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Lessons learned from the transition towards an innovative fishing technique

A case study on the introduction of the pulse trawl technique in the Dutch flatfish fishery

MSc Thesis report

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SUMMARY

This thesis identified the transition pathway of the pulse trawl technique on flatfish. The research focused on the period 1988 till 2014. In 1988, a ban on electric fishing was introduced, which is still in force today. Despite this ban, an innovative fishing gear was developed in the Netherlands, which used an electric stimulus to catch flatfish. Over time, this gear proved to be a good alternative to the heavily criticized conventional beam trawl. A transition of the beam trawl fleet towards the pulse trawl technique requires adaptations in the technical measures of the Common Fisheries Policy (CFP). Adjusting the technical measures in order to permanently admit the pulse trawl technique encounters a lot of resistance from other EU member states for various reasons.

The goal of this case study is to use the theory on transitions to explain and understand the transition pathway of the pulse trawl technique. Data for this study were obtained through a literature survey and through interviews with people from science, the Ministry, NGOs and industry. This research contributes to our overall knowledge on how transitions proceed and provides involved actors and institutions insight in the transition pathway of the pulse trawl technique. If a better understanding is generated on how transitions work and what factors are important to realize a transition, it provides policymakers and managers insight in how they can influence the pathway of a transition towards more sustainable systems and societies.

Through research it became clear that the transition pathway of the pulse trawl could be separated into two distinct time periods. The first time period shows how the pulse trawl technique was developed and tested, and tried to breakthrough in the Dutch regime. Eventually, the pulse trawl managed to breakthrough in the Dutch regime. Crucial to this breakthrough were the oil price developments and the growing criticism and concerns on the environmental impact of the conventional beam trawl. These developments exerted a lot of pressure on Dutch regime actors and institutions and stimulated the need for an innovative fishing technique that could be used as an alternative to the conventional beam trawl.

Once the Dutch regime had implemented and accepted the pulse trawl technique, the second time period started. A wider introduction of the pulse trawl technique was being hampered by the ban on electric fishing. Dutch regime actors and institutions were now trying to expand the number of licenses to use the pulse trawl technique, but a wider diffusion of this technique would require changes in the European regime. However, most European member states objected a further expansion of the number of licenses for the pulse trawl technique for various reasons. As a result, Dutch regime actors and institutions kept looking for opportunities to expand the number of licenses of the pulse trawl technique, while trying to convince other European member states of the advantages and importance of this fishing technique for the Dutch flatfish cutter fleet.

The research results clearly demonstrate that the transition pathway of the pulse trawl technique is continually influenced by various factors. Therefore, the transition pathway of the pulse trawl technique does not follow one specific pathway, but is build-up of a mixed transition pathway. The factors that led to this mixed transition pathway of the pulse trawl technique are:

- Technology-push character: a lot of attention has been paid to the development of the pulse trawl technique during the transition process, but little attention was being paid to the social aspects of the transition (cultural preferences, social practices, changing relationships).
- Competition: between fishermen with and without a pulse trawl license, between EU member states on the competitiveness of their fishing fleets, and between different pulse systems.
- Landscape level developments: like the oil price developments and the need for more sustainable fisheries by society.
- Regime level developments: this case study clearly demonstrates that the breakthrough of an innovation in a part of the regime (NL) does not automatically imply a complete breakthrough in the regime (EU).

Although there is no clear recipe for realizing transitions, this case study does provide new insights and knowledge on the course of transitions. The lessons learned from the pulse trawl case can be extrapolated to other fishery related innovations or other sectors. All this knowledge will ultimately contribute to a better understanding of transition processes.

SAMENVATTING

Deze scriptie heeft het transitietraject van de pulskor op platvis geïdentificeerd. Het onderzoek heeft zich gericht op de periode van 1988 tot 2014. In 1988 werd er een verbod op elektrisch vissen ingevoerd binnen Europa en dit verbod is nog steeds van kracht. Ondanks dit verbod is er in Nederland een vistechniek ontwikkeld die gebruik maakt van elektrische pulsen om platvis te vangen. In de loop der tijd bleek deze vistechniek een goed alternatief voor de zwaar bekritiseerde boomkor. Een transitie van de boomkorvloot naar de pulskor vergt aanpassingen in de technische maatregelen van het gemeenschappelijk visserijbeleid (GVB). Het aanpassen van de technische maatregelen om de pulskor permanent toe te staan stuit op veel weerstand bij andere Europese lidstaten om uiteenlopende redenen.

Het doel van deze casestudy is om het transitietraject van de pulskor te verklaren en te begrijpen doormiddel van de transitietheorie. Data voor deze studie zijn verkregen door een literatuurstudie en door interviews te houden met mensen vanuit de wetenschap, het ministerie, ngo's en de visserijsector. Dit onderzoek draagt bij aan de algehele kennis over het verloop van transities en het biedt betrokken actoren en instellingen inzicht in het transitietraject van de pulskor. Het beter doorgronden van transities en alle factoren die daarvoor van belang zijn biedt beleidsmakers en managers meer inzicht in het beïnvloeden van transitietrajecten. Daarmee kunnen ze transities sturen naar duurzamere systemen en samenlevingen.

Onderzoek wees uit dat het transitietraject van de pulskor het beste kan worden onderverdeeld in twee verschillende tijdsperioden. De eerste tijdsperiode laat zien hoe de pulskor werd ontwikkeld, getest en probeerde door te breken in het Nederlandse regime. Uiteindelijk wist de pulskor door te breken in het Nederlandse regime. Van cruciaal belang voor de doorbraak van de pulskor waren de olieprijsontwikkelingen en de groeiende kritiek en bezorgdheid over de milieueffecten van de boomkor. Deze ontwikkelingen oefenden veel druk uit op Nederlandse regime actoren en instellingen. Deze druk stimuleerde de behoefte naar innovatieve visserijtechnieken die als alternatief konden dienen voor de conventionele boomkor.

De tweede tijdsperiode startte nadat de Nederlandse regime actoren en instellingen de pulskor hadden geïmplementeerd en geaccepteerd. Een verdere uitbreiding van de pulstechniek werd echter belemmerd door het verbod op elektrisch vissen. Nederlandse actoren en instellingen probeerden het aantal pulslicenties uit te breiden, maar een verdere uitbreiding van deze techniek vergt veranderingen in het Europese regime. Het uitbreiden van het aantal pulslicenties stuitte op protest van andere Europese lidstaten om uiteenlopende redenen. Dientengevolge probeerden de Nederlandse regime actoren en instellingen te zoeken naar allerlei mogelijkheden om het aantal pulslicenties uit te breiden. Tevens probeerden ze andere Europese lidstaten te overtuigen van de voordelen en van het belang van de pulskor voor de Nederlandse platvisvloot.

De resultaten van het onderzoek laten duidelijk zien dat het transitietraject van de pulskor voortdurend word beïnvloed door allerlei factoren. Hierdoor verloopt het transitietraject van de pulskor niet volgens een vast patroon, maar bestaat het uit verschillende trajecten. De factoren die hebben geleid tot het gemengde transitietraject van de pulskor op platvis zijn:

- Technology push karakter: er is veel aandacht besteed aan de ontwikkeling van de pulstechnologie tijdens het transitieproces, maar er is weinig aandacht uitgegaan naar de sociale aspecten van een transitie (culturele voorkeuren, sociale praktijken, veranderende verhoudingen).
- Concurrentie: tussen vissers met en zonder pulslicentie, tussen Europese lidstaten om competitiviteit visserijsector en tussen verschillende pulssystemen.
- De ontwikkelingen op het landschapsniveau: zoals de olieprijsontwikkelingen en de behoefte aan een duurzame visserij vanuit de maatschappij.
- De ontwikkelingen op het regimeniveau: deze casestudy heeft duidelijk laten zien dat de doorbraak van een innovatie in een deel van het regime (NL) niet automatisch impliceert dat de innovatie totaal is doorgebroken in het regime (EU).

Alhoewel er geen kant-en-klaar draaiboek bestaat voor het laten slagen van transities, geeft deze casestudy wel weer nieuwe inzichten en kennis over het verloop van transities. De geleerde lessen van de transitie naar de pulskor kunnen worden geëxtrapoleerd naar andere innovaties binnen de visserij of andere sectoren. Al deze kennis zal uiteindelijk bijdragen tot het beter begrijpen van transitieprocessen.

ACKNOWLEDGEMENTS

I would like to thank my supervisors Simon Bush and Marloes Kraan for their advice and support during my thesis. By challenging and criticising my work, they managed to bring out the best of me. Furthermore, I would like to thank IMARES for the opportunity to let me work on such an interesting research topic. It was a great learning experience to study the perspectives of science, industry, policy, technology and society on such a sensitive topic in the Dutch fisheries. Of course, I would also like to thank all the interviewees for their time and cooperation. Their openness during the interviews was very helpful to me and essential for the detailed description of the transition process of the pulse trawl technique in this report. A final thanks goes out to all the people close to me for their inspiring words and support.

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LIST OF ABBREVIATIONS

ACFM	Advisory Committee on Fishery Management
AGRIFISH	Agriculture & Fisheries Council
CFP	Common Fisheries Policy
CSO	Civil Society Organisation
CFO	Cooperative Fisheries Organisation
DFF	Dutch Fishermen's Federation
DG MARE	European Commission Directorate General for Fisheries and Maritime Affairs
EFF	European Fisheries Fund
EL	Eastern longitude
EMFF	European Maritime and Fisheries Fund
EP	European Parliament
EU	European Union
FFA	Federation of Fishing Associations
FIP	Fisheries Innovation Platform
GO	Goedereede
HP	Horse power
ICES	International Council for the Exploration of the Seas
ILVO	Instituut voor Landbouw- en Visserijonderzoek (Belgium)
IMARES	Institute for Marine Resources & Ecosystem Studies
LEI	Agricultural Economics Research Institute
MLN	Million
MLP	Multi-level perspective
N	North
N.D.	No Date
NGO	Non-Governmental Organisation
NIOZ	Royal Netherlands Institute for Sea Research
NL	Netherlands
NSAC	North Sea Advisory Council
RIVO	Rijksinstituut voor Visserijonderzoek
SL	Stellendam
SNM	Strategic Niche Management
SSM	Snowball sampling method
STECF	Scientific, Technical and Economic Committee for Fisheries of the European Commission
TM	Transition Management
TX	Texel
UFA	United Fish Auctions
UK	Urk
UKI	United Kingdom
V	Volt
WGFTFB	Working Group on Fishing Technology and Fish Behavior
WWF	World Wildlife Fund

CHAPTER 1. INTRODUCTION

1.1 PROBLEM STATEMENT

Since the 1970s the Dutch cutter fleet started to specialize itself on catching flatfish. Current shares in the flatfish quota on the North Sea (table 1) shows the importance of flatfish for the Dutch cutter fleet (Task Force Duurzame Noordzeevisserij, 2006). Traditionally, the Dutch fishing fleet uses the beam trawl technique for catching their target fish species in the North Sea. The main target species of the beam trawl fishing fleet are plaice (*Pleuronectes platessa*) and sole (*Solea solea*)(Marlen, van et al., 2014). With the beam trawl technique, a fishing net is attached to a metal beam. This metal beam is carrying two 'shoes', which are solid metal plates on each side that support the beam and is dragged across the seabed. Tickler chains are secured to the net to stir up the bottom in order to startle the flatfish into the net (figure 1) (Marlen, van et al., 2014).

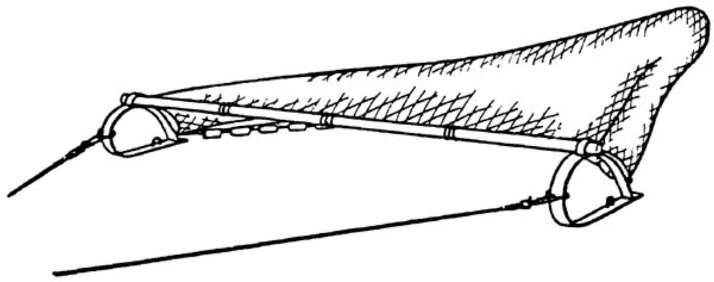


Figure 1. Beam trawl fishing gear: *Design of the conventional beam trawl (Løkkeborg, 2005).*

The Dutch trawl fleet is involved in an on-going transition process through the introduction of new technological innovations. This process was triggered by the report ''Fishing with Headwind''. The report provided an action plan for the beam trawl fleet on how to deal with the economic difficulties, to live up to the societal expectations and to become more ecological sustainable (Task Force Duurzame Noordzeevisserij, 2006). One of the proposed solutions in this report was to invest in technological innovations to the existing gears and fleet. Pulse fishing was mentioned as one of these technological innovation opportunities. With this pulse trawl technique, the tickler chains are replaced with electrodes that generate an electric pulse (see figure 3). These electric pulses cause a muscle contraction in the flatfish, through which they are being released from the bottom and get caught in the net (Quirijns et al., 2013). Scientific research has shown that the pulse trawl has the potential of being a more sustainable fishing technique compared to the beam trawl due to its reduced fuel consumption, higher selectivity for sole and reduced bottom impact (Quirijns et al., 2013). A case study performed by the International Council for the Exploration of the Sea (ICES) and the Scientific, Technical and Economic Committee for Fisheries (STECF) revealed that when the beam trawl is replaced with the pulse trawl and is sufficiently controlled, a reduction in bycatch and bottom impact can be achieved (ICES a, 2012).

Table 1. Dutch share in flatfish quota: *The Dutch have a large share in the total flatfish quota for the North Sea. Besides the figures presented in this graph, additional quota are in Dutch possession by flag vessels sailing under the flag of other European member states (Verbogt, 2014).*

Dutch share in total flatfish quota North Sea	
Plaice	36%
Sole	76%
Turbot	56%
Dab	62%

Switching from a conventional beam trawl to a pulse trawl costs around 250.000 to 300.000 euro for a 300 hp vessel and around 400.000 euro for a 2000 hp vessel, depending on the supplier and the lay-out of the vessel (Taal, 2014).

Next to the development of the pulse trawl technique for catching flatfish, the Institute for agricultural and fisheries research (ILVO) in Belgium, in cooperation with the Ghent University and Marelec NV, developed a fishing gear that uses electrical pulses to catch brown shrimp (*Crangon crangon*) as shown in figure 2 (Soetaert et al., 2013). This fishing gear is called the HOVERCRAN and the first prototype was installed and tested on a commercial shrimp cutter in 2008. ILVO was awarded with the runner-up price for the HOVERCRAN at the WWF International Smart Gear competition in 2009 (Verschueren & Polet, 2009). Although this fishing gear also uses electrical pulses to catch its target species, it cannot be compared with the pulse trawl technique on flatfish since it is a completely different gear with different characteristics (Soetaert et al., 2013). The HOVERCRAN also follows a completely different transition pathway compared to the pulse trawl on flatfish and is not as widely accepted and distributed in the Dutch fishing sector as the pulse trawl on flatfish (ICES a, 2012). However, this distinction between the pulse trawl on flatfish and the pulse trawl on shrimp has not always been made in the discussions and still causes confusion when talking about the pulse trawl technique (Soetaert et al., 2013). To avoid this confusion, this report solely focuses on the transition pathway of the pulse trawl on flatfish.

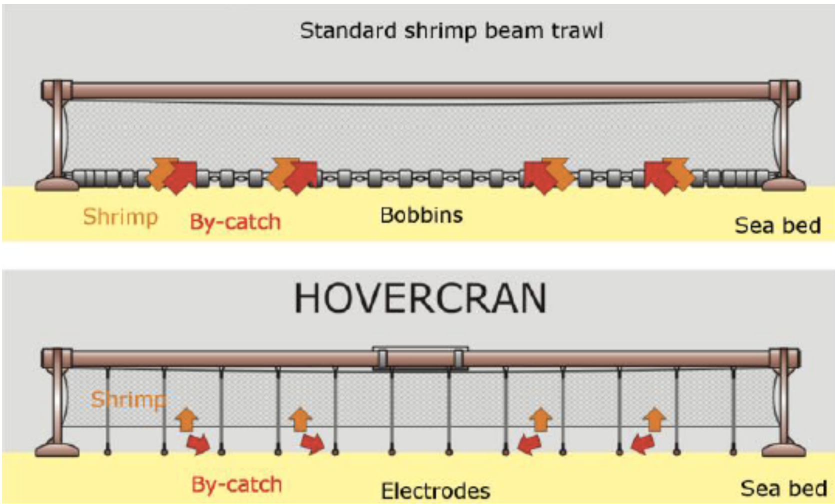


Figure 2. The HOVERCRAN: *It uses an electric field to startle shrimp in the net and allows non-target species, which are not triggered by the electric field, to escape underneath (Kratzer, 2012).*

Currently, the use of electricity in fishing practices is banned by the European Union (EU, 1998). The current EU ban Council Reg (EG) nr 850/98 of 30 March 1988, Article 31 Unconventional fishing methods states that “The catching of marine organisms using methods incorporating the use of explosives, poisonous or stupefying substances or electric current shall be prohibited.” Before the implementation of this ban on using electricity during fishing, research had been done on the pulse trawl technique. The research for using a pulse trawl started around 1970 in the Netherlands and continued until 1988 when the ban was introduced (Quirijns et al., 2013). This ban on electrical fishing may have been introduced out of fear for an increase in efficiency of the beam trawl fleet with the pulse trawl technique, while the fishing industry was already under severe international pressure (Soetaert et al., 2013)(Boddeke, 2014).

However, the EU allowed technical research on the pulse trawl in 1991, which initiated new research on the pulse trawl in the Netherlands. The research on the pulse trawl technique gained momentum starting from 2005 (Quirijns et al., 2013). Research showed promising results and acknowledged the potential of the pulse technique to be more sustainable compared to the conventional beam trawl. Therefore the European Commission (EC) granted experimental licenses to 5% of the beam trawl fleet. The Dutch Ministry of Economic Affairs provides these experimental licenses to Dutch fishermen (Quirijns et al., 2013).

Due to the positive experiences of Dutch fishermen with the pulse trawl, pressure from the rising fuel prices and the aim to make the fisheries more sustainable, the Dutch Ministry of Economic affairs decided to apply for an increase in the number of experimental licenses from 5% to 10% of the beam trawl fleet. The European Parliament initially blocked this request in January 2015 (Visserijnieuws a, 2014). However, based on Article 14 of Regulation (EU) No. 1380/2013, an alternative route for the increase to 10% experimental licenses was found. This article states that, "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, minimization and elimination of unwanted catches in a fishery" (EU, 2013). Based on Article 14, the increase to provide 10% of the Dutch beam trawl fleet with experimental licenses was granted in February 2014. This means that approximately 84 licenses are currently available for using the pulse trawl technique.

Figure 3. Pulse trawl fishing gear: *The electrodes generate an electric pulse to catch flatfish.*

It is the ambition of the Dutch government to obtain a permanent admission of the pulse fishery in European waters (Visserijnieuws a, 2014). For this, the EU's technical measures need to be adapted. The EU's technical measures are revised in 2015. Both the European Parliament (EP) and the European Council have to accept the changes in the technical measures. The European Commission (EC) has a mediating role and influences the decision-making process (European Commission, 2014).

Ever since the introduction of the pulse trawl technique, the Dutch government found little support from other European member states for allowing or expanding the application of this fishing technique. Changes to the EU's technical measures can only be made if other EU member states vote in favour of these changes through the European Parliament and Commission. Therefore, in order to realize a change in the EU's technical measures, support of other EU member states is required. A variety of reasons, claims and processes are responsible for the resistance from other member states to expand or permanently permit the pulse technique. Some of the arguments against the pulse technique relate to the uncertainty about ecosystem impacts, the research methods used, and how monitoring and enforcement should be regulated (ICES a, 2012). Other reasons and motives could be increased competitive advantage of the Dutch fleet (Task Force Duurzame Noordzeevisserij, 2006), commercial interests or political motives (Roos, 2014). The problems experienced with the pulse beam trawlers on shrimp in China also influenced the process (Soetaert et al., 2013). The case study in China showed that failed management of this new technology would result in the depletion of the targeted stocks (Yu et al., 2007).

While other new technological innovations in the Dutch flatfish fleet like the SumWing, flyshooting and twin rigging are broadly accepted; the pulse trawl technique remains a controversial fishing technique in the Netherlands (Visserijnieuws b, 2014), but especially within the European Union (De Standaard, 2014) (Douchin, 2014) (Ungoed-Thomas, 2014). For the Dutch flatfish cutter fleet it is essential that the pulse trawl technique on flatfish will be accepted and allowed by the European Union, since many fishermen heavily invested in this fishing technique and see no other alternatives with a similar economic and ecological performance at the moment (Boogaard & Mee, van der, 2014). The pulse trawl case is an interesting case to study from a transition theory perspective, because it concerns a fishing technique that has been widely introduced and accepted by the Dutch regime, but is a heavily debated fishing technique amongst other European member states. By identifying the transition pathway of the pulse trawl based on the multi-level perspective on transitions theory of Geels (2011), more insight can be gained in what made the uptake and acceptance of the pulse trawl technique by the Dutch regime possible. This information might give more insight in what is currently blocking the transition towards the pulse trawl in the European regime. Wider insights could be gained through this case study on how technological transitions fail or succeed. Ultimately it helps us in how to understand and influence long-term and complex transitions.

1.2 RESEARCH OBJECTIVE

This thesis research focuses on identifying the transition pathway of the pulse trawl technique on flatfish in the Netherlands by using the multi-level perspective on transitions theory of Geels (2011). Through analysing the transition pathway of the pulse trawl technique, more insight can be gained in how this innovation was picked-up by the regime in the Netherlands and by the European regime. This case study helps us in how to understand a long-term and complex transition. It also provides involved actors and institutions insight in how innovation processes proceed. Thereby it creates an opportunity for them to influence the transition process into a desirable direction, such as sustainable development. However, it must be noted that it also provides actors and institutions the opportunity to steer the transition process towards other directions. This case study also contributes to the wider knowledge and theory on transitions, since lessons can be learned from this case study that can be extrapolated to other fields of study.

The transition pathway might explain or provide more insight in what is currently causing the commotion within the Netherlands and at the European level concerned the wider introduction of the pulse trawl technique. This report identifies the transition pathway and enables the involved actors and institution to gain an understanding on how this transition is evolving. Once involved actors and institutions get a better understanding of the transition pathway, it could provide them more insight in how innovations proceed. That knowledge could create an opportunity to actors and institutions to influence the transition process into a desirable direction. Getting a better understanding about the transition pathway of the pulse trawl technique is relevant for the involved actors and institutions in the Netherlands, since a ban by the EU on the pulse trawl would have serious socio-economic consequences. The high investments made by vessel owners to change from beam trawling towards pulse trawling in combination with the current lack of alternative fishing techniques with a similar economic and ecologic performance would seriously threaten the continued existence of the Dutch flatfish fleet. It would have a negative impact on the Dutch fishing communities, fishing industry and the Dutch economy.

As described above, research on the pulse trawl technique already started around 1970 in the Netherlands. Information from the period 1970-1988 was hard to acquire, since some of the involved actors from that period already retired or passed away. Therefore, the research focuses on the period starting from 1988, when the ban on electrical fishing was introduced in Europe. Another important aspect is that this report solely focuses on the transition pathway of the pulse trawl on flatfish and not on the pulse trawl on shrimp as explained in the introduction. The literature study and interviews revealed that the transition pathway of the pulse trawl on shrimp was different to the transition pathway of the pulse trawl on flatfish and it concerns a different gear.

In order to identify the transition pathway of the pulse trawl technique on flatfish in the Netherlands, the following three questions are used to structure this report. The first question focuses on the start of the transition process after the ban of 1988. Therefore the first question is:

1. How did the invention of the pulse trawl technique develop into a fishing gear that was ready to be picked-up and accepted by the regime?

This question aims to identify the actors and institutions that were involved in the invention, research and development and diffusion process of the pulse trawl technique. Each of these actors and institutions had its own role in the transition process and exerted itself to the development of the pulse trawl with a certain vision and interest. Knowing the vision and interest of each of the involved actors and institutions helps to understand the actions that each of these actors and institutions have taken in the transition process. It is important to realize that a transition process does not consist of a fixed group of actors/institutions with a non-evolving vision and interest. Therefore it is important to know when they became involved, what their initial vision and interest was in the pulse trawl and whether their vision and interest changed along the transition process.

Eventually a transition can only take place when the technological innovation is being accepted and picked-up by the regime. This leads us to the following question:

2. What made the regime actors and institutions replace the beam trawl for the new technological innovation of the pulse trawl?

This question tries to identify the involved regime actors and institutions in the transition of the Dutch flatfish fleet from the conventional beam trawl to the pulse trawl technique. Each of these actors and institutions had a direct or indirect influence on the inventing, research and development and diffusion processes of the pulse trawl. They all did have their own vision and interest concerned the pulse trawl technique, which would explain their actions in the transition process. A regime is not a fixed group of actors and institutions, the composition of a regime changes over time, just like their vision and interests concerned a new technological innovation can change over time. Therefore it is important to know when they became involved, what their initial vision and interest was in the pulse trawl technique and whether their vision and interest changed along the transition process. All this information eventually provides an explanation for the transition from the beam trawl to the pulse trawl technique in the Netherlands.

However, there needs to be some kind of interaction between those actors and institutions that are involved in the inventing, research and develop and diffusion process of a new technological innovation and the actors and institutions at the regime level. If their visions and interests do not match and if their actions are of a non-supportive nature, it is hard for a technological innovation to be accepted by a regime. This leads us to the last question:

3. How did the actors and institutions that were involved in the inventing, research and development and diffusion process of the pulse trawl interact with each other and with the regime actors and institutions?

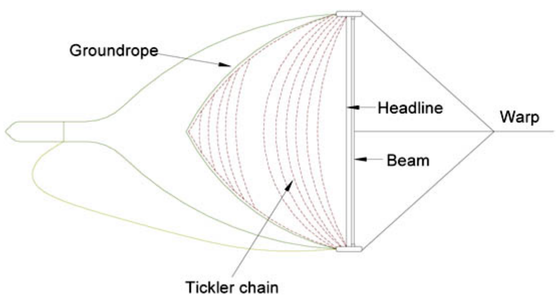
Before a technological innovation is picked-up and accepted by a regime, regime actors and institutions require information on the technological innovation and experience with the new technique. Sharing information and experiences on a technological innovation requires interaction between the different actors and institutions that are involved. This question aims to answer how the gathered knowledge and derived insights were communicated between actors and institution that were involved in the development process of the pulse trawl technique. This question also tries to answer how gathered knowledge and derived insights were communicated to the regime actors and institutions and how these responded to it, since this affects the visions, interests and actions of the regime actors and institutions.

1.3 BACKGROUND ON THE EMPIRICAL PROBLEM

The idea of catching fish with electricity dates back from the 1800s. However, the widespread development and use of electricity for fishing started around 1950 when it was used for population and community surveys for freshwater species (Soetaert et al., 2013). These developments contributed to the rising interest of applying electricity in marine fishing practices back in 1949. It triggered research on the testing of different fishing techniques with electricity on a variety of marine species. It soon turned out that the effects and behaviour of electricity in seawater differed to those noticed in freshwater. Seawater has a higher conductivity compared to freshwater and therefore research results obtained in freshwater should not be extrapolated to seawater (Soetaert et al., 2013). More information on pulse characteristics and the functioning of electric fields is given in Appendix 1.

Research in the Netherlands was initially focussed on the shrimp fisheries (1966-1979), but later the focus shifted to the flatfish fishery, mainly aiming for sole (1979-1985). It is unclear what caused the shift from shrimp to flatfish (Marlen, van, 1997)(IMARES researcher, 2014). De Groot and Boonstra (1970) came up with the idea to replace the heavy tickler chains and bobbins on the beam trawls for electrodes without loss of efficiency. By replacing these heavy tickler chains and bobbins for electrodes, they hoped to decrease the gear drag and thereby reduce the fuel consumption. This decrease in gear drag is partly explained by how the tickler chains and electrodes move relative to the seabed. While the tickler chains are moving perpendicular over the seabed, the electrodes move in a parallel direction over the seabed (see figure 4). Their first test results also revealed an increase in catch efficiency at daytime and a reduction of the damage to immature flatfish due to the less heavy fishing gear (Soetaert et al., 2013).

A



B

Figure 4. Difference in gear drag conventional beam trawl (A) vs. pulse trawl (B): *Figure A shows a conventional beam trawl. Its tickler chains move in a perpendicular direction over the seabed (Løkkeborg, 2004). Figure B shows the electrodes that are being used in a pulse trawl. These electrodes are positioned parallel to the seabed and thereby partly reduce the gear drag compared to the tickler chains that are being used in the conventional beam trawl.*

The development of this electrical fishing gear was stimulated by the crude oil price developments back in the 1970s (see figure 5), which started with the first oil crisis in 1973 and was followed by a second oil crisis in 1979 (Marlen, van, 1997). After 1979 the oil prices decreased and remained relatively stable till the crude oil price developments in the 2000s (Hoof, van, 2010).

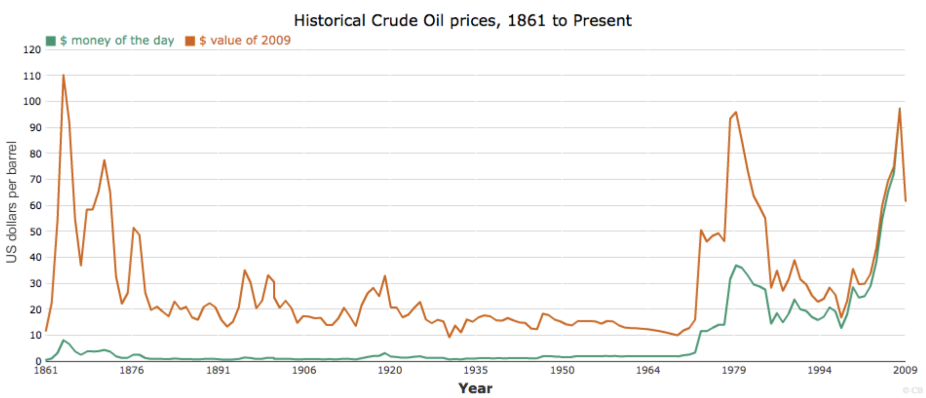


Figure 5. Crude oil price history: *Prices from 1861 till 2009 (BP Statistical Review of World Energy, 2010).*

So after the oil crisis of 1979 the urgency to find a fishing technique with a considerable reduction in fuel consumption declined. However, research on the development of an electrical fishing gear continued. This was also supported by the increasing concerns and criticism on the negative ecological effects of the conventional beam trawl. Fishermen themselves already expressed concerns over the possible effects of trawls on the seabed back in the 14th century and it increasingly gained public and international attention (Linnane et al., 2000). These international concerns were firstly expressed during the 58th council at the International Council for the Exploration of the Sea (ICES) in 1970. During this council it became clear that information was requested on the possible impact of trawls and dredges on the seabed and on the benthic fauna (Linnane et al., 2000). This triggered the stimulation for research on finding alternative fishing techniques that had the potential to reduce this impact.

The crude oil price developments initiated the research on finding a fishing technique with a lower fuel consumption compared to the conventional beam trawl. In a later stage also the increasing concerns and criticism on the conventional beam trawl did put pressure on the conventional beam trawl fisheries to change their fishing technique. These developments triggered the research on electrical fishing techniques, which could be used for catching a variety of commercial species like shrimp, flatfish and lobsters (Soetaert et al., 2013).

Research performed by Vanden Broucke (1973) revealed that a higher catch efficiency could be obtained with a pulse generator on shrimp and sole (Soetaert et al., 2013). These findings in combination with the findings by De Groot and Boonstra (1970) showed the potential of fishing with electricity and triggered further research with three to four meter beams in the United Kingdom, Germany, Belgium and the Netherlands. Although the results of the tests with the three and four-meter beam trawls showed positive results, it proved difficult to reproduce the positive results with larger commercial nine-meter beam trawls. According to Boonstra (1979) this was caused due to the increased power demand, the water resistance of the voluminous pulse generators, the electrode-connections in the water, the electrode material and the electrical efficiency, which were all leading to an accumulation of technical difficulties and frequent malfunctioning (Soetaert et al., 2013). Further research and development stagnated due to a lack of electrical power and the low fishing speeds, which were required to stimulate and catch the sole.

After a couple of years, new electrical generators became available that could meet the required high voltage peaks and research and development were resumed. Spectacular research results were obtained with electrical fishing in Germany, Belgium and the Netherlands. Similar electric tickler systems were used, but each slightly differed in the design rational (Linnane et al., 2000). Research by Horn (1982 & 1985) showed an increased catch weight of 114% and a reduction in bycatch of almost 50%. Belgium tested an electrified otter trawl and achieved higher sole catches, less undersized fish and more fish above the minimum landing size (Soetaert et al., 2013). Meanwhile in the Netherlands, the Netherlands Institute for Fisheries Research (RIVO) performed sea trials on the research vessel 'Isis' and later also on the commercial vessel UK141. Their new gear design caught 45% more sole during day and 65% more sole during night (Marlen, van, 1997). At the time the optimum voltage was around 700V with a 20Hz frequency. An ICES seminar with all leading scientists in this field of study was arranged in 1985 at the RIVO in Ijmuiden. It enabled all scientists/countries to compare their results and to exchange their ideas and experiences (IMARES researcher, 2014).

In 1986 attempts were made to commercialize the electric fishing gear in the Netherlands. This was done with the system that had been developed by the RIVO. All knowledge build up by RIVO over the past years was transferred to a private electronic company called Oranjewerf Ltd.-Giesselbach Ltd.. An extensive collaboration was started and a new prototype was being developed, which was more robust and allowed a quick interchange of components (Marlen, van, 1997). First tests on a commercial vessel were conducted in 1987 on the GO65. The commercial prototype showed higher sole catches and lower plaice catches compared to a beam trawl (Marlen, van, 1997). No differences in size selectivity were observed.

In 1988 however, all research and development activities on electrical fishing stopped very suddenly. Not just in the Netherlands, but also in the other European member states. According to Linnane et al. (2000) and Marlen, van (1997) the research and development in the Netherlands stopped for political reasons. As a result of the ban, all the research and development activities on electric fishing techniques stopped throughout Europe. In the Netherlands another important motivation to come up with an alternative for the conventional beam trawl disappeared, because crude oil prices had stabilized. The economic urgency to find a fishing technique with a considerable reduction in fuel consumption declined.

1.4 OUTLINE OF THE THESIS

This thesis research focuses on identifying the transition pathway of the pulse trawl technique on flatfish in the Netherlands by using the multi-level perspective on transitions theory of Geels (2011). The MLP on transitions theory forms the analytical framework of this thesis report and is discussed in chapter 2, along with the theory on transition pathways. In chapter 3 the used methodology for this thesis is discussed. The research results are presented in two different time periods. Chapter 4 deals with the time period from 1988 till 2010 and describes how the pulse trawl technique became accepted and implemented by the Dutch regime. In chapter 5, the focus is on the second time period that runs from 2010 till the end of 2014. Chapter 5 describes how the pulse trawl technique tries to breakthrough at the European regime level. The results are linked to a certain transition pathway in chapter 6, which is the discussion chapter. This discussion chapter is also going to reflect on the performed research and the obtained results, and tries to identify what broader lessons can be learned from this case study. In chapter 7 follows the conclusion, which provides answers to the formulated research questions of chapter 1.2.

CHAPTER 2. TRANSITION THEORY

2.1 INTRODUCTION

The aim of this chapter is to discuss the theory on transitions, which forms the analytical framework for the thesis research. As mentioned in the research aim, this report uses the multi-level perspective (MLP) on transition theory of Geels (2011) to identify the transition pathway of the pulse trawl in the Dutch flatfish fleet. This theory enables a holistic view on a transition pathway, since it looks at a transition from three different levels. A transition is not only analysed as a case on itself, but it is also placed in its broader context. Next to the development of a technical innovation, it requires to be adopted and selected by the regime. Next step in the transition process is the societal embedding of the technical innovation, which means that it needs to be accepted by a wider public and being integrated into existing socio-technical context (Geels, 2011). Using the MLP on transitions as the analytical framework can help to identify the transition pathway of the pulse trawl technique. Grin et al. (2010) identified five different transition pathways. Through the MLP on transitions it is possible to compare this case with the five different transition pathways and find out to which pathway the transition of the pulse trawl matches. This report identifies the transition pathway of the pulse trawl technique and enables the involved actors and institution to gain an understanding on how this transition is evolving. Once involved actors and institutions get a better understanding of the transition pathway and process, it enables them to learn more about the transition pathway. Thereby it creates an opportunity to them to influence the transition process into a desirable direction, such as sustainable development. However, it must be noted that it also provides actors and institutions the opportunity to steer the transition process towards other directions.

2.2 BACKGROUND TO TRANSITION THEORY

Most innovations and transitions occur out of a crisis. A crisis provides a chance for change, because existing institutions are already under pressure. Persistent problems are caused and maintained by processes that are embedded in our societal structures (Grin et al., 2010). In order to tackle these persistent problems, innovative practices and structural adaptation are required. However, structural adaptation and innovative practices come along with turmoil, uncertainty, lack of confidence, fear and impotence (Grin et al., 2010). These are aspects that have a negative influence on the transition process. The study of transitions tries to answer two questions, namely:

1. How may we understand transitions?
2. How may we influence transitions into a desirable direction?

A transition is a multi-actor process and involves interaction between actors from different domains like science, policy makers, social movements, user groups and special interest groups (Grin et al., 2010). It is also important to acknowledge that transitions are long-term processes of approximately 40 to 50 years. The breakthrough of a technological innovation can be very fast, around 10 years, but the preceding innovation process of the emergence of a new socio-technical system can take much longer (20-30 years)(Grin et al., 2010).

In this report a case is studied that involves a technological transition of an innovative fishing technique, which is perceived to be more sustainable compared to the conventional beam trawl technique. Sustainability driven technological transitions have certain special characteristics compared to most historical transitions (Geels, 2011). Whereas many technological transitions are of an emergent character, sustainability driven technological transitions are goal-oriented.

2.3 OUTLINE OF MULTI-LEVEL PERSPECTIVE ON TRANSITIONS

The multi-level perspective (MLP) on transitions theory has been developed by scholars who actively sought to bridge science and technology studies and evolutionary economics (Grin et al., 2010). So this theory contains notions of science and technology, evolutionary economics and sociology. This MLP on transition theory is an abstract analytical framework, which identifies relations between general theoretical principles and mechanisms (Grin et al., 2010). The theory is geared on answering particular questions on the dynamics of transitions (Grin et al., 2010). It shows the alignment between the three levels, which enables a transition to occur. By applying the multi-level perspective on transitions theory (see figure 8), a holistic view on the transition pathway can be generated since it studies the processes on and the interaction between the different levels. The MLP on transitions uses three different levels, the socio-technical regime level, the socio-technical niche level and the socio-technical landscape level. These levels are discussed below in more detail, along with how these levels are inter-related with each other and with the theory on transition pathways. These three concepts form a nested hierarchy as is shown in figure 6. As you can see the regimes are embedded in the landscape and the niches are in turn embedded in the regimes.

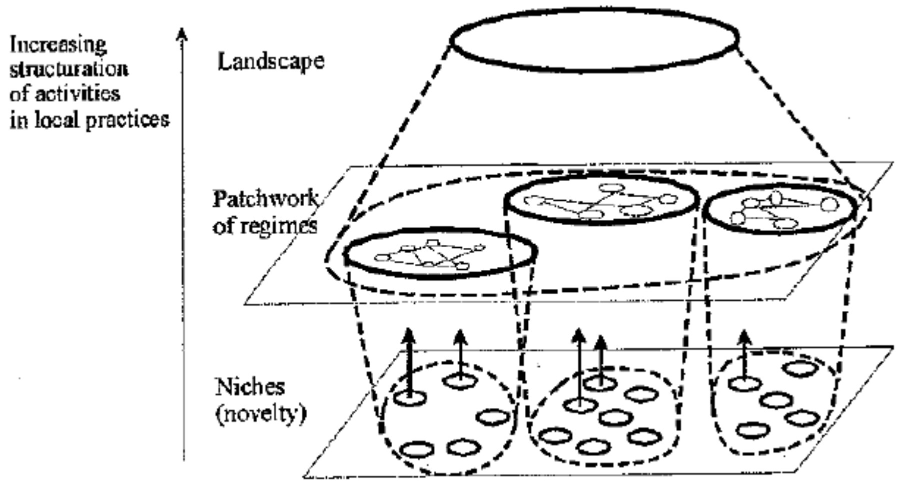


Figure 6. The MLP on transitions theory: *Here you see the nested hierarchy of the three different (Grin et al., 2010).*

Transitions require quite some time and effort before they take place, since they require changes in the socio-technical regime. These socio-technical regimes coordinate and guide the innovation process at the niche level and steer the innovations along a predictable trajectory (Grin et al., 2010). This coordinating, guiding and steering of innovations of the niche level by the socio-technical regime level is done according to the rules of the regime. According to Geels (2004) a regime contains three types of rules, being the regulative, normative and cognitive rules as is shown in table 2. Regulative rules are a clear, formal set of rules that constrain behaviour and regulate interactions.

These rules are about rewards and punishments, which are backed-up by sanctions (Geels, 2004). Normative rules concern norms, values, responsibilities, rights, duties and role expectations (Geels, 2004). Cognitive rules concern the frame we use to construct our own reality, through which we give meaning or sense to things and how we select and process information (Geels, 2004).

Table 2. Rule regimes: *A more detailed explanation and examples of the three types of rules in a regime. These regime rules influence, coordinate, guide and steer the innovations at the niche level (Geels, 2004).*

	Regulative	Normative	Cognitive
Examples	Formal rules, laws, sanctions, incentive structures, reward and cost structures, governance systems, power systems, protocols, standards, procedures	Values, norms, role expectations, authority systems, duty, codes of conduct	Priorities, problem agendas, beliefs, bodies of knowledge (paradigms), models of reality, categories, classifications, jargon/language, search heuristics
Basis of compliance	Expedience	Social obligation	Taken for granted
Mechanisms	Coercive (force, punishments)	Normative pressure (social sanctions such as 'shaming')	Mimetic, learning, imitation
Logic	Instrumentality (creating stability, 'rules of the game')	Appropriateness, becoming part of the group ('how we do things')	Orthodoxy (shared ideas, concepts)
Basis of legitimacy	Legally sanctioned	Morally governed	Culturally supported, conceptually correct

All these rules are linked together and are organised into a rule system. If a rule system is collectively shared, then such a rule system is called a social rule system. Such a social rule system structures and regulates social transactions and is backed by social sanctions and networks of control (Geels, 2004). These social rule systems are also called rule regimes. The rules in a rule regime are linked together, which makes it very hard to change one rule without affecting other rules. A regime owes its stability to the alignment of rules and this gives the regime its strength to coordinate activities (Geels, 2004). Innovations do occur and develop at the niche level, but these are predictable because they follow a certain trajectory, which is determined by the rule regimes. These rule regimes share particular perceptions, problem agenda's, preferences and norms that lead to certain trajectories, which co-evolve over time (Grin et al., 2010). However, sometimes the changes in a trajectory are so powerful that it results in mal-adjustments and tensions. These tensions lead to windows of opportunity for transitions. The MLP on transitions theory does incorporate emphasis on the alignments and interacting processes and acknowledges the importance of tensions, since these tensions form the windows of opportunity for transitions (Grin et al., 2010). So a transition should not only focus on the technological innovation, but also on achieving a transition in the rule regimes.

2.4 EXPLANATION OF THE THREE LEVELS

The MLP on transition consists of three different levels, which are the socio-technical landscape level, the socio-technical regime level and the niche innovations level as is shown in figure 7. Each of these levels is now discussed in more detail.

Socio-technical regime level

A characteristic of socio-technical transition is that it cannot simply replace existing systems but requires structural changes. Achieving structural changes is a real challenge since many existing structures/regimes stabilize themselves through lock-in mechanisms. Examples of lock-in mechanisms are investments made in machines, regulations, policies, peoples competencies, shared believes and discourses, consumer lifestyles and preferences (Geels, 2011). Making changes in policies comes along with politics, power struggles and differences in interests (Geels, 2011). Another major challenge of socio-technical technological transitions is that they require a multidimensional approach, since they involve interactions between technology, policy/power/politics, economics/business/markets and culture/discourse/public opinion (Geels, 2011). The interactions between all these different regimes take place at the socio-technical regime level, but socio-technical transitions start at a different level. They are developed in so called socio-technical niches (Hermans et al., 2013).

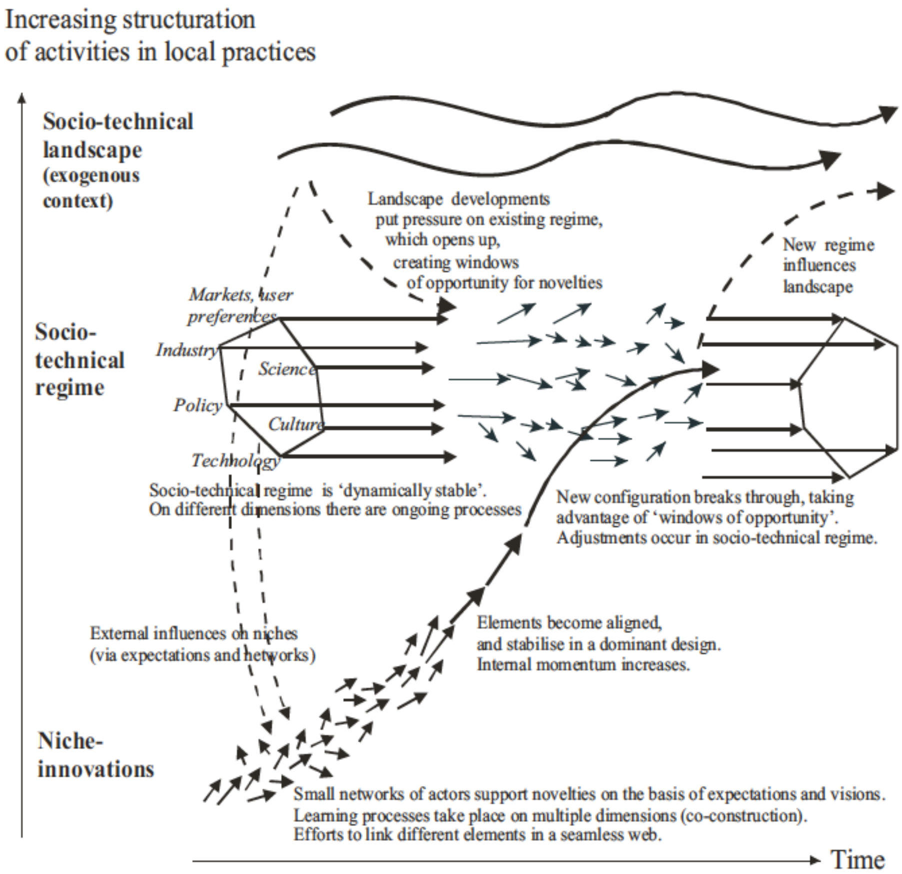


Figure 7. Multi-level perspective on transitions: *Dynamics between the three different levels (Geels, 2011).*

Socio-technical niche level

Niches can be described as protected spaces that enable emerging innovative technologies to be tested and developed. These niches are crucial for transitions, since they enable systematic change. Within a socio-technical niche the process of learning, experimenting and gaining experience with a new technology is very important. This process enables the actors in the niche to interact, share their ideas and to verify their own mental frameworks in discussion with others and thereby creating a social network. The actors within a niche hope that the new technology will eventually be taken up by the existing regime or will replace it (Hermans et al., 2013). With vision we refer to a future image an actor or institution wants to exert itself to (Grin et al., 2010). Gathering more insight in the interests of the actors and institutions involved can give a better representation of their role in the niche network. It is also interesting to see what actions the actors and institutions at the niche level have taken and to study the effects of these actions on the transition process (Grin et al., 2010).

Socio-technical landscape level

There is even a higher level described in the multi-level perspective on transitions, being the socio-technical landscape. Both the niches and the regimes are embedded in this wider context. The socio-technical landscape level includes demographic trends, political ideologies, societal values and macro-economic patterns (Geels, 2011). It takes a long time for actors at the niche and regime level to change the socio-technical landscape. The socio-technical landscape level does influence the processes at the regime and niche level and is therefore studied in order to place the transition of the pulse trawl technique in a wider context. However, its interaction with the niche and regime level is limited and the processes are relatively slow compared to the processes at the niche and regime level. Therefore the role of the processes at the landscape level is limited in the thesis report compared to the processes at the niche and regime level.

So the multi-level perspective on transitions consists of three levels, which are related to each other. A niches potential is not only determined by its internal characteristics. Niche innovations are important, but they can only diffuse more widely if they link up with on-going processes at regime and landscape levels (Grin et al., 2010). If you apply this to the pulse trawl case, then you need to understand that the transition of the pulse trawl from the niche level to the regime and landscape level is only possible if it links-up with the processes at those levels. The niche steers and is being steered by the regime and landscape level. If the visions, interests and actions of the actors and institutions on the niche level and regime level can be mapped and compared, then a better insight can be gained in the differences between these two levels. Differences between the visions, interests and actions of the involved niche and regime actors and institutions could hamper the transition process.

2.5 TRANSITION PATHWAYS

The main aim of this thesis is to identify the transition pathway of the pulse trawl technique on flatfish in the Netherlands by using the multi-level perspective on transitions theory of Geels (2011). According to the transition theory, transitions always take place according to a certain transitional pathway (see figure 3). These transitional pathways have a certain direction and pace, which can be influenced by policy and other institutional interventions (Wilson, 2007). Identifying the transition pathway of the pulse trawl helps the involved actors and institutions to understand the transition process of the pulse trawl technique. It might explain or provide them with more insight in what is currently causing the problems and resistance faced within the Netherlands and at the European level concerned the pulse trawl technique. Once involved actors and institutions get a better understanding of the transition pathway and process, it enables them to learn more about the transition pathway.

Grin et al. (2010) propose three different criteria that are important for the determination of the transition pathway. These three criteria are the timing of interactions, nature of interactions and types of landscape change. Timing of interactions is important for how and whether a transition will take place. If there is pressure from the landscape level on the regime, but there is no sufficiently developed niche innovation, than the transition pathway will differ from the situation in which a developed niche innovation is fully developed (Grin et al., 2010). It is debatable when a niche innovation is considered as fully developed. Niche actors and institutions can have a different perception on this compared to regime actors and institutions (Grin et al., 2010). Grin et al. (2010) proposed the following four indicators for niche innovations that are ready to break-through:

1. Learning processes have stabilized in a dominant design
2. Powerful actors have joined the support network
3. Price/performance improvements have improved and are expected to further improve
4. The innovation is used in market niches, which cumulative amount for more than 5% market share

These four indicators can be used in the case study on the transition of the pulse trawl technique in the Netherlands as criteria for establishing whether the pulse trawl was ready to break-through into the regime.

The second criterion that is important for the transition pathway is the nature of interactions, which can differ between the different levels. Niche innovations and landscape developments can either reinforce relationships with the regime or disrupt them through pressure or competition (Grin et al., 2010). Reinforcing landscape developments are stabilizing the regime and form no driver for transition, while pressure from the landscape level on the regime will result in stimulations for change and transitions. Like the landscape-regime interactions, the niche-regime interactions can differ in nature. If a niche innovation aims to replace the existing regime, it will have a competitive relationship with the current regime. When the niche innovation can be used to solve problems and improve performance of the existing regime, then the nature of interactions will take the shape of a symbiotic relationship between the niche innovation and the existing regime (Grin et al., 2010).

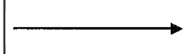
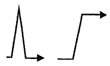
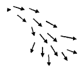
Third and final criterion is about the types of landscape change. Grin et al. (2010) describes four dimensions of change that from useful indicators for establishing the type of landscape change. These four dimensions are:

1. Frequency; Number of environmental disturbances per unit of time
2. Amplitude; Magnitude of deviation from initial conditions due to disturbances
3. Speed; Rate of change of disturbance
4. Scope; Number of environmental dimensions affected by simultaneous disturbances

These four dimensions result in five different types of landscape change as is shown in table 3. This table can be used to identify the type of landscape change experienced during the transition process of the pulse trawl.

By using the MLP on transition theory as the analytical framework for this case study, more is learned about the involved actors and institutions, their visions, actions and interest. That information helps to gain more insight on the timing of interactions, nature of interactions and types of landscape change. Information on these three criteria helps to identify the transition pathway of the pulse trawl. According to Grin et al. (2010) there are five different transition pathways, which are briefly discussed below.

Table 3. Types of landscape change: *The four dimensions as indicators for landscape change along with the interpretation of the changes (Grin et al., 2010).*

Frequency	Amplitude	Speed	Scope	Type of landscape change	Interpretation of the changes
Low	Low	Low	Low	Regular	
High	Low	High	Low	Hyperturbulence	
Low	High	High	Low	Specific shock	
Low	High	Low	Low	Disruptive	
Low	High	High	High	Avalanche	

Transformation pathway

With this transition pathway there are moderate landscape changes that create pressure on the regime for a transition. However, niche innovations are not sufficiently developed yet and cannot take advantage of the landscape pressure. Pressure from landscape changes only have an effect if the regime perceives them and acts upon them. Regime insiders tend to neglect these landscape changes and therefore outsiders are very important, because they translate landscape pressures and draw attention to negative externalities (Grin et al., 2010). Outsiders, like activists and entrepreneurs, might develop alternative practices and technologies. These alternatives may change the perception of regime insiders, which respond by modifying the direction of the development paths and innovation activities (Grin et al., 2010). So these outsiders, who act at the niche level, can be identified as the front-runners. Their routines and practices gradually trickle down and alter the regime rules. In this pathway the regime actors and institutions survive, since they adapt through cumulative adjustments and reorientations. These symbiotic niche innovations allow the basic architecture to remain intact (Grin et al., 2010).

De-alignment and re-alignment pathway

Changes on the landscape level are divergent, large and sudden, while potential niche innovations are not sufficiently developed. The changes on the landscape level result in a rapidly growing landscape pressure on the regime. If there are divergent landscape developments, which result in pressure on the existing regime, it may result in the disintegration of the regime. The regime will face major internal problems and collapses, which triggers the de-alignment and erosion of the regime due to increasing problems and the lack of a clear substitute, which in turn results in a loss of faith of regime actors (Grin et al., 2010). It will lead to the destabilization of regime rules (guiding principles, user preferences, selection criteria, regulations), thereby creating uncertainty about the coordination and guidance of innovations. Due to the lack of stable regime rules and the absence of a sufficiently developed niche innovation, space is created for multiple niche innovations that co-exist. These multiple niche innovations also create uncertainty, because the most successful innovations will make competing claims. A period follows of co-existence, uncertainty, experimentation and competition for attention and resources. Eventually one of these niche innovations becomes dominant and forms the core for re-alignment of a new socio-technical regime (Grin et al., 2010).

Technological substitution pathway
There is a sufficiently developed niche innovation, but it is not being picked-up and accepted by the regime because the regime is stable and entrenched. Existing problems are minor and regime actors pay little attention to innovations from outsiders. The developed niche innovation requires a specific shock, avalanche change or disruptive change at the landscape level that puts pressure on the existing regime. Tensions emerge on the regime level due to these pressures from the landscape level, and these tensions provide windows of opportunity for niche innovations (Grin et al., 2010). Actors and institutions at the niche level can use these windows, since they have stabilized and gained internal momentum. Diffusion is being realized through niche-accumulation, which means that a technology is applied in different niche markets so that technology/market combinations become robust (Raven, 2007). It leads to market competition and power struggles between newcomers and incumbents (Grin et al., 2010). If the innovation manages to replace the old technology, it results in knock-on effects and further regime changes. This pathway has a technology-push character, meaning that wider co-evolution processes will follow substitution (Grin et al., 2010). As it often results in the downfall of incumbent firms, it is a well-studied transition pathway in business studies and technology management.

Reconfiguration pathway
These are innovations at the niche level that have symbiotic relations with the regime. Innovations in this pathway are accepted and picked-up by the existing regime as add-ons or minor replacements to improve performance or solve small problems (Grin et al., 2010). It hardly alters the existing regime and its regime rules. However, each of these newly picked-up innovations can lead to additional technical changes, changes in user preferences and perceptions at the regime level. This could eventually lead to further adoptions of niche innovations. All these minor innovations could eventually add-up to major reconfigurations and regime changes (Grin et al., 2010). Such innovations are eventually adopted by the regime to solve local problems. The reconfiguration pathway differs from the transformation pathway in the sense that this transition pathway experiences substantial changes in the regime's basic architecture (Grin et al., 2010). So regime actors and institutions survive the reconfiguration pathway, but there will be a lot of competition and tension at the niche level between innovations.

Mixed transition pathway
This pathway consists of a mix of the previous described pathways. Often regime actors experience moderate pressure from the landscape level. But if the pressure continues to build-up into a certain direction, the landscape change takes a more disruptive form, which could eventually lead to a sequence of transition pathways. At first the regime tries to tackle problems within the regime through the use of internal resources, changing the direction of activities and the development trajectories (Grin et al., 2010). If they succeed in solving the problems, the transition fits to the transformation pathway.

When problems continue to exist and if the pressure from the landscape level continuous to grow, the regime actors and institution may become more willingly to incorporate symbiotic niche innovations and implement component changes. This still fits to the transformation pathway. But when these changes result in further adjustments, then it leads to a reconfiguration pathway (Grin et al., 2010). When these adjustments solve the problems, then the regime actors will survive. However, if the problems grow worse and the pressure from the landscape level starts to take on a disruptive form, then incumbent actors and institutions start to lose faith. This would create a window of opportunity for a sufficiently developed innovation to break-through, resulting in a technological substitution pathway (Grin et al., 2010).

If no sufficiently developed niche innovation is available, the regime will follow the de-alignment and re-alignment pathway. Multiple niche innovations co-exist till one becomes dominant and forms the core for the re-alignment of a new regime (Grin et al., 2010). Often it starts with a transformation pathway, which leads to a reconfiguration pathway that is followed by a de-alignment/re-alignment pathway (Grin et al., 2010). However, although this is a logic sequence of transition pathways in the mixed transition pathway, it is important to realize that pathways are not deterministic.

An oversight of the main characteristics of the five transition pathways is given in table 4.

Table 4. Transition pathways: *The main characteristics of the five different transition pathways according to Grin et al. (2010).*

Level	Transition pathways				
	Transformation pathway	De-alignment & re-alignment pathway	Technological substitution pathway	Reconfiguration pathway	Mixed transition pathway
Socio-technical landscape level	Moderate pressure on the regime for a transition	Changes on the landscape level are divergent, large and sudden	Lot of pressure from the landscape level on the regime	Landscape level has no role in this transition pathway	Pressure from the landscape level in the form of 'disruptive change', which could eventually lead to a sequence of transition pathways
Socio-technical regime level	Responds by modifying the direction of the development paths and innovation activities	De-alignment and erosion of the regime level due to increasing problems and lack of substitute, results in loss of faith of regime actors	Developed niche innovation will break through and replaces the existing regime	Innovations trigger further adjustments in the basic architecture of the regime	Depends on the transition pathway
Niche innovation level	Potential niche innovations are not sufficiently developed yet	Potential niche innovations are not sufficiently developed. Space for multiple niche innovations to co-exists, one will become dominant	Niche innovation has developed sufficiently	Innovations at the niche level have symbiotic relations with the regime and are eventually adopted by the regime to solve local problems	Depends on the transition pathway

2.6 FRAMEWORK FOR ANALYSIS

The MLP on transition theory is used as the analytical framework for this case study on the transition of the Dutch flatfish fleet from the beam trawl towards the pulse trawl. It is an adequate analytical framework for this case study since it looks at the transition process from multiple levels. This framework enables to place the visions, interests and actions of actors and institutions of different levels in a more holistic context. Besides that, it provides more insight in how niche actors and institutions interacted with the regime actors and institutions. Studying the timing and nature of interaction between these two levels is of importance for the determination of the transition pathway. The role of the socio-technical landscape is also taken into account in the MLP on transitions theory. Changes at the socio-technical level influence the visions, interests and actions of the actors and institutions at both the niche and regime level. An example of the influence of the socio-technical level on the niche and regime actors and institutions are the discussions on the pulse trawl that are conducted at the Dutch and European level. These discussions are part of the more global discussions on innovation and sustainability in our fisheries (Suuronen et al., 2012). This is an example of landscape changes that put pressure on existing regimes and influences niche innovations.

By using the MLP on transition theory as the analytical framework to study and analyse the transition in the Dutch flatfish fleet, the gathered knowledge and derived insights are used to identify the transition pathway of the pulse trawl. The theory on the transition pathways has been explained in chapter 2.5 and describes five transition pathways. Each of these five transition pathways has their own characteristics, direction and pace, which can be influenced by policy and other institutional interventions (Wilson, 2007). Identifying the transition pathway of the pulse trawl might explain or provide more insight in what is currently causing the problems and resistance faced within the Netherlands and at the European level concerned the pulse trawl technique. Identifying the pathway of a transition provides involved actors and institutions insight in how innovation processes proceed. Thereby it creates an opportunity for them to influence the transition process into a desirable direction.

3. METHODOLOGY

3.1 INTRODUCTION

As previously mentioned, a case study methodology is being used for this research. A more detailed explanation about the selected case study methodology is given in this chapter. The reasoning behind the selection of a case study methodology is also discussed in this chapter, along with the strengths and weaknesses of such a methodology. Furthermore, this chapter discusses how the formulated research questions are operationalized and what methods are used to obtain data. After describing the methods, also the reasoning behind the selected research methods is discussed.

3.2 CASE STUDY

The case that is being studied is that of the transition of the Dutch flatfish fleet from the beam trawl towards the pulse trawl technique. So a single case study design is chosen. It is important that the collection and analysis of information from the case study is guided by theory (Vaus, de, 2001). This is important because without a theoretical dimension this case study would be of little value for wider generalization, which is one of the goals of social science research (Ragin, 1994). Therefore the MLP on transitions and the transition pathway theory are used during this case study, which enables a holistic view on the transition and provides guidelines for those who want to influence the transition process. It describes the case, while taking into account information gained from many levels (Vaus, de, 2001).

However, there are a number of case study designs available, but a descriptive case study design was chosen for this research. The case of the pulse trawl fits to descriptive case study design since this research aims to understand the transition of the pulse trawl technique and hopes to provide insights in how to understand transitions by using the MLP on transitions and the transition pathway theory as the analytical framework for this case study. This case study design is used, because it can make a detailed and in depth assessment of the transition pathway of the pulse trawl. This means that instead of using the case to test, refine and develop theoretical generalizations, it aims to reveal patterns and connections on the basis of a particular theory (Yin, 2013).

A limitation of a case study is that although it deals with a whole case, it is impossible that the case study consists of everything about the case. Choices are made in how things are selected and organized and only certain aspects are highlighted in the description of the case (Vaus, de, 2001). So the description of the transition of the pulse trawl case is rather an interpretation instead of a mirror image. The selection of the theory that is used for the case study influences the decisions being made about what is relevant and important, and on the focus of interest (Guba & Lincoln, 1981). Another limitation of this research is that it has a retrospective design. This means that information is collected about an extended time period. It requires reconstruction of the history of the case, which is done through a literature survey and interviews with involved actors and institutions in this report. Limitations of this retrospective design are the loss of evidence, reconstruction of the past in the light of the present and mistaking the sequence in which events occurred (Vaus, de, 2001). To tackle these limitations, the transition of the pulse trawl technique is studied after the ban on electrical fishing in 1988, since information and involved actors and institutions are scarce for analysing the period prior to 1988. Multiple sources of evidence (triangulation) are used to tackle the associated problems of this retrospective design, since it increases the credibility and validity of the data.

3.3 DATA COLLECTION

Through a literature survey, meetings concerned the pulse trawl and through conducting interviews, a list was made of the most relevant actors and institutions involved in the transition process of the pulse trawl. A snowball sampling method (SSM) was used during interviews to identify most of the relevant actors and institutions involved in the transition process of the pulse trawl and to get a better insight in the network. With the SSM one actors/institution gives the researcher the names of other actors and institutions, which in turn name others and so on. Through the use of the SSM, the sampling group appears to grow like a rolling snowball (Cohen & Arieli, 2011).

Once the most relevant actors and institutions had been identified, a list was made of people that could be approached for the interviews. In total 17 actors/institutions were approached for an interview and 15 were willing to cooperate. The other two approached actors and institutions did want to leave the past behind and replied to the request for an interview with a brief written statement. In contrary to quantitative research, which aims to produce a sample that is representative in a statistical way of the whole population of interest, this qualitative research used purposive sampling (Curtis et al., 2000). This means that the focus is on explicitly selecting interviewees who are likely to generate appropriate and useful data, and including enough of them to answer the research questions (Curtis et al., 2000). Table 5 shows a list of interviewed actors/institutions for this research:

Table 5: Interviewed actors and institutions: *A list of all interviewed actors and institutions for the empirical data.*

Actors/Institutions	Number
Fishermen	3
Technological company	2
Ministry of Economic Affairs	4
Agricultural Economics Institute (LEI)	1
IMARES	1
NGO	1
Fisheries representative organization	2
ILVO	2

Semi-structured interviews were used as a method to acquire qualitative data. A semi-structured interview allows the researcher to set the agenda concerned the topics that are discussed. However, the interviewee's response determines the kind of information that is being produced about the topics and the relative importance of each of them (Green & Thorogood, 2014). This form of interviewing gives the interviewer flexibility in how to ask questions. Questions that are asked depend on how the interviewee thinks about the topics that are discussed (Runeson & Höst, 2009). It enables the interviewer to ask very actor/institution specific questions next to the initially identified relevant interview questions and topics described in chapter 3.4 below. This is useful, since interviewed actors and institutions have different backgrounds and interests and require different interview strategies. Semi-structured interviews allow using different interview strategies, while covering all the relevant topics for the research. If requested by the interviewee, several questions were sent ahead to the interview in order to give an impression of the topics to be discussed. All interview formats can be found in Appendix 2. In total 14 interviews were recorded with a digital voice recorder, since an accurately transcribed recording is the most reliable record of an interview (Green & Thorogood, 2014). These recorded interviews were then transcribed in a word-document and sent to the interviewees to verify the content. Once interviewees agreed upon the content, they allowed me to use it for my research. Some interviewees made certain nuances in their statements without changing the content in the interview transcript. The transcriptions are also useful since they can be easily reproduced and archived (Runeson & Höst, 2009). Some of the interviewed actors/institutions did not want to make the content of the interviews publicly available and therefore the decision was made to make none of the interviews publicly available. The interview transcripts are stored in the ENP-database for verification by the examiner and other parties with the authority to check these data from the ENP-group. Next to the 14-recorded interviews, one written interview was conducted. Questions were sent and answered by email. Limitations of this written interview are that the interviewee can prepare the answers and there is no opportunity to directly respond to the given answers of the interviewee. Despite these limitations, the written interview provided complementary information to this research.

During the literature survey, both scientific and non-scientific sources were conducted and are being used in this report. Reading both scientific and non-scientific sources enabled me to asquint myself with the available body of knowledge in my areas of interest (Kumar, 2005). Although non-scientific sources do experience problems with the availability, format and data quality, these sources also form a very useful tool to bring clarity and focus to my research problem, broaden my knowledge of the sector and contextualise my findings (Kumar, 2005). Scientific literature was acquired through consulting the Wageningen UR library and through the handed research reports from IMARES. A database for the non-scientific literature was created. This database contains articles from newspapers, magazines, annual reports from the government and other publications concerned the pulse trawl from 1988 till now. This non-scientific literature was found through using the following three search terms in Dutch on Google:

- Pulse trawl (pulskor)
- Electric trawl (elektrokor)
- Electric fishing (elektrisch vissen)

The database was classified per year, so the customised date range option in Google was used for the three search terms.

Several meetings concerned the pulse trawl were joined. This was done to get a better insight in the way people had conversations, the language and rhetoric they used, and their styles of (non- verbal) behaviour in certain settings (Mason, 2002). That information is useful for making my interview strategy, since more insight is gained how these people communicate and interact with others. According to Mason (2002) it also allows a researcher to become more involved in the social world of those you research. This can result in more trust, which is useful during interviews since it might allow the researcher to obtain more information. The following meetings were attended:

- Meeting IMARES with scientist from ILVO (Institute for Agricultural and Fisheries Research) in Oostende (Belgium) on 16-05-2014.
- Foundation Sustainable Shrimp fishery[1]; the most recent developments on the pulse trawl for shrimp were discussed in Emmeloord with shrimp fishermen, scientists, fisheries representative organizations and policymakers at 23-05-2014.
- Meeting with an Italian delegation consisting of fishermen, scientists and the coast guard about the Dutch fisheries sector/pulse trawl in Scheveningen at 03-07-2014. The United Fish Auctions (UFA), IMARES, LEI and the Ministry of Economic Affairs gave presentations to this Italian delegation.
- Pulse Trawl Flatfish meeting[2]; the most recent developments concerned the pulse trawl on flatfish and shrimp were discussed between scientists from IMARES, NIOZ and ILVO and flatfish fishermen. Research questions were formulated as part of the major pilot study on the pulse trawl. The meeting took place in Stellendam on 11-07-2014 and was also attended by Blueport Southwest, ProSea, some policymakers and the Fisheries College.

3.4 OPERATIONALIZATION RESEARCH QUESTIONS

The formulated research questions in chapter 1.2 need to be translated in operational research questions and topics for the interviews. Therefore research trees have been made for the three research questions. These research trees give an oversight of what data are desired along with the accompanying questions that need to be asked to obtain these data.

1. How did the invention of the pulse trawl develop into a fishing gear that was ready to be picked-up and accepted by the regime?

In order to identify the actors and institutions involved in the transition process of the pulse trawl, an interview was conducted with an IMARES researcher, who is one of the people that has been involved from the start of the development and testing phase of the pulse trawl in the Netherlands till now. Based on this interview it was possible to trigger a snowball sampling process. Two other actors that played a major part in the inventing, research and development and diffusion process of the pulse trawl after the ban in 1988 were approached, but both refused an interview and only gave a short written statement. They both refused being involved in any activities concerned the pulse trawl anymore, thereby indicating that the pulse trawl is a sensitive issue. Therefore most information on the starting period (1988-1998) had to be obtained through the literature survey, the interview with IMARES researcher and statements from the other interviewees.

To retrieve information on the vision, interests and actions of the actors and institutions that were involved in the inventing, research and development and diffusion process of the pulse trawl after the ban in 1988, the following questions formed the structure for the interviews:

[1] The Foundation Sustainable Shrimp fishery, which is also known as the 'Stichting Verduurzaming garnalenvisserij' in Dutch.
[2] The Pulse Trawl Flatfish meeting, which was also known as the 'Pulskor platvis kennisdag' in Dutch.

Research tree 1.1				
Head questions	Sub questions	Desired data	Methodology	Obtain data through posing these questions
1.1 How did the invention of the pulse trawl develop into a fishing gear that was ready to be picked-up and accepted by the regime?	1.1.1 Which actors and institutions were involved in this process?	Network of involved actors and institutions in the resumption on testing & developmentof the pulse trawl	Interviews, literature, meetings	- Whom did you have contact with?
				- Who was involved?
	1.1.2 In which part of the process at the niche level became the actors and institutions involved?	Determine the role of actors and institutions in the transition process at the niche level	Interviews, literature, meetings	- Were you involved in the inventing process of the pulse trawl?
				- Were you involved in the research and development process of the pulse trawl?
				- Were you involved in the diffusion process of the pulse trawl?
	1.1.3 What were the visions, interests and actions of these actors and institutions to resume the research on the pulse trawl?	The perception and role of the actors and institutions in this phase of the transition process	Interviews, literature, meetings	- Why did you become involved?
				- With what thoughts did you exert yourself to the development of pulse trawl technique? Did these thoughts change over time?
				- What was your contribution to the development of pulse trawl technique? Did your contributions change over time?
	1.1.4 Under what circumstances at the landscape level did this take place?	To determine the influence of the landscape level on the developments at the niche level	Interviews, literature, meetings	- What stimulated the inventing, research and development and diffusion process of the pulse trawl after 1988 according to you?

Based on the answers of the above questions, in combination with gathered literature, more could be said about the vision, interests and actions of the actors and institutions that acted at the niche level. Interviewed actors and institutions were asked about their vision, interests and actions at the start of the transition phase at the niche level. These actors and institutions were also asked about how the transition process evolved from that point and whether their vision, interests and actions changed during this process. This helps to describe the internal niche processes and how it evolved over time. It also enables to analyse whether a difference could be found in the visions, interests and actions of the niche actors and institutions who were involved from the start and those who entered the transition process at the niche level in a later phase.

Next to these questions, actor and institution specific questions were prepared before the interview, since fishermen, policymakers and scientist required different approaches. Other questions arose from the interview itself, since a semi-structured interview design was used. Information on the landscape level was mainly gathered through literature and data from the interviews.

So the questions posed in research tree 1.1 focuses on identifying the niche network, the visions, interests and actions of these niche actors and institutions and on identifying the processes that took place at the niche level. However, to realize a transition, changes at the socio-technical regime level are required. That resulted in the following research question:

2. What made the regime actors and institutions replace the beam trawl for the new technological innovation of the pulse trawl?

Research tree 1.2 shows how this research question was operationalized in interview questions and topics. For identifying the relevant regime actors and institutions, the SSM was used along with information obtained through the literature survey. As described above, space was created for inventing, research and development and diffusion of the pulse trawl in the Netherlands by the regime. Questions and topics in research tree 1.2 focuses on identifying how the transition process evolved at the regime level. Through the questions and topics in research tree 1.2, it is possible to reconstruct the regime network, to identify the visions, interests and actions of the regime actors and institutions and to identify the processes that took place at the socio-technical regime level. All interviewees are asked whether their visions, interests and actions changed along the transition process. This information gives insight in the internal socio-technical regime processes that took place.

Research tree 1.2				
Head questions	Sub questions	Desired data	Methodology	Obtain data through posing these questions
What made the regime actors and institutions replace the beam trawl for the new technological innovation of the pulse trawl?	1.2.1 What actors and institutions became involved at the regime level?	Network of all the involved actors and institutions on the regime level	Interviews, literature, meetings	- Whom did you have contact with?
				- Who was involved?
	1.2.2 What are the visions, interests and actions of these actors and institutions when they entered the transition process of the pulse trawl?	The vision, interests and actions of the regime actors and institutions	Interviews, literature, meetings	- Why did you become involved?
				- What were your initial thoughts concerned the pulse trawl technique when you became involvedl?
				- What is your contribution to the implementation of pulse trawl in the Dutch flatfish fleet?
	1.2.3 Did the visions, interests and actions of the actors and institutions at the regime level shift during the process?	Information on vision, interests and actions of actors/institutions involved at the start of the transition process and the vision, interests and actions of actors/institutions that entered the transition process in a later phase	Interview, literature, meetings	- What are your thoughts on the pulse trawl now?
				- How are you currently contributing to the acceptance and implementation of the pulse trawl technique?
				- Are you still involved in the implementation of the pulse trawl technique for the same reasons as at the start?
	1.2.4 Under what circumstances at the landscape level did this take place?	To determine the influence of the landscape level on the developments at the regime level	Interviews, literature, meetings	- What external factors influenced the acceptance and implementation of the pulse trawl in the Dutch flatfish fleet according to you?

The questions and topics discussed in research trees 1.1 and 1.2 give a good insight in the internal niche and regime processes and how the transition process at these two levels evolved. However, for an invention to become accepted and picked-up by the current regime, interaction between the niche and regime level is required. Studying the interaction between the niche and regime level resulted in the following research question:

3. How did the actors and institutions that were involved in the inventing, research and development and diffusion process of the pulse trawl interact with each other and with the regime actors and institutions?

Questions and topics discussed in research tree 1.3 aim to answer this research question. The interviewed actors and institutions from both the niche and regime level were asked about how findings and gathered knowledge were communicated within levels and between the two levels. Regime actors and institutions were asked whether they were involved in the processes taking place at the niche level and how they responded to the findings and developments at the niche level. Niche actors and institutions are asked whether they were involved at the processes taking place at the regime level and how they responded to the developments at the regime level. They are also asked about how the interaction between them was structured and how frequent the different actors and institutions interacted with each other. All of the obtained information on the questions and topics discussed in research tree 1.3 should enable to identify how actors and institutions interacted with each other within the two levels and between the two levels. The gathered data and information acquired during the interviews were also linked with the found literature for verification.

Head questions	Sub questions	Desired data	Methodology	Obtain data through posing these questions
How did the actors and institutions that were involved in the inventing, research and development and diffusion process of the pulse trawl interact with each other and with the regime actors and institutions?	1.3.1 How are the gathered knowledge and derived insights communicated from the niche level actors and institutions towards the regime level actors and institutions?	Information on the interaction between the niche level and regime level	Interviews, literature, meetings	- With whom did you have contact concerned the pulse trawl?
				- How do you communicate with fishermen/science/government/producer technology/sector/consumers?
				- How frequent?
				- What did you communicate?
	1.3.2 How do the actors and institutions at the regime level respond to the gathered knowledge and derived insights from the niche level?	What actions did the actors and institutions take at the regime level and how did it influence the transition process at the niche level	Interviews, literature, meetings	- What did you do with the gathered knowledge and derived insights on the pulse trawl?
				- Why?
				- When?
				- What was the effect?
				- With whom did you share the developments on the pulse trawl?
	1.3.3. How did actors and institutions interact with other actors and institutions within their own level?	Information on the interaction between actors and institutions within the niche level and within the regime level	Interviews, literature, meetings	- With whom did you have contact concerned the pulse trawl?
				- How frequent?
				- What did you communicate?

<u>Main research question</u>

Data and information collected with the questions and topics mentioned in research trees 1.1 – 1.3 are used to answer the three formulated research questions.

3.5 LIMITATIONS

One of the limitations of this case study is that the developments at the European regime level and the actions and interests of European regime actors and institutions are described from a Dutch perspective. No European regime actors and institutions were interviewed to give their perspective on the transition pathway of the pulse trawl technique. Limits had to be set on the number of interviews and the focus of this report was on the transition process of the pulse trawl technique in the Netherlands. However, it would be interesting and relevant to retrieve the perspective of relevant European regime actors and institutions on the transition pathway of the pulse trawl technique in follow-up research. It would complement the findings described in this report.

Another limitation of this case study is that not all approached actors and institutions did want to be interviewed, so information had to be obtained from other sources of information to fill the gap in the research. This was done through observations during several meetings concerned the pulse trawl technique and through a literature survey.

During the case study, it also became clear that the pulse trawl technique is a very sensitive topic. Varying interests and personal conflicts between the involved actors and institutions sometimes made it difficult for interviewees to give open responses to questions during the interview. To overcome this problem, trust was build with the interviewees by explaining the goal of my research and my position as an independent student of the Wageningen University within this research prior to the start of the interview. Besides this, agreements were made with the interviewees about the confidentiality of their information and on what information could or could not be used in the publicly available research report. The data obtained during the interviews are complemented with data obtained with the literature survey and the meetings. All these data enabled me to construct an overall picture on the transition pathway of the pulse trawl technique by using triangulation.

During this case study, only fishermen were interviewed that belonged to the first users (pioneers) of the pulse trawl technique aboard their vessel. It is likely that these fishermen have a different vision on the pulse trawl technique and also have different motives to make the transition from the conventional beam trawl to the pulse trawl technique. Therefore, it would be interesting and relevant to have interviews with fishermen belonging to the latest group of fishermen that received a license to use the pulse trawl technique in follow-up studies.

Despite these various challenges, sufficient empirical data were collected and the perspectives of all relevant Dutch stakeholder groups were covered. The empirical data are used to describe the transition process of the pulse trawl technique on flatfish in chapters 4 and 5.

4. THE TRANSITION FROM THE CONVENTIONAL BEAM TRAWL TO THE PULSE TRAWL TECHNIQUE IN THE NETHERLANDS

4.1 INTRODUCTION

In this chapter the results of the performed research for the first time period are presented. The first time period starts from 1988, when the EU ban on electrical fishing was introduced and runs till the moment on which the pulse trawl technique became accepted and picked-up by the Dutch cutter fleet. This chapter describes the transition process at both the niche and regime level. Relevant developments at the landscape level that influenced the transition process of the pulse trawl technique are also discussed.

4.2 TRANSITION PROCESS AT THE NICHE LEVEL

Inventing a pulse system

Research and development on an electric fishing gear had stopped in the Netherlands after the ban on the use of electric fishing techniques was introduced. There was a fear for an unwanted increase in fishing efficiency and fishing effort, while the beam trawl fleet was already under severe international criticism at the time. Fish quota problems already existed at the time, so an even more efficient fishing technique was undesirable since it would further complicate the political context in the Netherlands (Fisheries representative organization 2, 2014). During the interviews also another reason for the ban on using electricity with fishing was given. According to Employee of the Ministry of Economic Affairs 1 & 4 (2014) electricity was being used in the tuna fisheries in the Mediterranean Sea. Large schools of tuna were caught back then by using up to 1500V in the purse seine fisheries. This triggered a discussion amongst European member states about the use of electricity during fishing and eventually led to the European ban on the use of electricity in fishing practices.

However, the criticism on the beam trawl continued. All the results and knowledge that had been build up prior to the ban in 1988 showed the potential of an electric fishing gear. The family Verburg had recognized this potential. This family owned the company Verburg-Holland B.V. and they initiated the resumption on the research and development of an electric fishing gear on their own initiative. The project leader of the pulse trawl project at Verburg Holland B.V. had connections with people working at the Ministry, and so support from the Ministry for the project had been established (IMARES researcher, 2014). Despite the ban on electrical fishing, EU member states have the freedom to perform experiments and therefore technical research on an electric fishing gear was allowed. The Ministry facilitated the activities of Verburg Holland B.V. by giving time and space for research on one of the two research vessels of the Ministry (Employee of the Ministry of Economic Affairs 4).

Next to the support from the Ministry, Verburg-Holland B.V. received help from a scientist from the RIVO, which acted on personal title in the pulse trawl project as their scientific advisor. In those first years, exploratory research was done on the development of an electric fishing gear on flatfish, with a special focus on sole. Their goal was to develop an alternative for the beam trawl, since the beam trawl was criticized for its impact on the seabed and its high bycatch rates (Berge, van den and Bruijn, de, 2000a). Verburg-Holland B.V. was not very transparent at the time, because they feared competitors and tried to protect their industrial property rights (Berge, van den and Bruijn, de, 2000a). In those years a 4m and 7m-pulse trawl were developed, which were tested in large basins on land and in 1995 eventually at sea with a research vessel of the Ministry. The first trials showed that the quality of the fish improved, that there was a higher selectivity for larger soles, a decrease in caught benthos and a reduction in fuel consumption (Berge, van den and Bruijn, de, 2000a).

In 1998 both Verburg-Holland B.V and the Ministry were optimistic about the progress on the pulse trawl technique and they approached RIVO to give scientific guidance to the pulse trawl project (IMARES researcher, 2014). RIVO started with the testing of the 7m-pulse trawl that had been developed by Verburg-Holland B.V. in 1998 on the research vessel Tridens (Marlen, van, et al., 2007). The results of these tests were as follows:

- Catches for sole with the pulse trawl matched those of the conventional beam trawl
- Around 50% less plaice is caught with the pulse trawl compared to the conventional beam trawl
- The bycatch of benthos was reduced by 40% compared to the conventional beam trawl

These results were positive and further research on the pulse trawl was stimulated. In 2000 a 7m-beam trawl and a 7m-pulse trawl were compared in order to study their impact on the direct mortality of invertebrates living on/in the seabed. Samples were taken from the oyster grounds prior to fishing and from the trawl tracks of the two gears. The results showed a lower direct mortality for 15 taxa in the track of the pulse trawl, thereby showing the potential of the pulse trawl to have a reduced effect on benthic communities compared to the conventional beam trawl (Marlen, van, et al., 2001). After this experiment it was decided to develop a 12m-pulse trawl on request of the sector, since 12m-beam trawls were commonly being used in the Dutch commercial beam trawl fleet (Berge, van den and Bruijn, de, 2000b). Tests were done with a 12m-pulse trawl in 2001, 2002 and 2003 and eventually resulted in a gear that had equaling catches for both sole and plaice compared to a conventional beam trawl (Marlen, van, 2007).

<u>Pilot project on a commercial vessel</u>
In 2004 it was concluded that the 12m-pulse trawl was ready to be tested on a commercial fishing vessel (LEI researcher, 2014). The flatfish cutter UK153 was selected as the first commercial vessel to test the pulse trawl system that had been developed by Verburg-Holland B.V. (Stralen, van, 2005). UK153 was a cutter with a considerable share in sole quota and they had been approached in 2002 to become the first commercial vessel to test the pulse system in practice. Before starting with the pulse trawl on the UK153, the captain joined a research trip on the Tridens (Fisherman 3, 2014). When Fisherman 3 was asked why he was interested to join the pilot project, he said, "I joined a research trip on the Tridens and noticed that it was a well functioning fishing technique to catch sole with less power, a higher quality and less environmental impact" said Fisherman 3 (2014). Although he knew that the pulse trawl technique was still in its infancy, he saw potential and was willing to switch to the pulse trawl system in order to become the first commercial vessel with this fishing technique. Fisherman 3 (2014) said, "We were primarily interested in this fishing technique from an economic perspective. It is about catching your quota with the lowest possible costs". This quote suggests that

improving his economic performance was the main incentive to participate in the pilot project.

After making financial arrangements with the Ministry and the sector for the compensation of lost income and additional costs, a Verburg-Holland system was installed aboard the UK153 mid 2004 (Fisherman 3, 2014). This pulse system belonged to the Ministry and was installed on the UK153 for testing (Employee of the Ministry of Economic Affairs 2, 2014). Parties that were involved in the research on the commercial vessel were Verburg-Holland B.V., RIVO and the Agricultural Economics Research Institute (LEI). Verburg-Holland B.V. was working on optimizing the pulse trawl technique and on technical issues, while RIVO focused on ecological effect and impact studies (LEI researcher, 2014). The LEI became involved in order to monitor the economic feasibility of the pulse trawl technique and to measure whether this fishing technique could become profitable (LEI researcher, 2014). To do this, the results obtained with the UK153 were compared with vessels that had a comparable layout and performance as the UK153 before it switched to the pulse trawl. Four beam trawl cutters with a comparable layout and performance were found, and their results were used to make a comparison with the results obtained by the pulse trawl vessel (LEI researcher, 2014). These reference ships were used to compare catches, revenues, costs or combinations of these three.

Meanwhile the UK153 experienced a lot of technical problems with the pulse trawl gear (Fisherman 3, 2014). This affected the research results of both IMARES (RIVO merged into this new research institute in 2006) and LEI, because it made it hard to determine the performance of the pulse trawl technique compared to the beam trawl. A report, which compared the performance differences between the UK153 and two beam trawl vessels by Marlen, van et al. (2006), revealed the following conclusions:

- Landings of plaice and sole are significantly lower in the pulse trawl when compared to the conventional beam trawl.
- There was no significant difference in the catch rates of undersized plaice between the pulse trawl and the conventional trawl.
- In the pulse trawl, the catch rates of undersized sole were significantly lower than in the conventional beam trawl.
- The catch rates of benthic fauna (*Astropecten irregularis*, *Asterias rubens*, and *Liocarcinus holsatus*) were significantly lower in the pulse trawl compared to the conventional beam trawl.
- There are indications that undersized plaice are damaged to a lesser degree in the pulse trawl and will survive better with the pulse trawl. Based on previous research, these results would indicate a survival rate of plaice in the pulse trawl that is twice as high as in a conventional beam trawl. But since the method of determining damage to fish by visual observation is subjective, this conclusion should be treated with caution.

The report of Stralen, van (2005) concluded that the fuel consumption of the UK153 went from 38.000 liters per week with the beam trawl to 21.000 liter per week with the pulse trawl. That is a reduction of 45% in liters fuel consumption per week. Besides the fuel reduction, higher prices were paid for fish caught with the pulse trawl due to the improved quality of the fish. At the end of the pilot project with the UK153, a balance was made. The economic and ecological aspects of the pulse trawl gear were analyzed and reported to the involved regime actors, which had organized themselves in the steering committee pulse trawl. It was concluded that the pulse trawl gear was not yet economically feasible, but that is remained a fishing gear with potential (LEI researcher, 2014). The LEI researcher (2014) stated that, "When taking into account the technological progress of the gear, the increase in reliability of the gear, the growing knowledge on optimal fishing grounds for the gear, the rising fuel prices and its ecological performance compared the beam trawl, then it is a very interesting alternative for the beam trawl". However, at the end of the pilot project with the UK153 at the start of 2007, the Dutch fishing sector decided to stop funding further research on the pulse trawl. They heavily questioned the economic feasibility of the pulse trawl and did not believe that the gear could become profitable (LEI researcher, 2014) (Fisherman 3, 2014).

The UK153 decided to continue fishing with the pulse trawl on their own expense, since progress had been booked on the performance of the pulse trawl and the owner believed that further research on the pulse trawl was required (Fisherman 3, 2014). An arrangement was made with the Ministry about the use of the pulse gear, which was still owned by the Ministry, and they continued fishing with the pulse till mid 2007. Then they decided to sell their vessel to another ship-owner, which they were already planning for some time (Employee of the Ministry of Economic Affairs 4, 2014). Although the owner of the UK153 was very optimistic about the pulse trawl technique, they decided not to choose this fishing technique on the newly built vessel. When asked for his motivations to quit with the pulse trawl technique experiment, Fisherman 3 (2014) said, "At the time that we started to build a new ship, the pulse trawl technique was still a prohibited fishing technique. Therefore the bank was not interested to invest in the pulse trawl technique and we decided to switch to a flyshooter". This quote shows that the ban on using electricity to catch fish was a major issue for the UK153 to continue with the pulse trawl technique, since the uncertainty around the ban blocked investment opportunities.

<u>Study Group Pulse and SumWing</u>

As a consequence, the research and development of the pulse trawl came in an impasse. However, there was a group of fishermen who were interested in switching to the pulse trawl technique. This group saw potential in the pulse trawl technique, but acknowledged that there was still a lot of progress that needed to be booked. When Fisherman 1 (2014) was asked for his motives to resume research on the pulse trawl technique, he said, " We saw that it went wrong with the fuel price, the price for gasoline was going through the roof. There were many weeks in which the expenses were higher than the value of landings. So we were working hard for the whole week, while getting nothing in return and that is when the pulse trawl came into the picture". This quote indicates how this group of fishermen thought about the pulse trawl technique. Technological changes were required on the pulse trawl and the group of fishermen wanted to do this by organizing themselves in a group, while receiving support from other actors and institutions (LEI researcher, 2014). A new governance arrangement made its first appearance in the Dutch fishing sector, namely the establishment of the Study Group Pulse & SumWing in 2008 (Vos, de & Mol, 2010).

Five vessel owners participated in the Study Group Pulse and SumWing, being the owners of the TX68, the TX36, the SL1, the UK246 and the TX38 (LEI researcher, 2014). Since the owner of UK153 had build up quite some experience with the pulse trawl, he was approached to become the chair of the Study Group Pulse & SumWing. The participants of the Study Group Pulse & SumWing regularly came together to discuss how to move on with the pulse trawl technique. Visits to Verburg-Holland B.V. were organized to discuss progress on the technological aspects of the pulse technique. The company Verburg-Holland B.V. also continued to work on the pulse trawl after the pilot project with the UK153 and kept receiving support from the Ministry to keep on developing this technique (LEI researcher, 2014). Both IMARES and the LEI had a facilitating role in all Study Group by organizing meetings, making minutes of meetings and to act as liaison with the Ministry for arranging the experimental licenses (LEI researcher, 2014). All kinds of experts were invited to meetings of the Study Group to share and spread information. These experts ranged from fishnet suppliers to scientists that had done effect studies of the pulse trawl on elasmobranches (LEI scientist, 2014).

In 2008 the Ministry offered a subsidy to the five vessel owners for the installation of a pulse trawl system. This subsidy covered 40% of the investment in a pulse system up to a maximum investment of 176.000 euro (Employee of the Ministry of Economic Affairs 4, 2014). It took the Ministry a lot of effort, but eventually a derogation was arranged for 5% of the beam trawl fleet in the TAC and Quota regulation 43/2009 to switch to the pulse trawl technique, which enabled the use of the pulse trawl till mid 2011 (Employee of the Ministry of Economic Affairs 1, 2014). Despite the subsidy and the derogation, the five vessel owners could not make the transition to the pulse trawl technique, because Verburg-Holland requested more time and money for the development of a reliable pulse trawl system (LEI researcher, 2014). Time was a limiting factor, since both the subsidy and the derogation had a set time limit.

Meanwhile, another innovation had been successfully developed and implemented in the Dutch flatfish sector. This innovation was called the SumWing, which had been developed by HFK Engineering in cooperation with the TX36 and is shown in figure 8. The beam of a beam trawl is replaced with a wing, which results in a reduction of bottom impact and drag. This reduction on bottom impact and drag resulted in a reduction of 15% in fuel consumption and thereby a reduction in fuel costs (Technological company 2, 2014).

Figure 8. SumWing: *It has been developed to replace the beam of a beam trawl for a wing, thereby reducing the fuel consumption.*

In the Study Group, the idea was born on integrating the pulse system of Verburg-Holland B.V. into the SumWing developed by HFK Engineering in order to reduce the bottom impact and gear drag even further, with the goal to decrease the fuel consumption and costs even further (LEI researcher, 2014). According to Technological company 2 (2014), "The fishermen were already getting used to the SumWing and they considered it to be stupid to switch back to a pulse construction with a beam, while knowing that the SumWing functioned better". This quote shows that HFK had another vision on the application of the pulse trawl technique. However, this plan was not receiving priority of the company Verburg-Holland B.V., which kept its focus on sorting out the technical and financial challenges of their own pulse system (Visserijnieuws c, 2009).

In 2009, the TX68 decided to wait no longer and to switch to a pulse trawl system. When Fisherman 2 (2014) was asked for his motives to make a switch to the pulse trawl technique, he said, "Our choice to switch to the pulse trawl was based on reducing the fuel consumption. That was the main reason to switch, since the fuel prices kept rising. The catchability for sole was just as good with the pulse trawl as with the beam trawl, so we considered it to be a good alternative". Thereby they became the first commercial vessel that switched to a pulse trawl system. They choose to buy the pulse system that had been used on the UK153 from the government and to give it an update with the newest available technology by Verburg-Holland B.V. (Fisherman 2, 2014).

The other four vessel owners started to lose patience with Verburg-Holland B.V. and decided to develop a SumWing with an integrated pulse system in cooperation with HFK Engineering. Due to this decision, the Study Group Pulse & SumWing lost its function. Sharing knowledge had become difficult due to commercial interests and the group had split up in fishermen supporting the Verburg system (TX68) and fishermen supporting the HFK system (TX36, TX38, SL3 and UK246). After a failed mediation attempt between Verburg-Holland B.V. and HFK Engeneering, the Study Group Pulse & SumWing was split. The TX36, the SL3, the TX38 and the UK246 decided to move on with HFK Engineering and in October 2009 the first prototype Pulse Wing was installed aboard the TX36 (Visserijnieuws c, 2009). Soon after the TX36 started fishing with the Pulse Wing, the SL3 followed. Both vessels experienced great problems with the first prototype and as a result, the UK246 withdrew itself as the next candidate for the Pulse Wing (LEI researcher, 2014). HFK Engineering approached the Belgian research institute ILVO to sort out the problems of the first prototype of the Pulse Wing (Visserijnieuws c, 2009). According to Technological company 2 (2014), he had to turn to ILVO for help since IMARES scientists had signed a confidentiality agreement with Verburg-Holland B.V/Delmeco. This confidentiality agreement troubled the interaction between the Pulse Wing group and the research institute IMARES (Technological company 2, 2014). In the meantime, the SL3 experienced so many technological problems that they temporarily switched back to the beam trawl. After HFK Engineering had come up with a new pulse module and a more reliable system, the SL3 switched back to the Pulse Wing in 2010. Soon after that, the TX38 was the last vessel of the former Study Group Pulse that made the switch to a Pulse Wing (LEI researcher, 2014). Meanwhile, the Delmeco Group had acquired Verburg-Holland B.V. (Technological company 1, 2014).

<u>Making the step from innovation to implemented fishing technique</u>

The first results of the pulse trawlers showed positive financial results as is presented in figure 10. Presentations were given on the economic performance of the pulse trawl technique at a variety of fishing communities like Urk, Scheveningen and Stellendam (LEI researcher, 2014). These positive financial results started to change the attitude of the people in the fishing sector. A catch comparison was done between two pulse trawl vessels (TX36 and TX68) and a tickler chain beam trawler (GO4). Results showed a decrease in fuel consumption and costs, good catches and decent economic results as presented in figure 9 (LEI researcher, 2014). Results of the study of Marlen, van et al. (2011) also showed a decrease in bycatch of fish discards and benthic species, and a decrease in bottom impact with the pulse trawl (LEI researcher, 2014). Suddenly, the negative attitude of the fishermen had changed to a more optimistic attitude and more parties started to inform on the pulse trawl technique.

Once a leading fishing company had placed an order for four Pulse Wings, the rest of the Dutch flatfish fleet wanted to switch to the pulse trawl technique as well (LEI researcher, 2014)(Employee of the Ministry of Economic Affairs 4, 2014). This brings us to the end of the transition process at the niche level for this time period. Of course events at the niche level were influenced and affected by developments at the regime level. Therefore the transition process at the regime level is now going to be discussed, in order to get a multi-level perspective on the transition of the pulse trawl technique.

Ship	Fuel	Perc.	Fuel costs	Mean number of baskets (35 kg) per haul	Perc.	Landings	Gross Revenue	Net Revenue	Perc.
	(x1000 ltr)	(%)	(€; 1 ltr = 0.56€)		(%)	(kg)	(€)	(€)	(%)
GO4	35	**100**	19600	30	**100**	6620	29000	9400	**100**
TX36	14	**40**	7840	10	**32.9**	4580	25366	17526	**186**
TX68	19	**54**	10640	12	**40.1**	5078	25192	14552	**155**

Figure 9. Results catch comparison: *Summary of the overall performance for the three vessels GO4 (beam trawler), TX36 (Pulse Wing) and TX68 (Pulse trawl) (Marlen, van et al., 2011).*

4.3 TRANSITION PROCESS AT THE REGIME LEVEL

Inventing a pulse system

The initiative to develop a pulse system, after the ban on electrical fishing of 1988, came from the company Verburg-Holland B.V.. At the time, the Ministry was aware of the work on inventing a new pulse system. When asked about the role of the Ministry at this stage of the transition process, the Employee of the Ministry of Economic Affairs 4 (2014) said, "The role of the Ministry was mainly to provide time and space for research aboard the research vessels of the Ministry". Main reason for the Ministry to facilitate the research on inventing a pulse system was probably that the criticism on the beam trawl remained after the ban of 1988 and no alternative had been found since. Employee of the Ministry of Economic Affairs 2 (2014) stated that: "There was quite some criticism on the beam trawl, so then it is wise to look for an alternative. I think that the pulse trawl technique was considered to be the main alternative, because the Ministry had already invested a lot in it". Concerns and criticism on the growing environmental impact of the conventional beam trawl had already resulted in setting a limit on the maximum width of a beam trawl (12m) and a limit on the maximum hp of a vessel (2000hp) (IMARES researcher, 2014). The term ecosystem approach also became more and more important in fisheries management and was more frequently being used by ICES. The ecosystem approach no longer looked solely on the effects at single species, but on the ecosystem as a whole (IMARES researcher, 2014).

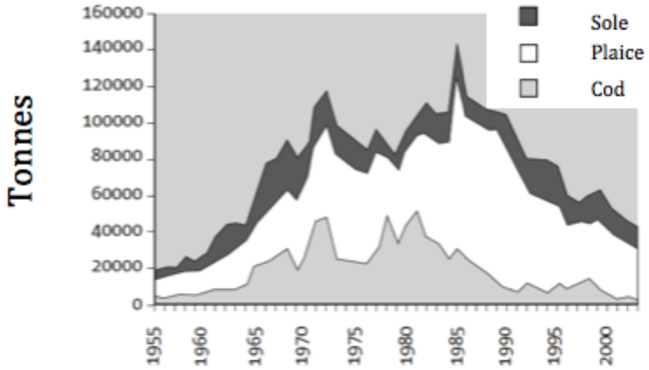


Figure 10. History of the total landings of Sole, Plaice and Cod in the Netherlands: All three landed fish species showed declining trends in the 90's and early 2000s (Task Force Duurzame Noordzeevisserij, 2006).

In the late nineties, the fishing industry became involved in the transition process of the pulse trawl technique through the Federation of Fishing Associations[3] (FFA), which represented a part of the fishing industry (Marlen, van, et al., 2014). Both the Ministry and the fisheries organisation acknowledged that the pulse trawl technique of Verburg-Holland B.V. worked (Berge, van den & Bruijn, 2000a). In order to continue the research on the development of the pulse trawl technique, financial investments were required. The fishing sector was only interested in investing when Verburg-Holland B.V. would develop a pulse trawl with a width of 12m, since these were used in the beam trawl fisheries (Berge, van den & Bruijn, 2000a). Although the fishing sector had already made investments in the pulse trawl project in the year 2000, many did not feel the need to invest in an alternative fishing technique for the beam trawl. They were sceptical about the pulse trawl and did not agree with the criticism on the beam trawl (Berge, van den & Bruijn, 2000a). However, according to the chair of the FFA, further research was necessary to solve the bycatch problems and to decrease fuel consumption (Berge, van den & Bruijn, 2000b). To continue research on the pulse trawl, an experimental license for research had to be arranged by the Ministry. Receiving such an experimental license was possible, but finding ways on legalizing the use of electricity during fishing practices would only be investigated by the Ministry after more research had been done on the pulse trawl technique (Berge, van den & Bruijn, 2000a).

More and more fishermen had trouble with keeping their heads above the water due to rising fuel prices, lower catches (see figure 10) and decreasing quota (Ministerie van Landbouw, Natuur en Voedselkwaliteit, 2006). Meanwhile, the European Commission announced that more money should be invested in sustainable fishing techniques and innovations and increased the budget that was available to invest in sustainability-linked innovations (European Commission, 2004). Before 2003, the Ministry made money available for innovations on an ad hoc basis, usually for research on the pulse trawl (Tweede Kamer der Staten-Generaal, 2008). This money came from the 'Diesel fund[4]' (Employee of the Ministry of Economic Affairs 2, 2014). After 2003 the European Fisheries Fund (EFF) became a much more prominent tool from Brussels. Eventually, the budget at the fisheries department at the Ministry had grown to 140 million euro (Employee of the Ministry of Economic Affairs 2, 2014). According to Employee of the

[3] The Federation of Fishing Associations, which was also known as the 'Federatie van visserijverenigingen' in Dutch. Nowadays this fishing association is called 'VisNed'.
[4] A fund of the Dutch Ministry for investments in sustainable fisheries (Stralen, van, 2005).

Ministry of Economic Affairs 2 (2014), “That money had to be invested over a longer period of time, so then we started to make strategic plans, an innovation plan for the duration of seven years”. It meant that structural investments could be done in alternative fishing techniques, like the pulse trawl technique. The major happenings for this phase are shown in figure 11.

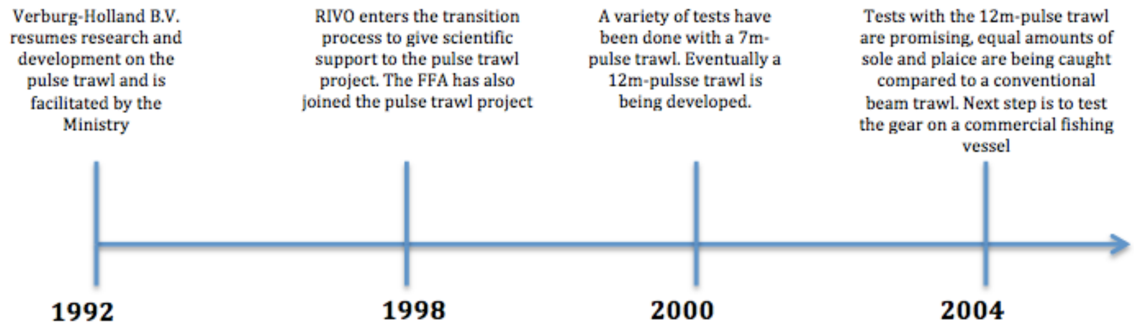


Figure 11. Timeline 1992-2004: *A timeline presenting the most important happenings in the phase of inventing a pulse system.*

<u>Pilot project on a commercial vessel</u>
Developments at the niche level made clear that the pulse trawl technique was ready to be tested on a commercial vessel. Now that the Ministry had made money available to invest in research on the pulse trawl technique and received permission of the European Commission to test the pulse trawl, it was important to find a fisherman that was willing to test this technique in practice. The LEI was asked to select a flatfish cutter that could be approached for the pilot project. When the LEI researcher (2014) was asked how they selected a suitable candidate, he said, “In consultation with the representatives of the fishing industry we decided to approach the UK153 around 2002/2003. The reasons for selecting the UK153 were that they owned a considerable amount of quota on sole, it was a modern cutter, the owner was a serious entrepreneur and he had a certain standing within the fishing industry”. Financial arrangements were made between the Ministry and the ship-owner of the UK153 and a Verburg-Holland system was placed aboard the UK153 in 2004.

In 2005, the Ministry started the steering group pulse fishing, which consisted of the Ministry and the representatives of the fishing industry, being the FFA and the Dutch Fishermen’s Federation[5] (DFF). This steering group supervised and guided the pilot project. IMARES and LEI acted as advisors for this group and provided information on the pilot project during meetings of the steering group pulse fishing (LEI researcher, 2014). NGO’s were not included in the steering group, but they followed the pilot project of the pulse trawl technique with great interest. World Wildlife Fund (WWF) and the North Sea Foundation supported research on alternative fishing techniques for the beam trawl (NGO employee, 2014). However, Greenpeace also criticized the pulse trawl pilot project, because according to them the pulse trawl was just a little step in the right direction. Greenpeace criticized the pulse trawl technique, because the nets were still damaging the seabed, it still caught unwanted bycatch and therefore they considered it an unsustainable fishing method (Greenpeace, 2005). WWF and the North Sea Foundation were also concerned about the lack of environmental impact studies. The NGO employee (2014) stated that, “In the beginning of the pilot project, we had indicated that research should not solely focus on what was caught in the fishing nets,

[5] The Dutch Fishermen’s Federation, which is also known as the ‘Nederlandse Vissersbond’ in Dutch.

but also to look at everything that was not retained in the fishing nets. Already back then they invested too little in ecosystem-oriented research". This quote suggests that Dutch NGO's were concerned about a too narrow focus on the technique, instead of research on the impact of this fishing technique on other domains, like ecosystem-oriented research.

In 2006 a group of interested beam trawl fishermen, Verburg-Holland B.V. and the steering group pulse fishing had a meeting about the wider introduction of the pulse trawl technique (Visserijnieuws d, 2006). The European Commission had indicated in 2005 that a wider introduction of the pulse trawl technique was possible if ICES would provide a positive advice on this fishing technique (Visserijnieuws d, 2006). ICES received a request in 2005 from the European Commission Directorate General for Fisheries and Maritime Affairs (DG MARE) to give advice on the ecosystem effects of allowing electric pulse trawling on a commercial scale (ICES, 2006). The ICES Working Group on Fishing Technology and Fish Behavior (WGFTFB) formed an ad hoc expert group. This expert group received seven reports on research conducted by RIVO to evaluate and a review and a summary of their advice and recommendations can be found in Appendix 4 (ICES, 2009). One of the complaints from the scientists was that not all the information on the pulse trawl characteristics was being shared:

"The evaluation of the system has been hampered by lack of detailed information on the pulse characteristics used (pulse shape, height, frequency etc.) all of which are known to affect fish in various ways" (ICES, 2006).

Their findings were reported to the Advisory Committee on Fishery Management (ACFM). This advice was adopted by the ACFM and forwarded to the STECF, which largely agreed with the WGFTFB advice and concluded:

"Although the development of this technology should not be halted, there are a number of issues that need to be resolved before any derogation can be granted".

However, the EU ultimately rejected this assessment and introduced a derogation to allow electric beam trawling on a restrictive basis under Annex III (4) of Council Regulation (EC) No. 41/2006 (ICES, 2007). The derogation stated that 5% of the fleet was allowed to use the pulse trawl on a restricted basis, provided that attempts were made to address the concerns expressed by ICES. This derogation has been granted every year since 2007 (ICES, 2009). Main concerns expressed by the expert group in 2006 concerned the potential spinal damage to cod, the potential effects on invertebrates and effects on electric sensory systems of elasmobranches. Around that time, a scientific paper was published by Yu et al. (2007) about the rise and fall of electrical beam trawling for shrimp in the East China Sea. This paper discussed how failed management of the electrical beam trawl in China had led to the misuse of electrical parameters, which resulted in damage to juvenile shrimps and other benthic species. As a result, this fishing method had been banned in China since 2001. ICES demanded more research and was precautionary concerned the permanent admission of the pulse trawl technique (Marlen, van, 2008). Therefore the Netherlands (IMARES) started with research on the pulse trawl effects on cod, invertebrates and elasmobranches to address the expressed concerns by the ICES expert group (ICES, 2009).

Although permission was granted from the European Commission for a wider introduction of the pulse trawl technique, the Dutch fishing sector remained pessimistic about the technique due to technological problems and lower landings (LEI researcher, 2014). During a meeting of the steering group pulse fishing at the end of 2006, the fishing sector representatives announced that the sector was not willing to invest in the pilot project anymore and they wanted to quit (LEI researcher, 2014). As a consequence the pilot project stopped and the UK153 decided to continue fishing with the pulse trawl technique on their own expense till they sold their vessel mid 2007 (LEI researcher, 2014). The pulse trawl technique developments came to an impasse. The major happenings for this phase are shown in figure 12.

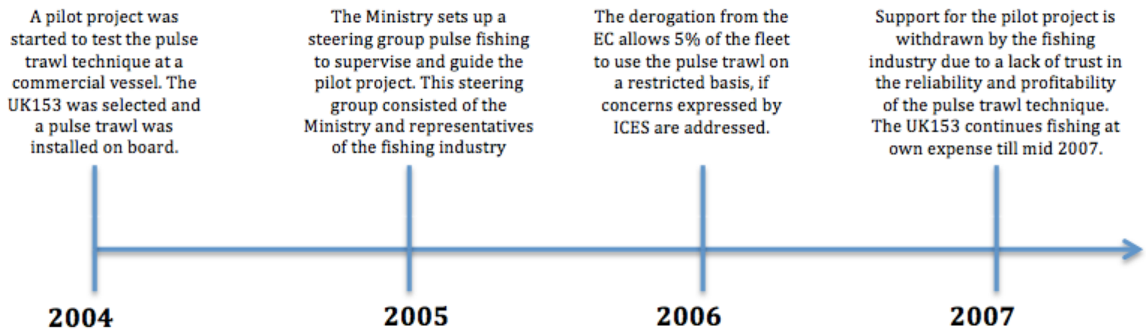


Figure 12. Timeline 2004-2007: *A timeline presenting the most important happenings in the phase of the pilot project on a commercial vessel.*

At the landscape level the concerns and criticism about the negative environmental impact of the conventional beam trawl remained growing. The fuel price was also rising as is shown in figure 13. Next to the rising fuel price, this figure also shows that the wage per adult crewmember equally declined, since labour costs are a share of the trip's profit. So if the costs for fuel increase and the gross returns of a trip remain stable, the remuneration for labour decreases (Hoof, van, 2010).

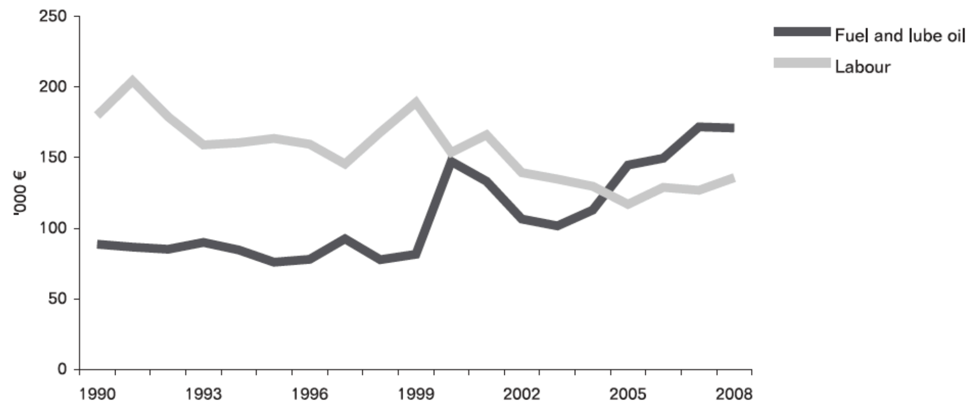


Figure 13. Dutch cutter fleet development in costs of fuel and lubricants and of labour: *Developments from 1990-2008, which are based on a real average per vessel (Hoof, van, 2010).*

Meanwhile the decreasing plaice quota (see figure 14) and the decreasing total landings of the Dutch cutter fleet (figure 10) put pressure on the regime level. The amount of catches decreased, which negatively affected the revenues, while costs kept rising due to the rising fuel prices. All these landscape pressures lead to a negative net result of the Dutch beam trawl fleet as is shown in figure 15.

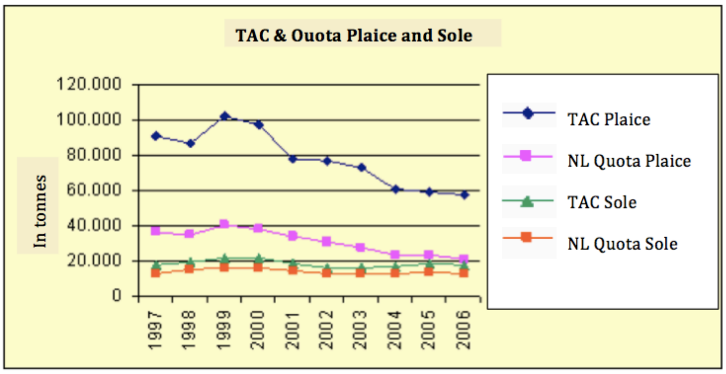


Figure 14. Developments in the TAC and Quota for plaice and sole: *Developments from 1997-2006 in tonnes (Productschap Vis, 2008).*

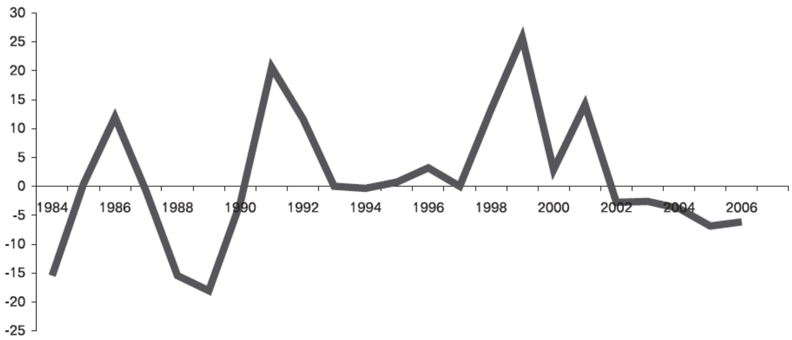


Figure 15. Net results of Dutch North Sea beam trawl fleet: *LEI statistics on the net results in million Euros (Hoof, van, 2010).*

Study Group Pulse & SumWing

Because of the deteriorating economic situation in the North Sea fisheries (see figure 16), the Ministry started the 'Task Force Sustainable North Sea Fisheries[6]' in 2005. This Task Force consisted of representatives of the fishing industry, Civil Society Organisations (CSO), scientists and policy officers. They were instructed to develop an economic and environmental sustainable perspective for the North Sea cutter fleet (Task Force Duurzame Noordzeevisserij, 2006).

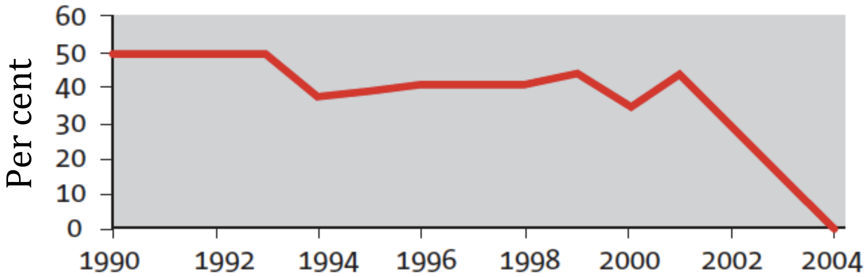


Figure 16. Solvability of the Dutch cutter fleet: *The solvability has drastically declined since 2001 (Task Force Duurzame Noordzeevisserij, 2006)*

This Task Force published an advice report in 2006, which was called 'Fishing with Headwind[7]'. The report described the urgent situation in the Dutch fishing industry and came with six messages for all actors and institutions involved in the Dutch fishing industry (see Appendix 3). One of the key issues described in the report was that innovation was required and therefore the report advised to setup an innovation

[6] The Task Force Sustainable North Sea Fisheries, which is also known as the 'Task Force Duurzame Noordzeevisserij' in Dutch.
[7] Fishing with Headwind, which is also known as 'Vissen met tegenwind' in Dutch.

platform. As a result the Ministry installed the Fisheries Innovation Platform[8] (FIP) in 2006. This platform should support innovations that stimulate a profitable and sustainable development of the North Sea (Task Force Duurzame Noordzeevisserij, 2006). The FIP consisted of people active in the fishing industry, scientists, CSO's, the Ministry and government (Visserij Innovatie Platform, n.d.). So the FIP was responsible for triggering and steering innovations in the fisheries sector, and one way of doing that was by setting up Study Groups[9] for fishermen.

During a FIP-meeting, LEI and IMARES were asked to give advice on how to continue with the pulse trawl technique now that the pilot project had stopped. The FIP was advised to continue investing in the pulse trawl technique, since it was considered as a serious alternative for the beam trawl with both economic and environmental benefits (Visserij Innovatie Platform, 2007). LEI advised the Ministry to upscale the pulse trawl project to five vessels and to commit a Study Group to the project (Visserij Innovatie Platform, 2007). The Ministry submitted this advice to the FIP and they unanimously agreed that the pulse trawl technique had to be a priority for the flatfish sector as being an innovative development on reducing fuel consumption and discards (LEI researcher, 2014). As a consequence, the Study Group Pulse & SumWing was established in 2008, which consisted of a group of fishermen that were willing to test and develop the pulse trawl technique further. These fishermen had followed the pilot project of the UK153 and in contrast to the majority of the fishing industry, they saw potential in this fishing technique. They expressed their interest in the fishing technique and were willing to develop and test this fishing technique even further (Fisherman 1, 2014)(Fisherman 2, 2014).

Now that a group of fishermen was found that were willing to test the pulse trawl technique on a commercial vessel, the Ministry had to ask the European Commission for permission on subsidizing the installation of the pulse trawl technique on five commercial vessels. They managed to arrange an investment scheme in 2008 for the five vessels that were part of the Study Group, which covered 40% of the investment in a pulse system, with a maximum investment of 176.000 euro per vessel (Employee of the Ministry of Economic Affairs 4, 2014). The Ministry had set itself the goal to replace 40% of the beam trawl cutters with another fishing method and to halve the amount of discards by 2013 (Tweede Kamer der Staten Generaal, 2008). Next to the pulse trawl technique, the FIP also supported other innovative fishing techniques like flyshooting, outrigging, hydrorigging and the SumWing. In 2008, the FIP granted a subsidy to integrate the pulse trawl technique in the SumWing in order to realize a further reduction in bottom impact and fuel consumption (BluePort, n.d.).

In response to the expressed concerns of the ICES expert group, the Ministry decided to invest in additional research in order to increase the chance of arranging the permanent admission of the pulse trawl technique. In 2009 the Netherlands, in consultation with the European Commission, requested ICES to review the research reports and to provide updated advice on the ecosystem effects of the pulse trawl (ICES, 2009). These research reports were:

[8] The Fisheries Innovation Platform, which is also known as the 'Visserij Innovatie Platform' in Dutch.

[9] A Study Group consists of fishermen from the same fleet segment but from different regions in the Netherlands. These fishermen work together, exchange knowledge and are facilitated by scientists. Main goal of these Study Groups are to overcome the lack of cooperation among fishermen from different regional areas, and at the same time stimulate and empower fishermen to innovate towards more sustainable fisheries (Vos, de & Mol, 2010).

1. The effect of pulse stimulation on biota – Research in relation to ICES advice – Progress report on the effects to cod (De Haan et al., 2009a).
2. The effects of pulse stimulation on biota – Research in relation to ICES advice – Effects on dogfish (De Haan et al., 2009b).
3. The effect of pulse stimulation on marine biota – Research in relation to ICES advice – Progress report on the effects on benthic invertebrates (Van Marlen et al., 2009)

The conclusions of these three reports can be found in Appendix 6. Based on the expert reviews of these three reports, ICES concluded that:

- The experiments are a valuable further step to evaluate the ecosystem effects of fishing with pulse trawls.
- The experiments indicate minimal effects on elasmobranches and benthic invertebrates.
- Laboratory experiments on elasmobranches, benthic invertebrates, and cod to test the effects of electric pulses were generally well designed and interpreted correctly. However, the experimental results have some weaknesses as discussed below.
- Electric pulses resulted in vertebral injuries and death of some cod that were in close proximity (<20 cm) to the conductor emitting the electric pulses. There is inconclusive evidence that the catch efficiency of cod by pulse trawls is higher than for conventional beam trawls (see attached review by Norman Graham). Widespread use of the pulse trawl has the potential to increase fishing mortality on cod as a result of injuries caused by electric pulses (and possibly higher capture efficiency) but further research is needed to draw firm conclusions.
- While the results of laboratory experiments are informative, many factors could result in different effects during actual fishing operations. In particular, specifications contained in the derogation for the pulse trawl allows a wider range of electric pulse characteristics than were tested in the experiments. Therefore, pulse trawls permitted under the EC derogation may generate substantially different effects than those observed in the experiments.
- This advice is narrowly based on the review of three reports provided by The Netherlands. Concerns and uncertainties raised in the advice may be addressed by further research, refinement of the derogation, and monitoring the fishing operations and performance of vessels using pulse trawls.

ICES came with further recommendations for research (Appendix 7) and the Netherlands was given permission to continue using the pulse trawl technique for 5% of the cutter fleet for the next 1,5 years.

Meanwhile, the TX68 and TX36 had already made the switch to the pulse trawl technique. At the end of 2009 the Treaty of Lisbon came into force. It influenced the decision making process around the provision of the derogation for 5% of the fleet on electrical fishing. This derogation had been part of the technical measures, which was annually being renewed during the TAC and quota allocation in consultation with the European Council. However, all of this changed when the Treaty of Lisbon came into force, because now also the European Parliament had a voice (Employee of the Ministry of Economic Affairs 1, 2014). Although the European Council can allocate the TAC and quota independently without involving the EP, this is not the case for all accompanying technical measures. These are treated in a separate regulation (Employee of the Ministry of Economic Affairs 1, 2014). So the European Council could no longer annually determine the technical measures by themselves without involving the EP. The European Council decided to take transitional measures and to treat the accompanying technical measures of the TAC and quota allocation as a separate regulation, which allowed the use of the pulse trawl for the next 1,5 year (Employee of the Ministry of Economic Affairs 1, 2014). Figure 17 highlights the major happenings for this phase in the transition process of the pulse trawl technique.

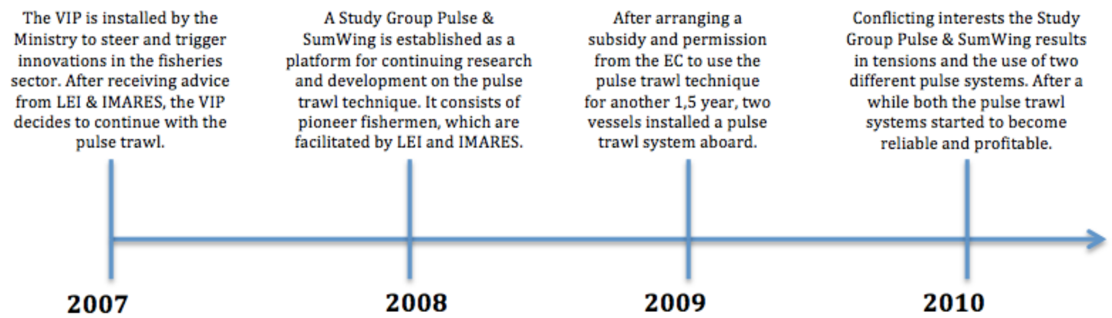


Figure 17. Timeline 2007-2010: *A timeline presenting the most important happenings in the phase of the Study Group Pulse & SumWing.*

In the meantime, a new electrical fishing technique on shrimp started to gain attention from the Dutch fishing sector. This pulse trawl on shrimp had been developed in Belgium by the ILVO. The Study Group on sustainable shrimp fisheries had visited ILVO to further explore the possibilities of this gear. Plans were made to test this gear on a commercial vessel somewhere in 2010 by using a subsidy from the Waddenfonds (Wadden Sea Fund) (Kenniskring visserij, 2009). This meant that the pulse trawl technique on flatfish was no longer the only innovative fishing technique using electricity to catch marine organisms in the Netherlands.

<u>Making the step from innovation to implemented fishing technique</u>

The commercial beam trawl vessels that had switched to the pulse trawl technique started to become successful and proved that it was a profitable fishing technique that could be used at both hard and soft soil types in the North Sea (Employee of the Ministry of Economic Affairs 4, 2014). Other vessels could still register for an experimental license, since the 5% corresponded with 22 vessels (Employee of the Ministry of Economic Affairs 3, 2014). When Employee of the Ministry of Economic Affairs 3 (2014) was asked how this was being calculated, he said, "We had 440 cutters at the time, if you include the shrimp cutters, so it is right when you have 22 experimental licenses". This means that no distinction in gear code or target species was made and that a broad interpretation of 5% of the cutter fleet was used.

However, the fishing sector struggled to get loans from the bank to invest in the pulse trawl technique and asked the government for a guarantee scheme (Visserijnieuws e, 2010). The uncertainty about the persistence of the 5% experimental licenses for the pulse trawl technique was an obstacle to invest in the technique for both the fishermen and the banks. However, something suddenly triggered other vessel owners to register for an experimental license at the Ministry. LEI researcher (2014) stated that, "After a leading fishing company had ordered four Pulse Wings, the other fishermen started to ask me where and how they could register. There were only a few more days to go before the registration period ended". The investment in four Pulse Wings by one of the leading fishing companies was a sign for other fishermen that the pulse trawl technique had perspective, otherwise such an investment could not be justified (LEI researcher, 2014)(Employee of the Ministry of Economic Affairs 4, 2014).

Regime actors and institutions did not interfere with the conflict at the niche level and left the choice between the Delmeco-system or the HFK-system to the fishing industry (LEI researcher, 2014)(Employee of the Ministry of Economic Affairs 4, 2014). Employee of the Ministry of Economic Affairs 4 (2014) said, "We have always encouraged that multiple suppliers would come. That has a competitive effect on the market, which only benefits the fishermen. Not only when considered price technically, but also in the development of the technique". This quote characterizes the attitude of most Dutch regime actors and institutions at the time. The Dutch regime actors and institutions kept their hands of the developments at the niche level. Both pulse trawl systems had to prove themselves in practice.

Eventually more fishermen had registered then pulse trawl licenses were available, so the amount of licenses was stagnating a wider transition to the pulse trawl technique (Visserijnieuws f, 2010). Three vessels that had registered for a pulse trawl license wanted to install a pulse trawl system for shrimp aboard (Visserijnieuws f, 2010). No distinction had been made concerned a pulse trawl on flatfish or shrimp in these first experimental licenses, so these vessels were allowed to switch to a pulse trawl system (LEI researcher, 2014). The pulse trawl technique had now made the step from an innovative idea to a broadly implemented fishing technique in the Dutch cutter fleet. The major happenings for this phase are shown in figure 18.

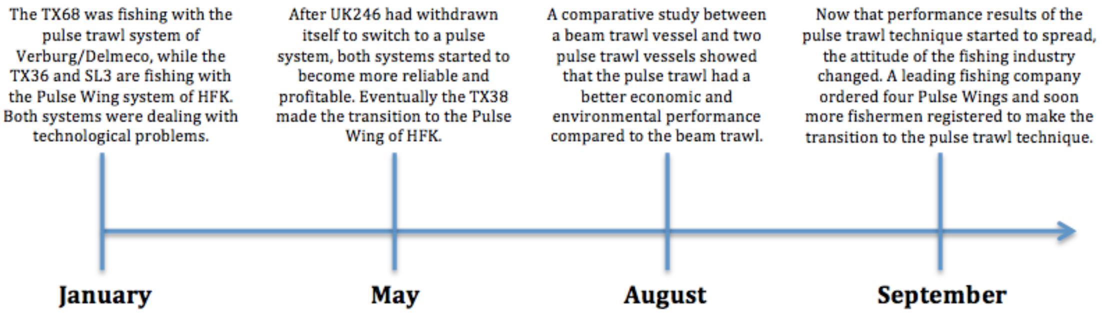


Figure 18. Timeline 2010: *A timeline presenting the most important happenings in the phase of making a step from innovation to an implemented fishing technique.*

4.4 CONCLUSION

The first time period describes how the pulse trawl technique was eventually being accepted and implemented by the Dutch regime actors and institutions. Relevant events for this time period that had a major influence on the transition pathway were the introduction of the Study group, the developments at the landscape level and the competition between two different pulse trawl systems. Now that the pulse trawl technique was being accepted and implemented by the Dutch regime actors and institutions, a new phase followed. A wider introduction of the pulse trawl technique would depend on the acceptance of the pulse trawl technique by the European regime actors and institutions. This part of the transition pathway is described in the second time period.

5. PERMANENT ADMISSION OF THE PULSE TRAWL TECHNIQUE IN THE EU

5.1 INTRODUCTION

In this chapter the results of the performed research for the second time period are presented. The second time period starts from 2010 when the pulse trawl technique was accepted and implemented by the Dutch flatfish fleet and runs till the end of 2014. It mainly describes how Dutch niche and regime actors and institutions tried to expand the application of the pulse trawl technique in the Dutch cutter fleet, while dealing with the European ban on electric fishing. This chapter describes the transition process of this time period at both the niche and regime level. Relevant developments at the landscape level that influenced the transition process of the pulse trawl technique in this time period are also discussed.

5.2 TRANSITION PROCESS AT THE NICHE LEVEL

Expanding the pulse trawl technique to 42 cutters

In total, 34 fishermen had registered to make the switch to the pulse trawl technique in September 2010. However, only 21 experimental licenses were available and therefore the number of registered fishermen exceeded the number of available experimental licenses (Visserijnieuws f, 2010). As a result of that, fishermen urged the DFF and VisNed to arrange additional licenses. Meanwhile, the pioneer vessels kept promoting the pulse trawl technique through demonstrations and by participating in research. Fisherman 2 (2014) said, “Often politicians were invited onboard at Scheveningen and then we did a couple of hauls offshore to demonstrate what we are doing. We showed them how lively the fish were and that they were completely undamaged”. Next to these fishing trips, demonstrations were given in the ports by using large tubs. People could hold their hands in the tub to feel the pulses from the pulse trawl (Fisherman 1, 2014). According to the Technological company 2 (2014), they actively tried to influence the perception of people concerned the pulse trawl technique. Technological company 2 (2014) said, “We were so enthusiastic that we went to every port day[10] and presentation opportunity to explain it to people and to let them feel the pulses”.

During the Agriculture & Fisheries Council (AGRIFISH) of December 2010, it was decided that the number of experimental licenses could be expanded to 42 (Rijksoverheid, 2010). The 36 fishermen that had registered for an experimental license received one in the order of registration. This meant that 16 fishermen were disappointed, because the maximum of 42 experimental licenses had already been reached (Pronk, 2011). Amongst the vessels that made the transition from the conventional beam trawl to the pulse trawl technique were normal cutters (max. 2000hp), euro-cutters (max. 300hp) and shrimp cutters (Deerenberg & Heinis, 2011).

Expanding the pulse trawl technique to 84 cutters

IMARES continued with research on the effect of the electric pulses on cod in response to the ICES Advice of 2009. In December 2010 they performed laboratory studies on small cod (0.12-0.16m) and large cod (~0.5m). Results showed that no spinal damage was found in small cod and that damage occurred in 50% to 70% of the large cod.

[10] Port days are organised for the general public to acquaint them with the work that is carried out in the ports.

However, above 180Hz no spinal damage was found in large cod. It was unclear what caused the spinal fractures in the cod (ICES a, 2012).

In 2011, IMARES carried out some reference measurements at sea. Measurements were done on the electric field of two vessels with the gear hanging vertically on the boom and with the gear lying flat on the bottom (ICES a, 2012). IMARES also performed a catch comparison between two pulse trawl vessels (TX36 and TX68) and a tickler chain beam trawler (GO4) as shown in figure 9. These three vessels fished side-by-side as much as possible (ICES a, 2012).

For the permanent admission or wider introduction of the pulse trawl technique, a control and enforcement system needed to be setup according to ICES (Marlen, van, et al., 2011). The project group that worked on the control and enforcement draft document consisted of representatives of the fishing industry, the pulse trawl producers, policymakers, scientists and control agencies (ICES a, 2012). This draft was presented to SGELECTRA and based on their input a new draft was made, which can be found in Appendix 10. IMARES started a project for the Dutch Ministry to prepare a document on the control and enforcement of the pulse trawl technique (ICES a, 2012). Next to presenting the concept-paper to the scientists, it was presented to fishermen. Propositions in the concept-paper to limit the maximum energy that could be sent down to the gear and the ban on additional tickler chains resulted in heavy debates with fishermen, which disagreed with the proposed limits on the maximum energy and the ban on additional tickler chains (ICES a, 2012).

In May 2012, results of a survey on the wider introduction of the pulse trawl for shrimp were published on the DFF website. 85% of the respondents opposed too the extension of the number of experimental licenses for pulse fishing on shrimp. The argument was that essential research on shrimp was missing (Nederlandse Vissersbond, 2012). Of the respondents that were shrimp fishermen, 73% was concerned about the ecosystem effects of the pulse trawl shrimp (Nederlandse Vissersbond, 2012). 78% stated that more research on ecosystem effects of the pulse trawl on shrimp should be done. 66% of the shrimp fishermen were worried about the ecosystem effects of the pulse trawl on flatfish (Nederlandse Vissersbond, 2012). Next to the results of the survey, the DFF also mentioned that it was not realistic that additional experimental licenses for pulse fishing on shrimp would be provided in 2012 (Nederlandse Vissersbond, 2012). The results of this survey clearly showed that Dutch shrimp fishermen were divided about the application of the pulse trawl technique. Shrimp fishermen expressed concerns and criticism on the pulse trawl technique for shrimp, but also on the pulse trawl technique on flatfish. A hotline had been established by the Steering group pulse fishing in 2012. Criticism on the pulse trawl technique could be reported to this hotline as long as the criticism was underpinned by arguments and was not done anonymously (Visserijnieuws k, 2012).

Delmeco and HFK were also confronted with a variety of claims on negative effects of the pulse trawl technique (Visserijnieuws i, 2012). During a meeting in Denmark, fishermen had stated to HFK that all the fish had died in certain areas where the pulse trawl technique was being used. In order to refute these claims, an appeal was made by HFK to IMARES and ILVO to publish scientific reports that would contradict these claims (Visserijnieuws i, 2012). Meanwhile, Dutch regime and niche actors and institutions tried to find support for the pulse trawl technique in other EU member states. A meeting was organized in Oostende (Belgium) to provide information about the pulse trawl technique. This meeting was attended by interested Belgian fishermen, scientists, policymakers and delegates from the EP (Visserijnieuws i, 2012). Although some Belgian fishermen were interested in switching to the pulse trawl technique, they were not willing to invest in this fishing technique as long as it was only allowed in the North Sea. Since Belgian fishermen have a small sole quota in the North Sea and therefore only fish at the North Sea for a maximum of four months a year, an investment in the pulse trawl technique could never become profitable for them (Visserijnieuws i, 2012). Only if the pulse trawl technique would be allowed on other fishing grounds, like the English Channel, the Bay of Biscay and the Liverpool bay, an investment in the pulse trawl technique could become profitable for Belgian fishermen (ILVO researcher, 2014).

Although the pulse trawl technique found little support in other EU member states for a variety of reasons, the pulse trawl technique started to be taken-up and tested by other EU member states as is shown in figure 19.

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

Figure 19. Developments in other EU member states: *The pulse trawl technique is being tested and implemented onboard fishing vessels in other EU member states. In total 51 vessels make use of the pulse trawl technique in four different countries at 01-01-2013 (Marlen, van, 2013). In Germany, the pulse vessels fishing on flatfish have Dutch owners. The pulse vessel on shrimp has a German owner. All pulse vessels in the United Kingdom (UKI) have Dutch owners, sailing under the UKI flag. The pulse vessel in Belgium has a Belgian owner.*

Next to the implementation of the pulse trawl technique in other EU member states, the share and importance of the pulse trawl technique in the Dutch cutter fleet continued to grow. This is in contrast to the conventional beam trawl, which continued to show a declining trend in hp-days due to the switch to other fishing techniques as is shown in figure 20.

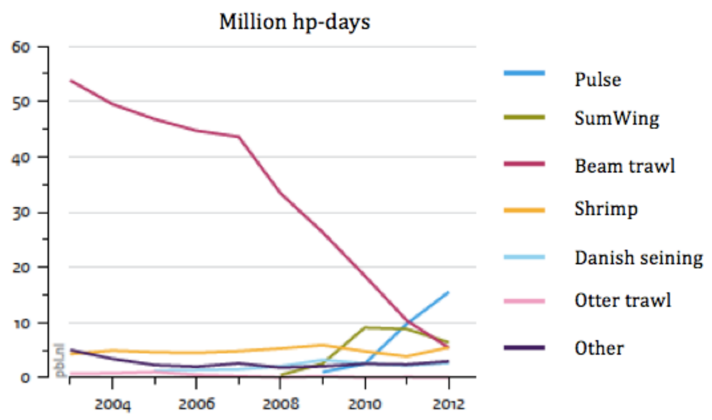


Figure 20. Hp-days for various fishing techniques: *This figure shows a decline of hp-days of the conventional beam trawl and a growing trend for alternative fishing techniques like the pulse trawl technique (Dirkx & Knegt, de, 2014).*

Although the wider introduction of the pulse trawl technique had come to a hold due to reaching the maximum number of experimental licenses, the pulse trawl technique continued to develop itself. A group of 15 fishing companies received a subsidy of a total of 420.000 euros for the further development of the pulse cables from the Ministry of Economic Affairs (Visserijnieuws l, 2013). They hoped to develop a stronger cable, which is better protected against short-circuiting and fibrates less. For the fishermen it should result in a cheaper, more reliable cable that requires less maintenance costs (Visserijnieuws l, 2013).

Research on effect studies of the pulse trawl technique also continued to be performed. Remarkable results were presented by ILVO about their effect study on cod, which they had performed at the start of 2013 in Norway. In contrast to the study performed by IMARES, ILVO found hardly any spinal injuries on cods exposed to electric pulses although a similar set-up was used (Visserijnieuws n, 2013). In a reaction to these results, IMARES and ILVO repeated this research again in October 2013. Again different results were found (ILVO researcher, 2014). According to ILVO researcher (2014), "It is not that we lack knowledge on the pulse, but we actually lack knowledge on the cod". This quote and these results suggest that explaining these differences in research results is difficult and it confirms the complexity of the effect studies on the pulse trawl technique.

After many discussions at the European level (see chapter 5.3), the EC had granted the Netherlands 42 additional experimental licenses. Now a total of 84 vessels were allowed to use the pulse trawl technique. Meanwhile, the pulse trawl technique continued to develop. The pulse technique is being tested in combination with a twin rigging fishing gear and in combination with a seewing (Visserijnieuws q, 2013)(Visserijnieuws r, 2014). The government of the United Kingdom granted an experimental license for the duration of six months for the pilot with the seewing in combination with the pulse trawl technique (Visserijnieuws r, 2014). Delmeco also sees opportunities for improving their pulse system. Delmeco wants to switch to a floating rig in order to get rid of the shoes of their system (Technological company 1, 2014). They are also thinking of an energy supply system underwater, which could replace the power cable (Technological company 1, 2014). HFK considers their system to be almost fully developed at this moment. Technological company 2 (2014) stated that, "You never know what is possible in the future, but we have already achieved so much that the investments and returns become less interesting".

All these developments around the pulse trawl technique are good from an innovative perspective; however, these developments also impede the control and enforcement. Both niche and regime actors and institutions are divided about the extent to which freedom for innovation is permitted. Some want to sharpen the current limits further as is stated by IMARES researcher (2014), while others want maximum room for innovation as stated by Fisherman 2 (2014). According to Employee of the Ministry of Economic Affairs 3 (2014) the purpose of the innovation is important in this regard, because the pilot project aims to test the pulse trawl technique as a more selective fishing technique in order to facilitate the landing obligation. Already before the latest expansion to 84 experimental licenses, this dichotomy about either limiting or broadening the regulatory limits was mentioned in the report of ICES (2012):

"It is necessary to expand the current understanding of electric trawling in general with the aim to determine further and appropriate threshold levels. However, it may be necessary to maintain broad regulatory limits so as to allow engineers to develop and optimize their pulse trawl designs. Due to the potential benefits of reduced fuel consumption, swept are and reduced catch rates while maintaining profit levels, there is a need to facilitate technical advancement in the field of pulse trawl technology while avoiding unnecessarily complex and potentially stifling technical legislation, while simultaneously servicing conservation, environmental and fisheries management requirements. This need becomes more acute as industry demand for such technology exceeds the current EU 5% limitations (as has become the case now). Future developments should continue to undertake extensive ecological impact assessments. As requests to expand the user base of the pulse trawl technology beyond the current 5% derogation limit are considered, new legislation will need to be drafted".

So now that the pulse trawl technique expanded beyond the 5% derogation limit up to 84 experimental licenses, new legislation needs to be drafted to keep the pulse trawl technique manageable according to the ICES report of 2012. This process however is impeded by the complexity of the technology and the conflicting interests between HFK and Delmeco (Employee of the Ministry of Economic Affairs 3, 2014)(Technological company 1, 2014)(Fisheries representative organization 1, 2014). Setting-up an adequate control and enforcement procedure is essential for the continuity of this fishing technique, since it will take away one of the concerns expressed by other European member states and scientists.

5.3 TRANSITION PROCESS AT THE REGIME LEVEL

<u>Expanding the pulse trawl technique to 42 cutters</u>

In 2010, ICES had arranged the first workshop on electric pulse trawls called WKPULSE. This workshop had two goals, namely:

- To review the in situ and tank experiments conducted following the request for additional information mentioned in the ICES Advice of 2006 on the electric pulse beam trawl.
- To review data on the measurement of field strength and pulse characteristics used in the pulse trawl system.

The workshop was held in IJmuiden and was attended by scientists from the Netherlands, Belgium, Germany, Russia and Denmark (ICES, n.d.). ICES also decided in 2011 to establish a special study group on electric fishing, which is named SGELECTRA.

After the registration period for an experimental pulse trawl license had closed, the number of registered fishermen exceeded the number of available experimental licenses. In total there was a derogation for 5% of the cutter fleet, which came down to approximately 22 vessels (Employee of the Ministry of Economic Affairs 3, 2014). Fishermen were placed on a waiting list and applications were processed in order of receipt (Visserijnieuws f, 2010). In an attempt from the fisheries organizations to obtain more experimental licenses, VisNed drafted a letter and sent it to the Minister for Economic Affairs, Agriculture and Innovation. This letter was an additional plea to support the pulse trawl technique and was supported by the NGO's WWF and the North

Sea Foundation (Employee of the Ministry of Economic Affairs 2, 2014)(NGO employee, 2014)(Visserijnieuws g, 2010). Although the North Sea Foundation considered the pulse trawl technique as a good alternative for the conventional beam trawl, they supported the letter under the following conditions:

1. A monitoring program should guide a wider introduction of the pulse trawl technique.
2. More effect studies should be conducted
3. Remote Electronic Monitoring should be introduced
4. If effect studies proved negative effects of the pulse trawl technique, the fishing technique should be adapted or blocked (NGO employee, 2014)(Stichting de Noordzee, 2012).

According to the Employee of the Ministry of Economic Affairs 3 (2014), "Back then, there was already pressure on expanding the amount of experimental licenses. Discussions followed with the EC on how we could expand these 22 licenses". During the Agriculture & Fisheries Council (AGRIFISH) of December 2010, it was decided that the number of experimental licenses could be expanded to 42 (Rijksoverheid, 2010). The expansion of the amount of experimental licenses was based on research Article 43 850/1998, and was approved by the EC after reaching a bilateral agreement between the Netherlands and the EC (Employee of the Ministry of Economic Affairs 3, 2014). These 20 additional experimental licenses were provided under the same conditions as the first 22, except for the explicit condition to participate in research. All these experimental licenses were provided on a temporary basis.

The fishing industry and IMARES started a monitoring program for the pulse trawl vessels targeting flatfish to fulfill the requirement of the EC for additional research by the provision of the additional experimental licenses (ICES a, 2012). Data on catches of all the pulse vessels were monitored and collected for a year (Quirijns et al., 2013). In total 10 trips with onboard observers from IMARES and ILVO would be done in 2012 and 20 vessels would participate in a self-sampling program[11] (ICES a, 2012).

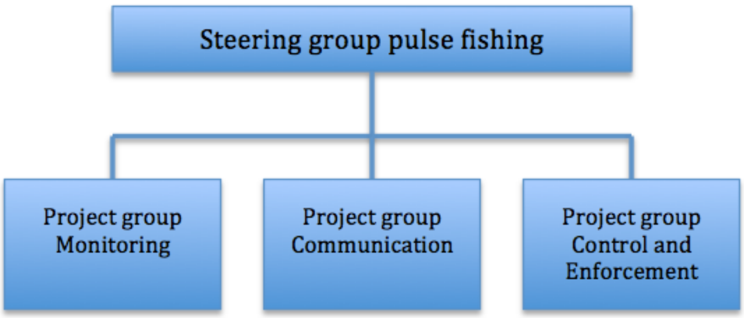


Figure 21. Steering group pulse fishing: *Structure of the steering group pulse fishing, which was established in 2011. The steering group pulse fishing is the overarching platform for the three project groups.*

Meanwhile, the Ministry had established a new steering group pulse fishing in 2011. This steering group consisted of the Ministry, the representatives of the fishing industry, LEI, IMARES and the North Sea Foundation (LEI researcher, 2014). Thereby a new

[11] The self-sampling was done by the fishermen. They estimated the catch of one haul and took a sample of that haul on a weekly basis. This sample was sorted in different categories and thereafter the weight of these categories was registered (Productschap Vis, 2012).

platform had been established for regime actors and institutions concerned the pulse trawl technique, because such a platform was missing due to the lifting of the FIP at the end of 2010 (Rijksoverheid a, 2010). Three project groups were falling under the steering group pulse fishing, as is shown in figure 21. The project group Monitoring focused on designing and carrying out scientific studies on catches and ecosystem effects of the pulse trawl technique (Visserijnieuws j, 2012). Providing information on the pulse trawl technique to all relevant actors and institutions in the Netherlands and abroad, and the promotion of this fishing technique was the main task of the Project group Communication (Visserijnieuws j, 2012). The Project group Control and Enforcement focuses on the technical aspects of the pulse trawl technique, which are relevant for arranging and adequate control and enforcement of the pulse trawl technique. The steering group pulse fishing gathers five to six times a year and for the project groups it varies (Employee of the Ministry of Economic Affairs 3, 2014)(Stichting de Noordzee, 2012).

Fishermen from Belgium, France and the United Kingdom started to express their concerns and criticism in the media after the expansion to 42 experimental licenses, as is shown in an article of the Sunday Times in Appendix 12. As a reaction to this trend, the steering group pulse fishing decided to provide more information to fishermen in Belgium, Germany and the United Kingdom (Visserijnieuws k, 2012). Several EU member states were visited by a Dutch delegation to talk about the pulse trawl technique. When asked how these meetings went on, Employee of the Ministry of Economic Affairs 4 (2014) said:

"We spoke to one of those fishermen that had stood in the article of the Sunday Times. I asked him: Do you really believe that these four cutters, which are the culprits according to you, come here every week all the way from Texel to catch dead sole? Do you truly believe that they come here to fish for dead sole? Why would only you catch dead fish, while they catch living ones? I have not heard the man anymore during the rest of the meeting"

This quote illustrates the polarization between proponents and opponents about the pulse trawl technique. During the meetings that I attended, there is a clear tendency to be either for or against the pulse trawl technique. This diverts the attention from having a constructive discussion on the pros and cons of the pulse trawl technique and on what is known and what requires more attention and additional research. The major happenings for this phase are shown in figure 22.

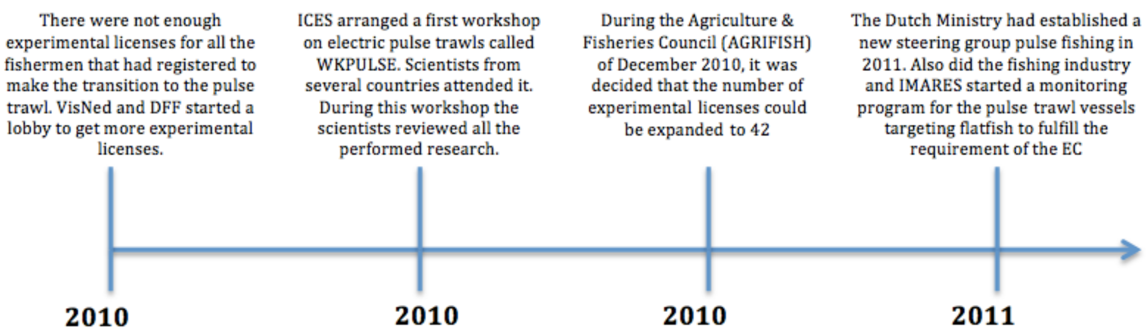


Figure 22. Timeline 2010-2011: *A timeline presenting the most important happenings in the phase of expanding the number of experimental licenses to 42 cutters.*

Expanding the pulse trawl technique to 84 cutters

Dutch regime actors and institutions began to incorporate the pulse trawl technique in their plans and policies (Appendix 8). In the VIBEG-agreement of 2011 for example, certain areas were closed to the conventional beam trawl, but were open to other more sustainable fishing techniques like the pulse trawl technique (Smit, 2011). These plans could only be carried out if a wider introduction of the pulse trawl technique would be made possible by the EC. A call was made to all parties involved in the VIBEG-agreement to dedicate themselves to the lifting of the ban on electric fishing as is shown in figure 23.

These parties shall endeavour their best effort to:

1. Collect relevant ecological and fisheries technical information. Parties shall do that by participating in launched research projects.
2. Undo the European ban on pulse fishing, which is part of the CFP.

Figure 23. Incorporation of the pulse trawl technique in policy: *The pulse trawl technique is incorporated in the plans of the VIBEG-agreement of 2011. In this agreement all involved parties are requested to dedicate themselves to the lifting of the ban on electric fishing (Anonymous 3, 2011).*

Therefore the Ministry asked the EC for a wider introduction or permanent admission of the pulse trawl technique at the Agriculture & Fisheries Council (AGRIFISH) of December 2011. The EC responded by promising that they would come back with a commission proposal for the expansion of the number of environmental licenses or the permanent admission of the pulse trawl technique before the summer of 2012. Their decision would rely on the advice of the STECF on the pulse trawl technique (Visserijnieuws h, 2011). In April 2012, STECF answered the request from the Dutch Authorities concerned a wider introduction of the pulse trawl technique. They came up with the following conclusions:

- STECF concludes that most ecological concerns raised by ICES have been adequately addressed. One ecological issue remains (possible avoidance mortality of cod), but this cannot be quantified at present.
- STECF concludes that provided that the current characteristics and the use of the gear remain unchanged, an increase in the proportion of the beam trawl fleet allowed to use the gear in the southern North Sea will reduce catches and fishing mortality for both target an non-target species including benthic organisms.
- STECF concludes that the critical barrier for lifting the derogation is control and enforcement and that the current provisions on the characteristics of the pulse trawl are not sufficient and not appropriate to prevent unregulated and harmful pulse trawl practices / technologies to be used.
- STECF concludes that a results based approach will be suitable to tackle the problem of control and enforcement and that the certification system under development by the Dutch could provide a basis for an appropriate regulatory framework (STECF, 2012).

Both in the conclusions and recommendations (see Appendix 9), the STECF stresses the importance of a control and enforcement procedure for the pulse trawl technique. A procedure document on the Control and Enforcement of Pulse trawling was drawn by IMARES. This draft procedure document was then presented to SGELECTRA for further consideration and rewritten (ICES a, 2012). The rewritten procedure document can be found in Appendix 10. An information report was also written and distributed at the Demersal working group of The North Sea Advisory Council (NSAC) in September 2012, which shortly described the development of the pulse trawl technique on flatfish and the latest advice of the STECF (Hartog, den, 2012).

The derogation for 5% of the fleet expired in 2012 and a decision needed to be made by the EC to extent this derogation or to make it a permanent regulation. They decided to make it a permanent regulation, without allowing any further adjustments to the regulation (Employee of the Ministry of Economic Affairs 1, 2014). Employee of the Ministry of Economic Affairs 1 (2014) stated that, "We tried to take-up a permanent admission for the pulse trawl technique in this regulation, but this was met with much opposition. There was too much resistance from other EU member states for a wider introduction of the pulse trawl technique. Even attempts to change the 5% of the derogation into 50% or 40% encountered resistance from other EU member states and the EC". The interviewees mentioned varying reasons to explain the resistance from other member states. These reasons can be found in table 6.

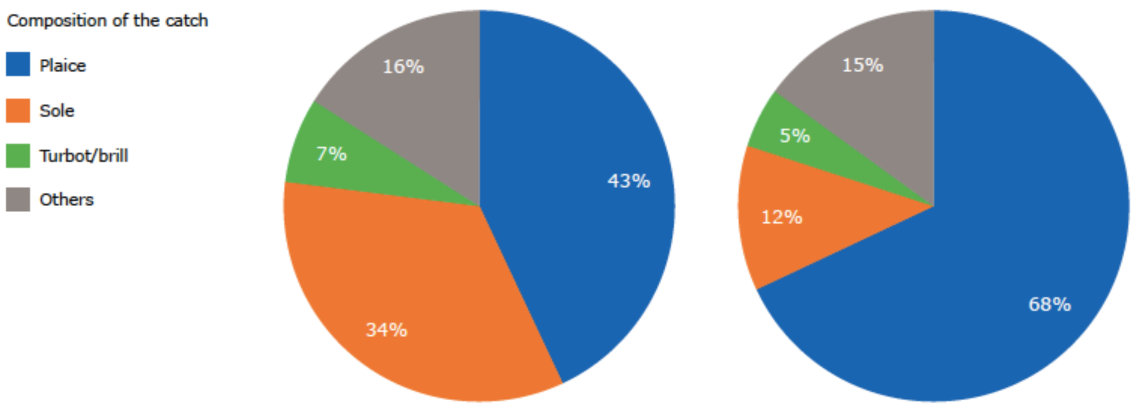
Table 6. Reasons for the resistance: *There is a lot of resistance from other EU member states for the wider introduction of the pulse trawl technique. This resistance is caused by a variety of reasons. This table mentions the reasons for the resistance from the perspective of the interviewees.*

Reasons for the resistance of other EU member states concerned the pulse trawl technique	Explanation	Source
Lack of interest	This fishing technique is very efficient for catching sole. Since the Netherlands owns 76% of the quota on sole, other countries lack an interest in this fishery.	(Employee of the Ministry of Economic Affairs 3,4, 2014)(Nederlandse Vissersbond employee, 2014)(LEI researcher, 2014)
Uncertainty	People are uncertain about the effects of this fishing technique on the ecosystem, the market and society.	(LEI researcher, 2014)(Employee of the Ministry of Economic Affairs 1, 2014)
Irritation	There is irritation about the fairly broad interpretation of agreements by the Dutch. Also do some consider it a procedural scandal on how the latests 42 additional experimental licenses were obtained.	(Employee of the Ministry of Economic Affairs 3, 2014)
Competition	The Dutch fleet is known to be innovative, large, successful and owns a lot of flag vessels in other EU countries.With the pulse trawl technique, the Dutch fleet would get an even stronger competitive position in Europe.	(Employee of the Ministry of Economic Affairs 1,2,3,4 2014)(Fisherman 1,2,3, 2014)(Nederlandse Vissersbond employee, 2014)(LEI researcher, 2014)(ILVO researcher, 2014)
Ignorance	Using electricity to catch fish has a bad reputation. Electricity is not visible to the naked eye and many people lack knowledge about electricity.	(Employee of the Ministry of Economic Affairs 2,3,4 2014)(Delmeco employee, 2014)(HFK employee, 2014)(VisNed employee, 2014)
Uncontrollability	It is difficult to control the efficiency of electrical fishing as was shown in the case study by Yu et al. (2007) on electric trawling on shrimp in China.	(NGO employee, 2014)(Employee of the Ministry of Economic Affairs, 2014)

Although attempts to adjust the 5% derogation failed, pressure from the fishing industry on the Ministry remained to arrange additional licenses (Employee of the Ministry of Economic Affairs 1, 2014). The next opportunity to arrange additional licenses was the discussion in the European Council about the European Maritime and Fisheries Fund (EMFF) for 2014-2021. According to Employee of the Ministry of Economic Affairs 1 (2014), "We, the Netherlands, figured that we could ask to take-up a provision in the regulation of the EMFF, which would allow to alter the technical measures". So the regulation on the EMFF, which has no relation to the technical measures at all, would allow altering the 5% derogation into 10%. When asked how other EU member states responded to this, the Employee of the Ministry of Economic Affairs 1 (2014) said, "This proposition also encountered a lot of resistance in Brussels and no one seemed to understand why we were doing this. To us it was a very important political issue, because the fishing industry really wanted more licenses, expectations had been raised and there were hardly any scientific objections against this fishing technique. With some power play we got it in the regulation". This quote emphasizes the political importance of expanding the number of experimental licenses for the pulse trawl technique.

It was a rather unusual way to take-up a provision in a regulation on a completely different topic. Especially the French disapproved with this state of affairs, but they had to accept it. If they would vote against the regulation, then they would also vote against important subsidies that had been taken-up in that regulation (Employee of the Ministry of Economic Affairs 1, 2014). Once the European Council and the EC had agreed to take-up the provision in the EMFF regulation, also the EP needed to consent with the regulation (Rijksoverheid, 2012).

	Pulse trawling	Beam trawling with chains
Fishing speed	5.5 nautical miles/hour	6.5 nautical miles/hour
Fuel consumption	4,100 litres/day-at-sea 2.21 litres diesel/kg fish	7,400 litres/day-at-sea 2.36 litres diesel/kg fish
Landings	1,900 kg fish/day-at-sea	3,100 kg fish/day-at-sea
Returns on fish	2.17 euros/litre diesel	1.23 euros/litre diesel



Discards	Around 50% (63 kg/hour) of the total plaice catch and 12% (5 kg/hour) of the total sole catch is thrown back into the sea. Less benthos is caught and discarded in pulse fishing than in beam fishing with tickler chains. For example, there was a sixfold reduction in starfish and a twofold reduction in crabs.	Around 50% (87 kg/hour) of the total plaice catch and 17% (6 kg/hour) of the total sole catch is discarded. More benthos is caught and thrown back into the sea in beam fishing with tickler chains than in pulse fishing.

Figure 24. Results monitoring program: *The pulse trawl and beam trawl technology are compared for vessels in the range of 1500-2000hp. All numbers are based on averages of 2012 (Quirijns et al., 2013)(Rasenberg et al., 2013)(Taal et al., 2013).*

Short after the agreement with the EC and the European Council about the EMFF regulation in October 2012, the French requested ICES to review the work of SGELECTRA and to provide an updated advice on the electric pulse trawl in November 2012 (ICES b, 2012). Conclusions of the updated ICES advice can be found in Appendix 11. These did not differ much from the conclusion of ICES and STECF earlier that year.

The first results of the monitoring program were also presented in 2013, which had been required by the EC for the provision of the additional experimental licenses in 2010. The results of the monitoring program are presented in figure 24.

In November 2013, the negotiations around the EMFF between the EC, EP and the European Council were in full swing. Meanwhile, the steering group pulse fishing had started with making an inventory on how politicians, fishing industries, scientists and CSO's in Germany, France, Belgium, Denmark, Sweden, Ireland, Spain, Italy, Poland and the United Kingdom think about the pulse trawl technique (Visserijnieuws m, 2013). The steering group did also plan to make a research and communication agenda, because there were still a lot of unanswered research questions that needed to be answered in order to gain more support for the pulse trawl technique. A communication plan should help to tackle the problem of misinformation around the pulse trawl technique (Visserijnieuws m, 2013). In order to inform other EU member states about the pulse trawl technique, a website was designed called: http://www.pulsefishing.eu/en. This website contains current and past research reports on pulse trawling, and the latest information on catches, discards, ecosystem effects and economic viability of pulse trawling on flatfish (Pulse fishing, 2014). Partners of this website are the Ministry of Economic Affairs, LEI, IMARES and the Cooperative Fisheries Organisation (CFO).

However, the EP decided not to include the expansion of the number of experimental licenses for the pulse trawl technique from 5% to 10% in the EMFF (Rijksoverheid a, 2014). The rapporteur from the EP decided not to include the provision, because the provision belonged to the negotiations on technical measures and not to the negotiations on the EMFF (Employee of the Ministry of Economic Affairs 1, 2014). This was a dramatic decision for the fishermen that had already invested in making the switch from the beam trawl to the pulse trawl technique (Rijksoverheid a, 2014). A quick response was required for those fishermen and therefore the State Secretary for the Ministry of Economic Affairs decided to schedule a meeting with the Euro commissioner and the president of the European Council (Rijksoverheid b, 2014). During that meeting it was decided that the number of experimental licenses could be expanded to 10% of the Dutch cutter fleet based on Article 14[12]. This meant that approximately 84 licenses were made available for using the pulse trawl technique (Rijksoverheid b, 2014). After setting-up and handing-over a programme description concerned the national pilot project on pulse fishing, the exemption was granted in March 2014 for a period of five years (Visserijnieuws o, 2014). The objectives of this pilot project are:

- To examine on wide scale how the pulse fishing method, whether or not combined with certain arrangements and adaptations of the net design, can contribute to greater selectivity on the part of the Dutch flatfish fleet and so reduce the impact of the landing obligation to an acceptable level.
- To gather missing/supplementary data and knowledge, with a view to full approval of pulse fishing in the North Sea (NSAC, 2014).

[12] This article states that: 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, minimization and elimination of unwanted catches in a fishery (EU, 2013).

To achieve the objectives of the pilot project, the following things will be done:

1. Applied research into the best methods for allowing unwanted organisms caught during fishing to escape by means of arrangements and/or adaptations of the nets, in combination with the pulse fishing method
2. A monitoring programme in which the participating fisheries play a major role. The aim is to gather both relevant data on the catches and knowledge concerning the manageability, controllability and enforcement of the technique in practice. The programme will also provide experience with the practical consequences of the landing obligation.
3. A research agenda, aimed at further expansion of the knowledge base, and at the long-term effects of electricity in the marine environment (NSAC, 2014).

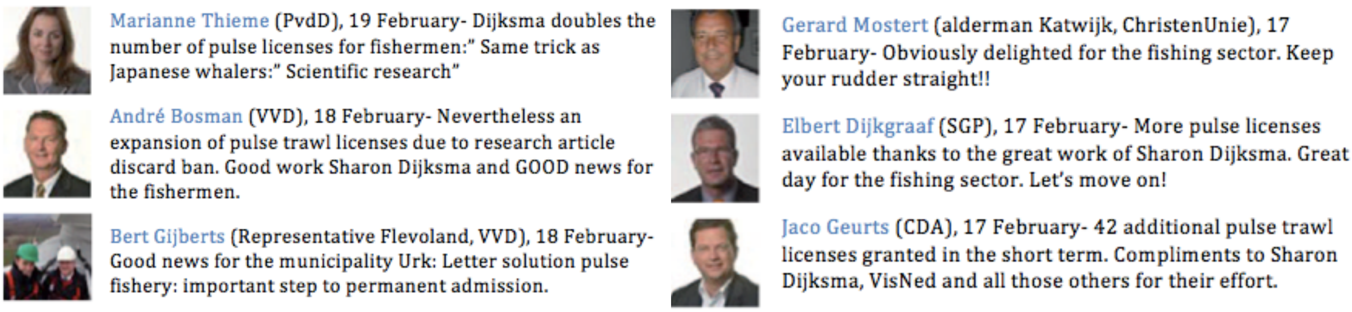


Figure 25. Reactions of various politicians (translated from Dutch): *Several politicians placed reactions on twitter concerned the expansion of the number of experimental licenses in February 2014.*

Although the expansion of the number of experimental licenses was hailed by a majority of Dutch politicians and fishermen and was criticized by few as is shown in figure 25, other European member states disapproved with the expansion (Employee of the Ministry of Economic Affairs 1, 2014). Belgian fishermen started a petition and hung black flags on their ships to protest to this expansion (Nieuwsblad, 2014). Sector representatives of other EU member states also expressed dissatisfaction. According to Fisheries representative organization 1 (2014), Danish colleagues said, "The Danish told me that if they asked the Ministry for a pilot project, they usually use two to three vessels. They thanked the Netherlands for the fact that conducting a pilot study on an experimental technique can now be performed with 42 vessels. This remark was not immune to cynicism". This quote gives a good reflection on how other EU member states thought about the expansion. It was perceived as a procedural scandal by some European member states (Employee of the Ministry of Economic Affairs 3, 2014). Although agreements on the EMFF were no longer applicable, the Ministry decided to take-up a restriction in the 42 additional experimental licenses. This restriction did not allow vessels that were part of the pilot project to use the pulse trawl technique above a latitude of 55°N (Employee of the Ministry of Economic Affairs 3, 2014). That had been a commitment made to the Danish during the EMFFA negotiations in exchange for their support. As a sign of goodwill to the Danish, the Ministry decided to take-up this restriction in the 42 additional experimental licenses.

Next to critics expressed by actors and institutions from other EU member states, also the Dutch actors and institutions are divided about the additional 42 licenses. Some Dutch fishermen joined their Belgian colleagues by hanging a black flag on their vessels too. Especially shrimp fishermen objected the expansion of the number of experimental licenses. They fear that sole fishermen will switch to shrimp fishing due to a lack of sole quota and they also blamed the pulse trawl on flatfish for the disappointing shrimp landings in the spring of 2014 (Visserijnieuws p, 2014). The Dutch NGO's also expressed criticism on the latest expansion of the pulse trawl licenses. NGO employee (2014) said:

"It is a bit like putting the cart before the horse. Now that we have these 84 experimental licenses, we are going to prove to the NSAC how sustainable this fishing technique is according to us. It is also important for everyone to realize that these 42 latest issued licenses have been provided on a temporary basis of five years. Suppose that after five years these licenses will not be made permanent, then you will end up with another problem. I would not assume so quickly that everything is going to be ok".

The provision of these 42 additional experimental licenses also has other consequences. LEI researcher (2014) expressed some of these consequences, he said:

"You make yourself vulnerable to sole quota and sole prices, which already can be seen for sometime. Prices for sole at a certain point dropped to six or seven euros per kilo, depending on the size of the fish. With an average price of seven euros per kilo sole it is not easy to fish profitable. I advocate a better and more structured view at the consequences of introducing a new fishing technique. There has been too much focus on obtaining as many experimental licenses as possible. There is a lack of an overall vision, which should also include the role of the pulse trawl technique within this overall vision".

There were also complaints from the fishermen who were among the last group of the 42 experimental licenses. They were unhappy about the latitude restriction of 55°N. During meetings of the steering group pulse fishing, the DFF and VisNed said that all pulse trawl vessels should be able to fish in a area stretching from 05.00° EL to 56.00° N (VisNed, 2014). Due to this restriction there was inequality between the fishermen with a pulse license and they feared that other countries would submit similar requests (VisNed, 2014). The DFF and VisNed proposed that fishermen belonging to the first group of 42 licensees, which do not fish above a latitude of 55°N, would switch their license with those fishermen belonging to the second group of 42 licensees, which have an interest in fishing above a latitude of 55°N (VisNed, 2014). Herein the Ministry differs in vision as is explained by Employee of the Ministry of Economic Affairs 3 (2014), which said, "From the perspective to create acceptance of the pulse trawl technique in other EU member states, it would not be wise to do this". Exchanging the licenses from the first group of 42 with the second group would be contradictory to their vision to find more support and acceptance for the pulse trawl technique in other member states.

Despite the differences of Dutch actors and institutions on how to manage the pulse trawl technique, about their responsibilities and on the application (permanent admission vs. regional admission) of the pulse trawl technique, a proposed research agenda has been presented to the NSAC focus group pulse trawl in November 2014. It serves both to comply with the conditions set for the pilot project pulse, as well as to address the issues and concerns of different (international) stakeholders (Rijnsdorp et al., 2014). The identified research areas are:

1. Governance: mapping the processes and stakeholders perceptions concerning the introduction of a new fishing gear, the pulse trawl.

2. Economy: gain insight into the economic performance of the pulse fishery.
3. Control and enforcement of the pulse fishery.
4. Ecology and technique: a total impact assessment of the Dutch flatfish pulse trawl fleet on a North Sea scale (Rijnsdorp et al., 2014).

An impact assessment will be done for the research area 'Ecology and technique'. This impact assessment consists of several projects. In figure 26 an overview of all the proposed projects and their coherence is given.

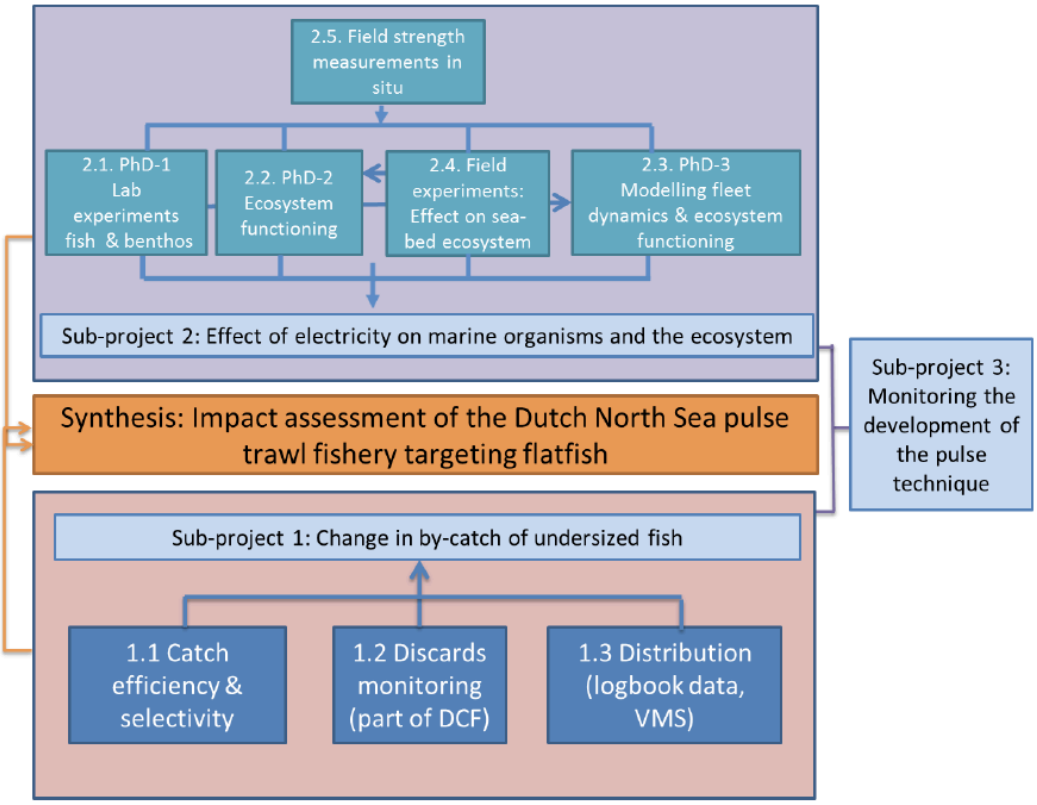


Figure 26. Impact assessment: *A schematic overview of the coherence of the projects for the impact assessment (Rijnsdorp et al., 2014).*

The other research areas of the proposed research agenda will also be covered. For covering the research areas 'Governance' and 'Economy', current and future policy-supporting research will be used (Rijnsdorp et al., 2014). During the meetings of the project group control and enforcement, attention will be paid to the research area 'Control and enforcement of the pulse fishery' (Rijnsdorp et al., 2014). So currently the Dutch regime actors and institutions are working on the fulfillment of their obligations to the EC, which were part of the provision of the additional 42 experimental licenses. So currently the pulse trawl technique is a broadly implemented fishing technique in the Netherlands, while being controversial in Europe. Dutch regime and niche actors and institutions are now trying to increase the acceptance of the pulse trawl technique amongst other EU member states.

Meanwhile, Dutch niche and regime actors and institutions continue to create support for the pulse trawl technique in other EU countries. An informative video was made about the pulse fishing technique, factsheets were made and distributed, and fishermen from other EU member states are invited to join fishing trips. A delegation of Italian fishermen and scientists were invited to see the pulse trawl technique in July 2014 and a group of Danish fishermen joined a fishing trip aboard a pulse trawl vessel in October 2014. During the North Sea AC, where both the fishing industries and NGO's from other EU member states are represented, a lot of information was presented about the pulse trawl technique by Dutch actors and institutions (Fisheries representative organization 1, 2014)(NGO employee, 2014). It was agreed to give an annual progress report to the North Sea AC, so that everyone can follow the progress around the pulse trawl technique (Employee of the Ministry of Economic Affairs 1, 2014). The major happenings for this phase are shown in figure 27.

Figure 27. Timeline 2011-2014: A timeline presenting the most important happenings in the phase of expanding the number of experimental licenses to 84 cutters.

5.4 CONCLUSION

This second time period clearly demonstrates that there is a difference between the acceptance of the pulse trawl technique by the Dutch regime and the European regime actors and institutions. Apparently the breakthrough of pulse trawl technique in the Dutch regime does not simply imply a breakthrough in the European regime. European regime actors and institutions objected a wider introduction of the pulse trawl technique. Eventually, a wider introduction of the pulse trawl technique was realised due to developments at the landscape level in the form of the landing obligation. However, the latest expansion has resulted in conflicting visions on the future of the pulse trawl technique amongst both Dutch niche and regime actors and institutions. The future of the pulse trawl technique is uncertain and unpredictable.

6. DISCUSSION

6.1 INTRODUCTION

This chapter links the two time periods to a certain transition pathway. Linking the time periods to a transition pathway is done according to the three criteria used by Grin et al. (2010) to determine the transition pathway. These three criteria are the timing of interactions, nature of interactions and types of landscape change. All three criteria are described for every phase of the transition process, in order to link each phase to a certain transition pathway. Each of these identified pathways act as sub-pathways for the pathway of a certain time period. The first time period consisted of four phases, while the second time period consisted of two phases. Eventually, the identified transition pathways for the two time periods form one transition pathway. The most relevant factors that influenced the transition pathway of the pulse trawl technique are discussed. Thereby the findings of this case study can either complement or contradict the theory on transition pathways. By testing or complementing the theory on transition pathways, this case study can contribute to our overall understanding on transition pathways, because lessons learned from this case study can be extrapolated to other fields of study. Each identified factor that influenced the transition pathway of the pulse trawl also describes what consequences it has for policymakers and managers. It describes how policymakers and managers can respond to such factors in order to influence a transition pathway into a desirable direction

6.2 IDENTIFYING THE TRANSITION PATHWAY FOR THE FIRST TIME PERIOD

<u>Inventing a pulse system (1988-2004)</u>

For linking this phase in the transition process to a certain pathway, the types of landscape change, the timing of interactions and the nature of interactions are summarized in table 7. Each of the three criteria is explained in more detail below. On the basis of these three criteria, this phase can be linked to a certain transition pathway.

Table 7. Linking the 'Inventing a pulse system' phase to a transition pathway: *This table shortly describes the three criteria used by Grin et al. (2010) for this phase in the transition process.*

Phase	Type of landscape change	Timing of interactions	Nature of interactions
Inventing a pulse system	The type of landscape change for this phase is regular, since the landscape developments that put pressure on the regime level are low in frequency, amplitude, speed and scope.	The pulse trawl technique was still under development. Due to the regular landscape change, there was moderate urgency for a transition towards the pulse trawl technique at this point.	If looked at the nature of interactions, it is clear that these were of an exploratory nature.

Types of landscape change

According to Marlen, van (1997) the aim of research had shifted along the project in the Netherlands. Where the emphasis before the ban of 1988 was on decreasing the drag of the gear and thereby reducing the energy consumption, more emphasis was put on environmental aspects along the project after research on the pulse trawl technique was resumed after the ban of 1988. This was probably the result of growing concerns and criticism on the conventional beam trawl in combination with a shift towards an ecosystem approach in the Common Fisheries Policy (CFP) in Europe, which also influenced the national policy in the Netherlands as expressed by Zevenboom et al. (2003).

Timing of interactions
The pulse trawl technique was still under development and was not ready to replace the conventional beam trawl at this stage of the transition process. Both the niche and regime network were small and some important regime actors and institutions had not been involved in this phase of the transition process.

Nature of interactions
First contacts were established between the policy, technology, science and industry dimensions. All parties were interested in the pulse trawl technique for various reasons. Main reasons were a reduction in fuel consumption, less bycatch and an alternative for the criticised conventional beam trawl.

Linking the transition phase to a transition pathway
This phase of the transition process of the pulse trawl technique links best to the transformation pathway. There is moderate pressure from the landscape level on the regime for a transition. At the regime level, the Ministry and Verburg-Holland B.V. respond to this moderate pressure by steering the development paths and innovation activities at the niche level towards the development of an electric fishing technique that could serve as a more environmentally sustainable alternative for the conventional beam trawl technique. However, this electric fishing technique is still under development in this phase of the transition process.

<u>Pilot project on a commercial vessel (2004-2007)</u>
For linking this phase in the transition process to a certain pathway, the types of landscape change, the timing of interactions and the nature of interactions are summarized in table 8.

Table 8. Linking the 'Pilot project on a commercial vessel' phase to a transition pathway: *This table shortly describes the three criteria used by Grin et al. (2010) for this phase in the transition process.*

Phase	Type of landscape change	Timing of interactions	Nature of interactions
Pilot project on a commercial vessel	The pulse trawl technique is still not sufficiently developed. Technical problems affect the economic and environmental performance of the pulse trawl technique.	The pulse trawl technique was still under development. Due to the regular landscape change, there was moderate urgency for a transition towards the pulse trawl technique at this point.	The nature of interaction shifted in convincing ICES, the EC and the fishing industry that this technique had potential to replace the conventional beam trawl.

Types of landscape change
Pressure from the landscape level on the regime has further increased due to the addition of rising fuel prices, a decrease in plaice quota and lower total landings. For this phase, the type of landscape change is best described as disruptive, since most of the landscape developments that put pressure on the regime level are relatively low in frequency, speed and scope but high in amplitude.

Timing of interactions
The fishing sector was now also confronted with landscape pressures that created a need for them to find an alternative for the conventional beam trawl. This meant that there was a window of opportunity for the pulse trawl technique to be taken-up by the regime. However, the fishing industry did not consider the pulse trawl technique to be an adequate alternative for the beam trawl at this point, since the UK153 was regularly coping with technological problems and disappointing catches compared to the

conventional beam trawl. As a consequence, the fishing sector withdrew its support for the pilot project. This had a great impact on the transition process, since only the Ministry and the fishing sector had directly supported the niche actors and institutions. Now that the fishing sector had withdrawn its support for the pilot project, only the Ministry and the niche actors and institutions remained as pioneers of the pulse trawl technique.

Nature of interactions
In the previous phase, the nature of interaction was more of an exploratory nature, while in this phase the focus was on testing the pulse trawl technique and comparing its performances to the conventional beam trawl. Niche actors and institutions were actively trying to convince regime actors and institutions that the pulse trawl technique has the potential to replace the conventional beam trawl, when more time for development is given.

Linking the transition phase to a transition pathway
In this phase of the transition process of the pulse trawl technique, the transformation pathway is shifting from a transformation pathway to a de-alignment and re-alignment pathway. There are divergent pressures from the landscape level on the regime actors and institutions that continue to grow larger. The UK153 acted as the frontrunner for the fishing industry, but the enthusiasm about the pulse trawl technique of the UK153 does not gradually trickle down and alter the attitude of the fishing industry at the regime level as would happen in a transformation pathway. As there is doubt from the fishing industry about the reliability and profitability of the pulse trawl technique, they withdraw their support for the further development of this fishing technique. However, the existing regime is facing major internal problems due to growing concerns and criticism about the environmental impact of the conventional beam trawl, rising fuel prices, decreasing plaice quota and lower total landings of plaice, sole and cod, which creates a window of opportunity for an alternative for the conventional beam trawl.

Study Group Pulse & SumWing (2007-2010)
For linking this phase in the transition process to a certain pathway, the types of landscape change, the timing of interactions and the nature of interactions are summarized in table 9.

Table 9. Linking the 'Study Group Pulse & SumWing' phase to a transition pathway: *This table shortly describes the three criteria used by Grin et al. (2010) for this phase in the transition process.*

Phase	Type of landscape change	Timing of interactions	Nature of interactions
Study Group Pulse & SumWing	This phase has a disruptive type of landscape change, since most of the landscape developments that put pressure on the regime level are relatively low in frequency, speed and scope but high in amplitude.	There was pressure from the landscape level on the regime actors and institutions to come up with an alternative for the beam trawl, but a dominant pulse trawl design was lacking.	The nature of interaction had shifted from a more steering role of the regime actors and institutions to a more supportive role. Interactions at the niche level became competitive.

Types of landscape change
Landscape pressures remain putting pressure on the regime actors and institutions to come up with an alternative for the conventional beam trawl. Concerns and criticism about the negative environmental impact of the conventional beam trawl, the rising fuel price and the negative net results of the Dutch beam trawl fleet remained as the main pressures from the landscape level on the regime actors and institutions at the end of this phase.

Timing of interactions
After finding renewed support for the pulse trawl technique at the FIP, the Study Group Pulse & SumWing was established for niche actors and institutions. Niche actors and institutions continued the research and development of the pulse trawl technique together with a group of pioneer fishermen that saw potential in this fishing technique. The Study Group Pulse & SumWing gave feedback to the Ministry about their progress and the barriers that were impeding the transition. The Ministry responded to the feedback by meeting these preconditions, thereby creating a window of opportunity for the transition to take place once the pulse trawl technique had sufficiently developed at the niche level. However, once the TX68 had bought and installed the pulse trawl system of Verburg-Holland B.V. aboard, a conflict arose at the niche level concerned the design of the pulse system. A group of fishermen preferred the integration of the pulse system in the SumWing of HFK. This resulted in conflicting interests between Verburg-Holland B.V. and HFK. So at the end of this phase there still was a window of opportunity for the pulse trawl technique to be accepted and implemented at the regime level, but the lack of a dominant pulse system design and uncertainty about the economical and environmental performance of the two pulse trawl systems on a commercial vessel hampered this fishing technique to make the technological transition at this stage.

Nature of interactions
In this phase the nature of interactions changed. The niche actors and institutions were organised in a Study Group and were supported by a broader network of regime actors and institutions that had organised themselves in the FIP. These regime actors and institutions in the FIP gave more space for the niche actors and institutions to develop the pulse trawl technique on their own. The group of niche actors and institutions saw the pulse trawl technique as an alternative to the beam trawl that would solve their economic problems, while also improving their environmental performance. However, although all niche actors and institutions shared their believe of the pulse trawl technique being a suitable alternative for the conventional beam trawl, they did not share the same vision concerned the design of the pulse trawl system. As a result, the nature of interaction at the niche level shifted and became competitive. This competition stimulated the development of the pulse trawl technique, but it also resulted in a tense atmosphere within the Study Group Pulse & SumWing.

Linking the transition phase to a transition pathway
This phase of the transition process does correspond closest to the de-alignment and re-alignment pathway. The large and divergent pressure from the landscape level on the regime actors and institutions reduced the trust in the survival of the conventional beam trawl technique. However, the regime actors and institutions do not have a sufficiently developed niche innovation that can serve as a substitute for beam trawl. An innovation platform is established for the regime actors and institutions to create space for multiple niche innovations that co-exist. Regime rules of regime actors and institutions are also under pressure, which allows a change in guiding principles, user preferences, selection criteria and regulations. This results in multiple niche innovations being supported and developed like the SumWing, flyshooting, hydrorigging and twinrigging. The pulse trawl technique is also selected as a fishing technique with the potential to replace the conventional beam trawl. A period followed in which the pulse trawl technique was further tested and developed. Eventually, competition at the niche level within the Study Group Pulse & SumWing resulted in two different designs of the pulse trawl technique.

These two pulse trawl systems were the pulse trawl system of Verburg/Delmeco and the Pulse Wing of HFK engineering. The competition at the niche level eventually resulted in a tense atmosphere within the study group and the lack of a dominant design, which could form the core for re-alignment of a new socio-technical regime.

Making the step from innovation to implemented fishing technique (2010)
For linking this phase in the transition process to a certain pathway, the types of landscape change, the timing of interactions and the nature of interactions are summarized in table 10.

Table 10. Linking the 'Study Group Pulse & SumWing' phase to a transition pathway: *This table shortly describes the three criteria used by Grin et al. (2010) for this phase in the transition process.*

Phase	Type of landscape change	Timing of interactions	Nature of interactions
Making the step from innovation to implemented fishing technique	The type of landscape change in this phase is disruptive, since most landscape developments that put pressure on the regime level are relatively low in frequency, speed and scope but high in amplitude.	Both the pulse trawl systems of Delmeco and HFK had now proved to be profitable and reliable at the niche level, while pressures from the landscape level remained.	The nature of interactions at the niche level is competitive, while the nature of interaction with the regime level took the shape of a symbiotic relationship.

Types of landscape change
High oil prices and the concerns and criticism on the conventional beam trawl technique still exert pressure on regime actors and institutions to come up with an alternative.

Timing of interactions
In this period, the timing of interactions was right to make the technological transition in the Dutch cutter fleet from the conventional beam trawl technique towards the pulse trawl technique. The fishing industry had changed their pessimistic attitude to an optimistic attitude concerned the pulse trawl technique, because it had a better economic and environmental performance compared to the conventional beam trawl. Once a leading fishing company had registered to make the change from the beam trawl technique towards the pulse trawl technique, more vessel owners followed.

Nature of interactions
The nature of interactions between niche actors and institutions is competitive. There are two different pulse trawl systems that have been developed by two different companies. Most actors and institutions at the regime level encourage this competition at the niche level and do not interfere, because they hope it will have a positive influence on the cost price and development of the pulse trawl technique. Once both pulse trawl systems were being installed and used aboard commercial vessels, the first results on the economical and environmental performance of the pulse trawl technique were presented. The niche actors and institutions focused their interactions on convincing regime actors and institutions that the pulse trawl technique can be used to solve economic problems and to improve the environmental performance of the fishing industry. This claim was now supported by research results from LEI and IMARES, and the fishing industry accepted and implemented the pulse trawl technique.

Linking the transition phase to a transition pathway
This phase of the transition process is closely linked to the de-alignment and re-alignment pathway of the previous phase. After the Study Group Pulse & SumWing was lifted, the two pulse systems continued to develop in separate niches. Eventually both Delmeco and HFK engineering came to a dominant design of their pulse trawl system.

Results on the economic and environmental performance of the pulse trawl systems were spread and changed the pessimistic attitude of the fishing industry towards the pulse trawl technique. The pioneer vessels had proved that the pulse trawl technique was reliable and profitable, which convinced other fishermen that it could serve as a good alternative fishing technique for catching sole. Once a large fishing company had ordered four Pulse Wings, more fishermen registered to make the transition towards the pulse trawl technique. Thereby the pulse trawl technique started a re-alignment process for a new socio-technical regime.

<u>Linking the first time period to a transition pathway</u>
Overall, this time period links best to the mixed transition pathway, consisting of the transformation pathway that is followed by a de-alignment and re-alignment pathway. At first the regime tried to tackle the problems within the regime through steering activities and development trajectories in the direction of the pulse trawl technique. However, the pressure from the landscape level continued to grow and the pulse trawl technique was not sufficiently developed yet to serve as an alternative for the conventional beam trawl. The fishing industry did also disagree with the expressed concerns and criticism about the environmental impact of the conventional beam trawl and they were not willing to invest in a banned fishing technique that also caught less fish. Problems like the rising oil prices, decreased landings, decreasing plaice quota, and the growing concerns and criticism on the environmental impact of the conventional beam trawl resulted in disruptive pressures from the landscape level on the regime. These problems led to a loss of faith in the conventional beam trawl amongst the regime actors and institutions. This opened up a window of opportunity, but there was no sufficiently developed niche innovation that could break-through at that moment. As a result, the transition process started to follow a de-alignment and re-alignment pathway. Multiple niche innovations co-existed like the SumWing, flyshooting, hydrorigging and twinrigging. The pulse trawl technique also got another chance to prove itself. Eventually, a Pulse trawl and a Pulse Wing were developed, which formed the core for the re-alignment of a new regime.

6.3 IDENTIFYING THE TRANSITION PATHWAY FOR THE SECOND TIME PERIOD

<u>Expanding the pulse trawl technique to 42 cutters (2010-2011)</u>
For linking this phase in the transition process to a certain pathway, the types of landscape change, the timing of interactions and the nature of interactions are summarized in table 11.

Table 11. Linking the 'Expanding the pulse trawl technique to 42 cutters' phase to a transition pathway: *This table shortly describes the three criteria used by Grin et al. (2010) for this phase in the transition process.*

Phase	Type of landscape change	Timing of interactions	Nature of interactions
Expanding the pulse trawl technique to 42 cutters	Disruptive for the Dutch regime actors and institutions and regular for the European regime actors and institutions.	The pulse trawl was fully developed in the Netherlands according to the four indicators of Grin et al. (2010). However, little powerful European regime actors and institutions had joined the support network.	There is a symbiotic relationship between the niche and the NL regime level, both try to convince EU regime actors and institutions of the pulse trawl technique. However, they find little response.

Types of landscape change
The type of landscape change can best be described as disruptive for the Dutch regime actors and institutions, because most of the landscape developments that put pressure on the Dutch regime level are relatively low in frequency, speed and scope but high in

amplitude. However, the type of landscape change on the European regime can best be described as regular, since the landscape developments that put pressure on the EU regime actors and institutions are relatively low in amplitude.

Timing of interactions

When looked at the timing of interactions in this phase of the transition process, the pulse trawl was fully developed in the Netherlands according to the four indicators of Grin et al. (2010). The learning processes had stabilized into two dominant designs (Pulse trawl & Pulse Wing)(1), powerful actors had joined the support network (2), price/performance improvements have improved and were expected to improve even further (3) and the pulse trawl technique was used in market niches, which cumulatively amounted for more than 5% market share (4). However, little powerful European actors had joined the support network and the pulse trawl technique did not amount for more than 5% market share on the European level. Although the Dutch regime actors and institutions experienced a lot of pressure from the landscape developments, these pressures had less impact on European actors and institutions. The European regime is stable and entrenched, and little attention is paid to the pulse trawl technique that is being developed and used on a small scale in the Netherlands. Eventually, the European regime actors and institutions allowed a wider introduction of the pulse trawl technique as a niche innovation, without fully accepting it. The ban on using electricity during fishing practices remained intact.

Nature of interactions

The nature of interactions in this phase of the transition process take the shape of a symbiotic relationship between the niche and the NL regime level, since both want the pulse trawl technique to breakthrough on the EU level. Initially the Dutch niche and regime actors and institutions commit themselves separately to the expansion of the number of experimental licenses, until the Dutch regime actors and institutions unite themselves in the steering group pulse fishing. The Dutch niche and regime actors and institutions try to convince other EU member states of the importance of this fishing technique for the future of the Dutch flatfish cutter fleet. This finds little response from other EU member states due to a lack of interest in this fishing technique. Besides, landscape level developments result in moderate pressure on EU regime actors and institutions to stimulate change and transitions.

Linking the transition phase to a transition pathway

When linking this phase of the transition process to a transition pathway, it links best with the technological substitution pathway. The transition towards the pulse trawl technique had started to change the regime rules of Dutch regime actors and institutions, but this transition could only be upheld if this rules regime would align with that of European actors and institutions. So a transition in the European regime rules was required in order to obtain a permanent admission of the pulse trawl technique. However, the pulse trawl technique was not being picked-up and accepted by the EU regime actors and institutions, since pressures from the landscape level exerted moderate pressure on EU regime actors and institutions. As a consequence, little attention is being paid to the pulse trawl technique that has been developed and implemented in the Dutch flatfish cutter fleet. Eventually, a way was found to extend the number of experimental licenses to 42 based on an Article that allowed further research on the pulse trawl technique.

Expanding the pulse trawl technique to 84 cutters (2011-2014)
For linking this phase in the transition process to a certain pathway, the types of landscape change, the timing of interactions and the nature of interactions are summarized in table 12.

Table 12. Linking the 'Expanding the pulse trawl technique to 42 cutters' phase to a transition pathway: *This table shortly describes the three criteria used by Grin et al. (2010) for this phase in the transition process.*

Phase	Type of landscape change	Timing of interactions	Nature of interactions
Expanding the pulse trawl technique to 84 cutters	The type of landscape change can best be described as disruptive for both the Dutch and European regime actors and institutions.	The introduction of the landing obligation provides an oppertunity for a wider introduction of the pulse trawl technique. However, there are still many uncertainties about the effects and its manageability.	Dutch regime actors and institutions and those at the European level initially had a competitive relationship.Currently Dutch regime actors and institutions try to involve and inform European regime.

Types of landscape change
The Dutch regime actors and institutions still felt pressure from the landscape level to come with an alternative for the conventional beam trawl, since criticism and concerns on the conventional beam trawl remained and plans were made to completely ban this fishing technique in certain fishing areas. However, the pulse trawl technique remained banned in the EU and little support was found for this innovation in Europe due to a lack of a European playing field. Where the type of landscape change for the European regime level was regular for the previous phase, it changed in this phase of the transition pathway due to the introduction of the landing obligation. All EU member states were confronted with this measure that should result in more selective and sustainable fisheries in Europe. This means that measures and innovations that could contribute to a more selective fishery have a chance to break through in the regime. The landing obligation provided an opportunity for Dutch regime actors and institutions to extend the number of experimental licenses. The type of landscape change for both the Dutch and European regime actors and institutions can therefore best be described as disruptive, since pressures from the landscape level are relatively low in frequency, speed and scope but high in amplitude.

Timing of interactions
Once the number of experimental licenses was expanded to 42 cutters, the pulse trawl technique gained attention amongst certain European regime actors and institutions. The Dutch flatfish cutter fleet proved successful with the pulse trawl technique and it was now having a competitive advantage compared to the fleets of other EU member states. Criticisms and concerns about the pulse trawl technique started to grow. Uncertainties about the (long-term) effects of the pulse trawl technique on the ecosystem and its manageability were brought up as arguments to block this innovation from completely breaking through in the EU regime. However, European regime actors and institutions are now also confronted with the landing obligation. It might allow the pulse trawl technique to finally break through in the European regime, but that will also depend on whether powerful European actors and institutions are still willing to join the support network of the pulse trawl technique. Therefore it is important that Dutch niche and regime actors and institutions will involve and inform these parties during the pilot project and focus future developments on increasing the selectivity of the pulse trawl technique.

Nature of interactions
For this phase in the transition process, the nature of interactions between the Dutch regime actors and institutions and those at the European level can best be described as competitive. After the amount of experimental licenses had been expanded to 42, it was clear to other EU member states that the pulse trawl technique was replacing the conventional beam trawl. The pulse trawl technique proved to be efficient, profitable and reliable in the Netherlands. Fishermen in other European member states also noticed this. However, they were unable to switch to the pulse trawl technique since it would require a high investment. Such a high investment could only be profitable for fishermen if they would own a sufficient sole quota in the North Sea, as this is the main catch with the pulse trawl technique. The Dutch cutter fleet and flagships own the largest share of sole quota in the North Sea. So fishermen with a conventional beam trawl in other European member states saw the success of the Dutch cutter fleet, while they did not have the opportunity to make the transition to the pulse trawl technique. This competitive advantage could result in the downfall of fishing companies that cannot make the transition to the pulse trawl technique in both the Netherlands and other EU member states (ILVO researcher, 2014)(Fisheries representative organization 1, 2014).

This imbalance resulted in a lot of pressure from the Dutch fishing industry on the Ministry to level the playing field for the Dutch fishermen by arranging even more pulse trawl licenses. As a result of this pressure, the fishing associations and the Ministry focussed on expanding the number of environmental licenses as quickly as possible. This went against the vision of other Dutch niche and regime actors and institutions, and as a result the nature of interaction between the Dutch niche and regime actors and institutions changed into a reproachful relationship. Examples are that the suppliers of the pulse trawl technique blame science for a lack of involvement, the Ministry accuses the suppliers of the pulse trawl technique of slowing down the setup of a control and enforcement procedure, and NGOs blames the Ministry for a lack of research on ecosystem effects.

After the number of experimental licenses had been expanded to 84, the nature of interactions between Dutch regime actors and institutions and those at the European level started to change. The nature of interaction shifted to a rapprochement interaction from the Dutch regime actors and institutions with the EU regime actors and institutions. Dutch regime actors and institutions try to involve and inform European regime actors and institutions in the pilot project of the pulse trawl technique. Fishermen from other EU member states are invited to join fishing trips aboard pulse trawl vessels. The introduction of the discard ban also puts pressure on the EU regime actors and institutions to look for more selective and sustainable fishing techniques.

Linking the transition phase to a transition pathway
This phase in the transition process links best to the technological substitution pathway. After the expansion of the number of pulse trawl licenses to 42, the conventional beam trawl is being replaced on a wider scale by the pulse trawl technique. The number of available licenses limits other Dutch fishermen to make the transition, while fishermen in other EU member states are limited by the high investments in the technique and insufficient sole quota in the North Sea. Those who cannot make the transition from the conventional beam trawl to the pulse trawl technique continue to struggle with high fuel prices, negative net results, and growing critics and concerns from society on the

negative environmental impact of the conventional beam trawl technique. This is in contrast to the fishermen that are using the pulse trawl technique, which are very efficient in catching sole and are profitable thanks to their reduced fuel consumption. As a consequence of this competitive advantage of the Dutch cutter fleet, fishermen in other EU member states start to oppose this new fishing technique. There was also a lot of uncertainty about the (long-term) effects of this new fishing technique and ignorance about the functioning of this fishing technique fed this uncertainty. As a result, the resistance at the EU regime level initially blocked a further expansion of the pulse trawl technique. However, the introduction of the landing obligation puts pressure on the existing European regime for change. This provides an opportunity for innovative fishing techniques and Dutch regime actors and institutions used this opportunity to allow further developments on and a wider introduction of the pulse trawl technique.

Linking the second time period to a transition pathway

This time period links best to the technological substitution pathway. It resulted in competition and power struggles between those fishing with the pulse trawl technique and those who could not or did not want to fish with this new fishing technique. In the Netherlands it managed to replace the conventional beam trawl technique in the flatfish cutter fleet. However, this substitution requires knock-on effects and further regime changes. A specially designed control and enforcement procedure is required for this fishing technique to keep it manageable. Maybe limitations should be installed on fishing areas, since the pulse trawl technique can be used in areas that were previously inaccessible for fishing with the conventional beam trawl. Next to a change in the regulative regime rules, a change is required in normative and cognitive regime rules. Fishermen should learn to fish wisely, which means that they have to try to distribute sole catches across the year and to decrease their number of discards. Otherwise the sole quota will be completely fished away within a couple of months, thereby putting pressure on prices and limiting a continues supply of sole over the year. Fishermen should also realise that the pulse trawl technique is not a solution to all the problems, but could be seen as a good step in a continuous process of improvement.

It seems that during the transition pathway of the pulse trawl technique, the focus was too much on implementing the technological innovation and little attention was being paid to changing the regime rules. There was a technology-push character from the Dutch niche and regime actors and institutions, while the use of electricity during fishing practices is not broadly accepted in the rule regimes of other EU member states. This way of fishing might be considered as inappropriate and conflicting with the normative and cognitive regime rules of other EU member states. The transition from the conventional beam trawl to the pulse trawl technique had also required some time in the Netherlands before it was accepted in the cognitive and normative rules regime of the Dutch flatfish sector. Only recently Dutch niche and regime actors and institutions are actively involving and informing a wider set of EU regime actors and institutions in the transition process of the pulse trawl.

The limited attention to changing the regime rules is also expressed by the disunity between the Dutch niche and regime actors and institutions. Especially the cognitive regime rules seem to differ between the involved actors and institutions. They have different priorities, problem agendas and beliefs concerned the pulse trawl technique. A shared vision on the future of the pulse trawl technique is currently lacking. This disunity partly hampers the creation of support for the pulse trawl technique at the European regime level. At this moment, attempts are made to catch-up with aligning the regime rules through the pilot project pulse. If sufficient support for the pulse trawl technique will be generated during this pilot project amongst European regime actors and institutions, then wider co-evolution processes can follow after substituting the conventional beam trawl with the pulse trawl technique.

6.4 THE OVERALL TRANSITION PATHWAY OF THE PULSE TRAWL TECHNIQUE

Now that the transition pathways for the first time period and the second time period have been identified, it is time to link these two together to one transition pathway. The first time period had links with transformation pathway and the de-alignment and re-alignment pathway, while the second time period had a link with the technological substitution pathway. So the transition of the pulse trawl technique consists of a mix of transition pathways and therefore it is clear that the transition pathway of the pulse trawl technique links best with the mixed transition pathway described by Grin et al. (2010). The transition pathway of the pulse trawl technique does not correspond to one of the four stereotype transition pathways, but has its own unique mixed transition pathway. There are several causes that resulted in this unique mixed transition pathway of the pulse trawl technique. The four most relevant causes for this unique mixed transition pathway are now discussed:

<u>1. Landscape level developments</u>

This case study showed the importance of external processes for a niche innovation to break through in a regime. The pulse trawl technique struggled with being accepted and implemented by the Dutch regime actors and institutions. However, developments at the landscape level exerted pressure on the regime actors and institutions, which led to a destabilization of the regime and opened a window of opportunity for the pulse trawl technique to break through. It is likely to assume that without these pressures from the landscape level, the transition would not have occurred. Although Grin et al. (2010) acknowledge the importance of the landscape level; it receives less attention in transition theory than the niche and regime level. This is because actors and institutions at the niche and regime level have relatively little power to influence landscape level developments in the short term. Despite the fact that niche and regime actors and institutions have little power to influence landscape developments, these landscape developments remain of importance for the pathway of transitions. But how should we deal with landscape developments that are beyond our control? Although regime actors and institutions have little power to influence landscape level developments, they do have the power to anticipate on landscape level developments. They can anticipate to landscape developments and use them to influence innovation processes.

If niche and regime actors and institutions want to anticipate on landscape level developments, they must make a selection. It is impossible to anticipate on all landscape developments and it would be pointless, since not all landscape developments are relevant. When talking about landscape developments, you can think of urbanization, globalization and climate change. Although all these landscape developments have a certain effect on regime and niche actors and institutions, their importance and influence on a transition process differs. The sustainable seafood movement, which responded to the overexploitation of the world's marine ecosystems, was a more relevant landscape development during this case study then urbanization. Therefore it is important for policymakers and managers to make a distinction between the relevance of various landscape level developments on their domain.

Once you have identified the most relevant landscape developments affecting your domain, it does not automatically imply that you can anticipate on these landscape developments. In this case study, two important landscape developments were the oil price developments and the need for more sustainable fisheries due to growing concerns and criticism from society on the overexploitation of the world's marine ecosystems and on the negative environmental impact of fisheries (discards and bottom impact in trawl fisheries). Oil price developments are hard to predict and it is even harder to anticipate on the fluctuations of the oil price, since it can be influenced by many factors. This type of landscape change is heavily subjected to change, and therefore it is beyond the control of a policymaker or manager to anticipate on such a landscape development. However, the growing need for sustainable fisheries is an example of a more stable, regular landscape level development on which policymakers and managers can anticipate. These examples illustrate that although certain landscape developments can be identified as relevant, there is a limit to the extent on which regime and niche actors and institutions can anticipate to these landscape developments. A distinction needs to be made in landscape develops that are dynamic and unstable, and landscape developments that are regular and stable. It is hard for policymakers and managers to anticipate on this first category, while they have the opportunity to anticipate on landscape developments belonging to the second category.

So instead of concluding that landscape level developments are important factors that cannot be influenced by regime and niche actors and institutions during a transition, the focus should shift on how to recognize and anticipate to relevant landscape developments. The report 'Fishing with headwind' is a good example of recognizing and anticipating to landscape level developments. However, a shared economic and environmental sustainable perspective for the North Sea cutter fleet is missing, because other EU regime actors and institutions with an interest in the North Sea were not involved. More attention should be paid on how policymakers and managers can use landscape development to influence a transition processes into a desirable direction. Thereby it is important that policymakers and managers make a distinction in the relevance and types of landscape developments. If they manage to do so, then it can be used as a tool to influence transitions.

2. Competition

Another factor that heavily influenced the transition pathway during this case study was the role of competition. There is the competition between fishermen and the competition between different EU member states that influences the transition pathway of the pulse trawl technique. This case study also clearly showed the competition between Dutch fishermen with a pulse trawl license and the Dutch fishermen without such a license. It resulted in a dichotomy in the Dutch flatfish-fishing sector, because fishermen using the pulse trawl technique were fishing successful and profitable, while fishermen without a pulse trawl license continued to struggle with the conventional beam trawl. As a result of this dichotomy, there was a lot of pressure on fisheries representative organizations and the Ministry to extent the number of pulse trawl licenses in order to level the playing field. However, the problems experienced with the conventional beam trawl also triggered some fishermen to switch to other alternatives like the twinrig or flyshoot technique. Currently, there is competition between Dutch fishermen for sole quota after the number of pulse trawl licenses has been extended to 84. It drives up the price for renting sole quota.

Competition can also positively influence a niche innovation, since it can spur innovation, reduce prices, it provides options for regime actors and institutions, and it can stimulate performance improvements. This case study clearly demonstrated the benefits of competition. It improved the performance of both gears and it reduced the price of the technique, thereby making it more accessible and attractive for regime actors and institutions to adopt the innovation.

Although competition can be productive for the development of a niche innovation, this case study shows that competition also has its drawbacks. As Grin et al. (2010) describe, it can lead to the fragmentation of resources, it can hamper the sharing of learning experiences and it can hamper the emergence of a stable set of rules. These three disadvantages of competition have in common that they result in uncertainty around a niche innovation. Both technological innovations in this case study are competing with each other in order to break through in the regime. They use the weaknesses and limitations of each other to strengthen their own position. As a result, learning experiences from one of the niche innovations cannot be extrapolated to the other niche innovation, leading to uncertainty. With the setup of a stable set of rules it is the same, since both parties try to use this to their advantage, thereby creating uncertainty about what rules should be installed. The regime actors and institutions opposing a transition will make use of this uncertainty, since it makes both niche innovations vulnerable to criticism. Criticism and concerns destabilize both niche innovations, which negatively influences their position to breakthrough into the regime level.

According to the theory on transition pathways of Grin et al. (2010), eventually one of the niche innovations will become dominant and forms the core for re-alignment of a new socio-technical regime. At this point however, it is uncertain which of the two niche innovations will become the dominant design that forms the core for re-alignment of a new socio-technical regime. Both niche innovations have been accepted and implemented by the Dutch regime and therefore a scenario is chosen in which these two innovations co-exist. In such a scenario, it is in the interest of both niche innovations to acknowledge that they share a specific problem, namely the ban on the use of electricity to catch fish. As long as this ban exists, the niche innovations cannot be completely accepted at the regime level. Cooperation on a certain level is crucial for the survival of both niche innovations. Making use of a specific, shared problem in order to reach an agreement is called problem structuring. Finding common ground is an intrinsic and crucial element for policymakers and managers to deal with competition.

So competition has both advantages and disadvantages for the development of a niche innovation. Thereby it creates a policy dilemma for policymakers and managers on how to manage competition during a transition process. Although Grin et al. (2010) acknowledge that competition has a certain influence on the pathway of a transition; there are no clear guidelines on how to deal with competition. According to Grin et al. (2010), “Managing transitions implies searching, learning and experimenting. As such, transition management is a quest, not a recipe for robust solutions”. So if there are no robust solutions on how to manage competition during a transition, how should policymakers and managers then respond to competition? This will be different for each transition. This case study can only help policymakers and managers with building competencies in recognizing and dealing with a policy dilemma like competition.

3. Technology-push character
This case study shows a strong technology push character, thereby it neglects necessary co-evolutionary dynamics as is described by Grin et al. (2010). A lot of attention was paid to optimize the niche innovation in order to replace the old technology, while little attention was paid to changes required in the rule regime. It corresponds to the findings of Grin et al. (2010), which identified that this is central problem of technology development in modern societies. Technology actors (firms, governments) tend to exclude certain actors and solely focus on technology development, while social aspects are being neglected. The majority of technology actors often consider technology as an instrument to reach a certain goal. It is used to provide a solution to environmental and social problems alike, which is also known as a technological fix.

There is also a smaller group that consider modern technology not as a solution, but as an uncontrolled cause for the exploitation and destruction of nature, people and culture. From their perspective, sustainability cannot be achieved through technological transition, but must be achieved through new socio-cultural values, different power structures and social innovation (Paredis, 2011). According to this view on technology, almost all industrial technologies and products take the form of techniques that plunder the earth's resources and externalize their costs (Paredis, 2011). However, they still believe in some manoeuvring room for the emergence of different, more appropriate and sustainable technologies, suited for and supportive of different societies (Paredis, 2011).

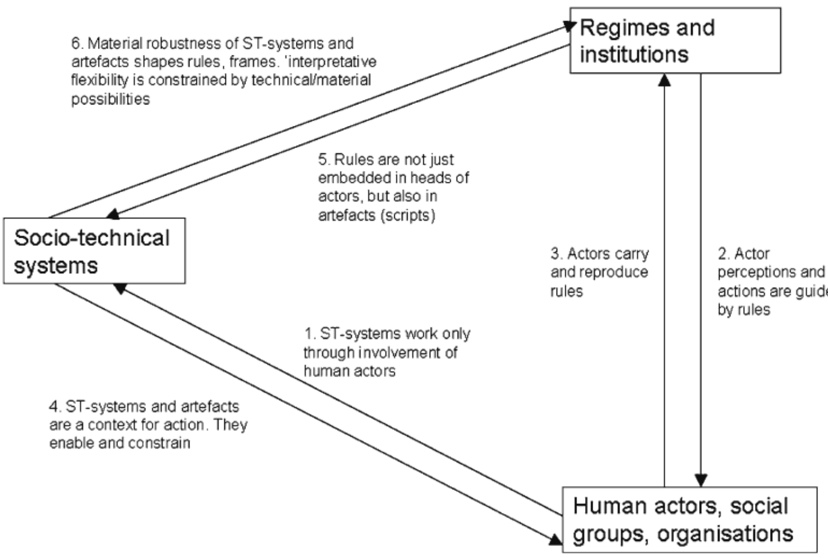


Figure 28. The interactions within a socio-technical system: *Arrow 1 shows how actors create and reproduce socio-technical systems; Arrow 4 shows how technologies shape perception, behavioural patterns and activities; Arrow 5 shows how rules are not only carried in an actor's head but also embodied in artefacts and practices; Arrow 6 shows how interpretative flexibility is limited by a certain obduracy of artefacts (Geels, 2005).*

The theory on socio-technical transitions opts for another approach, namely that technology and society are interrelated. Paredis (2011) states that, "Technology and society are shaping and being shaped by one another". This is characterized by how values influence technologies, how power relations change through technologies and how technologies shape daily lives (Paredis, 2011). So if we want to influence the direction of a transition, we need to understand the relation between technology and society (Johnson & Wetmore, 2009). According to Johnson & Wetmore (2009), "understanding how values are entwined in sociotechnical systems is crucial to steering technology to a future we want". Figure 28 shows how such a socio-technical system is buildup. While systems, actors and regimes can be distinguished analytically, they are always related in practice and exhibit six kinds of interactions (Paredis, 2011).

Now that more insight is gained in the relation between technology and society through socio-technical systems and the interactions within these systems, it gives policymakers and managers the opportunity to influence the direction of a transition. To avoid a technology-push character during a transition, policymakers and managers should realise that technology is socially constructed. As described by Paredis (2011), social groups from engineers over manufacturers to users, political decisions, institutions, cultural preferences, user behaviour etcetera have an influence on the conception, production, diffusion and use of technologies. So if policymakers and managers want to realize a technological transition, they should also realize a transition in social practices, social relationships, and social organization. They should not focus on individual products or processes, but on socio-technical systems and on the relations between the niche, regime and landscape levels in these systems (Paredis, 2011). A widely used strategy to realize a socio-technical transition is to increase pressure on current regimes, thereby working towards windows of opportunity to change regime structure, culture and practices. According to Paredis (2011) such a strategy can consist of the following elements:

- Translating landscape pressures (such as climate change, economic recession) into a necessity for regime change.
- Further increasing pressure on the regime through exposure of internal regime problems and formulation of alternative policies.
- Stimulating of niche development through networking, resource mobilisation, knowledge exchange and capacity building.
- Realisation of linkages between actors and developments at the three levels.
- Development of a long-term perspective on sustainable development that shapes expectations and aligns the activities of the involved social groups.

The two policy approaches that work out more detailed guidelines to influence transitions are Strategic Niche Management (SNM) and Transition Management (TM). These two policy approaches might give the involved policymakers and managers in this case study more detailed guidelines on how to influence the transition of the pulse trawl technique.

4. Regime level developments

During this case study, the MLP on transitions theory was used as the analytical framework to study the interactions between the niche, regime and landscape level along the transition pathway. The MLP on transitions theory describes how innovations are developed at the socio-technical niche level and can breakthrough at the regime level under certain circumstances. However, this case study shows that the breakthrough of a niche innovation into a regime does not automatically imply a complete breakthrough of a niche innovation at the regime level. Apparently a distinction needs to be made in this case study between a local regime, a national regime, a European regime and a global regime.

However, incorporating these three different regimes in the MLP on transitions theory would complicate the description and analysis of the interactions between the different scale levels even further. Besides, the MLP describes transitions as a consequence of interactions between different scale levels and is not based on geographical scales. Therefore it is not possible to use local, national, European and global regime scales in the MLP. Each regime consists of a set of rules that are shared by the engineering community involved in the design and production of technology, scientists, policy-makers, users and special-interest groups. All of them contribute to the evolution of socio-technical systems. Based on this information, it means that policymakers and managers need to include different regime actors and institutions to realize a transition in a national regime, then if they would try to realize a transition in a European regime.

When looking at the transition discussed in this case study, it is clear that a niche innovation did breakthrough at a national regime level. However, this national regime level is entrenched in a European regime. This European regime has its own set of rules, shared by a different engineering community involved in the design and production of technology, scientists, policy-makers, users and special-interest groups compared to the national regime level. In realizing a transition from the national regime to the European regime, the national regime will act as a sort of niche level according to the MLP on transition theory. So it is important for policymakers and managers to realize that making a transition in a European regime is a different process compared to realizing a transition in a national regime. These are two separate processes and therefore the MLP on transitions does not make use of these geographical scales. Each process thus needs to be analyzed on its own.

This brings us back to transition pathways, because if we need to analyze each process on its own, then each process will have its own sub-pathway. All these sub-pathways form no separate entities, but they form the overall transition pathway of an innovation as is shown in figure 29. The separate processes and sub-pathways give a very detailed insight in the interactions between the different levels in a certain phase, while all these separate processes and sub-pathways together construct an overall transition pathway, which gives insight in the overall transition process. All the separate processes and sub-pathways in this case study formed a mixed-transition pathway. Identifying a transition pathway helps policymakers and managers to understand how a transition evolved over time. Next to this insight, it provides information on how such a transition pathway emerged. It helps policymakers and managers to see the consequences of certain actions in a transition process, and it gives them insight in how interactions between the three levels of the MLP influenced the pathway of a transition.

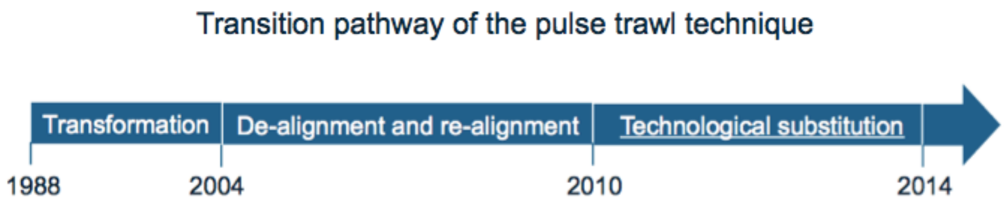


Figure 29. The transition pathway of the pulse trawl technique: *The transition pathway consists of three different sub-pathways, thereby forming a mixed transition pathway. Currently the transition pathway of the pulse trawl technique follows the technological substitution pathway.*

Although there are no clear recipes or guidelines for policymakers and managers to realize a transition since they are context-dependent, this case study does contribute to the searching, learning and experimenting process of unravelling how we can understand transitions. This case study gives further insights in the relevance of the landscape level, competition, socio-technical systems and the regime level for the pathway of a transition. These insights enable policymakers and managers to better understand transition and thereby it creates an opportunity for them to influence transitions towards more sustainable systems and societies.

7. CONCLUSIONS AND RECOMMENDATIONS

The main aim of this thesis study focuses on identifying the transition pathway of the pulse trawl technique on flatfish in the Netherlands by using the multi-level perspective on transitions theory of Geels (2011). This case study shows that there are no clear guidelines on the introduction of new fishing gears at the moment. Realizing transitions in fisheries is especially difficult, since transitions in fisheries are confronted with a high level of uncertainty. Determining the environmental impact of an innovative fishing technique is extremely difficult, because there are so many parameters that influence the potential impact of a new gear. There is also a lack of data on the environmental impact of current fishing techniques, which makes comparisons between different fishing techniques extremely difficult. Next to this uncertainty, there is the complexity of dealing with a transboundary natural resource. This means that the introduction of a new fishing technique does not solely have consequences for a single country, but also affects fisheries and fisheries management in other countries. Therefore, the introduction of a new fishing technique should not solely focus on the technological aspects, but also on social practices, relationships and organizations since technology and society are related. This case study provides wider insights on how technological transitions may fail or succeed in fisheries. Ultimately it contributes to our knowledge on how to better understand and influence long-term and complex transitions. Three research questions are formulated in this report in order to identify the transition pathway of the pulse trawl technique.

The first research question focuses on how the innovation developed at the niche level and was eventually being accepted and implemented by the Dutch regime actors and institutions. Initially, the pulse trawl technique was being developed by a small niche network of Dutch actors and institutions, which received support and protection from the regime level through the Dutch government. At a certain point the pulse trawl technique had developed itself sufficiently to be tested on a commercial vessel at the niche level. A commercial vessel was selected by the regime actors and institutions to conduct a pilot project. Meanwhile, the fishing industry had become involved at the regime level to also give support and protection to the niche network. However, at the end of the pilot project, there was little interest from the fishing industry to purchase a pulse trawl system due to doubts on the reliability and profitability of the gear. There was also a lot of distrust from the fishing sector about the motives of developing an alternative to the conventional beam trawl and on the results of the conducted research on the pilot vessel. A decision needed to be made by the regime actors and institutions on continuing the their support for the development of the pulse trawl technique or to withdraw their support. The fishing industry withdrew their support and thereby the pilot project came to an end. This period linked best to the transformation pathway described by Grin et al. (2010).

However, the niche network did not give up on the pulse trawl technique. Renewed support was found by a broader, more diverse set of regime actors and institutions. A group of fishermen was found that were willing to develop and test the pulse trawl technique further. Thereby this group acted as the frontrunners of the pulse trawl technique. The niche network organized itself in a Study Group, while receiving support and protection from regime actors and institutions that were actively trying to create optimal conditions for a transition. Meanwhile, competition had spurred on the development of the pulse trawl technique and eventually two different pulse systems were developed and tested. After both pulse systems were being installed and tested on the vessels of the frontrunners, the first results became to come in. These results demonstrated that both pulse systems were reliable and even more profitable then the conventional beam trawl. As a result, the flatfish fishing fleet accepted the pulse trawl technique and wanted to install the technique on a wider scale. This period linked best to the de-alignment and re-alignment pathway described by Grin et al. (2010).

The second research question focuses on under what circumstances the regime actors and institutions replaced the conventional beam trawl for the pulse trawl technique. One of the main pressures from the landscape level to resume the development of an electric fishing gear was caused by the growing critics and concerns on the environmental impact of the conventional beam trawl. There was a need for more sustainable fishing practices by society and this also influenced policymakers to increasingly adopt an ecosystem approach in fisheries management. However, the fishing industry did not agree with most of the criticisms and concerns on the conventional beam trawl that were expressed by society. Therefore, the majority of the fishing industry did not feel the need to make a transition to a new fishing technique. This changed when fishermen were confronted with another landscape development, namely rising fuel prices. They were already coping with decreasing quota and landings when the oil prices started to rise. It is likely that oil prices will continue to rise in the future. As a consequence, the economic position of most fishermen decreased due to negative net results of their fishing practices. This created a need for an alternative fishing technique for the conventional beam trawl and actors and institutions at the regime level broadly shared this need.

Several fishing techniques made use of this window of opportunity and the pulse trawl technique was one of them. However, it took some time before the pulse trawl technique was accepted and implemented by the Dutch regime due to internal niche conflicts and doubts about its reliability and profitability. Once the pulse trawl systems had proved themselves at the niche level, the Dutch fishing industry made the transition to the pulse trawl technique.

With the third question, the focus is on how niche and regime actors and institutions interacted with each other during the diffusion of this niche innovation. Now that the pulse trawl technique was accepted and implemented by the Dutch regime actors and institutions, the diffusion of this fishing technique was hampered by the ban on using electricity to catch fish. The EC granted EU member states a derogation for 5% of the fleet, but the number of registered fishermen in the Netherlands that wanted to make a transition to the pulse trawl technique exceeded this 5%. This is basically were a new transition process started, namely the breakthrough of the pulse trawl technique in the European regime. Now the Dutch regime actors and institutions formed a sort of niche network that was trying to get the pulse trawl technique to breakthrough at the European regime level.

Landscape developments exerted a lot of pressure on the Dutch regime actors and institutions to arrange a wider introduction of the pulse trawl technique. A broad interpretation of the 5% derogation was used to allow more fishermen to make the transition to the pulse trawl technique. The Dutch regime actors and institutions decided to organize themselves in the steering group pulse fishing. They looked for other opportunities to extend the number of pulse trawl licenses. Such an opportunity was found in the form of a research Article and after making a bilateral agreement with the EC, the number of experimental licenses was expanded to 42. In a reaction to this expansion of the number of experimental licenses, other EU member states started to agitate against the pulse trawl technique. European regime actors and institutions started to agitate against the pulse trawl technique for various reasons. Uncertainties around the pulse trawl technique were being used to halt a wider introduction of this technique, while some opted for a renewed ban. The main uncertainties that are being used to hamper the wider introduction of the pulse trawl technique concern the (long-term) effects on the ecosystem and its manageability. As discussed by Grin et al. (2010), the pulse trawl technique is confronted with turmoil, uncertainty, a lack of confidence, fear and impotence at the EU regime level. European actors and institutions that opposed the pulse trawl technique also started to make use of the uncertainty that was created at the niche level due to competition and internal niche conflicts.

As a result, Dutch regime actors and institutions started to respond to the criticisms and concerns expressed by European regime actors and institutions by organizing meetings and through conducting research. The steering group pulse fishing started with making an inventory on how politicians, fishing industries, scientists and CSO's in Germany, France, Belgium, Denmark, Sweden, Ireland, Spain, Italy, Poland and the United Kingdom think about the pulse trawl technique. Meanwhile, Dutch regime actors and institutions kept looking for opportunities to expand the number of experimental licenses. Eventually Dutch regime actors and institutions managed to take-up a provision in the regulation of the EMFF that would allow altering the technical measures. Other EU member states disagreed with this provision, but through power play it was kept in. However, the EP eventually decided to remove this provision, because the provision belonged to the negotiations on technical measures and not to the negotiations on the EMFF according to them.

This was a dramatic decision for the registered fishermen that already had invested in making the switch from the beam trawl to the pulse trawl technique. They demanded action and therefore the State Secretary for the Ministry of Economic Affairs decided to schedule a meeting with the Euro commissioner and the president of the European Council. During that meeting, the number of experimental licenses was expanded to 10% of the Dutch cutter fleet based on Article 14, which allows pilot projects that could facilitate the introduction of the landing obligation. After setting-up and handing-over a programme description concerning the national pilot project on pulse fishing, the exemption was granted in March 2014 for a period of five years. So they used the landing obligation, which is a consequence of the increasing need from society for sustainable fisheries at the landscape level, to expand the number of experimental licenses to 84. This period linked best to the technological substitution pathway described by Grin et al. (2010).

This leads to the conclusion that the transition pathway of the pulse trawl technique is built-up of several sub-pathways. These separate sub-pathways together form the mixed transition pathway of the pulse trawl technique on flatfish. There are several factors that influenced the transition pathway and caused this mixed transition pathway. The four most important factors that influenced the transition pathway of the pulse trawl technique are landscape level developments, competition, the technology-push character of the transition and the regime level developments. Thereby, this case study gives further insights in the relevance of the landscape level, competition, socio-technical systems and the regime level for the pathway of a transition. These insights enable policymakers and managers to better understand transition and thereby it creates an opportunity for them to influence transitions towards more sustainable systems and societies.

Currently, Dutch regime actors and institutions are more actively trying to inform and involve scientists, policy-makers, users and special-interest groups from other European member states. An informative video was made about the pulse fishing technique, factsheets were made and are distributed, and fishermen are invited to join fishing trips on vessels using the pulse trawl technique. With the setup of a research agenda for the pilot project pulse, the issues and concerns of different (international) stakeholders were addressed. Next to this research agenda, it was agreed to give an annual progress report to the North Sea AC, so that everyone can follow the progress around the pulse trawl technique. Although the future of the pulse trawl technique remains uncertain, Dutch regime actors and institutions increasingly seem to understand that support by a broader network of EU regime actors and institutions is required to realize a socio-technical transition at the EU regime level. It would be interesting and relevant to retrieve the perspective of relevant European regime actors and institutions on the transition pathway of the pulse trawl technique in follow-up research. It would complement the findings described in this report.

It is important for policymakers and managers to realise that technology is socially constructed. They should avoid a technology-push character by not solely focussing on realizing a technological transition, but also to focus on realizing a transition in social practices, social relationships, and the social organization of the European regime actors and institutions. This is of importance because social groups, ranging from engineers to manufacturers to users, political decisions, institutions, cultural preferences, and user behaviour etcetera have an influence on the conception, production, diffusion and use of technologies.

A remarkable thing is that although the landing obligation is a heavily debated and criticised measure amongst Dutch regime actors and institutions, it also provides a window of opportunity for the pulse trawl technique. The need for more sustainable fisheries by society at the landscape level resulted in pressure on the EU regime. It destabilizes the EU regime and the introduction of the discard ban in the EU is a reaction to this pressure from the landscape level. When the development and research on the pulse trawl technique would further focus on enhancing its selectivity, then it would be a legitimate claim to permanently admit this fishing technique in Europe. Maybe the discard ban will trigger other EU member states to start searching for applications of the pulse trawl technique in other fisheries. It is important for Dutch niche and regime actors and institutions to support such development and to continue with involving and informing European regime actors and institutions about the progress that is being booked in the Netherlands. Eventually the nature of interaction could take the shape of a symbiotic relationship between the Dutch niche and regime actors and institutions and those at the European regime level.

One important learning point from this case study is that niches do not only interact with the regime, but niches can also interact with each other. This case study solely focussed on the transition pathway of the pulse trawl on flatfish, but during the research it became clear that there is interaction with another niche innovation, being the pulse trawl technique for shrimp. It appears that these two niche innovations are both frustrating and stimulating each other. The interaction between these niche innovations influences the transition process, and in such a case it is useful and interesting to do a multi-niche analysis.

Another important issue concerns the absence of an implemented control and enforcement protocol for managing the pulse trawl technique. It is hard to setup a stable set of rules due to competition between the two pulse systems. The suppliers of the two pulse systems try to use this to their advantage, thereby complicating and slowing down the setup of stable rules. This lack of an implemented control and enforcement protocol creates uncertainty. The European regime actors and institutions that are opposing the pulse trawl technique make use of the created uncertainties, since it makes both niche innovations vulnerable to criticism. Criticism and concerns destabilize both niche innovations, which negatively influences their position to breakthrough into the regime level. Therefore, cooperation on a certain level is crucial for the survival of both niche innovations. To deal with this competition, policymakers and managers find common ground and make use of the shared problem, being the ban on the use of electricity.

As described in this report, a transition should not only focus on the technological innovation, but also on achieving a transition in the rule regimes in order to avoid a transition with a technological-push character. However, there seems to be a lack of tools to identify and to deal with a technological-push. The importance of realizing transitions in culture, social practices and relationships is acknowledged in transition theory, but more attention needs to be paid in future research on how to achieve a transition in these domains.

The final recommendation would be to come-up with an overall vision and a long-term perspective on the use of the pulse trawl technique. At the moment, such an overall vision and long-term perspective seems to be missing. It would be useful to construct an overall vision and long-term perspective on the pulse trawl technique that is supported by all Dutch involved actors and institutions. Such a shared overall vision and long-term perspective will also be useful for realizing a transition in the European regime.

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Figures

Figure 3: http://visserijnieuws.punt.nl/content/2012/10/eu-meer-vissers-met-innovatief-vistuig-pulskor, last accessed on 05-08-2014.

Figure 4B: http://www.ecomare.nl/en/encyclopedia/man-and-the-environment/fisheries/fishery-techniques/pulse-trawling/, last accessed on 05-08-2014.

Figure 8: http://www.sumwing.nl, last accessed on 27-10-2014.

Figure 25: http://www.scheepvaartkrant.nl/docs/Themabijlage_Visserij_Scheepvaartkrant_2014.pdf last accessed on 19-12-2014.

Appendix 1

There are two different pulse trawl systems for catching flatfish. Both systems have marginal differences in their pulse characteristics. These differences range from the number of pulses per second, the duration of the pulse, the number of electrodes, the distance between the electrodes and the number and size of the conductors (Quirijns et al., 2013).

Pulse characteristics

As described by Quirijns et al. (2013), the pulse characteristics consist of the following features:

- Amplitude in volt (V): The potential that is measured between two conductive parts.
- Electric field strength (volt/cm): The logical consequence of the amplitude and the electrode distance.
- Pulse frequency (Hz): The number of pulses per second.
- Pulse duration (μs): The duration of the pulse.
- The steepness of the leading and trailing edge of the pulse.
- The shape of the electric field (the direct consequence of the pulse shape, but it also depends on type and number of electrodes, the distance between electrodes, and the length/combination of the conducting and insulating parts).

The pulse that passes through the fish is of importance during fishing. The field strength (the potential difference across the body of the fish) and the resistance (conductivity) are determinative herein, as well as the duration of the pulse. Electric fields are not homogeneous in these pulse trawl systems. These electric fields have a three-dimensional gradient. Therefore, the potential difference depends on the position of the fish in the electric field and the length of the fish (Quirijns et al., 2013).

Different pulse effects under different circumstances

The electric field, which is being generated with the pulse trawl system, does not have the same effects under all circumstances and on all fish (and other organisms). According to Quirijns et al. (2013), the conductivity and the strength of the pulse under water depends on:

- The difference in conductivity of the seafloor and of the seawater;
- The soil composition: A silty soil has a better conductivity than a sandy soil;
- The salinity of the water: Salt water has a higher conductivity than fresh water;
- The water temperature: Warm water has a higher conductivity than cold water.

Quirijns et al. (2013) describe that the effect of the pulse varies according to:

- The conductivity of the fish and the anatomy of the fish;
- The intensity (μs and Hz) and the field strength (V/cm) of the pulse;
- The speed at which the fish gets caught with the pulse trawl system: a fish is less exposed to the electric field of a vessel with a higher speed;
- The length and rigging of the conductive and insulating electrical parts;
- The distance to the conductor: the closer to the conductor, the stronger the electrical pulses;

- The shape and length of the fish and/or the muscle mass: how longer the fish and/or the more muscle mass, the more powerful are the muscle contractions caused by the electric pulses;
- The orientation of the fish: it does matter whether a fish lays/swims parallel or perpendicular with respect to the electric field. The potential difference across the body is decisive.

Appendix 2

Interview formats

These are the questions that were posed during the interviews. The interview questions were posed in Dutch.

Interview with Technological company 1

- With what initial thought did Technological company 1 develop the pulse trawl technique?
- How and when did Technological company 1 become involved in the development of the pulse trawl technique?
- With which actors and institutions did Technological company 1 mainly have contact at the time?
- In which way does Technological company 1 contribute to the gathering of knowledge on pulse fishing?
- Pulse fishing is a controversial fishing technique within the Netherlands and banned within the EU. In what extent has Technological company 1 contributed to changing the negative image of pulse fishing?
- How does one nowadays think about pulse fishing at Technological company 1?
- What goal does Technological company 1 currently have with the pulse trawl technique?
- The number of pulse trawl vessels has increased in the past few years. What does Technological company 1 think of this development?
-What does Technological company 1 see as the main reason for Dutch beam trawl fishermen to switch to the pulse trawl technique?
- Do you see noticeable differences between the precursors (the pioneer fishermen that started fishing with the pulse trawl technique) and the fishermen that switched at a later stage from the beam trawl to the pulse trawl technique?
- In what way does the pulse trawl system of Technological company 1 differ from the pulse trawl system of Technological company 2?
- How has the pulse trawl technique changed over time?
- What would be the consequences if the EU would decide to withdraw the pulse trawl licenses?

Interview with employee of the Ministry of Economic Affairs 1

- How and when did you become involved in the testing of the pulse trawl technique?
- Which actors and institutions were informed/involved at the European level about the development of the pulse trawl technique?
- What goal and vision was propagated by the Netherlands to the involved European actors and institutions about the pulse trawl technique?
- How were developments and progress around the pulse trawl technique communicated towards the European level?
- What was the initial attitude of involved European actors and institutions to the development of the pulse trawl technique?
- Did the attitude of the involved European actors and institutions change along the development process of the pulse trawl technique?
- What is according to you the main reason for the resistance to the pulse trawl technique in other European member states?

- How are developments at the European level being communicated towards the involved Dutch actors and institutions?

Interview with fisherman 1
- What was your initial thought about the pulse trawl technique?
- How and when did you become involved in the testing of the pulse trawl technique?
- What was your main goal with switching from the beam trawl technique to the pulse trawl technique at the time?
- Which actors and institutions were involved when you made the switch to the pulse trawl technique?
- How do you contribute to the gathering of knowledge on the pulse trawl technique?
- Pulse fishing is a controversial fishing technique within the Netherlands and banned within the EU. In what extent have you contributed to changing the negative image of pulse fishing?
- How do you nowadays think about pulse fishing?
- What goal do you currently have with the pulse trawl technique?
- The number of pulse vessels had increased in the past few years. What do you think about this development?
- What do you see as the main reason for Dutch beam trawl fishermen to switch to the pulse trawl technique?
- Why did you choose for the pulse system from Technological company 2 instead of the pulse trawl system of Technological company 1?
- What agreements were made in the pulse trawl license?
- In what way has the pulse trawl system changed over time?
- What would be the consequences if the EU would decide to withdraw the pulse trawl licenses?

Interview with fisherman 2
- What was your initial thought about the pulse trawl technique?
- How and when did you become involved in the testing of the pulse trawl technique?
- What was your main goal with switching from the beam trawl technique to the pulse trawl technique at the time?
- Which actors and institutions were involved when you made the switch to the pulse trawl technique?
- How do you contribute to the gathering of knowledge on the pulse trawl technique?
- Pulse fishing is a controversial fishing technique within the Netherlands and banned within the EU. In what extent have you contributed to changing the negative image of pulse fishing?
- How do you nowadays think about pulse fishing?
- What goal do you currently have with the pulse trawl technique?
- The number of pulse vessels had increased in the past few years. What do you think about this development?
- What do you see as the main reason for Dutch beam trawl fishermen to switch to the pulse trawl technique?
- Why did you choose for the pulse system from Technological company 1 instead of the pulse trawl system of Technological company 2?
- What agreements were made in the pulse trawl license?
- In what way has the pulse trawl system changed over time?
- What would be the consequences if the EU would decide to withdraw the pulse trawl

licenses?

Interview with Technological company 2
- With what initial thought did Technological company 2 develop a pulse trawl system?
- How and when did Technological company 2 become involved in the development of a pulse trawl system?
- With which actors and institutions did Technological company 2 mainly have contact at the time?
- In which way does Technological company 2 contribute to the gathering of knowledge on pulse fishing?
- Pulse fishing is a controversial fishing technique within the Netherlands and banned within the EU. In what extent has Technological company 2 contributed to changing the negative image of pulse fishing?
- How does one nowadays think about pulse fishing at Technological company 2?
- What goal does Technological company 2 currently have with the pulse trawl technique?
- The number of pulse trawl vessels has increased in the past few years. What does Technological company 2 think of this development?
-What does Technological company 2 see as the main reason for Dutch beam trawl fishermen to switch to the pulse trawl technique?
- Do you see noticeable differences between the precursors (the pioneer fishermen that started fishing with the pulse trawl technique) and the fishermen that switched at a later stage from the beam trawl to the pulse trawl technique?
- In what way does the pulse trawl system of Technological company 2 differ from the pulse trawl system of Technological company 1?
- How has the pulse trawl technique changed over time?
- What would be the consequences if the EU would decide to withdraw the pulse trawl licenses?

Interview with Fisherman 3
- What was your initial thought about the pulse trawl technique?
- How and when did you become involved in the testing of the pulse trawl technique?
- What was your main goal with switching from the beam trawl technique to the pulse trawl technique at the time?
- Which actors and institutions were involved when you made the switch to the pulse trawl technique?
- How did you contribute to the gathering of knowledge on the pulse trawl technique?
- Pulse fishing is a controversial fishing technique within the Netherlands and banned within the EU. In what extent have you contributed to changing the negative image of pulse fishing?
- The fishing industry decided to withdraw their support for the pilot project in 2007. What was their reason to do that?
- Why did you switch to a different fishing technique aboard your new vessel in 2007, despite being optimistic about the pulse trawl technique earlier that year?
- How do you nowadays think about pulse fishing?
- The number of pulse vessels had increased in the past few years. What do you think about this development?
- What do you see as the main reason for Dutch beam trawl fishermen to switch to the pulse trawl technique?

- What do you see as the cause for the negative image of the pulse trawl technique amongst the other European member states?
- The sole quota is nearly fully fished for this year in a relatively short time. How do you think it is going to regulate itself?
- Would you reconsider fishing with the pulse trawl technique again?

Interview with Fisheries representative organization 1
- What was the initial thought of Fisheries representative organization 1 about the pulse trawl technique?
- How and when did Fisheries representative organization 1 become involved in the development of a pulse trawl system?
- What goal do fishermen have with the pulse trawl technique according to you?
- With which actors and institutions does Fisheries representative organization 1 mainly have contact?
- In what way is Fisheries representative organization 1 involved in the development of the pulse trawl technique?
- Pulse fishing is a controversial fishing technique within the Netherlands and banned within the EU. In what extent has Fisheries representative organization 1 contributed to changing the negative image of pulse fishing?
- What is according to you the main reason for the resistance to the pulse trawl technique in other European member states?
- The number of pulse trawl vessels has increased in the past few years. What does Fisheries representative organization 1 think of this development?
- What do you see as the main reason for Dutch beam trawl fishermen to switch to the pulse trawl technique?
- Did the view of Fisheries representative organization 1 on the pulse trawl technique change over time?
- How does Fisheries representative organization 1 see the future of the pulse trawl technique?

Interview with Employee of the Ministry of Economic Affairs 2
- When you started your job at the Ministry (2005), the developments around the pulse trawl technique did already run for a couple of years. What was, according to you, the most important reason for the Ministry to explore the possibilities of this fishing technique and to invest in it?
- What goal(s) did the Ministry try to achieve with this fishing technique according to you?
- In what way did the Ministry support the development of the pulse trawl technique?
- Which actors and institutions were involved at the time?
- How did the fishermen, scientists, the technological companies and the Ministry communicate with each other?
- How were developments and progress around the pulse trawl technique communicated towards the European level?
- I understood that the fishing industry did no longer want to invest in the pulse trawl technique in 2007, but the Ministry wanted to continue investing in the pulse trawl technique. What is your view on that?
- What was the main reason for the pioneers (first five fishermen) to switch from the beam trawl to the pulse trawl technique according to you?

- Do you remember what agreements were made with the involved actors and institutions in the pulse trawl licenses?
- What position did the Ministry take once another pulse trawl system had been developed?
- What influence did the competition between the two pulse trawl systems have on the transition process?
- You have no longer been (directly) involved in the developments around the pulse trawl technique for a number of years. If you look back now on your period at the Ministry, would you have done things differently?
- What is according to you the main reason for the resistance to the pulse trawl technique in other European member states?
- During one of my interviews, I heard that the government relaxed the reins somewhat along the transition process. As a result, the fishing industry got more freedom to steer the developments around the pulse trawl technique. What is your view on that?
- How do you currently think about the pulse trawl technique?

Interview with Employee of the Ministry of Economic Affairs 3
- When you started your job at the Ministry (2005), the developments around the pulse trawl technique did already run for a couple of years. What was, according to you, the most important reason for the Ministry to explore the possibilities of this fishing technique and to invest in it?
- What goal(s) did the Ministry try to achieve with this fishing technique according to you?
- In what way did the Ministry support the development of the pulse trawl technique?
- Which actors and institutions are currently working on the permanent admission of the pulse trawl technique?
- How do fishermen, scientists, the technological companies and the Ministry communicate with each other?
- How are developments and progress around the pulse trawl technique communicated towards the European level?
- What is according to you the main reason for the resistance to the pulse trawl technique in other European member states?
- In February 2014, the number of experimental licenses was expanded to 84. Why did the Ministry of Economic Affairs support this expansion of the number of experimental licenses?
- Currently, there are still a number of fishermen that use an experimental pulse trawl license, because there are uncertainties about the effect of this fishing technique on the ecosystem. What do you think of the provision of 84 experimental licenses, since with such a high number of licenses it is hard to speak of an experiment and even harder to switch back to another fishing technique?
- Why were four different types of experimental licenses provided?
- How is determined which fishermen receive a license and which fishermen not?

Interview with Employee of the Ministry of Economic Affairs 4
- Do you know the reason for allowing technical research on electric fishing by the EU in 1991?
- From who came the initiative to resume research on an electric fishing technique with Verburg-Holland BV after the ban of 1988?
- What was, according to you, the most important reason for the Ministry to explore the

possibilities of this fishing technique and to invest in it?
- What goal(s) did the Ministry try to achieve with this fishing technique according to you?
- In what way did the Ministry support the development of the pulse trawl technique?
- What actors and institutions have been involved during the transition process since 1992?
- How do fishermen, scientists, the technological companies and the Ministry communicate with each other?
- How were developments and progress around the pulse trawl technique communicated towards the European level?
- I understood that the fishing industry did no longer want to invest in the pulse trawl technique in 2007, but the Ministry wanted to continue investing in the pulse trawl technique. What is your view on that?
- What was the main reason for the pioneers (first five fishermen) to switch from the beam trawl to the pulse trawl technique according to you?
- Why were four different types of experimental licenses provided?
- What position did the Ministry take once another pulse trawl system had been developed?
- What influence did the competition between the two pulse trawl systems have on the transition process?
- You have no longer been (directly) involved in the developments around the pulse trawl technique for a number of years. If you look back now on your period at the Ministry, would you have done things differently?
- What is according to you the main reason for the resistance to the pulse trawl technique in other European member states?
- During one of my interviews, I heard that the government relaxed the reins somewhat along the transition process. As a result, the fishing industry got more freedom to steer the developments around the pulse trawl technique. What is your view on that?
- How do you currently think about the pulse trawl technique?

Interview with the NGO employee
- What was the initial thought of the NGO about the pulse trawl technique according to you?
- How and when did the NGO become involved?
- What goal did the NGO have with the pulse trawl technique according to you?
- With which actors and institutions does the NGO mainly have contact?
- In what way does the NGO influence the development of the pulse trawl technique?
- What is according to you the main reason for the resistance to the pulse trawl technique in other European member states?
- What is the opinion of the NGO about expanding the number of pulse trawl licenses to 84 in February 2014?
- Has the point of view of the NGO on the pulse trawl technique changed over time?
- How does the NGO see the future of the pulse trawl technique?

Interview with Fisheries representative organization 2
- What was the initial thought of Fisheries representative organization 2 about the pulse trawl technique?
- How and when did Fisheries representative organization 2 become involved in the development of a pulse trawl system?

- What goal do fishermen have with the pulse trawl technique according to you?
- With which actors and institutions does Fisheries representative organization 2 mainly have contact?
- In what way is Fisheries representative organization 2 involved in the development of the pulse trawl technique?
- Pulse fishing is a controversial fishing technique within the Netherlands and banned within the EU. In what extent has Fisheries representative organization 2 contributed to changing the negative image of pulse fishing?
- What is according to you the main reason for the resistance to the pulse trawl technique in other European member states?
- The number of pulse trawl vessels has increased in the past few years. What does Fisheries representative organization 2 think of this development?
- What do you see as the main reason for Dutch beam trawl fishermen to switch to the pulse trawl technique?
- Did the view of Fisheries representative organization 2 on the pulse trawl technique change over time?
- How does Fisheries representative organization 2 see the future of the pulse trawl technique?

Interview with LEI researcher
- How and when did the LEI become involved?
- What goal did the LEI have with the pulse trawl technique according to you?
- What role did the LEI have in the transition process of the pulse trawl technique?
- With which actors and institutions did the NGO mainly have contact?
- In what way does the LEI influence the development of the pulse trawl technique?
- What is according to you the main reason for the resistance to the pulse trawl technique in other European member states?
- What is the opinion of the LEI about expanding the number of pulse trawl licenses to 84 in February 2014?
- Has the point of view of the LEI on the pulse trawl technique changed over time according to you?
- How does the LEI see the future of the pulse trawl technique?

Interview with ILVO researchers
- When did ILVO start its first research on the application of the pulse trawl technique?
- Where did the demand for research on the pulse trawl technique come from?
- Which actors and institutions were involved in the research?
-How were research results communicated?
- To whom were research results communicated?
- What is the vision of ILVO on the future of the pulse trawl technique on flatfish according to you?
- What is the vision of ILVO on the future of the pulse trawl technique on shrimp according to you?
- How do other involved actors and institutions think about the pulse trawl technique?
- What are the main concerns and uncertainties about the pulse trawl technique at the moment according to you?
- What role does ILVO have around the concerns and uncertainties of the pulse trawl technique according to you?
- What needs to be done to get a permanent admission of the pulse trawl technique

according to you?

Appendix 3

The 6 main messages in the report 'Fishing with headwind' for all involved actors and institutions in the Dutch fishing industry (translated from Dutch):

1. Various 'issues' in the flatfish fishery should be addressed to the benefit of the development of the stock (excessive fishing effort, discards), the (bottom) ecosystem (soil disturbance), and the environment (high fuel consumption). Although flatfish, and especially sole, undeniably remain of high economic importance to the Dutch fishing industry, possibilities provided by other fish species and fishing methods should also be fully utilized in the future.

2. The current flatfish fishery, which merely uses the conventional beam trawl, has no sustainable future perspective. A profitable fishery with less impact on nature and the environment and with a better energy balance can be achieved in the future by decreasing the fishing effort. Moreover, we see opportunities for smaller vessels with less power, and multifunctional fisheries. An adjusted beam trawler can remain part of such a fleet.

3. Social acceptance is essential for the future of the North Sea fishing fleet. This social acceptance is achieved through the establishment of a so-called social contract between the sector and the relevant CSO's, in which the accepted future vision of the North Sea fisheries, thus a 'license to produce', are stipulated for a prolonged period of time.

4. Fragmentation in the fishing industry leads to less power. For a profitable fishery where supply and demand are better coordinated, more cooperation is needed between both entrepreneurs within links of the supply chain as between different links in the supply chain.

5. To accomplish a transition, a major investment of 300 to 400 million euro is required for the medium term.

6. Innovative entrepreneurs have the future and should therefore be encouraged to implement their ideas. Support can be provided through an implementation program, the provision of space in policies and regulations, the creation of incentives for innovators, the setup of a FIP, and through the provision of education and information.

Appendix 4

Advice of the ICES ad hoc expert group on the pulse trawl technique in 2006

- "The available information shows that the pulse trawl gear could cause a reduction in catch rate (kg/hr) of undersized sole, compared to standard beam trawls. Catch rates of marketable sole above the minimum landing size from research vessel trials were higher but commercial trials suggested lower catch rates. Plaice catch rates also decreased for all size classes. No firm conclusions could be drawn for other species but there was a tendency for lower catch rates"

- "Because of the lighter gear and the lower towing speed, there is a considerable reduction in fuel consumption and the swept area per hour is lower".

- The gear seems to reduce catches of benthic invertebrates and lower trawl path mortality of some in-fauna species.

- There are indications that the gear could inflict increased mortality on target and non-target species that contact the gear but are not retained.

- The pulse trawl gear has some preferable properties compared to the standard beam trawl with tickler chains but the potential for inflicting an increased unaccounted mortality on target and non-target species requires additional experiments before final conclusions can be drawn on the likely overall ecosystem effects of this gear".

ICES recommendations on additional data needed:

- "Further tank experiments are needed to determine whether injury is being caused to fish escaping from the pulse trawl gear. The experiments need to be conducted on a range of target and non-target fish species that are typically encountered by the beam trawl gear and with different length classes. In these trials it should be ensured that the exposure matches the situation in situ during a passage of the pulse beam trawl. Fish should be subjected to both external and internal examination after exposure".

- "If the pulse trawl were to be introduced into the commercial fishery, there would be a need to closely monitor the fishery with a focus on the technological development and bycatch properties".

Appendix 5

Trends in the Dutch cutter fishery

	1990	2000	2006
Number of vessels	553	402	346
Engine power (1.000 hp)	559	428	308
Employment	2.486	1.831	1.399
Value of landings (mln euro)	315	290	256
Value of landings (mln euro, prices of 2006)	410	296	256
Quota sole (tonnes)	18.000	16.500	11.800
Quota plaice (tonnes)	88.700	38.600	20.300
Quota cod (tonnes)	11.500	8.800	2.000

Source: Salz et al., 2008 (translated from Dutch).

Appendix 6

Conclusions and recommendations of the report on the effects on cod
The present results clearly demonstrate that cod of the length range tested (0.41-0.55 m) might be affected by pulse stimulation, depending on the position of the fish relative to the conductors of the electrodes.

Cod exposed outside the distance range of 0.4 m from the electrodes, representing fish in the region just outside the trawl, did not react to exposure and these fish returned also to normal feeding behaviour. No effects were found in the "far field" distance range of 0.4 m from a conductor, and only minor effects in the "above field" distance range of 0.2-0.3 m. However, more severe effects occurred in the "near field" distance range of 0.1-0.2 m from a conductor.

Cod exposed in this range can suffer severe vertebral injuries. In the closest range 5 cases showed vertebral injuries (Table 2), while 6 of the 20 exposed fish did not survive the highest exposures. In comparison, no mortality was observed in the other treatment groups. These injuries were the result of strong muscle contractions during exposure. In all observed cases, including the single case observed in the pilot study the vertebral injuries were found in the same location under the third dorsal fin (Figure 3, 5 and 6). Fish exposed above the center of the pair of conductors did show similar but milder muscle contraction during exposure. They did not get injured and responded well to feeding cycles.

The present study indicates that the pulse amplitude should be reduced by 15 % of the nominal setting to reduce the effects and vertebral injuries. The present pulse settings, however, are optimized for catching sole after many field trials. In wintertime an increase of 15 % is needed to maintain catching efficiency on sole, which further raises the chances of vertebral injuries in cod, as they tend to stay close to the bottom in that season with increased possibility of getting in close range of the electrodes and subsequently being exposed to field strengths of values equivalent to the tested "near field" category or higher (15 % amplitude increase in winter), which can cause injuries found in this study.

Tests on undersized cod were not carried out in our study due to time and budget constraints. Consequently the effects on such fish that may come in contact with the gear, but may not be captured, remain unknown. Being shorter in length the effects will likely be less, but may require further attention.

In most cases cod in the length class tested here will be retained by the relatively small cod-end mesh size in this fishery (i.e. 80 mm). Spinal injuries and haemorrhages around the vertebrae will have a negative effect on the appearance of the landed fish and its commercial value.

Conclusions of the report on the effects on dogfish
No evidence was found of an effect of the degree of the electric exposure on feeding response or likelihood of injury or death. There was no evidence that fish sustained injuries as a result of the exposures. Respectively 8 and 9 months after the experiment a single specimen of the "above field" category and "near field" category died.

In the 14 days observation period after the exposures no aberrant feeding behavior could be distinguished. Fish in all tested groups started feeding normally the same day directly after the exposures. In a period of 7 months after the exposures all exposed groups produced eggs in numbers varying between 5-39 per group.

Conclusions of the report on the effects on
Exposure to pulse stimuli as used in the Verburg-Holland system does not seem to severely affect the benthic species tested (ragworm (*Nereis virens L.*), common prawn (*Palaemon serratus L.*), subtruncate surf clam (*Spisula subtruncata L.*), European green crab (*Carcinus maenas L.*), common starfish (*Asterias rubens L.*), and Atlantic razor clam (*Ensis directus L.*)).

The survival of three species was lowered by 3:7%, i.e. ragworm, green crab and razor clam. Food intake might be affected as found for green crab (lowered by 5:15%), which may have contributed to their lower survival. The other species (common prawn, surf clam and starfish) showed no significant effects (Table 13).

Surf clam and starfish did not show any behavioural reaction at all, they did not move. The other species showed very low responses in the far field exposure range. In the medium and near field ranges the reactions were stronger. The behaviour depends on species, prawns often jump up, crab stiffens; ragworm gave jerky movement as response, while razor clam sometimes uses its foot and siphon to move away.

Conventional beam trawling with heavy tickler chains affect the marine ecosystem by favouring short lived over long-lived species (Lindeboom and de Groot, 1998). Pulse beam trawling was shown to result in significantly lower bycatches of benthic invertebrates compared to conventional tickler chain beam trawling, and gave indications of lower trawl path mortality (24% vs. 36% median) for 15 abundant benthic species (Van Marlen et al., 2001).

Mortality increase, if at all, was low (3:7% for ragworm, green crab and razor clam), and food intake and behaviour recovered after exposure. It is therefore plausible that the effects of pulse beam trawling, as simulated in this study, are far smaller than the effects of conventional beam trawling.

Appendix 7

ICES advice for further research in 2009

1. The work carried out by IMARES as a response to the ICES advice on pulse trawling is notable for the high quality of the experiments. Detailed measurements of electric field parameters both in natural environment and during the experiments are noteworthy. A particular attention was given to the control groups of animals, which were subjected to the same manipulations as the test groups but not electrically exposed to minimize the influence of transfer and handling. An additional positive point of the study is the use of an electric pulse simulator with pulse characteristics similar to the commercial Verburg pulse system. The numbers of fish both in the test and control samples were adequate. The presentation of the mortality results (as proportions), as well as the occurrence of spinal injuries in cod, along with their associated binomial confidence intervals (at 95%, say) (using "Statxact" for example) is informative. Moreover, at the same time a simple power analysis could be performed indicating the necessary sample size for future experiments (based on the deviance in these preliminary results).

2. With respect to benthic invertebrates, the results clearly show a low level of impact on the complete range of species tested. These species are considered representative of those encountered in the beam trawl fisheries. Based on all known literature on the expected mortalities of such species from traditional tickler chain beam trawls, it is therefore reasonable to assume that the impact of a pulse trawl with a pulse configuration corresponding to the experimental pulses on benthic invertebrates is less by a higher order of magnitude. It is important, however, that for the gear to be used with low impact that the existing prohibition on the addition of tickler chains in front of the electrode arrangements contained in the EU derogation should be maintained. Otherwise, tickler chains will cause additional ecosystem impact.

3. The experiments carried out on elasmobranches show only a very limited effect on the species tested and it is unlikely the pulse trawl system will have a major impact on elasmobranch species. It was shown that general well-being of exposed dogfish was good in that they produced eggs and exhibited no aberrant feeding behavior.

4. The results show that the system is capable of inflicting vertebral damage leading to mortality of cod that were in close proximity (<20 cm) of the conductors. Also, inconclusive evidence suggest that the system may have a higher fishing efficiency for cod than the conventional gear (See attached review by Norman Graham of De Haan D., van Marlen B., Kristiansen T.S., Fosseidengen J.E., 2009a in Annex 1), but further research is needed to address this question and reduce cod mortality.

5. The derogation for use of the pulse trawl in Council Regulation (EC) No 43/2009 defines the voltage (V) and current power (KW =V*A) that can be used. However, it is not altogether clear from the reports how representative the experimental set up is with respect to the limits set within the derogation. The author's note that the tank tests were conducted "with pulse characteristics equivalent to the nominal menu settings…. which represent the average settings of the pulse properties…. " They then go on to note that these can be varied by +/- 20%. This raises concerns that the full range of settings were not tested and it is unclear what the impact of the 'maximum' setting could be.

6. ICES previously advised that the effects across different length classes encountered by the fishery should be considered. This issue has only been partially addressed as the experiments on cod were conducted on a narrow range of fish (41–55cm). Fish length has been shown to be important in terms of reaction and the results cannot be extrapolated beyond the length groups tested. The effects on small fish and larger fish can only be estimated based on previous experimentation and in this respect the authors refer to the work by Stewart (1975), which showed lower effects for smaller fish. Based on all known literature, large fish are expected to be more negatively affected (e.g., more vertebral damage) (Snyder, 2003). The relative impact on the catchability of larger fish is unclear.

7. Due to commercial confidentiality, details on the pulse frequency, pulse shape, pulse duration, voltage/power of the pulse trawl are not widely available which hinders review of the potential impact of the system on target and non-target species. All of these factors are important as discussed by Snyder (2003).

8. It is also noted that the specifications in the derogation granted by the EC are not specific enough to assure that the results of the experiments discussed in this advice are applicable to all of the pulse trawls allowed under the derogation.

Appendix 8

The NGO Stichting de Noordzee incorporated the pulse trawl technique in their vision on the future of the North Sea. Their 2011 report contained this table (translated from Dutch), which explains their zonation plan for the North Sea. Each zone in the North Sea would allow only certain fishing techniques.

Zone 1	The reserves are within the protected areas. Nature in this non-fishing area serves as a reference for the other zones.
Zone 2	Areas were passive fishing is allowed. Passive fishing techniques include gillnetting, trammel, traps, lines, hooks, long-lines and hand-lines. These areas are located both inside and outside the protected areas.
Zone 3	Areas were passive and semi-passive fishing is allowed. To semi-passive fishing techniques belong the Danish seine, Scottish seine and flyshooting. These areas are located both within and outside the protected areas.
Zone 4	Areas where next to semi-passive and passive fishing techniques also trawl fishing is allowed. These areas are located outside the protected areas. This includes forms of trawling in which the net is dragged over the seafloor, but not through the seafloor. Examples are the otter trawl, twinrig, pulse wing, pulse trawl, eco-catcher, hydrorig, twinspan, outrig and shrimp trawl. Generally, the rollers at the bottom of the net ensure that the net is dragged across the seafloor. No chains are attached to the net. The flatfish are startled into the net through electric pulses or jets of water.
Zone 5	Areas where next to all other techniques also fishing techniques are allowed that alter the seafloor. These areas are located outside the protected areas. These forms of trawling pull chains through the soil to startle the flatfish into the net. Sometimes chain mats are used. The chains are used in beam trawl, sumwings or otter trawls.

(Stichting de Noordzee, 2011)

In the VIBEG-agreement of 2011, the pulse trawl technique was also incorporated in the plans and policies, as is discussed in the report of Deerenberg & Heinis (2011). The report stated that:

The principle VIBEG-agreement of 9 February 2011 describes five different areas, which distinguish themselves by allowing certain types of fishery. Relevant to the appropriate assessment of the beam trawl fishery is the breakdown in:

- Closed areas for all trawl fisheries (zones 1 & 2).
- Areas open to sustainable and innovative trawl fisheries, like the pulse trawl (zones 3 & 4).
- Areas open to all types of fisheries, so also to trawl fisheries using chains (zone 5).

Appendix 9

The following recommendations were given by STECF in April 2012:

- STECF recommend that the control and enforcement issues are resolved before the proportion of the beam trawl fleet using pulse trawls is increased.

- STECF recommend that any extension of the fishing area should be considered only after an impact assessment on the effects of the pulse trawl on the ecosystem, in particular when species not subject to a prior impact study, such as *Nephrops*, could be encountered by the gear.

- STECF recommend that any application of pulse technology in other gear types should be considered only after an impact assessment on the effects of the new pulse gear on the ecosystem, in particular when species not subject to a prior impact study.

Appendix 10

OBJECTIVES

The objectives of this document are:

1. To ensure that work on-board fishing vessels with pulse trawl systems is safe for the operators.
2. To ensure that using pulse trawl systems meet requirements of ecosystem sustainability. Although such requirements are not yet formally defined, elements should include:
    a. Maintaining catches within international regulations (TACs).
    b. Reduction of fish and benthos discards to agreed levels.
    c. Reduction of impact on marine habitats.
    d. Avoidance of any unforeseen hazard on the marine ecosystem (e.g. spinal damage in cod).

ADVICE

Definition of documents

Type manual. This document is issued by the system manufacturer on delivery of system. It describes in detail the pulse system in terms of physical components and electrical performance. The document also describes the protocol for measuring the physical dimensions and electrical performance, which are the basis for issuing of the type approval certificate.

Type approval certificate. This will be issued by a certifying agency and will confirm that the pulse system, as inspected on the vessel, meets the physical and performance criteria as described in the type manual.

Concerning legislation

Fishing with electrical pulse beam trawls is allowed under the following conditions:

1. A pulsating electrical field may be generated on, at maximum, two towed fishing gears on any vessel. Energy transfer is by use of an array of electrodes towed parallel with the direction of fishing. An electrode may consist of a linear combination of electrically isolated connecting parts and conductors. An electrode and isolating connectors are defined as cylinders of diameter and material as specified in the type manual.

2. Fishing with pulse trawls is permitted in the North Sea, Skagerrak and Kattegat, the British Channel, Irish Sea and Bay of Biscay (ICES areas IV, ……)

3. A type approval certificate is required for each system. The certificate is to be issued by an accredited certifying agency. The certificate should de-scribe the components and performance of the system in detail including:
    a. A unique description of each pulse system as identified in the type manual (e.g. DELMECO pulse trawl, type X; HFK Pulse Wing, type Y).
    b. Type manual information must define physical and performance parameters of the pulse trawl.
    c. System parameters to include: product name, serial numbers and type of data storage medium monitoring the electrical output of the system.

d. Physical parameters. To include number, length, conductor and connector diameters and materials. Electrode spacing must also be specified. In addition the quantity and identifying type numbers of pulse modules, where applicable.
e. Performance. To include pulse shape, amplitude and frequency, power output and field strength as defined below.
f. The field strength is to be defined as: The measurement of the potential difference between adjacent electrodes divided by the electrode spacing in meters. Voltage measurements are to me made as de-scribed in the type manual with gear hanging in seawater. Salinity and temperature must be measured in situ and used in calculation of field strength. NB if electrode spacing's are to be asymmetrical then this must be defined specifically in the type manual with spacing and individual field strength values included for each electrode pair.
g. The type manual must define the protocol to allow the annual safety and performance certification to be carried out as required in 4 be-low.

4. Safety protocols. Within the type manual the manufacturer should provide a safety inspection protocol for the system. This must detail recommended inspection procedure at daily, monthly and annual intervals as appropriate. It should include a description of the safe handling procedure for sys-tem use. A certifying safety and performance inspection of the pulse gear system is to be carried out annually as per the type manual and a type approval certificate issued. A current type approval certificate must be available for inspection on the vessel during fishing operations by compliance agency personnel when the pulse trawl is on board. A copy of the type approval certificate must be lodged with the relevant compliance agency by the certifying agency before fishing operations may commence.

5. The electrical power, as measured at the generator output, before feeding through cables of any single pulse gear may not exceed 1.0 kW (instead of the former 1.25 kW) per meter of beam length or width of the electrode array as detailed in the type manual.

6. The width of the electrode array is to be defined as the horizontal distance between first and last electrodes. This may not exceed the width of the beam trawl and should not exceed 12 meters

7. The electrical power, at the generator output, must by logged automatically and continuously and the records stored in a secure medium. Access to this data logger should be available only to authorized compliance and certification persons. Adequate storage capacity for previous 3 months data must be available. Data records should include input from navigation system of date, time and position. In addition electrical power information is to be collected from the output of each pulse generator control unit on the vessel. Recordings should be made at 1-minute intervals.

8. Apart from active electrodes, the addition of tickler chains, net ticklers or any other device contacting the seabed, which could provide mechanical stimulation, whether perpendicular or parallel with the direction of motion of the fishing gear, is prohibited.

9. One cross chain or other weight attached on the electrodes in front of the first conductors, aimed at forcing the electrodes to the seabed is allowed as an exception to 8

above. The weight of the cross chain should not exceed xx kg/m (still to be decided). Chain length may not differ from the certified array width by more than 10%.

Explanation of section 3:
An accredited certifier, such as a Classification Bureau or Agency, can issue the certificate. This is sometimes called "Third-party certification" and involves an independent assessment declaring that specified requirements pertaining to a product, person, process, or management system have been met. When a producer offers a standardized system, a type-certificate might be sufficient. This would be a "first-party certification", for which an individual or organisation providing the good or service offers assurance that it meets certain claims. An intermediate form is the "second-party certification", an association to which the individual, manufacturer or user i.e. fishermen's or manufacturers trade organisation provides the assurance (source: http://en.wikipedia.org/wiki/Certification).

Concerning inspection and control
Inspection activities are to be distinguished at three levels:

Level 1: To be carried out by compliance staff. Routine inspections aimed at checking physical characteristics such as: beam length, availability of a certificate, array width, dimensions of electrodes and conductors and integrity of data storage medium. This level does not require electro-technical expertise.

Level 2: To be carried out by compliance staff or authorized personnel. Accessing and reading data from the data storage medium as a routine inspection. This need not include a physical inspection of the whole system but should note if the integrity of the secure data storage medium is suspected to have been compromised.

Level 3: To be carried out by certifying agency. Conducting a field strength measurement and power output check at sea if Level 1 and Level 2 inspections call for further inspection. These measurements are to be carried out as per the protocol de-fined in the type manual for the system and will require electro-technical expertise.

Concerning enforcement and sanctioning
Modification of the pulse system will be regarded as a breach of the certifying regulations.

Concerning implementation
At any adaption of the regulations pulse fishers should comply as per date of change.

Meeting the new rules may call for investments and adaptations in the existing pulse systems for the fishers already working under the current derogation, possibly linked to type-certification.

One may opt for a transition period during which existing pulse systems can be depreciated and gradually adapted to the new rules. Such a period might be restricted at 6 to 12 months.

Appendix 11

Request
France requested ICES to review the work of SGELECTRA and to provide an updated advice on the ecosystem effects of pulse trawl, and especially on the amount of injury and mortality for targeted and non-targeted species that contact the gear but are not retained.

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

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

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

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

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

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

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

Appendix 12

This article of the Sunday Times gained a lot of attention within the Netherlands and gives an indication of how some fishermen in other European member states express their discontent about the pulse trawl technique.

Zapped: Britain's fishing graveyard

UK fishermen claim nets used by the Dutch that send out electric shocks are annihilating fish stocks

Jon Ungoed-Thomas Published: 24 June 2012

Jeff Loveland says the sea off Kent stinks of dead fish (Dwayne Senior)

THE Dutch trawler fleet is being blamed by British fishermen for "annihilating" stocks of juvenile Dover sole with a net that sends electric shocks into the sea floor.

The Dutch vessels are allowed to fish 12 miles off the Kent coast, but British crews claim their pioneering electric shock technology is devastating marine life and destroying the fishing grounds. They are urging fisheries officials to investigate.

The electrified nets are designed to give bottom-lying Dover sole a minor shock to move them into the nets. Dutch officials say the method — known as "pulse trawling" — causes less damage to the sea floor and nearby species.

Research has shown the electric nets can kill nearby cod, cracking their vertebrae and causing internal haemorrhaging. Most marine life in the area, however, should not be adversely affected.

British fishermen believe vast numbers of fish are being killed and are meeting Dutch officials to voice their concerns. They are also to send dead fish caught in their nets for laboratory examination. Tom Brown, secretary of Thanet Fishermen's Association, said his members complained it was like "fishing in a graveyard" after the pulse trawlers had been in the area. "What they don't catch, they annihilate," he said. "Virtually everything is dead."

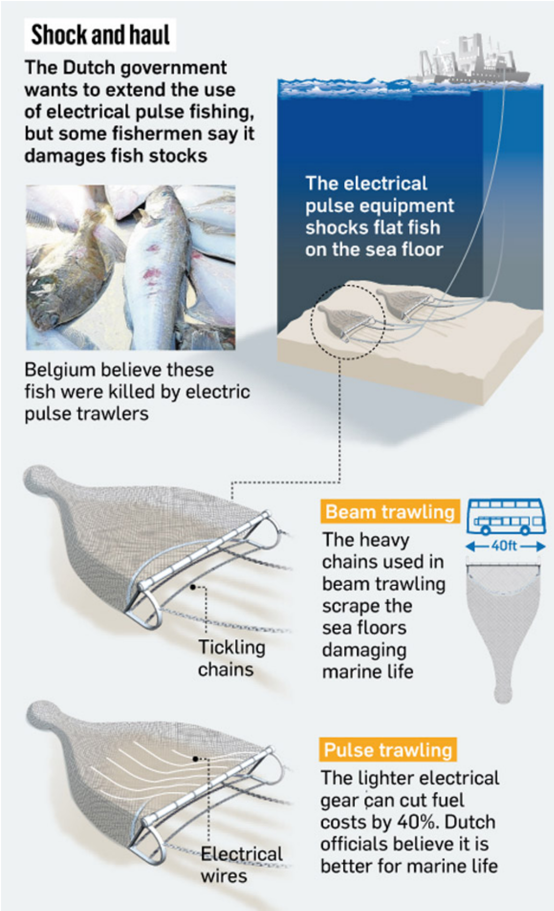
Jeff Loveland, who owns two fishing boats in Ramsgate, which mainly catch Dover sole and skate, said: "This is absolutely devastating for us because we never caught so many fish that [were] already dead.

"You can have as many as 50 dead Dover sole in an hour and a half. We would hardly ever see a dead fish before."

The crews believe that repeated exposure to the minor shocks is killing the fish.

Loveland said about seven Dutch trawlers were fishing off the Kent coast using pulse nets. He said: "It is a waste of time going to that area now. It stinks of dead fish."

Fishing crews in Essex have similar concerns. Roger Free, a fisherman from West Mersea, said many of the dead fish he had pulled up in the area were juveniles. He is convinced the Dutch trawlers are to blame.



"I have fished there for 30 years and have never seen anything like it. I think the [electric] pulse is killing the food in the sea bed," he said. "Three years ago, I caught 40 tons of sole in those grounds in one year. It was the best year we've ever had. There is nothing there now that I can catch."

The fishermen are concerned that there are inadequate checks on the power being used to shock the fish.

Electrical beam trawling was extensively used in the East China Sea in the 1990s to catch shrimp, with 10,000 trawlers equipped with the pulse equipment. There were, however, few controls on the amount of power being used and it was subsequently banned for damaging the shrimp population and injuring other marine life.

In 2007 the European Union agreed to permit pulse trawlers on an experimental basis, but with a lower voltage than that deployed in the East China Sea. Two years later, the Dutch started commercial trials and they are now lobbying for the technology to be approved for wider use.

European research has confirmed the potential damage to fish. One report for the Dutch government revealed that out of 20 cod subjected to the shock treatment at close range, four died and x-rays showed four others had vertebral fractures with haemorrhages.

The International Council for the Exploration of the Sea said in a report published in 2009 that more research was required on which species of fish could be harmed and the various voltages that were being used. It warned: "The gear could inflict increased mortality on target and non-target species that contact the gear, but are not retained."

Dutch officials said the latest advice from the European commission's scientific committee said the technology reduced mortality in the target species and had a reduced impact on habitats compared with traditional trawling.

Thijs van Son, a Dutch government spokesman, said: "Research shows less damage, compared with the traditional beam trawl." He confirmed Dutch officials would meet British fishermen this week to discuss their concerns.