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Research agenda shrimp pulse fishery

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Background

The Dutch fishers targeting shrimp are using mainly the traditional shrimp beam trawl gear. However, this fishery is characterized by high discards because small mesh sizes (e.g. 20 mm) are used to catch shrimps. Criticism on this shrimp fishery already started in the 1960's. This has focused particularly on the high catches of undersized flatfish, mainly plaice, in the nursery grounds of the most important flatfish species. Research has shown that these bycatches have an effect on the stocks of these flatfish species, and that the SSB (spawning stock biomass) for plaice can be improved by 16%, and that of sole by 8% when discarding by all shrimp trawlers could be avoided (Revill, 1999).

In the recent decennia, many developments have taken place to improve the selectivity of the shrimp fishing gears. Some of these improvements were the sieve net (Boddeke, 1965; Van Marlen et al., 2001), sorting grids (Van Marlen et al., 2001) and a device called the 'letter box' (Quirijns et. al., 2008). They are effective technologies to reduce discards in the shrimp fishery, but usually are not effective for the smallest length classes below 10 cm. In addition, the use of electricity was found an effective technology for catching shrimps with the potential of reducing discards (Boonstra and de Groot, 1974). Recently, the development of a pulse gear for catching shrimps has taken up again as an opportunity to decrease discards, inspired by developments in the flatfish pulse fishery.

As mentioned before, already in the 1970's it was known that shrimps jump when they are stimulated by electricity (De Groot & Boonstra, 1974). In the years 2000, this fact was taken on by ILVO with the basic idea of developing a shrimp pulse gear with a raised groundrope without bobbins. The main aim of this gear is to selectively catch shrimps jumping up with the lowest possible level of discards and minimize contact with the seabed. This gear configuration was called the 'Hovercran'. From 2008, the Hovercran was tested at sea and developed further. During tests close to the Belgian coast, ILVO managed to catch as many sized shrimp with the Hovercran as with a conventional shrimp beam trawl gear. Based on this success, between 2011-2014, five Dutch shrimp vessels began to experiment with the gear and the technique was further developed with adaptions to the footrope and the use of bobbins, deviating a bit from the original idea.

Currently, the Dutch government sees the pulse application in shrimp trawls as a promising alternative to the conventional ones, particularly in reducing discards and seabed disturbance (*personal communication with the Dutch Ministry of Economic Affairs*).

Research with more emphasis on possible effects of pulse fishing on a larger group of ecosystem components than just the main target species started in 1998 with the pulse trawl prototypes produced by the Verburg-Holland company. This research was focused on the effects of the pulse fishery targeting flatfish. This concerns the catches of target species, by-catches of undersized fish and benthos, and seabed impacts,

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as well as fundamental research on a number of chosen representative species under pulse stimulation (Quirijns et al., 2013; De Haan et al., 2011; De Haan et al., 2008; De Haan et al., 2009; Van Marlen et al., 2009; Van Marlen et al., 2007).

Research into the effects of the pulse gear targeting shrimp has started in 1999 by ILVO, although at a low level. The technical development by ILVO, however, already started in 1997 and has never stopped since then. The main aim has been to develop a fishing gear with improved selectivity and reduced seafloor disturbance. In the period 2009-2011, a fishing vessel has been rented for continuous sea trials focussed on a new design of fishing gear. The work on Dutch vessels started in 2012 with a short catch comparison that was performed with a conventional-shrimp beam trawl gear and a pulse trawl gear. In 2013, an extensive monitoring was carried out on board of one Dutch shrimp pulse vessel (Verschueren et al., 2014). Based on this monitoring, the technical requirements were set (annex 1). In addition, between 2012-2016, two PhD students from the University of Ghent study the effect of pulse on marine organisms for the purpose of determining the safe range for pulse parameters (Soetaert et al., 2013; Soetaert et al., 2014). In this research, all life stages of a selection of fish and invertebrate species are studied, including 5 stages in the development of eggs, 7 stages in the development of larvae, juvenile and adult animals. The results of these studies will be available in early 2016. A study on possible causes of the increased occurrence of ulcers in dab and sole, by some claimed to originate from pulse fishing, is planned in 2015.

The Dutch shrimp fishery mainly takes place in the Dutch coastal zone, the Wadden Sea and the area around Sylt (ICES 2010). Around 80% of the shrimp fishery is located in Natura-2000 areas. The North Sea coastal zone has, in accordance with Natura-2000 designation, an improvement target for the quality of habitat type 1110_B permanent flooded sandbanks (North Sea coastal zone) and the Wadden Sea has an improvement target for habitat type 1110_A, permanent flooded sandbanks (tidal zone) (LNV 2008a; LNV 2008b). From 2012-2014, IMARES examined the effects of shrimp fishery in Natura-2000 areas. Within this research, a comparison was made between the effects of a conventional shrimp gear and a pulse shrimp gear on a Natura-2000 area. The analysis of the results encountered difficulties because of the diversity of fauna on the seabed in the research area. No significant effect from both fishery types could be found in the study (Glorius et al., 2015)

Electric fishing, however; is prohibited in the EU and only possible with a derogation (EC Regulation 850/ 1998) (EC, 1998). In the legislation was initially included that a maximum of 5% of the beam trawl fleet could receive a derogation for pulse fishing (targeting flatfish & shrimp) (EU, 2009). However, the interest in the Dutch flatfish and shrimp fleet was that high that a waiting list for pulse derogations resulted.

Eventually, the number of pulse derogations was doubled in 2014 to 84 pulse derogations. This doubling was achieved by setting up a pilot project on the basis of Article 14 of the new Common Fisheries Policy with the prerequisite that with a larger number of vessels more data could be generated concerning effort allocation, landings and bycatches. Initially, this was focused on the flatfish sector, with the aim of facilitating the introduction of the landing obligation. Flatfish pulse gear have a significantly lower fuel consumption and less discards than the traditional flatfish beam trawl (Van Marlen et al., 2014) indicating the flatfish pulse trawl to be a better alternative to the traditional flatfish tickler chain beam trawl. But also the shrimp fishers sent in applications for additional derogations. Article 14 describes the following (EU, 2013):

Article 14 describes the following:
'In order to facilitate the introduction of the obligation to land all catches in the respective fishery in accordance with Article 15 ("the landing obligation"), Member States may conduct pilot projects, based on the best available scientific advice and taking into account the opinions of the relevant Advisory Councils, with the aim of fully exploring all practicable methods for the avoidance, minimisation and elimination of unwanted catches in a fishery.'

When setting up the pilot project, a comprehensive research agenda was prepared for the flatfish pulse fishery (Ministry of Economic Affairs, 2014). It is of interest, given the worries and concerns that are expressed by various stakeholders about the expansion of the pulse gear for flatfish (but also other species such as crabs, razor clams, and shrimps), to develop a long-term research agenda which can improve the knowledge of pulse fishing.

For the shrimp pulse fishery, a long-term research agenda is still lacking. Therefore, the Ministry of Economic Affairs asked IMARES and ILVO to develop a research agenda for the shrimp fishery pulse in consultation with the shrimp fishing industry.

The main aims of both the Dutch ministry and the fishing industry with the shrimp pulse technique are:
- Maximal ecological gains (improve gear selectivity and reduce discards and seabed disturbance);
- An economically viable Dutch shrimp fishing sector;
- Within the current legislation (technical requirements are stated in Annex 1).

Needs for this research agenda for both the Dutch ministry and the sector are:
- Transparent communication taking account of feedback and concerns expressed by stakeholders.
- A scientifically sound and internationally recognised knowledge base about the effects of electricity in the marine environment.

Shrimp fishermen are only allowed to fish in the Exclusive Economic Zone (EEZ) with a NBwet permit. The first 4 pulse shrimp vessels (derogation since 2011) received a NBwet permit. For the new pulse derogations (since 2014), the NBwet permit must still be requested. It is therefore also important that the research in the research agenda meets the information requirements for a NBwet permit. Besides, it is important to examine the effects of the pulse shrimp gear on the Natura-2000 conservation goals more extensively.

Research Agenda

Introduction

The research agenda for the pulse shrimp fishery is described below. It is a combined document produced by IMARES, LEI and ILVO with input from both the Dutch ministry and the Dutch shrimp fishing sector.

The underlying question that will be answered by implementing the research agenda is:

What are the (in)direct effects on the marine ecosystem of fishing with shrimp pulse gear?

The question should be answered on both vessel and fleet level within a certain framework with clear boundaries. Figure 1 gives an overview of the structure of the research agenda where in yellow is indicated what is already (partly) examined. It is of interest that the latest technical developments are included in the research to continuously link research to practice.

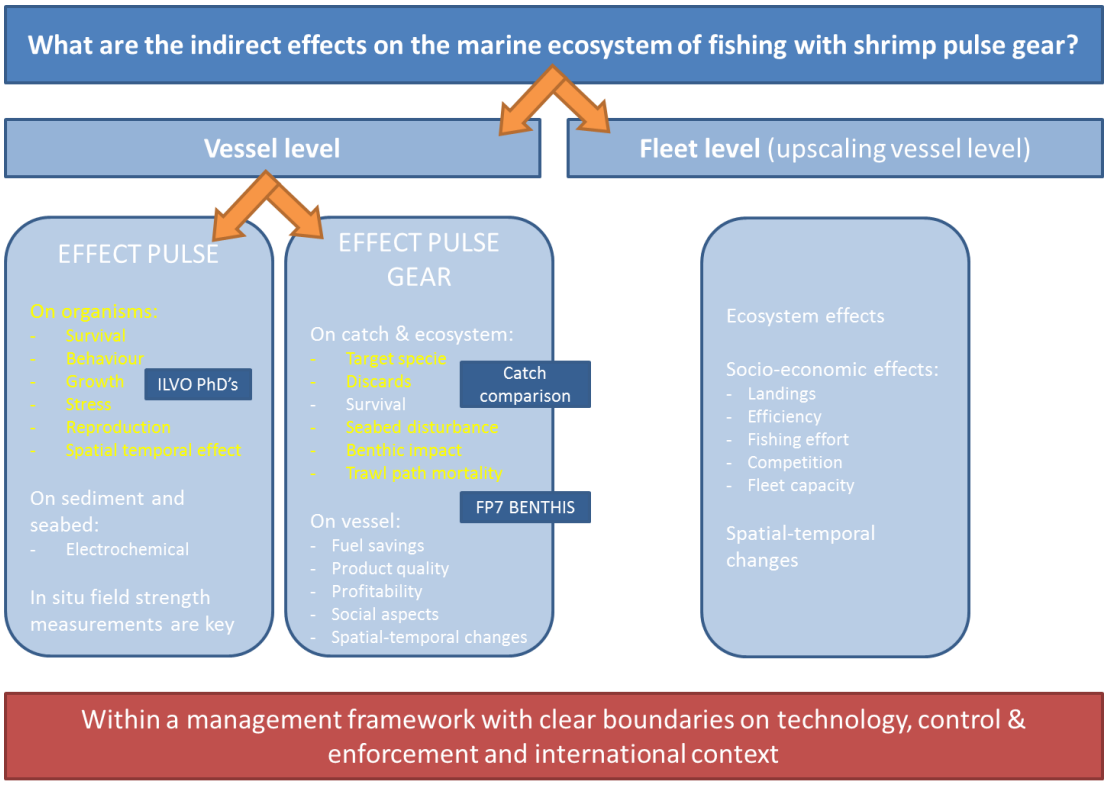

Figure 1. Structure of the research agenda pulse fishing in which in yellow is stated what has already been (partly) examined.

Research areas

In this note, the necessary research for the shrimp pulse fishery is described (including what is known and what must be known) in which a distinction is made between the following components:

1. Ecology
- Effect of the pulse stimulation itself on marine organisms and ecosystems
- Effect of the shrimp pulse gear (both the stimulation and the gear configuration) on the catches and the ecosystem on both vessel and fleet level

2. Socio-economic
- Economic impact of changing to pulse fishing at vessel level
- Economic impact of switching towards a complete shrimp pulse fishing fleet
- Impact of introducing shrimp pulse fishery on a European level
- Social research into the behaviour of fishers and other stakeholders in relation to shrimp pulse fishery

3. Technology
- Monitoring of the technical development of the shrimp pulse fishery
- Examining optimal configurations for achieving the objectives

4. Management
- Governance issues related to the shrimp pulse fishery
- Monitoring and enforcement in the shrimp pulse fishery
- Technical requirements in shrimp pulse fishery
- Communication and transparency, both nationally and internationally

5. Additional research is proposed into the impacts of the flatfish pulse on shrimps and the shrimp stock. This was listed as a topic in the flatfish pulse research agenda as well.

1. Ecological Research

1.1 Effect pulse on marine organisms and the ecosystem

One of the parts of the ecological research is the study of the effect of exposing marine organisms (mammals, fish, and invertebrates) to electric pulse fields. The following topics will be included in the study:

- *Survival* of organisms after exposure.
- *Behaviour* of organisms after exposure. Do the organisms experience stress after exposure? Do the organisms behave differently en does this influence feeding patterns, predation or growth?
- Effect on *reproduction* after exposure. Does the animal show normal spawning behaviour and normal reproduction after exposure?

A first step in this field of research has been made by two PhD students at the University Ghent in Belgium, running over the years 2012-2016. They study the effect of electric pulse fields on survival, tissue damage, behaviour and reproduction of marine organisms such as sole, cod and sharks. The results will give a better insight into the safe thresholds of the parameters of pulse fields. The results are being published at present and should completely become available early 2016.

The present Dutch research program includes the follow-up of this research and aims to be complementary. A model will be developed to predict the behaviour of marine organisms that are exposed to electric pulse fields. This PhD has been described in the research agenda for the flatfish pulse.

Further research will deal with the effect of electric pulses on the sediment and the seafloor. These are laboratory and field trials to study the effects on the ecosystem functioning (geochemical effects). This PhD has also been described in the research agenda for the flatfish pulse.

It is important that the pulse parameters used in the experiments are a true reflection of what is used in the commercial fishery. Therefore, *in situ* field strength measurements will be carried out at various distances from the electrodes of the fishing gear placed on the seafloor.

1.2 Effect of the pulse gear on catches vessel and fleet level

The Dutch ministry and fishing sector aim to increase the selectivity and reduce the seabed disturbance in the shrimp fishery. It is therefore important to examine the catches and change in catches of the pulse shrimp fishery. The research question is:

To what extent will the catch of the shrimp fleet change when the fleet switches from a fleet of traditional shrimp beam trawl vessels to a fleet of shrimp pulse trawl vessels?

To assess the amount of catch in both scenario's, it is necessary to scale up catch (both landings and discards) data from current fishing practices. In addition to monitoring current practices, it is therefore necessary to gain more information on the technical selectivity, the fishery distribution and fishing intensity of both gears. The catch of a fleet is determined by (i) the technical selectivity of the fleet, (ii) the fishing grounds and (iii) the fishing season.

The following research projects are proposed to deliver the data for this sub-project:

1.1. Get more insight into the selectivity and efficiency of the shrimp beam trawl and the shrimp pulse trawl. Catch comparison trips will be arranged at the same vessel where one side will be equipped with the traditional shrimp beam trawl gear and one side is equipped with the pulse trawl gear. A total of 8 comparison trips in different fishing areas and seasons will take place. The aim of this research is to demonstrate the true difference in selectivity, while eliminating factors such as choice of fishing area and season. These data will be used to scale-up data from research 1.2.

1.2. Investigate catch as this occurs in current practice. To achieve this, a comprehensive catch monitoring program will be established. This will exist of a self-sampling programme and observer trips. It must be calculated how many trips must take place to get representative results for the pulse shrimp fleet. The data resulting from this research will be scaled-up (with data from the other research projects) to eventually assess catch levels in a 100% shrimp beam trawl and a 100% shrimp pulse trawl scenario.

1.3. Investigate the spatial and temporal distribution of the shrimp pulse and beam trawl fleet. For this purpose, VMS data will be collected from all pulse shrimp vessels. The data resulting from this research will be used to scale-up the data from research project 1.2.

For both the catch comparison trips and the monitoring programme, the used pulse fishing gear must be described and documented. Consequently, the results can be assigned to a certain gear modification after which analysis can be done on the optimal gear configuration per area to reduce discards and seabed disturbance. The data will be analysed for both Natura-2000 areas and other areas. Besides, an extra analysis will be done on certain Natura-2000 species and their occurrence in the catch.

1.3 Long-term ecological effects of the shrimp pulse gear

To gain insight into the long-term effects of the shrimp pulse technique, a field experiment will be conducted in a closed area. The field experiment is designed to compare the effects on the seabed of the shrimp pulse fishery with the effects of the shrimp beam trawl fisher on relevant fishing grounds. For this study, a closed area will be set that will be divided into three parts: 1) only shrimp pulse fishery; 2) only conventional shrimp beam trawl fishery; 3) reference area. The area will be monitored before fishing activities take place and afterwards. The area will be experimentally fished for 4-5 years and monitored each year. The research will take place in one or two important Natura-2000 areas.

2. Social-economic research

2.1 Economic impact of switching to pulse at vessel level

The research focuses on fuel savings, product quality, profitability and the payback period of investment in the shrimp pulse gear. The research also focuses on monitoring the profitability of the shrimp pulse fishery. It will take into account the prices of shrimp and the influence of any increased supply of shrimp on these prices.

Based on LEI Fisheries Accountancy Data network and empirical data:

- Changes in fuel consumption conventional gear & pulse gear per day at sea
- Changes in catchability of shrimp conventional gear & pulse gear per day at sea
- Changes in shrimp revenues conventional gear & pulse gear per day at sea
- Investments for replacement conventional gear into pulse gear
- Changes in net results conventional gear & pulse gear per day at sea

Above mentioned subjects are measured on vessel level.

2.2 Economic impact of switching towards a shrimp pulse fleet
Based on the impact results on vessel level an impact on fleet level can be given. Under condition that all shrimp vessels are able to make the transition to shrimp pulse the next changes of fleet level will be described:
- Changes in shrimp landings
- Changes in shrimp prices
- Changes in total revenues
- Changes in total costs
- Indication of the total fleet capacity for shrimp

2.3 Effect in Europe of the shrimp pulse
Not only Dutch fishermen fish on shrimp. It is important to know what the effects of fishing with pulse gear are for the Netherlands but also other (EU-)countries (like Germany and Belgium). The main question is what the effect on shrimp prices for European market is by introducing pulse gear into the Dutch shrimp fisheries.

2.4 Social research on behaviour
Surveys and / or interviews with shrimp fishers. Research on the level of application of the shrimp pulse fishery in the Netherlands and Europe. Research will also be done on the degree of compliance with regulations for the shrimp pulse fishery.

3. Technical research

3.1 Monitoring the technical development in shrimp pulse fishery
A link to what actually happens in the fleets is important and therefore it is proposed to monitor the technical development in shrimp pulse fishery. This is also essential for control and enforcement purposes. In addition we see a need to measure field strength of a number of gears in situ at sea to have reference points.

3.2 Research into optimal fishing gear configurations to meet the objectives
It is proposed to carry out comparative fishing experiments on a range of fishing gear configurations used in practice, and trying to find an optimal configuration meeting the objectives of ecosystem advantages (the lowest possible level of discards and sea bed disturbance) and economic viability. This relates to the research under 1.2.

4. Control and governance issues.

4.1 Governance aspects in shrimp pulse fishery
Research will be done on stakeholder perceptions, not only fishermen, but also policy makers and NGO's, and at an international level. Similar work was done in 2014 for the flatfish pulse fishery. In the shrimp sector problems concerning the use of flatfish pulse trawling are often mentioned, and this will be taken into account.

4.2 Control and enforcement in shrimp pulse fishery
A pilot study, financially supported by the Dutch Ministry of Economic Affairs, will be conducted in 2015 & 2016 on the subject control and enforcement in shrimp pulse fishery, similar to the one that will be carried out for flatfish pulse fishery. In this study the production of a monitoring and control system, also referred to as the 'black-box', will be guided and practical experience will be gathered with inspections at sea.

4.3 Technical requirements on a shrimp pulse fishing gear
A list of technical requirements has been defined, but we proposed to investigate whether these can be improved related to finding optimal gear and stimuli configurations meeting the objectives. This relates to the research under 1.2.

4.4 Communication and transparency

The aim is to write 'peer-reviewed' publications about the research to ensure credibility and acceptance by the scientific community. In addition the results will be discussed and commented on in ICES WGELECTRA, providing feedback from scientists from a range of nations.

We opt for an open and transparent communication about the research and its results with Dutch and European stakeholders. In the Netherlands the "Steering Group Pulse Fishery" can be used for communication with various stakeholders. Within Europe the "Pulse Focus Group" of the "North Sea Advisory Council" (NSAC) is the forum to use.

5. Additional research: effect flatfish pulse on shrimps

In addition research is proposed on the effect of flatfish pulse fishery, using distinctly different pulse characteristics, on shrimps and the shrimp stock. Part of this work has already been done by the two PhD-students from University Ghent under guidance of ILVO-Fishery of Ostend, Belgium (Soetaert et al., 2014). One of the proposed PhD-workers from the flatfish pulse agenda will work on producing a predictive model including the effect on shrimps. The model should be verified and validated with the research outcomes to be expected.

Laboratory experiments will be carried out using the both the shrimp and the flatfish pulse on egg-carrying female shrimps by the PhD-students from University Ghent to appraise effects on reproduction.

EU-project BENTHIS will provide information on direct effects of flatfish and shrimp pulse gear on benthic invertebrates. Samples will be taken from fished and unfished areas before and after trawling.

The geo-temporal effort allocation of flatfish trawlers on shrimp grounds will be monitored and analysed. The existing pulse monitoring programme will be used for retrieving the relevant data.

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Annex 1: Technical requirements in the shrimp fishery

Pulse Fishing Gear for Shrimp

General

A specific derogation will be issued on the name of the company before fishing with pulse gears can be carried out. The technical requirements of such a pulse fishing gear for shrimps will be given in this derogation. For control and enforcements purposes the skipper or vessel owner has to keep on-board a Technical File describing the pulse gear in use and meeting the technical requirements as below.

Technical gear requirements

Type of groundrope	(straight) groundrope with bobbins
Net type	square net (no V-shape)
Max. distance beam & groundrope	4 m
Diameter bobbins	between 170mm and 270mm
Width of bobbins	between 80mm and 180mm
Cross-sectional shape of bobbins	rectangular or elliptical
Spacing between bobbins	minimum 600mm
Total weight of groundrope & electrodes	maximum 250 kg

Conditions:

- All bobbins should be able to turn freely (without much friction) around the groundrope. Groundrope constructions (e.g. made of rubber) hampering such free movement are not allowed.
- The spacing between bobbins is to be measured from the centre line of one bobbin to the centre line of the next bobbin aside.
- The use of a sieve net or other selective devices and the mesh size used in the cod-end should be in accordance with existing legislation.

Technical requirements pulse system

Pulse type	unipolar pulse (no negative part)
Pulse shape	DC between half sinus and square wave
Maximum voltage (V_{peak})	65 V
Maximum voltage RMS (V_{rms})	3.25 V_{rms}
Pulse duration	maximum 0.5 ms
Pulse repetition frequency	5 - 8 Hz
Entry power	max. 0.2 kW/m beam length or gear width
Polarity of first & last electrode	Fixed (+ or -)
Polarity betw. intermediate electrodes	Fluctuating (+ of -)
Max. field strength betw. two electrodes	0 xxV_{rms}?/m (±10%)
Distance between electrodes	min. 0.65 m
Number of electrodes	max. 12 (each with 1 conductor)
Length of electrodes	max. 2.75 m
Length of conductors	max. 1.50 m
Diameter of conductors	max. 12 mm

Conditions:

- Electrical power delivered = Electrical power coming from the vessel's power generator and led to the electrical feeding cables. The advice is to ensure a CE Safety Certificate.
- The electrodes should have isolating parts consisting of one continuous isolating material, not disconnected such as rubber discs.

Additional conditions:
Companies with a derogation to use pulse fishing gears for shrimps are obliged to participate with research programmes. The research outcome may lead to adaptations to the technical requirements of the shrimp pulse fishing gear. Both in terms of gear technology, and electrical equipment.

Comment:
The requirement of monitoring and storing the data of the electrical performance of the shrimp pulse fishing gear over the last 100 hauls using a control and monitoring device (black-box), as given in the existing derogation will be kept for this category of pulse fishing gears.

Annex 2. Overview of future research proposed in the shrimp pulse fishery

The studies that are covered in other studies such as the flatfish research agenda are not part of this list.

Proposed research	Proposed activity
1.1 Effect of pulse on marine organisms and the ecosystem	In situ field strength measurements on shrimp pulse fishing gear. Outcome is reference field strengths to be used in laboratory experiments (PhD-studies)
1.2 Effect on catches	Comparative fishing using a HOVERCRAN gear (and other groundrope configurations) and a conventional gear. Catch and bycatch monitoring programme on a fleet level. Research in spatial and temporal effort allocation for the shrimp fleet.
1.3 Ecological effects on the long-term	Field study in a closed area on effects of flatfish and shrimp pulse gear on the ecosystem, compared to an unfished reference area.
2. Socio-economic aspects	1 & 2. Monitoring economic performance of shrimp pulse fishers, on vessel and fleet level. Calculation of pay-back times of investments, research on price elasticity of shrimps in the market depending on the level of landings. 3. As 1&2 but on a European scale. 4. Interviews with shrimp pulse fishermen. Research into compliance of regulations and technical requirements.
3. Technical development of pulse gears	Monitoring of 'technical creep', technical use and development in shrimp pulse fishing.
4.1 Governance aspects	Research into stakeholder perceptions, e.g. policy makers, NGO's and fishermen, both national and international.
4.2 Control and enforcement	Pilot study on control and enforcement in shrimp pulse fishery, similar to the one that will be carried out for flatfish pulse fishery. Guidance in production of a monitoring and control system, also referred to as the 'black-box' and practical experience with inspections at sea.
4.3 Technical requirements	Research into optimal technical requirements both concerning the pulse characteristics and the groundrope configuration.
4.4 Communication and transparency	Publication of peer-reviewed articles in scientific magazines. Communication within ICES WGELECTRA. Open and transparent communication to the outside world.
5. Effect of flatfish pulse on shrimps	Continuation of laboratory experiments by PhD-students ILVO/ University Ghent, e.g. on egg-bearing female shrimp under a range of pulse characteristics (both for catching shrimps and flatfish).