and 39 per group. However, the control group did not produce eggs. Additionally, 14 dogfish and 7 thornback ray (*Raja clavata*) were exposed to the pulse used for catching brown shrimp. The same number of individuals were included in each control for each species. 24 hours after exposure to this pulse no mortality, spinal injury and neither macroscopic nor microscopic damage had been detected (Desender, *pers. comm.*). To further investigate the impact of pulse exposure on the electric sensory system of elasmobranchs studies were performed on the prey detection ability towards an artificial electrical simulated prey. Fifteen dogfish were exposed perpendicular to the shrimp and 8 to the flatfish pulse. Also 30 non exposed fish were included as a control. The normal food response was observed one week before exposure in the experimental group. A bite response towards the artificial simulated prey dipole, was observed one day before and 3 consecutive days following exposure to the shrimp or pulse trawl electrical field (or control). During the exposure to both the shrimp as well as the flatfish pulse, the animal was generally subjected to strong reflexes and muscle contractions which paralysed the fish during the 5 second pulse period. Their eyes were observed to close during the period of the pulse. Observation of the bite response showed no difference between the control or experimental groups either before or after exposure to a shrimp or flatfish electrical field. A bite response one day after exposure was demonstrated in 66% (20/30), 73% (11/15) and 88% (7/8) in control and shrimp or flatfish exposed fish respectively after the introduction of food-derived scent. On day three after treatment the control and exposed groups to the shrimp or flatfish pulse, demonstrated respectively 80% (24/30), 87% (13/15) and 88% (7/8) bite response at least once towards the prey simulating dipole. Also no significant differences in the timing between onset of searching behaviour and biting, on average 94 seconds, was observed between groups.

Polet *et al.* (2005a) assessed the survival and behavioural effect of electric pulses used in shrimp trawls on various demersal fish and invertebrates encountered in shrimp bycatch. Survival tests until 14 days following exposure indicated that the pulses have no effect on the survival and general behaviour for: *Pandalus montagui*, plaice, sole, dab, ray, turbot, cod, armed bullhead, dragonet, pogge, fivebearded rockling, gobies (*Pomatoschistus* spp.), swimming crab, shore crab, hermit crab, and *Spisula subtruncata*. A number of other, less mobile species like hermit crab, starfish, and brittlestar, were also tested. Usually, no change in behaviour was observed. Only shrimps are seen to react strongly to the pulses and the majority of the other species regularly caught in shrimp trawls appear to be unaffected.

Additionally Desender *et al.*, (2015a) investigated the short-term effects, after 24 hours, of the pulse used for electro-trawling for brown shrimp on marine fish species inhabiting shrimp fishery areas. 25 European plaice, 30 Dover sole, 20 Atlantic cod, 19 bull-rout, 20 armed bullhead were exposed to the shrimp pulse for a 5 s period. The same amount of individuals were used in a control group for each species. Under the circumstances as adopted in this study, the electrical field seemed to have only limited immediate impact on the exposed animals. No mortality or spinal injury was observed for all fish species up to 24 hours after exposure. Behavioural responses recorded 10 minutes before, until 20 minutes after exposure were variable and species dependent. Round fish species, cod in particular, were displaying more active and agitated fast swimming activity during exposure. The majority of flatfish showed only minor reactions and remained close to the bottom throughout the observation period. However, 15% of the exposed sole actively swam upwards during exposure. No significant differences in activity before and after exposure were found. Mild multifocal petechial haemorrhages and suffusion, encountered mainly in plaice and sole, were not significantly different between exposed and control groups. Upon histological examination, in two exposed plaice, a focal small haemorrhage between muscle fibres was found, which was not encountered in control animals. In addition, the number of melanomacrophage centres in the spleen of exposed cod was significantly higher than in the non-exposed animals.

The effect on invertebrates is a major concern, because these animals may be exposed repeatedly and are often not caught, which might conceal possible effects. Two exploratory studies with a limited number of animals have been carried out in which various invertebrates were exposed to the commercial electrodes and pulse settings used in flatfish fishery. Smaal and Brummelhuis (2005) exposed 19 species of molluscs, echinoderms, crustaceans and polychaetes to electric pulses of twice the amplitude and an increased exposure time of eight times longer than the settings used in practice on commercial vessels targeting sole. Reactions during exposure were minor or negligible and the survival rate after three weeks did not differ from the control group. Van Marlen *et al.* (2009) exposed a selection of benthic invertebrates to three subsequent bursts of 1 s at a variety of distances from the electrode, ranging from 0.1 to 0.4 m. No significant effects on survival were found for common prawn (*Palaemon serratus* L.), surf clam (*Spisula solidissima* L.), and common starfish (*Asterias rubens* L.). Ragworm (*Allita Virens* S.) and European green crab (*Carcinus maenas* L.) showed a 3-5% reduction in survival when all exposures were lumped together. For the nearfield exposure a 7% lower survival was also found for Atlantic razor clam. For the other species (common prawn, sub-truncate surf clam, and common starfish) no statistically significant effects of pulses on survival were found. Surf clam seemed not to be affected at all, common prawn seemed to show lower survival in the highest exposures (near and medium field), while common starfish showed lower survival, but not for the highest (nearfield)

exposure. Food intake turned out to be significantly lower (10-13% less) for European green crab, except in the far-field exposure for which the reduction (~5%) was non-significant. No effect at all was found for ragworm, surf clam and razor clam, lower food intake for common prawn, and higher for common starfish, but all these results were statistically non-significant. To further investigate the effects on the most sensitive groups of polychaetes and crustaceans, more elaborate studies were carried out using a large number of species and various pulse settings. Soetaert *et al.* (2014) exposed ragworm (polychaete) and the electro-trawls target species brown shrimp (*Crangon crangon* L., crustacea) to a homogeneously distributed electric field with varying values of the following parameters: frequency (5–200 Hz), electric field strength (150–200 V.m⁻¹), pulse duration (0.25–1 ms) and exposure time (1–5 s). Pulse parameters of polarity and shape were also varied. To reduce possible variation in electric field generation, plate electrodes were used. The goal was to determine a range of safe pulses causing no effect at all and thereby also to evaluate the effect of the pulses already being used on commercial electro-trawls. Behaviour during and shortly after exposure, 14-d mortality rates, gross and histological examination were used to evaluate possible effects. The vast majority of shrimp demonstrated a tail flip response when exposed to electric pulses depending on the frequency, whereas ragworm demonstrated a squirming reaction, independent of the frequency. No significant increase in mortality or injuries was encountered for either species within the range of pulse parameters tested. Examination of the hepato-pancreas of shrimp exposed to 200 V.m⁻¹ revealed a significantly higher severity of an intranuclear baculoform virus (IBV) infection. These data reveal a lack of irreversible lesions in ragworm and shrimp as a direct consequence of exposure to electric pulses administered in the laboratory. Nevertheless it was argued that repetitive exposure may have a larger impact and that the effect on IBV warranted further research. Therefore, an additional experiment (Soetaert *et al.*, 2015d) was conducted in which brown shrimp was exposed 20 times in 4 days using commercial electrodes and pulse settings to catch shrimp (shrimp startle pulse) or sole (sole cramp pulse) and monitored for 14 days post first exposure. In this study, commercial wire-shaped electrodes and pulse settings were used, similar to the two exploratory studies (Desender *et al.*, 2015a;b). The survival, egg loss, moulting and the degree of intranuclear bacilliform virus (IBV) infection were evaluated and compared to stressed but non-electric-exposed and non-stressed non-exposed shrimp as well as to shrimp exposed to mechanical stimuli. Despite the large number of exposures, no differences in mortality, egg loss and moulting behaviour were observed between the electrically and mechanically stimulated shrimp. Moreover, no effect on the rate of IBV infection was observed.

It is suggested that the evidence from the stated studies on invertebrates demonstrates that there is reason to assume that the effects of electrical stimulation on invertebrates has a larger impact than that from conventional mechanical stimulation.

D.2 Effect on early life stages

Experiments (Desender *et al.*, 2015b) were carried out on different developmental stages of cod (*Gadus morhua*) as this round fish species is considered to be a vulnerable to electrical pulses. Three stages of embryonated eggs, four larval stages and one juvenile stage were exposed to a homogeneous electrical field of 150 V.m⁻¹ for 5 s in an effort to grossly exceed the commercial pulse trawl impact. In all egg stages, no significant differences in mortality caused by the exposure were detected. However, in the egg stage exposed at 18 days post fertilization (DPF), the initial hatching was significantly lower in the exposed group (0.27, 95% CI:[0.23;0.32]) as compared to the control

group (0.35, 95% CI:[0.30;0.40]). Larvae exposed at 26 days post-hatching (DPH), exhibited a significantly greater mortality rate ($P=0.0014$), with survival percentage in the exposed group equal to 0.53 (95% CI:[0.46;0.61]) and in the control group to 0.69 (95% CI:[0.63;0.75]). In the other larval and juvenile stages, no short-term impact of exposure on the survival was observed. Morphometric analysis of larvae and juveniles revealed no significant differences in yolk resorption, notable deformations and size measurements of length, eye, head, and muscle height of the notochord.

Furthermore, impact on an egg stage exposed 1 DPF and a larval stage 12 DPH of sole (*Solea vulgaris* L.) was examined. Exposure revealed no negative effect on survival one week following exposure. Morphometric measurements regarding length, eye, head, and muscle height of the notochord were identical for exposed or control groups. In addition no differences in deformations or yolk resorption were noted.

D.3 Conclusion

The tank experiments in which a variety of species and life stages were exposed to pulse stimuli of commercial strength and duration, or higher, did not show evidence of lesions, except for cod which developed spinal injuries and haemorrhages. The effect observed in one experiment with shrimp, with an extreme exposure duration, could not be reproduced.

The species differences in the spinal fractures imposed by pulse trawl seems to be related to the building plan of the animal. Species with a heavy musculature and a large number of vertebrae (cod) seems to be more vulnerable for spinal fractures than species with a lighter musculature and fewer vertebrae (sole and sea bass). Further research is needed into the morphological and physiological basis of the differences in vulnerability across species.

E. Impact of pulse trawling on habitats and species with special reference to those species covered by the on Natura 2000 species and habitats Directives

E.1 Species

In the request a number of species were mentioned, none of them being studied for the effect of electrical stimuli. Nevertheless, an assessment was made extrapolating from the experimental results reviewed in the previous section (D) and the likelihood that the species will come into contact with the pulse trawl.

Likelihood of adverse impact should be read here as the product of the likelihood of contact and the potential adverse effect. Another term that can be used is risk (as product of the consequence and probability of a hazardous event or phenomenon). The likelihood of contact is based on a review of the distribution of the species (Heessen *et al.*, 2015) relative to the fishing areas. The potential adverse effects is estimated to be low for the sole pulse as none of the species resembles the species which show spinal fractures in the experiments carried out with pulse trawls. This potential was estimated to be very low for the shrimp pulse as the voltage and frequency used in this fishery is much lower than in the sole fisheries.

Species	Flatfish pulse trawl			Shrimp pulse trawl		
	Likelihood of contact	Potential adverse effect	Likelihood of adverse impact	Likelihood of contact	Potential adverse effect	Likelihood of adverse impact
<i>Petromyzon marinus</i> (Sea lamprey)	low	low	low	moderate	very low	low
<i>Lampetra planeri</i> (Brook lamprey)	low	low	low	moderate	very low	low
<i>Lampetra fluviatilis</i> (River lamprey)	low	low	low	moderate	very low	low
<i>Alosa alosa</i> (Allis shad)	low	low	low	moderate	very low	low
<i>Alosa fallax</i> (Twaite shad)	low	low	low	moderate	very low	low
<i>Salmo salar</i> (Atlantic salmon)	low	low	low	low	very low	low
<i>Tursiops truncatus</i> (Bottlenose dolphin)	zero	unknown	zero	zero	unknown	zero
<i>Phocoena phocoena</i> (Harbour porpoise)	zero	unknown	zero	zero	unknown	zero
<i>Lutra lutra</i> (Otter)	zero	unknown	zero	zero	unknown	zero
<i>Halichoerus grypus</i> (Grey seal)	Very low	unknown	very low	very low	unknown	very low
<i>Phoca vitulina</i> (Common seal)	Very low	unknown	very low	very low	unknown	very low

E.2 Natura 2000 Habitats

In the request a range of potential habitats were mentioned. To assess the likelihood that pulse trawling will have an adverse impact on these habitats, we distinguished between the likelihood that pulse trawling will occur in the habitat, the likelihood that the electrical pulses will adversely affect the typical species (see above list) and the likelihood that the pulse trawl will have a physical effect. The physical effect is assessed relative to the effect of the traditional gear.

The likelihood of an adverse electrical effect was assessed to be low for the sole pulse because none of the experimental studies revealed any adverse impact on the benthic invertebrate species tested, and there is no evidence that the typical fish species are adversely affected (see section E.1). The effect of the shrimp pulse was assessed to be very low because of the lower field strength and lower frequency.

The physical effect of the pulse trawls is expected to be less than the physical effect of the conventional gear. The rationale for this is that the sole pulse trawl is towed at a

speed of around 5 knots as compared to the 6–7 knots of the conventional beam trawl gear. The physical impact of a bottom trawl increases with the speed at which the gear is towed over the seabed (Rijnsdorp *et al.*, 2015). Recent studies have shown that the penetration depth of a sole pulse trawl is less than that of a conventional beam trawl (Teal *et al.*, 2014; Depestele *et al.*, 2015). For the shrimp pulse trawl, the physical effect will be similar if the pulse trawl deploys a traditional bobbin rope, but will be much lower when a Hovercran rigging is applied (Polet *et al.*, 2005).

Habitat	Likelihood of contact	Potential adverse electrical effect	Adverse Physical impact relative to traditional gear	Comment
Flatfish pulse trawl				
Sandbanks which are slightly covered by seawater all the time	moderate	low	lower	
Estuaries	low	low	lower	
Mudflats and sandflats not covered by seawater at low tide	zero	low	lower	
Coastal lagoons	low	low	lower	
Large shallow inlets and bays	low	low	lower	
Reefs	moderate	low	Similar for delicate reefs, lower for more sturdy reefs	
Submarine structures made by leaking gases	zero	zero	similar - lower	physical structures
Shrimp pulse trawl				
Sandbanks which are slightly covered by seawater all the time	high	very low	similar - lower	
Estuaries	low	very low	similar - lower	
Mudflats and sandflats not covered by seawater at low tide	moderate	very low	similar - lower	
Coastal lagoons	moderate	very low	similar - lower	
Large shallow inlets and bays	zero	very low	similar - lower	
Reefs	moderate	very low	similar - lower	
Submarine structures made by leaking gases	zero	zero	similar - lower	

E.3 Conclusion

We conclude that the likelihood of an adverse impact of the pulse trawl on the Natura 2000 species and habitats is low (sole pulse) to very low (shrimp pulse). Negative effects seem to be restricted to cod-like fish.

The assessment of the ecosystem effects of pulse trawling is based on the extrapolation of the results of experimental studies which could only show adverse effects in cod. The number of species studied, however, is rather small, and none of the Natura 2000 species listed were exposed to the commercial pulse stimulus to study their response.

The estimation of the effect of electrical stimuli was therefore based on a hypothetical predictive framework that explains the sensitivity of fish to develop lesions, in particular spinal fractures and the related haemorrhages, in response to the exposure to the commercial pulse stimuli. The predictive framework assumes that the sensitivity is related to the number of vertebrae and the relative size of the musculature as supported by the available experimental data. It is emphasized that our interpretation is uncertain since the framework is not based on a detailed analysis of the morphology and biomechanics of the fish species involved, nor of their physiology, and the number of species studied is very low.

F. Comments on ICES conclusions in 2012

Comments on the present status were given related to the ICES conclusions in 2012:

- 1) Current scientific knowledge indicates that the introduction of electric pulse systems could significantly reduce fishing mortality of target and non-target species, including benthic organisms, assuming there is no corresponding increase in unaccounted (avoidance) mortality.

WGELECTRA's view in 2015:

This statement still holds and is backed up by new references, e.g. van Marlen *et al.*, 2014.

- 2) Recent developments have resulted in pulse trawl systems requiring less power and new trawl designs that reduce the pressure on the seabed. However, operational issues such as the determination of critical pulse characteristics (power, shape, frequency, etc.) to determine maximum acceptable thresholds, still remain unresolved.

WGELECTRA's view in 2015:

Critical pulse characteristics (power, shape, frequency, etc.) to determine maximum acceptable thresholds were not studied following a fundamental methodology, but an improved set of limits was recently suggested for control and enforcement purposes, based on effect studies (*personal communication* De Haan and Van Marlen).

- 3) Questions remain regarding delayed mortality, long-term population effects, and sublethal and reproductive effects on target and not-target species. ICES notes that in freshwater fish, the effects from electric trawls are generally sublethal. However, no information is available on whether the effects in freshwater are transferable to the marine environment. Further work on marine effects is needed to resolve these issues.

WGELECTRA's view in 2015:

The research focused on saltwater pulse trawling instead of freshwater organisms. Concerning sublethal effects a study showed that lesions in dab (*Limanda limanda* L.) could not be attributed to pulse fishing (De Haan *et al.*, 2015a). Similar lesions have been reported in the past. Discard survival studies are currently being conducted, showing that short-term survival of flatfish (sole (*Solea vulgaris* L.), plaice (*Pleuronectes*

platessa L.), and dab) in pulse trawls is higher than 0, and that this depends on seawater temperature, tow duration, time spent on the fish processing line, and possibly weather conditions and sea state. No studies were done recently on long-term effects. Studies also show little effect of electrical stimuli on larval stadia of sole (Desender *et al.*, 2015b).

- 4) It is unclear whether the current legislative framework is sufficient to avoid the deployment of systems that are potentially harmful. While the systems currently under development do not appear to have major negative impacts, ICES considers that the existing regulatory framework is not sufficient to prevent the introduction of potentially damaging systems. Guidelines and procedures for Control and Enforcement are being formulated by a Dutch project group and should be of help in preventing potential damage.

WGELECTRA's view in 2015:

There is progress in developing Guidelines and procedures for Control and Enforcement. This topic was discussed at the WGELECTRA 2015 meeting, resulting in the following conclusions:

Differing requirements exist for Control and Enforcement and scientific purposes.

Limits for flatfish gears based on the present state of knowledge, and subjected to review in future that should be defined are:

- Maximum V_{peak} ,
- Minimum distance of electrodes,
- Maximum electric power in kW per m length,
- Maximum duty cycle.

After some discussion the group agreed that it was not necessary to restrict the maximum electrode length because this will be limited by physics anyhow. The details are also to be given in Technical Files of the Pulse Fishing Systems. These limits are subject to revision when new insights emerge from scientific work.

Currently the Dutch Ministry in collaboration with the Inspection Agency (NVWA) are taking the lead in formulating a new set of regulations and requirements, with input from this WG. This process is still continuing.

- 5) Many of these issues will be addressed in future research proposed by SGELECTRA, and ICES supports these proposals. ICES furthermore supports research into the potential use of the startle pulse as an alternative to the currently used cramp pulse response, as well as research into lighter trawls with the net raised off the bottom and gears with no bobbins or tickler chains disturbing the seabed. The determination of critical pulse characteristics also requires further investigation.

WGELECTRA's view in 2015:

A Pulse Trawl Impact Assessment Study is currently negotiated between IMARES and the Dutch Ministry of Economic Affairs and will run between 2016 and 2019. A total of four WP's are planned to produce predictive models based on mechanistic reasoning, and to be calibrated from field and laboratory experiments. Contact is Adriaan Rijnsdorp at IMARES (adriaan.rijnsdorp@wur.nl).

- 6) ICES considers that the available data are insufficient to recommend the large-scale use of the electric pulse trawl in fisheries. Consideration could

be given to experimental increases, beyond 5% in the beam trawler fleet, in selected areas to further investigate the outstanding issues mentioned above.

WGELECTRA's view in 2015:

The current situation in the Netherlands is that a total of 84 pulse fishing licences have been issued under the condition that these vessels contribute to data collection for scientific studies.

- 7) ICES recognizes that conventional beam trawling has significant and well demonstrated negative ecosystem impacts, and if properly understood and adequately controlled, electric pulse stimulation may offer a more ecologically benign alternative.

WGELECTRA's view in 2015:

In the debate of pulse trawling it should be realized, that it is meant to replace conventional beam trawling, a fishery with identified and significant ecosystem impacts that were deemed negative.

Annex 4: Abstracts of presentations at WGELECTRA 2015

Pulse trawling: The impact of electrical pulses on prey detection by small-spotted catshark (*Scyliorhinus canicula*) (Marieke Desender)

In response to the question urged by ICES, De Haan *et al.* (2009) exposed dogfishes to the flatfish pulse under laboratory conditions. Only weak responses were suggested and no increased mortality, macroscopic lesions nor aberrant feeding behaviour was observed. Additionally in experiments performed in 2014 by Desender, dogfish and thornback ray were exposed to the pulse used for catching brown shrimp, revealed as well no mortality, no spinal injury, and no macroscopic nor microscopic damage.

Despite these reassuring results, this does not prove that the electro-receptor organs, Ampullae of Lorenzini (AoL) are left undamaged as only dead fish pieces were provided to feed on.

This is the first study to examine the role of pulsed direct current (PDC) used in pulse trawls on the electro-detection ability of *Scyliorhinus canicula*. by means of an artificially created electrical field mimicking the bioelectric field emitted by their prey. Their food or electro response was recorded before and after exposure towards the flatfish and shrimp electrical field. Clearly the bite response was not affected in comparison between control or exposed groups (Figure 2) or before or after exposure. Also no differences in the timing between onset of searching behaviour and biting was observed (Figure 3). Still the impact on the complex behaviour of sharks towards pulse trawls, or anthropogenic E-fields in general merits further investigation.

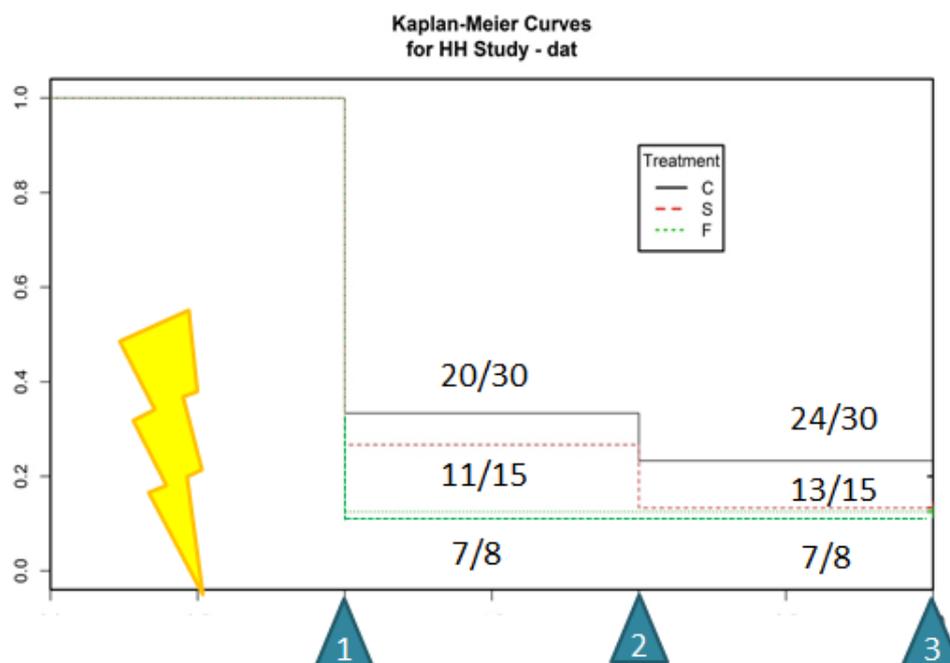


Figure 2. Kaplan-Meier survival plot of the electro-response after one, two and three days following treatment. C= control; S= exposure to the shrimp pulse; F=exposure to the

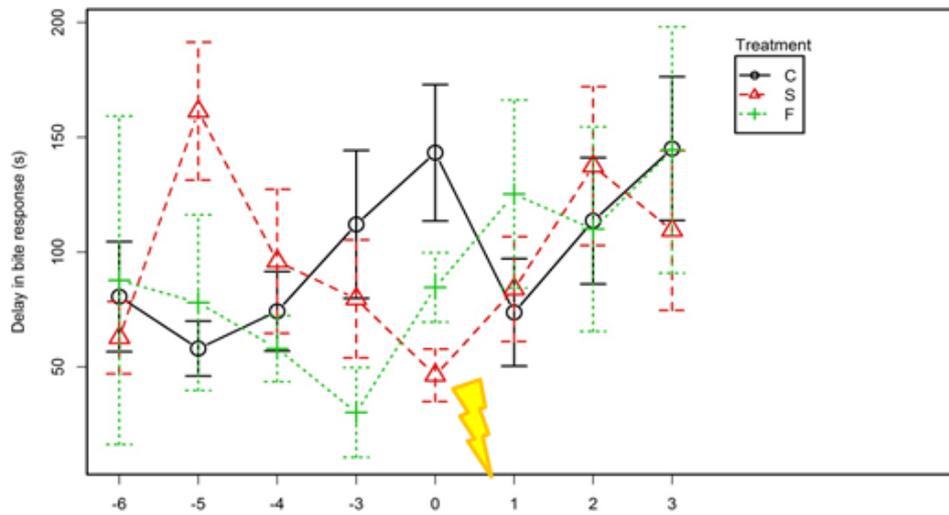


Figure 3. The mean delayed time to elicit a bite response towards a food source (on observation day -6 until -3) or towards a prey simulated dipole (day 0-3) between control (=C) and exposed (S=shrimp pulse; F= flatfish pulse) sharks per day. The treatment was given on day null, after testing of the electro-response.

Annex 5: Review of WGELECTRA with respect to the ICES request from the French authorities

January 15, 2016.

The review group consisted of Norman Graham, Dominic Rihan and Heino Fock and worked by correspondence and WebEx. It was not possible for the review group to complete their task within the deadline as the report of WGELECTRA was only made available on January 6.

In this review we have taken the original 7 conclusions from the advice provided in November 2012 and have assessed whether the work presented in WGELECTRA (2015) in any way changes the ICES advice given in 2012.

General observations

The report of WGELECTRA provides a useful synopsis of work carried out since the previous ICES advice (ICES 2012) and highlights that considerable work has been undertaken. To a large extent, the report confirms previous observations regarding the potential impact of pulse systems on individual fish species (flatfish, gadoids, elasmobranchs, larvae and benthic species). In addition, the report of WGELECTRA provides a helpful response to the request from the French authorities in relation to the wider ecosystem impacts and specifically the impacts on NATURA 2000 sites and specifically on:

- The issues of lesions associated with the use of the pulse trawl;
- On the mortality for target and non-target species that contact or are exposed to the gear but are not necessarily retained on board;
- On the effects on sensitive species and habitats listed under the Habitats Directive¹.

Specific comments

Here we note the key elements of the ICES 2012 advice and consider whether the additional information presented in WGELECTRA (2015) may change the advice in any substantive way.

- 1) Current scientific knowledge indicates that the introduction of electric pulse systems could significantly reduce fishing mortality of target and non-target species, including benthic organisms, assuming there is no corresponding increase in unaccounted (avoidance) mortality.**

The report of WGELECTRA does not alter the original advice.

Previous work has highlighted that pulse trawls tend to have a lower cpue for both plaice and sole and a range of other species. Pulse trawls are generally less efficient compared with conventional beam trawls due to a combination of lower catchability

¹ Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora OJ L 206, 22.7.1992, p.7

and towing speed meaning that the spatial footprint per hour of fishing is less than conventional gears.

While the studies indicate that pulse systems pulse trawls also caught about 80% in benthos per unit of area and 62% per hour compared to the conventional beam trawl. Most of the benthos bycatches consisted of epi-fauna species. When looking into species composition the pulse trawl caught 75% per area and 58% per hour less epi-fauna. However, given lack of information on the design of the pulse system configurations and in particular the presence or absence of tickler chains, it is not possible to determine whether there are any significant reductions in unaccounted mortality of epi-fauna that contact but are not retained by the gear, beyond the reductions that would be associated with the reductions in swept-area.

Based on these latest trials and earlier studies there would seem a substantial body of evidence to support the ICES conclusion of 2012 regarding fishing mortality.

The work presented also suggests that the impact on invertebrates is no more severe than conventional gears although there appears to be an error in the conclusion in the WGELECTRA report:

*“It is suggested that the evidence from the stated studies on invertebrates demonstrates that there is **reason to assume that the effects of electrical stimulation on invertebrates has a larger impact than that from conventional mechanical stimulation.**”*

- 2) Recent developments have resulted in pulse trawl systems requiring less power and new trawl designs that reduce the pressure on the seabed. However, operational issues such as the determination of critical pulse characteristics (power, shape, frequency, etc.) to determine maximum acceptable thresholds, still remain unresolved.**

The work of WGELECTRA 2015 does not alter the ICES advice presented in 2012.

Research into the operational issues and in particular the critical pulse characteristics remain unresolved so this conclusion remains relevant. Parameters including maximum V_{peak} , minimum distance of electrodes, maximum electric power in KW per m length and maximum duty cycle are identified as critical by WGELECTRA. However, there is little discussion or explanation as to why these and only these are the critical parameters and why other parameters such as pulse shape that may lead to different impacts are not considered. WGELECTRA (2015) discuss these parameters in the context of the development of a control and monitoring protocol, but does not provide any definitive definition of what constitutes maximum acceptable levels that should be used in the flatfish fishery and how such limits relate to other fisheries (e.g. the shrimp fishery).

It appears that a relatively powerful pulse is needed to deliver equivalent catch efficiency to the conventional beam trawl gear targeting sole. Other fisheries where the pulse trawl has been tested and in particular the shrimp trawl fishery, the impacts are likely to be lower as the principles and the actual pulse deployed are much more benign compared with the system used in the sole fishery. In this sense the impacts from the flatfish fishery are probably a “worst case” scenario.

However, WGELECTRA (2015) notes that “Critical pulse characteristics (power, shape, frequency, etc.) to determine maximum acceptable thresholds were not studied following a fundamental methodology, but an improved set of limits was recently suggested

for control and enforcement purposes, based on effect studies (personal communication De Haan and Van Marlen).”

While WGELECTRA (2015) notes that developments have been made in developing an “improved set of limits” potentially critical characteristics such as pulse shape are not identified in the list of characteristics that should be limited (controlled). Furthermore, there is no information presented on the specific limits proposed or on how these limits were derived.

Added to this there is a certain amount of variation in the type of pulse trawl systems currently being tested in the flatfish fishery. For instance Table 4 of the van Marlen *et al.* (2014) report shows differences between two different pulse systems tested during these trials. The pulse durations vary between 220 and 380 μ s and the voltage varies between 45 to 50 volts. There is no indication of whether the differences in the characteristics of the pulses generated are significant in likely impacts. This highlights the need for standardization to give confidence that the results from the studies are representative and realistic.

In summary, there appears to be a general lack of progress in identifying critical pulse characteristics and subsequent testing which would allow conclusions to be drawn on whether the current proposed limits are sufficient or not. This remains one of the main unresolved issues and the review group encourage the undertaking of structured experiments that are able to identify the key pulse characteristics and thresholds below which there is no evidence of negative impact.

3) Questions remain regarding delayed mortality, long-term population effects, and sublethal and reproductive effects on target and not-target species. ICES notes that in freshwater fish, the effects from electric trawls are generally sublethal. However, no information is available on whether the effects in freshwater are transferable to the marine environment. Further work on marine effects is needed to resolve these issues.

The work of WGELECTRA 2015 does not alter the ICES advice presented in 2012.

The review group consider that recent experiments have expanded the knowledge base significantly (additional species, life stages, reproduction, feeding behaviour) and provided greater insight into more medium term effects.

Extensive work on mortality and potential sublethal and reproductive effects on target and not-target species is reported and reviewed by WGELECTRA for both the flatfish and brown shrimp pulse trawls. This has included work on commercial and non-commercial fish species, elasmobranchs, invertebrates and also on the early life stages of cod and sole. The impacts on sensitive species and habitats listed under the Habitats Directive have also been assessed qualitatively.

The work presented in WGELECTRA (2016) confirms that spinal fractures in cod remain an issue with the pulse system used in the sole fishery, but that this only affects larger individuals and work has shown that smaller cod tend not to suffer the same fate. This is important given that once retained in the trawl, the smaller individuals are those that are most likely to escape (via codend selectivity) and it seems, based on the evidence presented, that there is unlikely to be any significant elevation in post escape mortality than would be observed in conventional beam trawls.

In recent years technical regulations have attempted to mitigate the catches of all cod in beam trawls (large mesh panels) due to the previously poor state of the cod stock in the North Sea. While the recovery of the cod stock has to some extent negated the issue,

it is possible that spinal injuries may result in a reduction in the numbers of large cod that would otherwise have escaped via these large mesh panels. However, given the limited efficacy of large mesh escape panels in beam trawls to exclude cod (Depestele *et al.* 2009²), the overall impact at a stock level is likely to be marginal. Furthermore, the impact on larger cod that come into contact with the gear, but are not retained, may also result in elevated contact mortality. The overall impact of potential increases in contact mortality at a stock level cannot be determined.

The additional work on sea bass and other flatfish species is useful, but it remains unclear what the potential impact on other flatfish species that may encounter a pulse trawl may be for example turbot and brill which are an important bycatch species in this fishery.

The additional investigations on sea bass are helpful and show that spinal injuries are likely to be species-specific across gadoid species and a number of hypothesis are presented to explain why this may be the case e.g. differences in spinal structure (number and size of vertebrae relative to fish length).

A study by Desender *et al.* (2015) of the likely impacts of the pulse tested in the brown shrimp fishery demonstrated little or no impact on a range of marine fish species inhabiting shrimp fishery areas. No mortality or spinal injuries, even in cod were observed although the number of melano-macrophage centres in the spleen of exposed cod was significantly higher than in the control fish. According to Agius and Roberts (2003)³ melano-macrophage centres act as focal depositories for resistant intracellular bacteria, from which chronic infections may develop. Melano-macrophage centres increase in size or frequency in conditions of environmental stress.

It is important to note that undertaking experiments on every species encountered by pulse trawls is not possible. A better understanding of the key anatomical factors that cause spinal damage and relating these to the anatomical characteristics of the key species encountered in the fisheries may provide a pragmatic solution to identify susceptible species and or age groups.

In relation to sublethal effects, WGELECTRA reports on the research carried out by de Haan *et al.* (2015) which established no direct link between the use of the pulse trawl and lesions on the skin of sole or dab. The results of this work indicating is no evidence that exposure to pulses of varying strengths results in lesions forming. However, a report from Devriese *et al.* (2015)⁴ indicates that there are unexplained increases in dab lesions in Belgian surveys since 2010 in areas where pulse trawlers are operating consistently. Further detail on how the trials were conducted by de Haan and in particular details of the pulses tested would be useful as it is not altogether clear how representative these trials are of the full-scale system. This is an area the reviewers suggest there should be further research to establish whether there is a linkage between the pulse trawl and increased lesions.

2 Depestele, J., Polet, H., Van Craeynest, K., Vandendriessche S. 2009. A compilation of length and species selectivity improving alterations to beam trawls. ILVO, Belgium. 58pp.

3 Agius C and Roberts R.J. (2003). Melano-macrophage centres and their role in fish pathology. *J Fish Dis.* 2003 Sep; 26(9):499-509.

4 Lisa Devriese L., Soetaert M., Bekaert K., Desender M., Chiers K., Decostere A. (2015). Huidzweren bij vissen in het Belgisch deel van de Noordzee. Trends in prevalentie en exploratie van

Mogelijke oorzaken ilvo mededeling 188. April 2015. ISSN 1784-3197. Wettelijk Depot: D/2015/10.970/188

The pragmatic, albeit subjective, analysis on the potential impacts of pulse trawls on individual species in NATURA sites/listings in the absence of quantitative observations, provides a useable frame work to assess potential levels of risk. Such a framework, where species with similar morphological characteristics and that have been directly observed are used as proxies, is likely to be the only feasible approach to use as the basis of management decisions. Consequently, managers should also be aware that for many species, it is practically not possible to obtain definitive advice for each and every species that is likely to encounter a pulse trawl. However, it is considered that such comparisons would be better supported by a more structured synopsis that could be used as a cross reference between species with similar characteristics and therefore used as proxy indicators. It is important to note given the differences observed between cod and Sea bass for example, indicates that care is required when extrapolating between species with broad morphological commonalities e.g. gadoids and a more detailed understanding of the key factors will be required if proxies are to be used when determining the likely impact on a given species.

The review group note that many of the experiments to date have focused on determining short-term mortality and the longer term impacts have not been evaluated, with the exception of longer term impacts on the reproduction of spotted dogfish. In addition gross cumulative impacts of repeated exposure to have not been addressed and this is an area that warrants further investigation.

In addition, as the role of specific pulse characteristics have not been tested in a fully systematic manner and that the current legislation may not cover all the aspects necessary, it is not possible to ascertain whether the systems used can be adjusted to exceed thresholds that may result in a negative impact or whether the pulse characteristics used under experimental conditions are actually reflective of those used by the fleet.

- 4) It is unclear whether the current legislative framework is sufficient to avoid the deployment of systems that are potentially harmful. While the systems currently under development do not appear to have major negative impacts, ICES considers that the existing regulatory framework is not sufficient to prevent the introduction of potentially damaging systems. Guidelines and procedures for Control and Enforcement are being formulated by a Dutch project group and should be of help in preventing potential damage.**

As the current legislation has not been amended since 2012, the work of WGELECTRA 2015 does not alter the ICES advice presented in 2012.

See previous comments on understanding of critical pulse characteristics

- 5) Many of these issues will be addressed in future research proposed by SGELECTRA, and ICES supports these proposals. ICES furthermore supports research into the potential use of the startle pulse as an alternative to the currently used cramp pulse response, as well as research into lighter trawls with the net raised off the bottom and gears with no bobbins or tickler chains disturbing the seabed. The determination of critical pulse characteristics also requires further investigation.**

The review group consider that for brown shrimp, the use of a startle pulse is sufficient to maintain catch rates of this species. There is no evidence that suggests that this type of pulse has significant detrimental impacts on bycatch species encountered in this fishery.

The issue of comparing startle and cramp pulse responses has not been addressed. It seems to be accepted that the startle response works well for species such as shrimp but, for sole, the cramp response is more effective. It is unclear whether any research will be carried out under the Pulse Trawl Impact Assessment referred to in the WGELECTRA report.

One of the main potential benefits of the pulse trawl compared to conventional beam trawls is the likely reduction in the impacts on the seabed. However, it is still unclear whether the impact between a conventional beam trawl fitted with a pulse system and a standard conventional beam trawl is any different.

This has been consistently highlighted but it is not clear what groundgears are currently being used with the pulse trawl and how they compare with the conventional tickler chain arrangement. Without this information it is difficult with any degree of certainty to compare the two gears in terms of physical impacts. It is also not clear what work is planned on reducing the seabed impact of the pulse trawl through the use of lighter groundgears and how this relates to the current gear configurations used.

While WGELECTRA (2015) notes that penetration of pulse trawls is less than conventional trawls, it is not clear by how much or whether such reductions are sufficient to result in a significant difference in epi-faunal mortality.

As noted above, the critical issue of pulse characteristics still remains largely unresolved and therefore the review group considers that further work on the determination of critical pulse characteristics is still needed with a view to defining standardized pulse characteristics.

6) ICES considers that the available data are insufficient to recommend the large-scale use of the electric pulse trawl in fisheries. Consideration could be given to experimental increases, beyond 5% in the beam trawler fleet, in selected areas to further investigate the outstanding issues mentioned above.

The review group consider that the Issuing 84 licences to support the previous scientific advice is not in the spirit of the previous advice and that such a level of expansion is not justified from a scientific perspective. This level of scientific derogations amounts to around 35% of the entire Dutch beam trawl fleet greater than 18m in overall length (based on STECF data⁵), which potentially could use the pulse trawl to target flatfish. This is well in excess of the 5% limit included in the current legislation. At this level this is essentially permitting a commercial fishery under the guise of scientific research.

7) ICES recognizes that conventional beam trawling has significant and well demonstrated negative ecosystem impacts, and if properly understood and adequately controlled, electric pulse stimulation may offer a more ecologically benign alternative.

This conclusion remains valid and many of issues around the likely ecosystem impacts have been the subject of extensive research and assessment. The advice provided in 2012 considers that electric pulse stimulation may offer a more ecologically benign alternative". The Review group consider it that this should be viewed in the context that

⁵ Scientific, Technical and Economic Committee for Fisheries (STECF) – The 2015 Annual Economic Report on the EU Fishing Fleet (STECF-15-07). 2015. Publications Office of the European Union, Luxembourg, EUR 27428 EN, JRC 97371, 434 pp.

the pulse trawl offers an alternative that may have less impact than a conventional beam trawl, not that the pulse trawl is ecologically benign. In general the work of WGELECTRA (2015) shows the impacts of the pulse trawl in the flatfish fishery in the North Sea are less when compared to conventional beam trawls. The issue of adequate control and monitoring and the standardization of gear types remain the outstanding issues of most concern.

Conclusions

- 1) There is further evidence to support the conclusion that the pulse trawl significantly reduces fishing mortality of target and non-target species, including benthic organisms, assuming there is no corresponding increase in unaccounted (avoidance) mortality and that the pulse used is within the limits set out in the legislation.
- 2) There appears to be a general lack of progress in identifying critical pulse characteristics and subsequent testing which would allow conclusions to be drawn on whether the current proposed limits are sufficient or not. Some critical parameters have been identified but there is little discussion or explanation as to why these and only these are the critical parameters and why other parameters such as pulse shape that may lead to different impacts are not considered. This remains one of the main unresolved issues and the review group encourage the undertaking of structured experiments that are able to identify the key pulse characteristics and thresholds below which there is no evidence of negative impact.
- 3) The role of specific pulse characteristics have not been tested in a fully systematic manner and therefore the current legislation may not cover all the aspects necessary, it is not possible to ascertain whether the systems used can be adjusted to exceed thresholds that may result in a negative impact or whether the pulse characteristics used under experimental conditions are actually reflective of those used by the fleet.
- 4) Extensive work on mortality and potential sublethal and reproductive effects on target and not-target species is reported and reviewed by WGELECTRA for both the flatfish and brown shrimp pulse trawls. This work has expended the knowledge base significantly and provided more insight into the short and medium term effects on a wider range of species. Other than spinal injuries in cod, the studies largely show little or no adverse impacts on the different species tested.
- 5) The research carried out has established no direct link between the use of the pulse trawl and lesions on the skin of sole or dab. However, other research (Devriese *et al.* (2015)) has provided conflicting results. The review group encourages further research in this area.
- 6) The pragmatic, albeit subjective, analysis on the potential impacts of pulse trawls on individual species in NATURA sites/listings in the absence of quantitative observations, provides a useable frame work to assess potential levels of risk. However, it is considered that such comparisons would be better supported by a more structured synopsis that could be used as a cross reference between species with similar characteristics and therefore used as proxy indicators.

- 7) There is no new information on the longer-term effects of using the pulse trawl and these remain largely unknown. In addition gross cumulative impacts of repeated exposure have not been addressed and this is an area that warrants further investigation.
- 8) As the current legislation has not been amended since 2012 then it is still unclear whether the current legislation is sufficient. The issue of control and monitoring remains unresolved although through the Dutch initiative highlighted by WGELECTRA progress has been made in developing a robust control and monitoring system which could be integrated into future legislation.
- 9) Several of the research issues identified by ICES are still unresolved and it is unclear whether further research is planned. The potential use of a startle rather than a cramp pulse response, groundgear construction and the determination of critical pulse characteristics would seem to still require further investigation.
- 10) The issuing of 84 licences to carry out further scientific data collection is not in the spirit of the previous advice and that such a level of expansion is not justified from a scientific perspective.
- 11) Many of issues around the likely ecosystem impacts have been the subject of extensive research and assessment. In general this work shows the impacts of the pulse trawl in the flatfish fishery in the North Sea are less when compared to conventional beam trawls. The issue of adequate control and monitoring and the standardization of gear types remain the outstanding issues of most concern.

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15 January, 2016