Information sheet

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Electrofishing in Marine Fisheries

Summary

Electrofishing exploits the effects of electric fields on the target species to aid their capture. The challenge is to design the gear so that the electric field is strong enough to stimulate the target species and make it available for capture, while minimising any adverse effects on other species. Larger fish are more likely to be affected by an electric field than smaller fish, because for a given field strength they are likely to be subjected to a greater potential difference from nose to tail or across the body. Species specific differences in behaviour have been found for fish, molluscs and crustaceans.

Because electrical stimulation is used, reduced mechanical stimulation is required to capture the target species, which reduces mechanical effects on the environment and species encountered. Therefore electrofishing gear offers the potential for improvements in selectivity and reduced mechanical effects on other species and habitats.

Recent developments in electrofishing in European waters have concentrated on reducing fuel consumption and the environmental impact of gears derived from beam trawling for flatfish and brown shrimp. There have also been studies of electric fishing for razor clams (*Ensis* species) in Scottish and Welsh waters. All these developments have been carried out under derogation from EU regulations outlawing electrofishing.

There is a substantial research programme aimed at characterising the environmental effects of electrofishing using pulsed electric current for flatfish and brown shrimp. This technique is called ‘Pulse trawling’ in Europe. The main improvements that have been quantified are reduced mechanical effects on the seabed and reductions in quantities of fish and invertebrate species such as starfish and crabs discarded. There is also potential for improved selectivity as to size and species selection but it is uncertain whether this has been fully realised in the commercial fishery.

Adverse effects in the form of increased spinal damage have been revealed on larger specimens of cod although the effects are not always consistent; injuries are considered to be related to fish condition and have been limited to specimens likely to be retained by the gear and large enough to be marketed. The possible effects on species affected by the trawl but not captured by it has been raised and investigating this effect forms a part of the ongoing research aimed at describing the environmental effects of electric pulse trawling. A ‘gap analysis’ has been carried out and the intention is to hold regular ‘dialogue

meetings' with fishery, governmental and environmental stakeholders to review and guide the work. The first meeting was held in July 2015 in The Hague, The Netherlands

The future development of electrofishing in European waters presents a number of challenges:

- The introduction of electrofishing has demonstrably changed the spatial pattern of fishing and hence is likely to alter the pattern of competition between fishers for fish resources.

- The effects on novel target species such as *Nephrops* and razor clam need to be fully understood and their environmental and fishery management consequences assessed before further developments are undertaken.

- There is a need to effectively define and control power and electric field characteristics and enforce them in the commercial fishery. This should result in the level of electric field strength required to result in effective fishing whilst minimising effects of mortality or stress on non-target organisms. The aim should be to stimulate target species to be captured, not induce mortality.

  Currently work is underway by IMARES (the Institute for Marine Resources and Ecosystem Studies) in The Netherlands to define pulse characteristics and fishery management procedures for the pulse trawl, including detailed technical specifications for each vessel held in a dossier on board and develop a limiter control system to ensure compliance within a regulated fishery.

Further information

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Introduction

Systematic observations of the effects of electricity on fish date back to the 1930s and the 1950s. In the 1970-1980s European fisheries development organisations in The Netherlands,[1] UK,[2] Belgium,[3] France[4], Germany,[5] carried out research and development in the use of electrofishing in marine fisheries, in some cases in collaboration with private companies.

The main motivation for this work was to develop gears which saved fuel particularly during the post 1974 'oil shock' period when the price of oil rose rapidly and electrofishing, which was perceived as being more energy efficient than conventional towed gears, offered the opportunity to save fuel.

However, none of these research programmes resulted in a commercially viable fishing gear, largely because it was difficult to make the electrofishing gear robust enough for use in commercial fishing. The method was banned in 1988 in The Netherlands because of fears of increased fishing effort in the beam trawl fleet, and development in the other European nations also ceased around that time. European Union Legislation (EU Council Regulation 850/98) banned the use of electricity in 2000. Since then all legal electric fishing in European waters has taken place under an agreed derogation (that is a permit) from the authorities from these regulations (see below).

Since the 1990s there has been an increased focus on reducing the impacts of trawling, particularly beam trawling, on seabed habitats. Electrofishing techniques have the potential to reduce the mechanical effects because of the reduced weight of gear, there being no tickler chains to disturb the seabed, slower optimal towing speed and to be more selective because larger fish respond more readily to electro stimulation. This led to a revival of interest in electrofishing and a high level of collaboration between public and private sectors in The Netherlands in the development of the 'Pulse trawl' derived from the beam trawl and the development of the 'Hovercran' gear derived from the shrimp beam trawl gear in Belgium.

In a separate development in the early 2000s, it was discovered that razor clams (*Ensis* species) could be induced to emerge from the seabed through electrical stimulation, rendering them available to collection by divers. Although the method is banned by law an illegal electro fishery has developed on this species due to its high value.

The purpose of this information sheet is to review these developments in marine electrofishing and discuss the environmental and fisheries' management implications of this method.

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[1] IMARES (formally RIVO-DLO)

[2] Seafish (formally Whitefish Authority) and Marine Scotland (formally SoAFD)

[3] IVLO Institute for Agricultural and Fisheries Research (formally RvZ)

[4] IFREMER

[5] Institute Fūr Fangtechnik

Existing Regulation

Article 31 of Council Regulation (EU) 850/98; Unconventional fishing methods;

"The catching of marine organisms using methods incorporating the use of explosives, poisonous or stupefying substances or electric current shall be prohibited."

This is amended by Council Regulation (EU) 227/2013 allowing pulse fishing in the southern North Sea, see Figure 1.

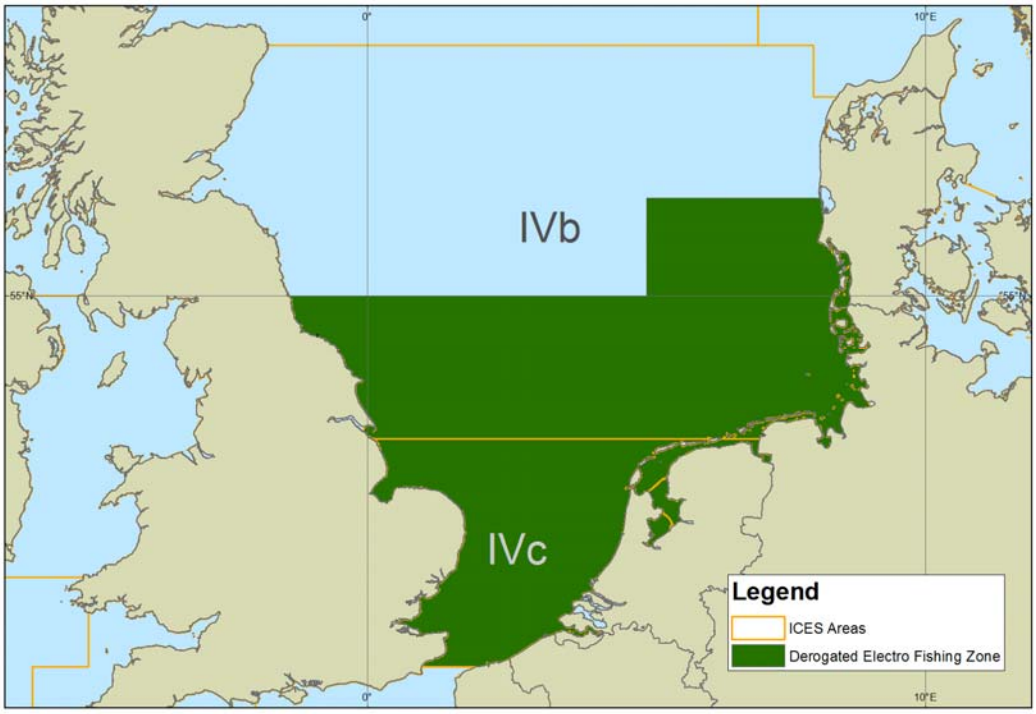

Figure 1 Permitted zone for electrical pulse trawling.

Conditions were attached to the regulation concerning number of vessels as a proportion of each nation's fleet, powers and voltages to be used, together with recording devices to record fishing activities. The original specification is being updated by work being undertaken in The Netherlands (see page 12) to clearly define and control power, voltage and other characteristics together with measures to record electronically vessel activities in tamperproof files.

Electrofishing for razor clams has been permitted under derogation in South Wales (Woolmer, et al, 2011) and in Scotland (Murray, et al, 2014) in order to study the environmental effects of this method of fishing. In Scotland legislation has been brought in to deter electrofishing for razor clams through a requirement for a special licence for fishing for razor clams and an increase in the level of fine.

European electrofishing gears

Three main gears have been developed in Europe for marine electrofishing; pulse trawling developed in The Netherlands, designed to replace beam trawling in the southern North Sea, 'Hovercran' beam trawl gear, designed to trawl for brown shrimp (*Crangon crangon*) developed in Belgium and the illegal razor clam fishing gear, which consists of a towed electrode array which stimulates the razor clams (*Ensis* species) to emerge on the surface of the sediment, after which they are harvested by divers.

'Pulse' trawling for flatfish

The gears used for pulse trawling (Figure 2) are originally based on beam trawling gear, but with substantially modified ground gear. The tickler chains are replaced with electrode arrays and in the case of the HFK Sum Wing with pulse trawl, the beam is replaced by a hydro-dynamic wing which is neutrally buoyant, with its position above the seabed maintained by hydrodynamic forces and a single central runner. The Delmeco gear is closer to the conventional beam trawl in design, with shoes supporting the beam at each end. There is a reduction in damaged fish and so quality of the catch is improved (cited in Quirijns et al., 2015). This often means that although catch rates are reduced in the pulse trawl fishery, profits increase through a combination of fuel savings and increased landing prices

Figure 2 HFK Sum Wing with pulse trawl (left) and Delmeco trawl (right).

Hovercran trawl for shrimp

The Hovercran gear is being developed for use in the brown shrimp (*Crangon crangon*) fishery with modified ground gear and electrodes (Figure 3). This gear is used in inshore waters of the southern North Sea. The intention behind this gear is to catch shrimp by stimulating them to jump high enough to be captured in the trawl, and reduce the weight of the footrope to enable fish and other bycatch species to escape (see page 8). However in practice it proved necessary to retain some bobbins on the footrope. Ground contact and bycatch were reduced (Verschueren, 2015).

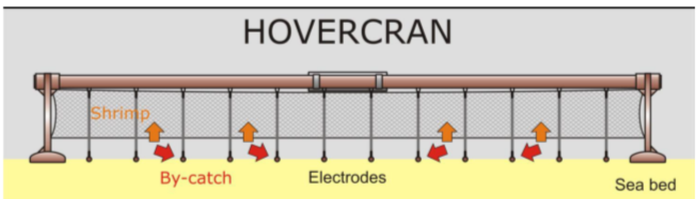

Figure 3 Principle of the Hovercran trawl where electrodes stimulate the shrimp to jump over a raised footrope into the gear

Capture mechanisms

For marine electrofishing the main aim is to elicit a minimum response to stimulate the fish or shellfish into a position where it can be successfully captured, thus enabling a less invasive fishing technique than was previously necessary. Responses to electrofishing vary between species and size of organism, and this has potential to enable improved size and species selectivity.

Response by fish

The responses of fish range from a ‘minimum response’ consisting of an involuntary contraction of the musculature at the make or break of a weak electric field, through to behaviour that results in involuntary swimming, and the extreme response of electro narcosis at very high field strengths, where the fish cease to respire and sink

However, behaviour varies between species and size of individual specimens. This is because for a given field strength larger fish are likely to be subjected to a greater potential difference from nose to tail or across the body, and are likely to exhibit an increased response to a given electrical field. In extreme cases the muscular contraction is sufficient to result in vertebral damage; see page 7. The waveform of the electric field; direct current (DC), pulsed direct current or alternating current (AC) also has an effect on the fish’s response. Experiments carried out in the Netherlands in 1969 (cited in van Marlen, 1997) found that pulsed DC elicited responses at lower field strengths and development of these gears has used this stimulus.

Pulse trawls use electrodes instead of heavy tickler chains to stimulate sole and plaice to elevate off the seabed and hence become available to the net.

Response by shellfish

For brown shrimp (*Crangon crangon*), the response consists of a ‘tail-flip’ reaction which results in continuous swimming at an elevation above the substrate of around 10 cm. After around 15 seconds ‘pulse fatigue’ sets in when the animals cease to respond. It was found (Polet, 2004) that the tail flip behaviour of the shrimp was different from a range of undersized fish species which tended to stay nearer the seabed. Hovercran trawl gear aims to reduce bycatch of undersized fish through the use of differing configurations of ground gear designed to enable escape of the undersized fish below the footrope, whilst the brown shrimp catch is maintained or even increased by electrical stimulation. The speed of towing is the same as conventional shrimp gear; see Lüdemann & Koschinski, (2014) and Verschueren, (2015).

Stewart, (1974) found that Norway lobsters (*Nephrops norvegicus*) could be induced to leave their burrows if subject to electrical stimulation. Pulsed electric fields caused muscular contractions, but if these were sufficiently disturbing the animals took evasive action either by walking slowly out of the field or by using a strong tail flick to make a rapid response, ejecting the animals from their burrows by their secondary exits. It was demonstrated that improved catch per effort could be achieved in field studies using an electrified beam trawl in the Moray Firth and The Minch fisheries (Stewart, 1975a).

Electrical responses of bivalves have been reported for razor clams (Woolmer, et al., 2011; Murray et al., 2014). It was found that razor clams emerged from the sediment within 37 seconds of the stimulus being applied and reburied within around 7.5 minutes. The illegal electrofishing for razor clams relies on divers to harvest the razor clams once they have emerged from their burrows. Other bivalves and crustaceans were investigated, but did not all show as vigorous response.

Environmental effects

Replacing the heavy tickler chains on beam trawl gear with an electrode array means that the mechanical foot print of the gear is lighter on the seabed; reductions in penetration depth for both the Sum wing trawl with pulse (van Marlen, et al, 2009) and the Delmeco trawl (Depestele et al., 2015) (Figure 2) and also the optimal speed of trawling is lower (reduced from approximately 6.5 to 5.0 knots). Therefore from the point of view of reduced mechanical effects on the seabed and fuel consumption, there are clear advantages of this method.

The fact that larger fish are more stimulated by electric fields means that there is potential for increasing the selectivity of electrofishing. However, it also means that adverse effects due to vertebral damage are likely to occur in larger fish, so larger fish such as cod have been examined for adverse effects.

Effects on cod

Laboratory studies into the effects of pulse fishing on cod discussed in Soetaert, et al, (2015) cite studies that have shown that larger fish are more susceptible to vertebral damage than smaller fish and the closer fish are to the electrodes the stronger their behavioural response, hence the higher their risk of vertebral damage. Cod exposed to electrical fields of the same strength as used in the pulse trawl beyond 200 mm from the electrode did not show any injuries, and those beyond 400 mm did not exhibit any reaction to the electrical field. Fish this close to the electrode would be expected to be within the mouth of the trawl and hence be retained. The highest probability of fractures of the spinal column occurred in marketable sized fish and no injuries were observed in cod that were small enough to escape through the meshes of the nets. As well as field strength, the nature of the electric field was important; lower frequencies induced more injuries than higher frequencies.

However, two repeats of these experiments by different laboratories failed to replicate these effects, with no injuries observed for cod at these distances from the electrodes (Quirijns et al., 2015). The differences in effect were ascribed to differences in the body condition of the fish used (e.g. differences in muscular system, mineral content). Some injuries could be induced, but with much higher field strengths than used in commercial gear.

The rates of spinal injury in cod retained in the trawl were examined in an experiment designed to compare pulse trawling with conventional beam trawling (van Marlen et al, 2014). Spinal fracture was observed in 4 of the 48 cod caught in pulse trawls, whilst one spinal haemorrhage was observed in the 48 cod caught in the conventional trawl. Around 2% of whiting in the catch were affected in a similar way. All of these fish were marketable fish retained by the gear. The catch rate of cod per unit area in pulse trawls was 31% of the conventional beam trawl.

The results on spinal damage obtained from the field studies are considered to be valid, but no longer consistent with the laboratory studies, which took place on farmed cod. Further tests on bone and muscle densities would increase understanding of the reasons for the differences.

Effects on other fish species

Comparisons of laboratory survival rates of plaice and sole captured in conventional beam trawls compared with electro fished specimens showed improved survival for electro fished specimens of plaice after 192 hours but no significant difference in survival for sole. Specimens of dab were exposed to electrical stimuli as expected under fishing conditions and examined both internally and externally for lesions immediately after exposure and five days later. No adverse effects could be ascribed to the electrical stimulus (cited in Quirijns et al., 2015).

Elasmobranch fishes such sharks, dogfish and skates and rays, use electro receptor organs in prey sensing as described in Gardiner et al, (2014). Dogfish subjected to electric fields showed behavioural responses but no injuries (cited in Quirijns et al., 2015). However, there is work on progress in Belgium on the effects of exposure of the receptor organs to electric fields, which has not yet been published (Polet *pers. comm.*).

Effects on benthic invertebrates

Soetaert et al., (2015a) and Murray et al., (2014) report laboratory experiments on a range of benthic organisms, molluscs, echinoderms, crustaceans and polychaetes using behavioural and mortality rates as indicators and most of these organisms showed no significant effects.

In a more in depth study Soetaert et al., (2015b) examined the effects of laboratory exposure to electrical pulses in brown shrimp and ragworm. There was no effect of electric field on survival rates. However, microscopic examination of the brown shrimp indicated a raised severity of a natural virus infection in those animals treated with the highest field strength. The authors attribute this differential viral infection to be as a result of the electric stimulation causing stress. This level of electrical exposure would only occur in a very narrow band along each electrode and for a shorter duration than used in this study.

Trawl path mortality

The above discussion relates to catches retained by the gear. There is clearly scope for fish and other species to be damaged in the gear and not retained. This has been studied for benthic species (Teal et al., 2014) using sampling from the trawl path post fishing. However, there is high variability so it has proved difficult to detect differences post trawling for these species, although the studies are continuing.

There have been anecdotal reports which suggest that dead fish have been found in the vicinity of pulse trawling. The pathology associated with pulse trawling is very well described (see above) so given samples in good enough condition, it should be possible to identify whether pulse trawling could be the cause of mortality.

Chemical effects

The passage of electrical current through seawater will inevitably result in some corrosion of the metal electrodes through electrolysis, and there is potential for the production of hydrogen, oxygen, chlorine and sodium hydroxide. There is also potential for interaction between these materials and the sediments and for other electrical effects on seabed sediments.

However, this aspect has been very little studied, although video observations by Woolmer et al., (2011) of razor clam *(Ensis)* fishing using a continuous DC stimulus, show gases being evolved at the anode. Divers participating in razor clam fishing report that metal diving components can degrade in normal contact with the field, which the diver is not aware of, and that electrodes will rapidly erode. Stewart, (1974) reports pulses of bubbles being generated at the electrodes when pulsed DC was used, with the pulses timed to coincide with the DC pulses.

Gases were not observed in laboratory experiments using continuous Alternating Current (AC) for stimulation of razor clams by Murray et al., (2014). Part of the planned research programme in Holland (see below and Quirijns et al., (2015)) will include a study of the effects of electrical pulses on sediments and geochemistry.

Comparisons between gears

When new technology is introduced into a fishery, there are likely to be effects on fishery practice. Therefore, initial trials are required conducted in a structured way to examine the differences between the two gears fished in the same way. This should be followed by a period when the commercial fishery is observed to understand how the changes in technology affect fishing practices. In the introduction of the pulse trawl in the southern North Sea both comparisons have been made.

Comparative trials

A comparative trial has been carried out by van Marlen et al., (2014) in which the activities of three vessels (one Sum Wing with pulse trawl, one Delmeco ‘multi wing’ and one conventional beam trawl) were co-ordinated in an experimental design to examine differences between catches in the electrical and conventional gear.

This study found a 57% reduction in terms of discarded weight per unit area and a reduction of 44% in terms of discarded weight per hour for fish in the pulse gear compared with the conventional beam trawl gear. The difference between two trawls in terms of discards per unit area and per hour reflects the reduced optimal speed of the pulse trawl (5.0 knots) compared with conventional gear (6.5 knots). The most important improvement was due to reduced discards of flatfish, but also a reduction due to demersal fish as well. There were size selectivity improvements for plaice and sole that were in line with laboratory predictions of Stewart, (1975b).

There was a reduction of 80% in surface living benthic discards per unit area and 62% per hour in the pulse gear. For infaunal benthos, that is organisms which live in the sediments, there was a fivefold increase of this component in the pulse gear catches, although the absolute quantities caught were small. Whilst benthic species respond to electric fields (see above), the differences in catches were considered to be mostly attributed to differences in the way in which the electrode array interacts mechanically with the seabed and the benthic species compared with conventional gears.

Surveys of commercial fishing

Since the introduction of the pulse trawl, many of vessels in the Dutch flatfish fleet have changed to this type of trawling (Turenhout, 2015) and the pattern of fishing has changed with fishing being concentrated in the southern and western waters of the southern North Sea off the Thames estuary (Rijnsdorp, 2015). Therefore, whilst comparative fishing experiments are vital to obtain an overview of the main differences in environmental effects between the gears, there is a need for more extensive work to monitor and model the effects of this innovation on ecosystems.

Monitoring of the commercial catches of conventional beam trawls and pulse trawls carried out in 2012 by Rasenberg et al.,(2013). These results, based on self-sampling (where the fishermen collect samples) and observer sampling were characterised by high variability indicating uncertainty. There were similar discard percentages (around 50% discarded by weight) in the plaice catches in both fisheries and a small reduction in the percentage discard of sole in the pulse fishery. However, the average quantity of plaice caught and discarded per hour was lower; 27-66 kg/hour, in the pulse trawl compared with 87 kg/hour in the beam trawl.

The lack a reduction in discard percentages of plaice in the commercial pulse trawl when the experimental trials indicated improved selectivity (van Marlen et al., 2014) would require further analysis. It may be due to differences in the patterns of fishing and discarding. The reduction in catches and discards per hour of plaice implies a lower impact of the pulse trawl on the plaice population and is in line with increased targeting of sole by the pulse trawl fishery.

Discards of starfish and crabs were lower in the pulse trawl, with pulse trawling catching 16% and 42% respectively of the quantity caught in the conventional beam trawl. This indicates that the commercial implementation of the pulse trawl has successfully reduced the quantity of macro benthos (starfish, crabs etc) retained in line with the experimental results. There were insufficient cod caught in either gear to make a reliable comparison.

Fisheries management implications

There are clearly fishery management challenges arising out of the development of the electrical fishing gear. There has been an important precedent in the East China Sea, where pulse trawling was introduced in the Chinese Penaeid shrimp fishery in the early 1990s (Yu, et al., 2007)

Here, the increased efficiencies brought about by the use of electrical gear led to a greatly increased catch which was not properly managed and controlled and resulted in severe overfishing of the resource. Although there were measures to control electrical output and other settings in place, a lack of equipment integrity meant that they could be altered in commercial practice. The unregulated use and misuse of the electrical fishing apparatus negated the advantages of electrical fishing and the use of electrical fishing was banned in 2001.

There is a clear need to ensure that the environmental impact of electrofishing is well understood and that management measures are implemented to control the effects and ensure that the fisheries do not suffer similar results to that of the Chinese example cited above.

Key elements;

- Sound fishery management, including knowledge of the dynamics of the stocks and appropriate management

- A good understanding of the effects on species which encounter the gear; whether lethal or non-lethal, captured or not captured, including reproduction and long term effects

- An understanding of the effects on the marine ecosystem, and measures to avoid undesirable effects

- Good technical regulation of the gear, with limits on output characteristics and specifically tuned to avoid undesirable effects. Electricity has the capacity for non-lethal stimulation to enable capture. However, there is the risk of excessive field strength which may result in stress effects as discussed above for brown shrimp, or excessive mortality, particularly in larger specimens. There is a need to avoid a repetition of the situation seen in the Chinese fishery discussed above when manufacturers and vessel owners found methods to increase field strength and the electrical device became an indiscriminate electrical killing apparatus rather than a stimulus device.

  See overleaf (page 12) for discussion of measures to control electric field characteristics.

- There is a need to understand the changes in fishery behaviour relating to the introduction of the new technology. For example the pulse trawler men are quoted (Fishing News International Oct 2015) that they can fish more easily off the French and English coasts rather than their traditional beam trawling grounds off the South Holland and Belgium coasts; this was also discussed at the dialogue meeting (Turonhout, 2015 presentation).

  Such changes will inevitably result in different patterns of effects between the pulse and non-pulse gears, since different environments will be affected. It is also likely to result in different patterns of competition between fishers, since in the above example the UK and French fisheries inside 12 Nm are likely to be in closer proximity to pulse trawling than they were to beaming and so potentially be in closer competition for fish.

Next steps

Electrofishing has been shown to be commercially viable and more profitable than some conventional methods. However, there is a need to take a strategic view of each method if its potential is to be realised.

Pulse trawling research

Pulse fishing has attracted a great deal of criticism in its implementation (Sunday Times; 24 June 2012) and from French fishermen (CNPMEM, 2015) and it has been discussed at the North Sea Advisory Council. In response the Dutch government have commissioned a gap analysis (Quirijns et al., 2015) and set up an ongoing research programme to fill the gaps in knowledge and set up a stakeholder dialogue group to provide a forum for discussion.

They have a continuing research programme with the objective;

- To provide a scientific basis to assess the consequences of the transition of beam trawling to pulse trawling the ecosystem (bycatch, benthos, ecosystem functioning)

Full details are given in Quirijns et al., (2015) and discussed at the dialogue meeting (see below).

Major strands of the research include;

- Laboratory experiments on fish and benthos; to examine the effects of electrofishing.
- Field experiments: Effect on seabed ecosystem and on species in the trawl path post fishing (partly due to be undertaken in the BENTHIS project)
- Modelling fleet dynamics & ecosystem functioning

Control of electric field characteristics

IMARES has set out to define pulse characteristics and fishery management procedures for the pulse trawl, including detailed technical specifications for each vessel held in a dossier on board and develop a limiter control system to avoid excessive electric fields.

The scheme is in draft form but includes measures which would define and limit the electric field in terms of power and voltage, duration and frequency of the pulse. The system would collect records of the vessel's activities and the voltage discharge of the array that would only accessible by the manufacturer of the gear and the authorities. New statistical codes for reporting pulse trawl activities are proposed within the European Union, to distinguish it from conventional beam trawling.

Hovercran shrimp trawling

The Hovercran trawl has the potential to improve species and size selectivity of brown shrimp trawl gear, with unpublished IVLO data demonstrating a discard reduction between 50 % and 75 % (Polet, *pers. com*). However, commercial implementation remains under development (Lüdemann & Koschinski, 2014).

Assessment and management of shrimp fisheries and stocks is still in development. Currently there are no catch limits and the stock is believed to be growth overfished (ICES, 2015a) which means that it would benefit from improved selectivity. ICES, (2013) highlight the benefits of better management measures for this fishery. There is a need to ensure that the electric fishing does not have a destabilising effect on the fishery through the introduction of viable management measures.

Nephrops trawling

Most of the main *Nephrops* stocks are outside the area currently permitted for use of pulse gear which is targeted on flatfish. Although not being practised on this species electrical fishing has the potential for use on *Nephrops* stocks, as it induces them to emerge from their burrows (see above). However, there is a risk that electrical fishing could change the way in which *Nephrops* stocks would be exploited because it could change the ratio of catchability of males to females. Currently, in many *Nephrops* stocks, males are more catchable than females (ICES, 2015b) because females spend more time in their burrows incubating their eggs and it is believed that this aids conservation of the females in the stock. If electric fishing were to encourage the emergence of female *Nephrops* from their burrows then this would have to be taken in to account in *Nephrops* fishery management.

The gap analysis in Quirijns et al., (2015) makes reference to proposed research on behavioural studies in *Nephrops*, though no details are given.

Razor clam (*Ensis*) fishing

Knowledge on the effects of electrical fishing for razor clam has advanced in recent years (Woolmer, et al, 2011; Murray et al., 2014). However, there is a need to improve knowledge of the biology and population dynamics of razor clam and develop a management strategy for the species before a fishery could be permitted.

Websites

North Sea Advisory Council
http://www.nsrac.org/?s=Pulse+fishing

Pulse fishing International dialogue meeting

http://pulsefishing.eu/en/news/international-dialogue-meeting-july-2015
Pulse fishing gap analysis
http://pulsefishing.eu/sites/pulsefishing.eu/files/pf_research/paper/C091.15%20Rapport%20Flatfish%20pulse%20fishing...gapsII-SS-lcs.pdf

Razor clam workshop Marine Scotland
http://www.gov.scot/Topics/marine/Licensing/FVLS/razorlicence/razorworkshopminutes

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