# Flatfish pulse fishing

## Research results and knowledge gaps

Floor Quirijns, Wouter Jan Strietman (LEI), Bob van Marlen, Mascha Rasenberg

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(IMARES - Institute for Marine Resources & Ecosystem Studies)

Client: Ministry of Economic Affairs
P.O. Box 20401
2500 EK THE HAGUE

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P.O. Box 68
1970 AB IJmuiden
Phone: +31 (0)317 48 09 00
Fax: +31 (0)317 48 73 26
E-Mail: imares@wur.nl
www.imares.wur.nl

P.O. Box 77
4400 AB Yerseke
Phone: +31 (0)317 48 09 00
Fax: +31 (0)317 48 73 59
E-Mail: imares@wur.nl
www.imares.wur.nl

P.O. Box 57
1780 AB Den Helder
Phone: +31 (0)317 48 09 00
Fax: +31 (0)223 63 06 87
E-Mail: imares@wur.nl
www.imares.wur.nl

P.O. Box 167
1790 AD Den Burg Texel
Phone: +31 (0)317 48 09 00
Fax: +31 (0)317 48 73 62
E-Mail: imares@wur.nl
www.imares.wur.nl

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## Summary

Knowledge about the effects of pulse fishing is spread out over various reports and policy documents; a complete and accessible overview of knowledge is lacking. Pulse fishing is relatively new: in this fishery, fish are caught by means of electric pulses. Those pulses cause muscle contractions in fish, resulting in them being released from the sea bottom and caught in the net. Because the pulse technique is relatively new and because electric fishing is not permitted in Europe, the development of this fishery brings up a lot of questions. The fishery study group Pulse and SumWing (part of the fishery study group Flatfish) asked IMARES and LEI to make a summary of the available knowledge on the effects of pulse fishing and of lacking knowledge. This report summarises effects on landings and discards, effects on the ecosystem, management of the fishery and $CO_2$ emission. At the end of the report, we give an overview of knowledge gaps.

An important observation is that the results of the studies may not be comparable amongst each other. The conditions under which the studies were carried out may differ. This complicates drawing firm conclusions about 'the' effects of 'the' pulse fishery. Instead, we draw conclusions on the effects that were measured under specific conditions. We came to the following conclusions:

- Cod and whiting: chance of fractures in spinal column of large cod;
- Dogfish: minimal effects (no mortality or change in behaviour besides muscle contractions), although effects on the functioning of electro receptors was not studied;
- Benthic invertebrates: some species did not respond to pulse (for example spisula and starfish); other species did (razor clam, shrimp, green crab and rag worm). Observed effects were reduced survival rates and food uptake;
- Marketable plaice and sole: the pulse gear catches similar amounts of marketable sole as the conventional beam trawl, but lower amounts of marketable plaice;
- Plaice and sole quality & survival: these species with pulse trawl are less damaged and have a higher chance of survival than plaice and sole caught with conventional beam trawl;
- Discards: less discards for all species categories that are discarded;
- Fuel consumption: pulse trawl has a lower resistance than the conventional beam trawl, resulting in reduced fuel consumption and $C0_2$ emission.

Despite the large number of studies that have been carried out, several topics need more investigation:
- Indirect (or: delayed) mortality;
- Long term effects on species that encounter pulse trawl gear and on their populations;
- Non-mortal effects;
- Effects on reproduction;
- Minimum and maximum values for pulse characteristics (is there a 'safe range'?)
- Effects of pulse fishing on first life stadia of marine organisms that reproduce in shallow water;
- Effects on substrate and water column: can use of pulse result in toxic matter?

International scientists stated that control and enforcement issues should be resolved before the number of vessels using pulse trawls is increased. In 2012 procedures for control and enforcement were developed, but they are not being used yet.

# 1. Introduction

This report summarises existing knowledge on the effects of electric pulse fishing on flatfish. We will specifically examine the effects of pulse fishing on catches and discards, the effects on the ecosystem, the management of pulse fishery and $CO_2$ emissions. This knowledge is distributed over various reports and policy documents whereby a complete, accessible overview of the subject has been lacking until now. For this reason, the fisheries study group Pulse en SumWing (part of the flatfish study group) asked research institutes LEI and IMARES to summarise the knowledge and identify the knowledge gaps.

The fishery study groups are financed by the policy supporting research of the Ministry of Economic Affairs.

## Objective

The aim of this report is to present a simple and clear overview of the knowledge currently available about catches, discards and the effects of the pulse technique on the ecosystem. We will also consider the management of electric pulse fishing. After this overview it must become clear where the knowledge gaps lie.

The pulse technique is applied to both the flatfish and shrimp fishery. This report focuses only on the pulse fishery targeting flatfish.

## Reading guide

In chapter 2, we first explain the operation of the pulse technique in the flatfish fishery and in the various conditions occurring in the North Sea. In chapter 3, we give a short historical overview of pulse fishing in the Netherlands and the current (European and Dutch) policy on pulse fishing. In this overview we sometimes refer to socio-economic research, but do not discuss the results. In chapter 4, we consider the results of research conducted into the effects of the pulse technique on the catches and its effects on the ecosystem. Chapter 5 discusses the management of pulse fishing. Finally, in chapter 6 we indicate which subjects require extra research.

## 2. Introduction of pulse: its operation and effects

In the Netherlands, demersal fishing traditionally took place with the conventional beam trawl. In recent years, a gradual transition has taken place to pulse fishing, in which the tickler chains have been replaced by electrodes. The fishing gear is almost the same, the difference is in the way the flatfish are startled. This clearly distinguishes the electric pulse technique from the beam trawl with tickler chains.

**Information from a fishery study group member**
Fishers transfer to the pulse fishery because with this technique they use much less fuel. The lower fuel consumption is mainly due to slower fishing speeds; when fishing, a pulse fishing vessel fishes approximately 1.5 nautical miles an hour slower than a conventional beam trawl vessel. Another advantage of the slower speed is that in total shorter fish distances are covered, so that seabed disturbance per vessel is reduced.

This introductory section explains the operation of the pulse technique in flatfish fishery and the various conditions occurring in the North Sea.

### Operation of the pulse technique in the flatfish fishery

Flatfish spend a large part of their day on or in the seabed. In the flatfish fisheries, fishers use techniques to startle the fish from the seabed so that they can be lifted up into their nets (while steaming). In the conventional beam trawl fishery tickler chains are used to startle the fish (figure 2.1, left). These are steel chains attached along the breadth of the net opening or further back in the net on the ground line, which are dragged along the seabed.

**Figure 2.1. From left to right: traditional beam trawl, HFK pulswing, Delmeco pulskor**

An electric pulse vessel has no tickler chains, but cables/electrodes containing isolated and conductive elements which are hung in the direction they are to be dragged (figure 2.1 centre and right). Electric shocks transmitted through the conductive elements create a pulsating field. Fish entering this field experience a small electric shock.

The electric shocks cause the muscles of the flatfish to contract, so lifting them from the seabed. It appears that this is mainly true for sole and to a lesser extent in other flatfish species. The fish is not killed or stunned by the electric shocks, but only startled. Once the electric shocks have passed, the muscles relax and the fish tries to dig itself in again or swim away.

## Electric pulse system used in the Netherlands

Two companies have developed a pulse prototype for the Dutch flatfish fishery: Delmeco (previously Verburg-Holland) and HFK Engineering (see figure 2.1). These systems have their own individual pulse characteristics [1]. The differences are marginal, but lie mainly in the characteristics of the pulse, the number of pulses per second, the duration of the pulse, and the number of electrodes, but also in the distance between the electrodes and the number and size of the conductors.

### Pulse characteristics

Pulse characteristics can be defined as follows [2][3][4]:
- Amplitude in volts (V): potential measured between two conductive elements.
- Electrical field strength (volt/cm): the logical consequence of the amplitude and the electrode distance.
- Pulse frequency (Hz): number of pulses per second.
- Pulse duration (µs): duration of pulse.
- Gradient of the pulse wave form (pulse shape)
- Shape of the electric field ('composition of field', resulting directly from the pulse shape but also dependent on the type and number of electrodes and the distance between the electrodes and the length/combination of conductive and isolating elements).

In catching fish, the electricity that is transmitted through the fish is most important. Field strength (potential difference across the body of the animal) and resistance (conductivity) are determinant here, as is the duration of the electricity. Electrical fields are not homogeneous in the pulse trawls and have a three-dimensional action. The potential difference therefore depends on the position of the fish within the field and the length of the fish.

### Effects of pulse under different conditions

The electric field generated by the pulse does not have the same effects under all conditions and for all fish (& other organisms)[3][4][5]. The conductivity and strength of the pulse under water depends on:
- The difference in conductivity of the seabed and the seawater;
- The composition of the seabed: more silty seabed have a better conductivity than sandy beds;
- The saline content of the water: saltwater conducts better than freshwater;
- The water temperature: warm water conducts better than cold water.

The effects of the pulse vary depending on:
- The conductivity of the fish and its anatomy;
- The intensity (µs and Hz) and the strength of the field (V/cm) of the pulse;
- The speed at which the fish are caught with the pulse fishing gear: if a vessel is fishing at a greater speed the fish are exposed to the electric field for a shorter time;
- The length and arrangement of the conductive and isolating electric elements;
- The distance to the conductor: the closer to the conductor, the stronger the electric shock;
- The shape and length of the fish and/or muscle mass: the longer the fish and/or the greater the muscle mass, the more powerful the muscles contract as a result of electric shocks;
- The orientation of the fish: it makes a difference whether a fish is swimming or floating parallel to or perpendicular to the electric field. The potential difference across the body is determinant.

## 3. Electric pulse fishing in the Netherlands - history and policy

The development of electric pulse fishing started in the 1970s but it owes its present form to mayor steps taken from 2005 onwards. There have been rapid developments since then. This chapter provides a historical overview of pulse fishing in the Netherlands and of current (European and Dutch) policy on pulse trawling.

### Historical development of electric pulse fishing in the Netherlands

1970-1990: The first steps taken towards using electric pulse in fishery [2]

- 1970-1988: Pulse fishing is considered as an experimental fishery and is therefore permitted;
- 1970-1985: Development of electric pulse trawl gear for shrimp and flatfish fisheries by the Dutch Institute for Fisheries Research (RIVO);
- 1985: ICES[1] seminar on electric fishing with participants from Belgium, the Netherlands, Germany and England [6];
- 1986: Development of a pulse prototype for flatfish on the GO65, in cooperation with Oranjewerf B.V. – Giesselbach B.V.;
- 1988: A European (and Dutch) ban on electric fishing terminates the RIVO study.

1991-2000: Technical research into electric fishing is permitted again by the EU

- 1992-1998: Verburg-Holland B.V. and the Dutch Ministry of Agriculture investigate the technical possibilities for the pulse trawl. They carried out fishing tests (a.o. sole) and experiments with a trawl in containers on land in which a trawl can be placed;
- 1992-2000: Experiments with a pulse trawl gear of 4 and 7 meters wide [2];
- 1998-2000: European research project REDUCE studies the effects on catches and mortality of benthic invertebrates in the trawl path [7].

2001-2010: field trials on commercial use of electric pulse trawls

- 2004-2005: Study of RIVO carried out on board of the Tridens into catch differences between the beam trawl and the pulse trawl and exploratory research into the survival of undersized sole and plaice caught by both trawl types [8];
- 2005: RIVO study into the effects of the pulse trawl and conventional trawl on sole and plaice regarding their condition, survival and catches, and stress hormone blood levels [9];
- 2005: Preliminary RIVO study into the effects of electric pulses on invertebrates [10];
- 2005: The Ministry of Agriculture creates a steering group on electric pulse fishing with representatives from the fishing industry, the Ministry and LEI/RIVO (later: IMARES);
- 2005-2006: Tests with field ship UK153 and the Verburg-Holland system: ecological study with comparisons of pulse trawl catches and conventional beam trawl catches by IMARES [11];
- 2005-2006: Comparative study by LEI of the pulse trawl and the conventional beam trawl regarding: production costs, necessary investments, prognoses and monitoring of economic results, fuel consumption and fish prices;
- 2006: Request to ICES for advice through STECF, on the effect of electric pulse fishing on the ecosystem; this is discussed by the WGFTFB expert group (ICES-FAO Working Group on Fishing Technology and Fish Behaviour);

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[1] International Council for Exploration of the Sea

- 2006-2009: The European DEGREE project is launched [12], involving an LEI study on the financial profitability of electric pulse fishing and monitoring of catches on board the TX68. The project is a precursor to the BENTHIS project.
- 2007-2011: In 2006, ICES advises on the pulse technique and raises additional questions which result in further laboratory studies by IMARES on benthic invertebrates, dogfish and cod [1][13][14][15]
- 2007: The 'Kotteroverleg', representing the fishing industry, withdraws its support for research on pulse fishing because of disappointing plaice catches. As a result, financing of the research project with the UK153 ceases [16]; the UK153 continues testing electric pulse trawls on its own initiative [17];
- 2007: LEI advises positively on the economic feasibility of electric pulse fishing to the Steering group, Fishery Innovation Platform and the Ministry of Agriculture;
- 2007: From 2007 onwards, the Netherlands receive an annual exemption to equip 5% of the beam trawl fleet with electric pulse trawls;
- 2007-2008: Minister Verburg agrees to expand pulse fishing to five trawlers. The Dutch government provides the five investors with subsidies of up to 40% of their investment in pulse fishing [18];
- 2008: LEI and IMARES establish the first expert group with support from the Ministry: Study group Pulse en Sumwing [18];
- 2008: IMARES calculates the potential savings of fuel when using pulse trawlers and others trawlers in project ESIF [19][20];
- 2009: ICES assesses recent IMARES studies and submits additional recommendations [21];
- 2009, May: The first of the 5% trawlers permitted to fish using pulse, the TX68, is equipped with the pulse trawl by Verburg-Holland (later acquired by Delmeco);
- 2009, December: HFK Engineering develops its own pulse system (Pulswing, a combination of the pulse and sumwing). The system is installed on the TX36, the 2$^{e}$ trawler from the pioneer group;
- 2010: The electric pulse gear is installed on the remaining three trawlers;
- 2010: ICES organises a workshop focusing on electric pulse fishing: ICES WKPULSE [22]
- 2010 October: Another fourteen trawler owners invest in the pulse fishing gear and the maximum number of derogations, 5% of the fleet or 20 vessels, is reached;
- 2010 December: The European Commission agrees to a 22 additional temporary derogations for pulse fishing for the Netherlands [23].

2011-2013: Electric pulse trawling is up-scaled to 42 trawlers
- 2011: In June the derogations for the additional 22 exemptions are extended [24];
- 2011: ICES launches the SGELECTRA study group, specifically focused on pulse fishing [25][26];
- 2011: A new steering group for electric pulse fishing is established, with participation from the Ministry of Economic Affairs, the fishing industry and scientific community, with the objective of developing regulations, control and enforcement protocols and policy on pulse fishing;
- 2011: IMARES studies the catches and carries out comparative research into the conventional beam trawl, the HFK Pulswing and the Delmeco pulse trawl while fishing in proximity to each other during one fishing week [27];
- 2011: IMARES continues studies the effects of electric pulse on cod [27];
- 2011: IMARES answers a helpdesk question from the Ministry of Economic Affairs and provides an overview of studies on electric pulse and recommendations for follow up studies [2];
- 2012: STECF submits recommendations on pulse fishing and underlines the importance of a proper control and enforcement [28];
- 2012: IMARES draws up a control and enforcement protocol [29];
- 2012: All temporary exemptions are in use; 42 trawlers are fishing with electric pulse trawls;

- 2011-2013: the additional 2011 exemptions are granted on the condition that more data is collected. The fishing industry and IMARES start the pulse monitoring programme. Data on catches is collected for over a year.

2013: Additional studies
- 2011-2013: The pulse monitoring programme comes to an end and results are expected end 2013;
- 2012-2013: Launch of the European BENTHIS project. One of its studies continues to research the effects of electric pulse fishing on benthos, with the first results expected end 2013;
- 2013: Follow-up tests on cod are carried out in Norway by IMARES and ILVO in order to compare results of earlier data;
- 2013 October: IMARES discusses the latest study results with ICES SGELECTRA;
- 2013-2015: The twinrig pulse system is developed by Masterplan Sustainable Fishery;
- 2012-2016: In Belgium, PhD students study the ecological effects of pulse fishing on different species.

**Policy on the introduction of the pulse trawl**

In the European Union there is a ban on electric fishing (EU Regulation 850/98). Since 2007, for the southern part of the North Sea, each Member State has been granted a derogation for 5% of their beam trawl fleet, allowing that part of the fleet to use pulse trawls. In 2010 and 2011 the EU granted a total of 42 experimental pulse derogations to the Dutch fishing industry. This included 3 shrimp-fishing vessels and 39 flatfish-fishing vessels. A number of Dutch companies with interests in trawlers fishing under a foreign flag - British and German - have also been granted permission to fish on flatfish using pulse. The Netherlands is making full use of this derogation and there is a waiting list of fishers wishing to use pulse trawl as well.

The Dutch government takes a very positive stand on the pulse trawl as an alternative for the beam trawl [23][31] and is endeavouring to increase the number of derogations for pulse fishing in European waters. On 13 March 2013, the European Parliament and the Fisheries Council amended Article 31 of the Regulation on technical measures [30], permitting the use of electric current in fishing [32] and therefore permitting pulse fishing. The EU has, however, set the following limitations for electric pulse fishing [32]:
- Per Member State, maximum of 5% of the beam trawl fleet may use electric pulse fishing;
- A maximum of 1,25 x the length of the beam trawl may be used to its full power (KW);
- A maximum of 15 volts (V) may be used between the electrodes;
- The vessel must be equipped with automatic registration of actual KW and V use, recording at least the last 100 hauls;
- It is prohibited to use tickler chains in front of the footrope.

The Ministry of Economic Affairs is aiming for complete approval of pulse fishing in Europe [33]. It is evident that reluctance from the other Member States to use electric fishing must first be addressed [31][33] in order to gain compliance and amend current regulations. A number of Member States have asked for more research results in order to come to a decision, without specifying the kind of research required [34]

# 4. Effects of electric pulse fishing

As it is a relatively new technique, the development of pulse fishing raises many questions. For this reason over the past decades the fishing industry, the Dutch government, the European Commission and ICES have commissioned a large number of studies into its effects. This chapter gives a summary of the conclusions of the performed studies.

The effects of electric pulse fishing can be categorised as effects on:

- Fish, sharks and benthic species
    - These animals can end up in the catch and are either landed or discarded. Relevant is the survival chance of the fish discarded.
    - These animals can come into contact with the gear and remain in the trawl path. This can cause injury, long term effects and/or influence the chances of survival.
- The catch composition
    - Share of marketable fish or other animals in the catch.
    - Share of discards in the catch.
- Fuel consumption and $CO_2$ emissions

Before describing the effects of pulse fishing we will discuss the limitations of the various studies. We will also discuss the differences in the effects caused by the entire pulse gear and the effects caused only by the pulse part of the gear.

### Study limitations

The various studies into the effects of electric pulse fishing cannot always be comparable because of varying research conditions:

1. The studies focused on a limited number of species because of limitations in means (research grants, time, manpower) and the practical limitations of researching certain effects. Because of the constraints, in many cases, the study concentrated on the effects on a limited number of fish and benthic species indicative for the ecosystem;
2. Various types of pulse systems and modernised pulse systems were used causing the lack of comparison of the results;
3. The study methodology has improved over time, partly because of assessments by ICES experts.

Because of these limitations it is not possible to make a judgement on the effects of pulse fishing, unless they refer to effects of measures under specific conditions.

### Distinction in the effects of the pulse and the whole gear

The executed studies focused on the effects caused by the whole pulse gear and those caused by the electric pulses of the various pulse systems. Where possible, effects were attributed to either the electric pulses themselves or the whole pulse gear. This is essential because the design of the pulse system - the pulse characteristics and gear design - and the way it is used have diverse effects on fish, benthic species, plants and the soil structure.

For example, damage caused by the electric pulses is typical of the pulse gear. Mechanical damage caused by contact with other parts of the gear is not typical for the pulse trawl because organisms also suffer this kind of damage in traditional beam trawl fishing.

### Effects on fish, sharks and benthic species

The reactions of fish, sharks and benthic species to electric pulse fishing vary according to species. These effects have been studied with laboratory tests and fishing tests at sea using the Delmeco and HFK pulse systems ([1][2][13][14][15]). The laboratory tests focused on species representative for their species group in the North Sea. An overview of the results for each species group is given below.

In 2012, fishers regularly encountered flatfish with ulcers on their skin. The cause of these ulcers has not yet been investigated. Some fishers suspect that they were caused by electric pulse fishing. There has been no evidence to confirm this and there are indications to suggest there is no connection to the amount of pulse fishing and the number of ulcers on fish. [34]

Cod and whiting

The most notable effect found in the studies on cod and whiting is the risk of spinal fractures in the larger cod. This is caused by strong muscle contractions as a reaction to the electric pulses [1][14] (table 4.1).

The length of the cod and its distance from the conductor were recognised as important factors for the appearance of this effect: smaller fish, measuring 12-16 cm, were not injured while larger fish, measuring 40-60 cm, had an increased chance of fracture [1]. Regarding distance, the cod were injured at a 10-20 cm distance from the conductor; at a distance of 40 cm no injuries were observed [14]. At the minimum distance of 5 cm to the conductor the chance of mortality was 50-70% [1]. The most recent study looks at the effects of different pulse parameters [1].

In the autumn of 2013 a follow-up study was done to confirm the results. This was initiated by the conflicting results from a new study by Soetaert in 2013 in which he used the same methods, repeating the previous study [1] and investigating the effects in a homogeneous field: he recorded no injuries in any of the set-ups. The results of the follow-up study executed by IMARES and ILVO, are published in 2013.

**TABLE 4.1. DAMAGE TO THE SPINES OF ROUND FISH, BASED ON TWO STUDIES [1][14]**

| Study | Result |
|---|---|
| Administering electric pulse to 20 cod under laboratory conditions [14] | Effect on cod closer than 10 cm to electrode:<br>• 4 dead shortly after pulse stimulation (20%);<br>• 2 dead in observation period following the pulse stimulation (10%);<br>• Total of 6 died (30%).<br><br>Of the 16 fish that survived initially:<br>• 5 had haemorrhages near the spine;<br>• 4 had a broken spine;<br>• 9 of 16 had injuries (56%). |
| Spine examination after being caught at sea [1] | - HFK gear: spinal fractures in 7% of the 27 cod caught;<br>- Delmeco gear: spinal fractures in 11% of the 18 cod caught;<br>- Both gear: spinal fractures in ~2% of the 47 whiting caught;<br>- Conventional beam trawl: no fractures ascertained: 0% of the 48 cod caught; |

Sharks and rays

Sharks and rays have sensitive electro-receptors to observe electric fields. This helps them orientate themselves and detect their prey, which emit weak electric fields [21]. The electro-receptor system can be disturbed when they enter the strong electric field of the pulse trawl.

The effects of electric pulses on dogfish have been studied under laboratory conditions [15]. The conclusions were as follows:
- Electric pulse did not cause mortality;
- Physical reactions in proximity to the electrodes such as muscle contractions, bending and swimming towards the surface;
- Little effect on behaviour and food intake after tests;
- Egg production not affected.

ICES advised to conduct additional tests in order to determine if electro-receptors still function when sharks or rays enter a strong electric field [21]. Such a study is now being carried out in Belgium and the results are expected by the end of 2013 and in 2014 [35].

Benthic species

The effects of electric pulse on benthic species have also been studied under laboratory conditions [13]. The conclusions were as follows:
- Certain species, such as spisula and starfish, did not react; other species, such as razor clam, shrimp and crab, did react;
- Certain species (crabs and clams) showed a lower chance of survival (3-5%);
- The food intake of the common littoral crab dropped by 5-15% during the whole observation period.

## Survival chances for undersized plaice and sole

In 2004 and 2005, studies were carried out on board of the research vessel 'Tridens" into survival and physical condition of undersized plaice and sole caught with the pulse gear and the conventional beam trawl gear. The chance of survival for plaice and sole was examined by transferring the fish caught into survival tanks with registration of survivors at regular intervals. The conclusion from these tests was that the pulse gear caused less damage to the fish than the conventional beam trawl. This could mean that the chance of survival for plaice and sole is higher when caught with the pulse gear [9].

These kind of tests have been criticised by the fishing industry and other researchers: it is not a watertight method of proving chances of survival because fish can also die from the test set-up itself. An improved test method is being developed and the Ministry of Economic Affairs has asked IMARES to develop alternative methods [33].

## Chance of survival for benthic species in the trawl trail

The trawl path left by the fishing gear of both the pulse trawl and the conventional beam trawl is influenced by the mechanical components that at the front of the trawl touch the seabed and at the back of the gear dragging a full net along it. With the pulse trawl, the trawl path is also affected by the electric pulses.

A portion of the benthic species in the trawl path ends up in the catch and another portion remains on the seabed. In order to analyse fishery effects on the ecosystem it is essential to investigate the effect on species that are not caught but are left behind in the trawl path. A study at sea executed in 2000 with gears of 7 metres, gave strong indications of increased chances of survival for benthic species in the trawl path of the pulse trawl as opposed to the traditional beam trawl [7][36].

In 2012, the European BENTHIS study project was started, focusing on the effects of pulse fishing in its current form on seabed ecosystems. The first results of tests conducted in the summer of 2013 are expected by the end of 2013. The BENTHIS project will also develop a model that calculates the impact of the fish trawl on the seabed ecosystems based on the number of vessels, geographical distribution of fishery and the fish trawls being used, with results expected in 2017.

## Catch composition, landings and discards

The effects on catch composition, discards and landings were studied at sea, the catches of conventional beam trawls were compared to those of pulse trawls [11][27]. The main findings are described below.

Catch composition

A catch is composed of landings – the portion that is brought to land and sold – and the portion that is discarded in the sea. The pulse monitoring programme of 2011-2013 collected data on the catch composition [37]. The data were partly collected by fishers and partly by IMARES and ILVO researchers on that went on board as observers.

Landings – marketable fish

Various sources demonstrate that pulse vessels catch comparable or even larger quantities of marketable sole than conventional beam trawl vessels and also catch less marketable fish of other species.

Two studies compared fishing outcomes between vessels with a pulse gear and vessels with a beam trawl gear [11][27]: the pulse gear caught less marketable fish – an average of 68%. The pulse monitoring programme showed that the pulse vessels caught similar amounts of sole as vessels with tickler chains although less plaice was caught [37]. A LEI study - yet to be published – demonstrates that the pulse fishery catches more marketable sole than the beam trawl fishery; however, other species are caught in lower quantities [38].

If the marketable amount of fish is expressed in kg per litre of fuel we can state that the pulse gear roughly catches 1.5 times the amount of landings per litre, namely 0.3 kg/litre. The conventional beam trawl catches 0.2 kg/litre [27]. Recent LEI findings may require adjustment of this estimate.

Discards

Discards are the organisms which are caught but not landed and therefore thrown overboard. This includes undersized fish, fish without a quota, commercially uninteresting fish and benthic species. The pulse monitoring programme showed that the pulse fishery is discarding less than the conventional beam trawl fishery with tickler chains (see table 4.3) expressed in either kg/hour or numbers per hour [37]. The comparative study of one week between three vessels with the different fishing techniques demonstrated similar results in 2011 [27].

**TABLE 4.3. DISCARDS BY VESSELS WITH A CONVENTIONAL BEAM TRAWL (CONV.) AND VESSELS WITH PULSE TRAWL (PULSE). THE PERCENTAGE IN RELATION TO LANDINGS IS SHOWN IN BRACKETS. TWO SOURCES: ONE WEEK OF COMPARATIVE STUDY BETWEEN THREE VESSELS (PULSE HFK, PULSE DELMECO AND CONVENTIONAL) [27] AND PULSE MONITORING, COMPARED TO REGULAR DISCARDS MONITORING BY IMARES [37].**

| **Discards** | **Conv.** | **Pulse** | **Pulse/Conv. (%)** |
|---|---|---|---|
| Plaice [37] | 87 kg/hour (49%) | 27 kg/hour (42%)*<br>66 kg/hour (52%)** | 31-76% |
| Sole [37] | 29 kg/hour (17%) | 6 kg/h (15%)*/<br>4 kg/h (10%)** | 14-21% |
| Commercially uninteresting fish [27] | 174 per hour | 128 per hour | 74% |
| Benthic species [27] | 4972 per hour | 3170 per hour | 64% |
| Starfish [37] | 8453 per hour | 1411 per hour | 17% |
| Crab [37] | 1120 per hour | 465 per hour | 42% |

* Pulse monitoring programme: sampling by fishers
** Pulse monitoring programme: sampling by observers

### Fuel consumption and $CO_2$ emissions

A comparative study from 2011 shows that fuel consumption of the pulse is lower than the fuel consumption of the conventional beam trawl gear [27]. The vessel with tickler chains used 5.3 litres of fuel for each kilogram of landed fish. The vessel with the Delmeco pulse gear used 3.7 litres fuel/kg and the vessel with the HFK Pulswing used 3.1 litres fuel/kg. This is respectively 70% and 58% of the fuel consumption of the vessel with tickler chains.

In 2008, model based predictions showed that gas emissions such as $CO_2$ would decline if a change was made from a conventional beam trawl fishery to a pulse fishery [39]. See table 4.4 for the results. The gear resistance of a typical beam trawler of 2000 pk would reduce by 25%, resulting in fuel savings of 34.6% per annum. $CO_2$ emissions would drop from 2788 tonnes/year to 1796 tonnes/year (35.6%).

**TABLE 4.4. DIFFERENCE IN FUEL CONSUMPTION AND GHG-EMISSIONS FOR A DUTCH REFERENCE VESSEL (2000PK) WITH BEAM TRAWL AND WITH PULSE TRAWL. [39]**

| [tonnes/yr] | **Conv. (Speed 6.5 kn)** | **Pulse (Speed 5.5 kn)** | **Pulse/Conv. % reduction** |
|---|---|---|---|
| Gas oil | 1075.62 | 703.48 | 34.6 |
| $CO_2$ | 2788.41 | 1796.26 | 35.6 |
| $SO_x$ | 21.51 | 14.07 | 34.6 |
| $NO_x$ | 49.17 | 39.51 | 19.7 |
| HC | 35.72 | 23.01 | 35.6 |
| CO | 312.52 | 222.54 | 28.8 |

### Comparing effects conventional beam trawl and pulse

The conventional beam trawl causes more mechanical damage to captured species, species that are left on the seabed, and the seabed itself than the pulse gear, see table 4.5. This has to do with the fact that the weight of the chains make the beam trawl much heavier. However, the pulses released by the pulse trawl can cause other damage: there is a chance of spinal fractures in roundfish such as cod, of distorted behaviour in sharks and rays and in some benthic species.

Pulse trawl catches are smaller than conventional beam trawl catches, resulting in a lower total amount of landings and discards. Fuel consumption, however, is decidedly lower in the pulse fishery creating a higher number of landings per litre of fuel, a beneficial situation for the pulse fishers.

Currently, 42 vessels have changed from beam trawl to pulse trawl. There are still vessels using beam trawl. What effect would a full transition to pulse fishing have on catches, discards and the ecosystem? In 2012, ICES carried out a scenario study into the effects on discards if a full transition to pulse were to be implemented [25]. Predictions based on a model [40] and the latest field data [27], showed that the total number of discards of cod, haddock, sole, plaice and whiting would decrease.

**TABLE 4.5. COMPARISON BETWEEN CONVENTIONAL TRAWL AND PULSE TRAWL**

| | | **Conventional** | **Pulse** |
|---|---|---|---|
| **Catch size** | Target fish species | Larger catch size of most species | Smaller catch size |
| | Vulnerable fish species | | |
| | Benthic species | | |
| **Survival chance** | Discards | Small chance of survival because of mechanical damage due to heavy chains | Higher survival chance because of less mechanical damage due to lighter gear |
| | After contact with the gear (in the trawl path) | | Higher survival chance because of less mechanical damage due to lighter gear<br>Roundfish: possibility of broken spine<br>Sharks and rays: possible effects on electro-receptors<br>Benthic species: specie dependent. Some species are not affected by pulse, while others have a decreased survival chance or food intake. |
| **Fishery** | Landings | Possibly less marketable sole for each fishing hour and more marketable fish from other species. | As much or more marketable sole for each fishing hour and less marketable fish from other species. |
| | | Less marketable fish per litre of fuel. | More marketable fish per litre of fuel - 50% more. |
| | Discards (selectivity) | More discards | Less discards:<br>24-69% less plaice;<br>26% fewer non-commercial fish;<br>36-83% fewer benthic species |
| | Fuel consumption | Higher fuel consumption | Lower fuel consumption. Reduction of 35% |
| | Seabed disturbance | Heavier gear, higher fishing speed with a larger fishing area covered for each fishing hour. | Lighter gear without chains and lower fishing speed with a smaller fishing area covered for each fishing hour. |

## 5. Electric pulse fishing management

By introducing a new fishing method it is important that it is developed in a sustainable way, so that besides economic profitability, it meets the conditions for ecological sustainability. This means that catches of target species must meet total allowable catch (TAC) requirements and that discards must be limited. Unwanted effects on the ecosystem must be avoided. Technology must be manageable, maintainable and enforceable; its safety must be guaranteed for users and inspectors.

The Ministry of Economic Affairs, fishery representatives, pulse trawl producers, the Dutch Food and Consumer Product Safety Authority (NVWA), foreign experts, the Shipping Inspectorate and IMARES are working together on control and enforcement procedures. They have also collaborated on a confidential report concerning the conditions for managing electric pulse fishing [29]. As a result, general conditions and basic requirements could be proposed and incorporated into European and national legislation. Moreover, the specific characteristics of the pulse trawl could be recorded in a document accompanying the vessel. The procedures have not been implemented.

# 6. Knowledge requirements for the future

This chapter deals with the current knowledge gap. This is the knowledge needed to regulate electric pulse fishing internationally and the knowledge required on the potential ecological risks. ICES and the Scientific Technical and Economic Committee for Fisheries (STECF) are the two most important international scientific institutions in Europe that have commented on the knowledge required regarding pulse fishing.

ICES advises that pulse fishing is a possible alternative to traditional beam trawl fishing, because, based on current knowledge, it is less damaging to the environment [41]. According to ICES there is currently too little information available to justify expansion of the pulse fleet; it advises that any expansion should only be permitted if more studies into its ecological effects are carried out. This includes the following matters:

- Indirect mortality (enters with delay);
- Long term effects on populations;
- Effects that are not fatal;
- Effects on reproduction;
- Pulse characteristics.

STECF advised that proper enforcement and control of pulse fishing must be in place before the number of pulse fishers is increased [28]. Moreover, expansion of the pulse fishery to new locations or with other trawls must only be considered after impact studies have been made on the ecosystem and on species currently without an impact study.

In their 2013 article Soetaert and his colleagues raised the following pertinent questions [5]:

- Is there a safe range of pulse characteristics within which the pulse has no significant effect on marine organisms?
- What are the effects of the use of pulse in shallow waters on the first life phases of marine organisms that breed in shallow water?
- Does the pulse affect the substrate and the water column, possibly creating toxic substances?

In the Netherlands, the government, fishing industry and researchers are in the process of discussing the next necessary steps and trying to meet the demands for new knowledge by setting up new studies and follow-up actions.

**TABLE 6.1. KNOWLEDGE REQUIREMENTS OR ACTIONS TO DEVELOP PULSE FISHING**

| Required knowledge or actions | Subject |
|---|---|
| Enforcement and control of pulse characteristic settings. The suggested enforcement and control methodology must be tested in practice. This also requires determining threshold values for pulse characteristics for effects on different species. | Management |
| Impact studies on species that will come into contact with pulse if pulse fishing is expanded, for which the effects are currently unknown. The effects of geographical and seasonal distribution are also relevant here. | Pulse effects |
| Studies into the effects on target species and by-catch species:<br>- Long term indirect mortality<br>- Long term effects on populations<br>- Non-fatal damaging effects<br>- Effects on reproduction<br>- Effects on juvenile marine organisms<br>- Effects on electroreceptors of sharks and rays | Pulse effects |
| Effect on substrate and water column | Pulse effects |
| Further development pulse technique – shock pulse instead of cramp pulse, use of pulse on non-seabed disturbing fish trawls. | Pulse technique |

## Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2017 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

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## Justification

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The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

Approved: Gerjan Piet
Senior researcher

Signature:

Date: 3 December 2013

Approved: Dr. Nathalie Steins
Department Head Fisheries

Signature:

Date: 3 December 2013