Deliverable 5.4

Report on investment theory, its application in fisheries and the lessons on key factors influencing the investment behaviour.

Due date of deliverable: month 54 (March 2017)
Actual submission date: month 62 (November 2017)

Grant Agreement number:	312088
Project acronym:	BENTHIS
Project title:	Benthic Ecosystem Fisheries Impact Study
Funding Scheme:	Collaborative project
Project coordination:	IMARES, IJmuiden, the Netherlands
Project website:	www.benthis.eu

Main Contributors:
Katell Hamon
Birgit de Vos
Wageningen Economic Research
(Netherlands)

Katrien Verlé
Arne Kinds
ILVO
(Belgium)

Sara Bonanomi
Matteo Ferraris
Greta Falavigna
Emilio Notti
Elena Pagliarino
Andrea Pronti
Antonello Sala
Roberto Zoboli
CNR I
(Italy)

Olivier Guyader
Claire Macher
IFREMER
(France)

Mustafa Zengin
Central Fisheries Research Institute
(CFRI, Turkey)

M.Selcuk UZMANOGLU
Marmara University, Vocational School of Technical Sciences
(External Partner, CFRI, Turkey)

Ole Ritzau Eigaard
J. Rasmus Nielsen
Technical University of Denmark
National Institute of Aquatic Resources
(DTU Aqua, Denmark)

Frank Jensen
Christian Elleby
IFRO
(Denmark)

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 312088

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 312088

DOCUMENT CHANGE RECORD

Authors	Modification	Issue	Date
Katell Hamon	Draft structure		
Katrien Verlé & Arne Kinds	Added info on the Belgium case		15/03
Ole Ritzau Eigaard & J. Rasmus Nielsen	Added info on Baltic case		12/05/2017
Emilio Notti	Added info on the adriatic case		13/05
Selcuk Uzmanoglu&Mustafa Zengin	Adde some info on the Blacksea case study		14/05/17
Claire Macher	Bay of Biscay CS		15.05
Birgit de Vos	Added info on the Dutch case		19/05/2017
Katell Hamon	Finishing off		Oct 2017

SUMMARY

In this deliverable we investigated the drivers of investment in fisheries and how those can be activated to stimulate investment in alternative technologies to protect the benthos. To capture a wider range of factors than quantitative factors only we modified the work plan and included interviews with fishing industries in all regions. As a result we identified a wide range of reasons why fishers have (or have not) invested in alternative gears. As expected, the profitability of alternative technology is an important factor to invest but we also found many others. Those drivers were classified as economic, technical, regulatory, social, governance and environmental drivers. As advice to managers we also identified where and how interventions could improve uptake of technology.

TABLE OF CONTENTS

1. INTRODUCTION

Demersal fisheries have major impacts on marine ecosystems and particularly on benthic ecosystems (Halpern et al. 2008; Jackson et al. 2001). Through alternative, less disruptive gears, the fishing industry can partially decrease their impact on the bottom while maintaining their fishing activity. Alterations to gear design can result in changes in the operation of the gear, its usability on specific fishing grounds, the catchability of target species or the species and size composition of the catch. All those changes mean that fishers must adapt their way of fishing when adopting alternative gears and the transition can be challenging. In the project BENTHIS, one of the key objectives is to “Study and test, in close collaboration with the fishing industry, innovative technologies that reduce the impact of demersal fisheries on benthic ecosystem on a regional basis”. To investigate whether those technologies can then be used on a large scale by the fishing industry, we also set ourselves “to study which factors facilitates the introduction of new technology to mitigate ecosystem impacts by fishing activities”.

Investment in fisheries has already been studied for a number of years. Nøstbakken et al. (2011) reviewed the available studies and concluded that while many theoretical models had been developed, the empirical analysis were rare, based on past performances with high uncertainty about future. The future expectations are calculated using Net Present Value (NPV), which corresponds to the cumulative gains expected in the future where future gains are discounted i.e. future gains are corrected to be worth less than immediate ones. However, the NPV approach has a number of drawbacks as highlighted in Ferraris and Pagliarino (2014). The main drawbacks identified by the authors are that investment is seen as a decision taken at a fixed point in time without uncertainty and that investment is seen as irreversible. They propose an alternative approach based on real option theory that allows for decisions to be more flexible to take into account, market uncertainty and technology flexibility. In their review, they found a number of applications of Real Option Approach (ROA) in fisheries (Ferraris and Pagliarino, 2014) but those are mainly applied to determine the entry in a fishery not the choice of gears for agents already operating in it.

While both methods have been used to try and predict investment, they are limited in the identification of investment drivers because they limit the analysis to economic drivers (fish stocks are included as natural capital). The studies discussed in Nøstbakken et al. (2011) focused on the economic drivers of investment. Most of them identify profit as an important driver in investment decisions in fisheries. However, they also find that profit does not capture all the investment dynamics, there is large uncertainty around investment behaviour that is not captured by economic variables alone. For example there is a lag of several years between high profits and investment Bjørndal and Conrad (1987), Bockstael and Opaluch (1983, 1984) observed a threshold under which investment does not occur. Those likely come from the way fishers (or rather vessel owners) deal with uncertainty by delaying their decisions until they get more information or by risking investment only if they expect exceptional returns.

In addition, investment models are by definition based on past performances and entail high uncertainty about the future (Nøstbakken et al. 2011), especially when trying to model situations that have not occurred yet such as the introduction of a specific new technology.

And lastly, the main problem faced when trying to model investment in fisheries has been the lack of data (Nøstbakken et al. 2011). Data on economic performances of a gear that has not been used commercially are not available. While fuel use could be tested and estimated on a small sample, key information such as catch composition is so variable in nature that it cannot be estimated on limited samples.

In BENTHIS, we wanted to identify factors that facilitate or slow down the adoption of alternative technology in the bottom trawl fishery. We have collected quantitative and qualitative information about investment decisions of fishers in alternative gears to bottom trawls. The quantitative information was used to statically compare gear performances and in one case, the Dutch pulse fishery which was wildly adopted in the course of the project and where we could collect sufficient data, we statistically explored the drivers of investment. In parallel, we worked with the fishing industry to collect qualitative information behind their decisions to invest (or not) in alternative gears. Interviews where done in all regions to investigate the boosters or barriers of investment. Those have been categorised in economic, technical, regulatory, social, governance and environmental drivers and potential actions points for managers have been identified.

2 MATERIAL AND METHODS

2.1 Cases investigated

Investment decisions have been investigated in all regional seas of the BENTHIS project. The full list of cases in which investment in alternative gears have been covered is available in Table1.1. For the different case studies different tools have been used to try to understand the reasons behind the decisions to invest or not in gears that are believed to be less damaging to the benthos. We used a mixed of quantitative and qualitative analysis to identify key factors influencing gear investment decisions.

Table 1.1 List of gear substitution cases studied in BENTHIS

Traditional gear	Alternative gear	Targeted species	Region	Adoption
Beam trawl 70-90 mm	Pulse trawl	sole	North Sea	In the Netherlands only
Beam trawl <30 mm	Pulse trawl	Brown shrimp	North Sea	In the Netherlands only
Beam trawl	Modified Beam trawl	Sea snail	Black Sea	Tested in Turkey but not adopted
Bottom Trawl 40D	Experimental 36S	Whiting and red mullet	Black Sea	Tested in Turkey but not adopted
Bottom Trawl 40D	Experimental 40T90	Whiting and red mullet	Black Sea	Tested in Turkey but not adopted
Bottom Trawl 40D	Experimental 40S	Whiting and red mullet	Black Sea	Tested in Turkey but not adopted
Bottom Trawl	Experimental otterboards		Mediterranean Sea	Adopted in Mediterranean bottom trawl fishery
Otter trawl 90-120 mm	Creels	Nephrops (+ Flatfish, trawls)	Baltic Sea, Kattegat	Tested in DK but not adopted
Otter trawl 90-120 mm	Creels	Nephrops (+ Flatfish, trawls)	Baltic Sea, Kattegat	Adopted in Sweden only
Otter trawl 90-120 mm	Otter trawl with short sweep lengths	Nephrops + Flatfish	Baltic sea, Kattegat	Tested in DK but not adopted
Mussel dredge	Light-weight dredge	Blue mussels	Baltic Sea, Coastal areas	Adopted in Denmark only
Bottom trawl with Thyboron boards	Bottom Trawl with Jumper boards	Nephrops + mixed demersal species	Bay of Biscay	Tested but not adopted yet
Bottom trawl	Nephrops pots	Nephrops	Bay of Biscay	Small number of vessels using Nephrops pots part of the year for several years
Bottom trawl	Bottom trawl + Diverse selective devices developed in R&D projects	Nephrops + mixed demersal species	Bay of Biscay	Adoption of some of the devices

Baltic Sea

In the Baltic Case Study a series of gear-technological innovations and alternatives have been investigated by DTU Aqua, SLU and UCPH in collaboration; a) catch and profitability of Danish creel fishery compared to otter trawl fishery targeting Nephrops in Kattegat; b) Swedish creel fishery compared to trawl fishery targeting Nephrops in Kattegat and Skagerrak; c) Reduction of benthic impacts of Danish Nephrops trawl fishery in Kattegat by use of shorter trawl sweep lengths (as well as targeting catch towards Nephrops and avoid cod with low or expensive quotas); and d) Reduction of benthic impacts from blue mussel dredging by use of a modified (light) mussel dredge.

Bay of Biscay

Alternative jumper boards were studied in BENTHIS as an option to mitigate bottom trawlers impacts on Benthos however, the jumper are not yet adopted and analysis of the investment in this technique can only remained limited. The opportunity for the development of an alternative Nephrops creel fleet was also discussed (see D7.9 this project) with regards to economic viability in the current context. Regarding investment behaviours, ,an historical approach on investment in selective and lower “impacting” gears was adopted in the Nephrops fishery in the Bay of Biscay to explore factors of investment and complement information collected on the new devices that were explored in BENTHIS project. Evolution of fishing techniques, technological progress and responses from fishers were described based on a literature review, an assessment of Research and Development projects and interviews with experts of the fishery to highlight the key factors influencing the investment behavior.

Over the past decades, the main technical breakthrough recorded in the Bay of Biscay Nephrops fishery was the introduction of the twin trawl technique. First experimented during the mid-80’s, the twin trawl technique consists in replacing a single trawl by two smaller trawls towed in parallel with two or three wires. The main advantage of the twin trawl technique is that the area swept by the gear is increased by 40% with a same engine power, underpinning higher catch rates for demersal species living close to the bottom (i.e. Nephrops, monkfish, flatfish). The twin trawl technique is less effective for catching demersal fish species living above the bottom (e.g. gadoids, hake) as vertical opening of twin trawls is less than vertical opening with single trawls.

According to Marchal et al. (2007), use of twin trawls in the Bay of Biscay Nephrops fishery started in the early 90’s. The proportion of trawlers using the technique increased from 10% of the total number of vessels in 1990 to approximately 70% in the early 2000. According to IFREMER ongoing annual surveys of fishing vessels activities, the proportion of vessels using twin trawls in the Bay of Biscay Nephrops fishery kept increasing with as much as 85% of the fleet using twin trawls by 2015 as shown in the figure below. According to IFREMER data, generalisation of twin trawls concerns all vessel size categories active on the Nephrops fishery, including smaller 10-12 m trawlers.

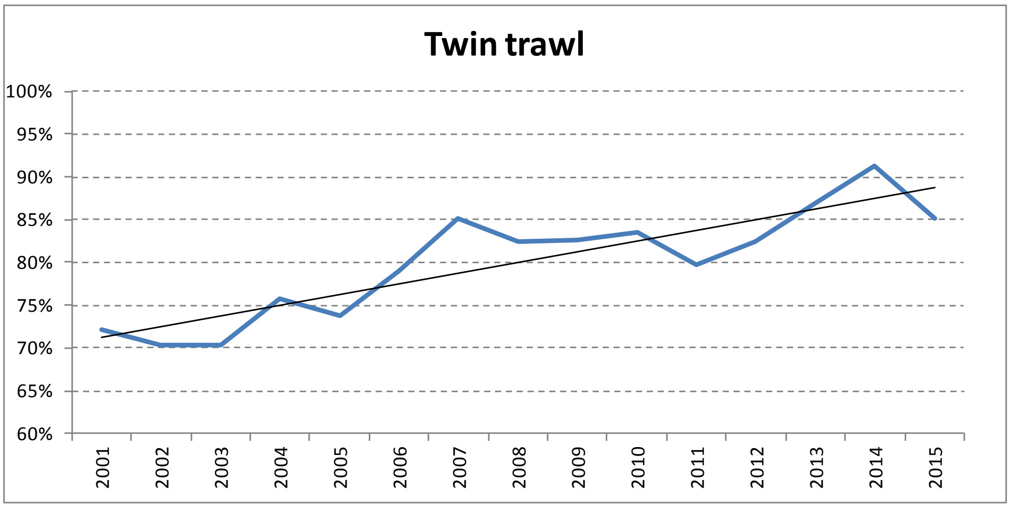

Figure 1 : Evolution of the proportion of Bay of Biscay Nephrops trawlers using twin trawls between 2001 and 2015

Source : IFREMER Enquêtes activités[1]

For the Bay of Biscay trawler fleet, the emergence of twin trawls was accompanied by the appearance of new groundropes (diabolos, metallic spheres), which allowed fishing on harder grounds, areas that could scarcely be exploited before (Marchal et al., 2007).

Trawl netting also modernized with the emergence of new material used to manufacture more rigid and more resistant net panels, in particular for the codend[2]. Due to the stiffness of the twine used, meshes do not open as with other traditional twines. However, according to fishers associations, these modern twines are not generalized across the Bay of Biscay trawling fleet as mesh panels utilising this material prove difficult to repair on board with traditional mending techniques.

According to fishers associations met, no significant technological innovation leading to increase catching effectiveness of Bay of Biscay trawlers emerged over the past few years in addition to the generalization of twin trawls described in the foregoing paragraphs. Recent technological improvements focused mostly on trawls doors and mesh size in some parts of the trawls (wings, back), mainly as a response to the need to decrease fuel consumption , hence improving fishing efficiency. For 15 years, several projects mainly dedicated to selectivity improvement have been running in the fishery. Information on these projects were collected through literature review and interviews and are detailed in annex 1.
Some of the adjustments were adopted and transposed in the national legislation.

Black Sea

The Samsun Shelf Area (SSA) is one of the most important fishing areas along the Turkish Black Sea coasts. There are two fishing gears with benthic impact used in SSA. The gear specifications are presented in Table 1.2. The beam trawls are being actively used in shore waters in depths of 5-30 m and bottom trawl are operating in sub littoral zone at higher depths 40-80 m. The Black Sea Case study is being conducted in Samsun Shelf Area (SSA) to outline the impact of drag-nets (beam and bottom trawl) on the benthic habitat operating for a long period along the southern Black Sea.
The Samsun Shelf Area is a special ecosystem discharged by two major rivers of Anatolia (Yeşilırmak and Kızılırmak). The biodiversity of benthic and bentho-pelagic species is limited due to anoxia in the Black Sea over depths of 150 m. The bottom topography is largely flat and composed of fine sand-silt sediment (mud) that makes the region available for trawl fishery (Knudsen et al, 2010).

[1] http://sih.ifremer.fr/Description-des-donnees/Donnees-collectees/Activite-des-navires

[2] See for example Brezforce twine at http://www.ledrezen.com/969-brezforce/947-filet-brezforce.html

The bottom trawl fisheries began to flourish in the Black Sea coast of Turkey by the end of the 1950s. In addition, the rapa whelk invaded the Black Sea ecosystem in 1940 and has spread rapidly throughout whole Turkish Black Sea coast. The fishery on rapa whelk became commercial by 1980s and reached an industrial scale still supporting a large fishery in the SSA. For this reason, SSA is under high pressure of drag-nets since 1980s (Zengin, 2011).

The most important issue in the fishery is that it is not economically viable because of low fish prices. To compensate the low prices, fishers also fish illegally in summer during the closed season when catch rates and prices are high.

The study area (SSA) includes the near shore water of three miles where fishers operate illegally during the closed season. Seasonal samplings were carried out around the depths ranging between 30 and 120 m and by using 400 and 900 meshes and modified 40 mm diamond mesh size in codend of traditional bottom trawl.

The impact of bottom dragging nets (algarna and bottom trawls) which were widely used along the southern Black Sea littoral on benthic ecosystem have been investigated by the marine surveys held in 2013. In 2014, sea trials were realized in order to test options for mitigation of the impacts. In this context, three different trial studies were planned for three fishing gears (pots, algarna and bottom trawl). Thus, the options for mitigation of the impact on benthic ecosystem and the related sea trials were designed as the following:

1) The trials of passive gear design (pots) in sea snail fishery,
2) The modification of algarna (beam trawl):
    - use of sledges instead of traditional shoes to decrease the dragging effect,
    - the removal of steel rope between shoes
    - the measurements for fuel save
3) The selectivity studies to reduce the discard rate by modification of the fishing net in terms of mesh size and design in bottom trawl fishery (red mullet and whiting).

Table 1.2. The gear specifications of two drag nets in Black Sea (SSA) that has impact on benthic ecosystem (Zengin et al., 2016)

Specifications	Characteristics	Bottom trawl	Beam trawl
Habitat type	Active fishing area and average depth (m)	-Littoral zone: shallow, smooth, silt -40-80 m	-Coastal zone: shallow, smooth, silt -5-30 m
	Bottom type	Sand, silt	sand, silty-sandy-silt, gravelly sediment
	Characteristic invertebrates	*Mytilus galloprovincialis, Modiolus sp, Crangon crangon,*	*Rapana venosa, Mytilus galloprovincialis, Chemelea gallina, Crangon crangon, Upogebia pusilla, Liocarcinus depratur*
Primary target species	Mixed-species fisheries	whiting, red mullet, turbot	-
	Single-species fisheries	-	sea snail
Vessel	Engine power (kW)	422	107
	Trawling speed (knots)	2.5-3	1.5-2.5
	Overall length (m)	21.5	9.9
	GRT	71.2	7.1
	One or two vessels (single or pair trawling)	single	Single
	Number of trawls per vessel	1	2
Gear	Type	two panel, Italian modified model	Traditional
	Codend: stretched mesh size (mm)	40	72-88
	Trawl circumference (stretched mesh size in mm)	500-975	-
	Trawl height (m)	0.5-2.5	-
	Beam height (cm)	-	20-22
Trawl doors	Model	bottom-rectangular	-
	Length (m)	1.2-2	-
	Height (m)	0.8-1	-
	Weight (kg)	50-150	-
	Spread (m)	22-28.5	-
Groundgear	Length (m)	20-37	2.5-3.5
	Weight (kg)	25-375	3-5.5
Beam	Width (m)	-	2-3
	Complete beam weight in air (kg)+nets (kg)	-	24-58
	Beam shoes (number)	-	2
	Beam shoes (width in mm)	-	70-100
	Beam shoes (length in mm)	-	200-350
	Shoes claw (depth in mm)	-	50-70

Mediterranean sea - Central Adriatic

Fishing grounds in the Mediterranean Sea are suitable to trawling fisheries. Basically, bottom trawling has deeply affected the benthic ecosystem in Mediterranean Sea by causing structural and functional changes on seabed faunal communities and changes, damages and degradation in important habitats, such as seagrass and maerl beds. The impact of a bottom trawl depends on the size and type of gear components, their penetration attitude as well as the speed and distance over which the gear is towed.

Technical innovations for reducing the benthic impact in the Mediterranean Sea have been selected and tested with the aim to reduce physical contact and fuel consumption.

The majority of physical impact in bottom trawl fisheries is due to otterboards. As the otterboards can dig into the sea bed, additional ground contact forces apply to the otterboard and, particularly on soft ground and at low towing speeds, the spread of the doors could be higher due to the extra spreading force produced by the ground shear.
In order to reduce the physical impact of bottom trawl gears, experimental otterboards have been developed and evaluated in comparison with traditional otterboard design. The otterboards were preliminary designed and tested through scaled models in wind tunnel and flume tank (Mellibovksy et al., 2015) and tested in full scale through a number of sea trials, so as to verify performances in real operating conditions and to collect feedback from fishers about potential implementation of such novel otterboards. The experimental otterboards showed better geo-mechanical performances compared to their traditional reference doors, in terms of drag resistance, which directly affected fuel consumption and with respect to the net opening that was maintained and in some cases increased. The physical impact was determined in in terms of quantity of sediment resuspension, and the novel otterboards showed better attitude and a reduced impact. It is important to highlight that several fishers started adopting novel otterboards tested.

<u>North Sea</u>
In the North Sea case study, several fleets were investigated where traditional beam-trawls would be replaced by electric trawls (so-called “pulse trawls”), both in the Netherlands and in Belgium. In the Dutch case, ex-post analysis could be conducted on the sole fishery where the pulse trawl has been widely adopted in the course of the project. Since 2014, 84 vessels have been operating with pulse trawls in the Dutch fisheries. Despite a slow start in the early 2010’s, the pulse technique rapidly convinced most fishers with the better selectivity towards sole and lower fuel costs (Haasnoot et al, 2016).

On the other hand, in the Belgian case, a widespread switch to the pulse trawl did not occur. Therefore, it was attempted to understand the reasons why the pulse trawl was not adopted. It would seem that Belgian fishers were initially in favour of introducing pulse trawling. However, after the rapid growth of the Dutch pulse fishery in the North Sea around 2011, opinions changed. Pulse fishing was perceived to have caused widespread fish mortality and other damage, despite scientists claiming the opposite. This was followed by a media campaign against pulse fishing. Consequently, the Belgian Producers Organisation (PO) gave a negative advice on the introduction of the pulse trawl in Belgium and thus pulse fishing remained limited to scientific experiments. In 2014 a single license was given to a commercial vessel. It took till August 2015 before the PO changed its opinion and an official letter to the Flemish minister of fisheries was sent to ask for licences to allow Belgian pulse fishing in the North Sea and the Western waters.

Furthermore, investments in other technological innovations that aim to improve the traditional beam-trawls in terms of selectivity, fuel consumption and bottom impact did occur. In the sole fishery, the introduction of the *Sumwing* was widespread. This gear is more hydrodynamic as a wing profile replaces the traditional beam. It has been introduced in both the Dutch and Belgian fisheries. Another example of an alternative to the traditional beam trawl is the Ecoroll beam. It has a wing-like profile and wheels on both sides. Its development was inspired by the Sumwing, but adapted to the Belgian practice of using chain mats instead of tickler chains, for fishing on rocky substrates.

An overall aim within the case studies was to identify key factors that influence investment behaviour and potential bottlenecks for transitioning to innovative gears in the future.
In the Netherlands roughly four main waves of can be distinguished whereby fishers switched to the pulse fishing. Unlike the traditional beam trawl, with pulse trawling, the tickler chains are replaced by drag wires through which electric impulses are sent. The aim of these impulses is to shake up fish that can be found on the sea bottom, so that they are easier to catch. As electric fishing is forbidden by the European Union, as derogation needs to be requested.

These four transition waves are all connected to the derogation that was granted to the Netherlands. The derogation was both a limitation (it was simply not allowed to switch more fishers), and stimulus. By all the effort that the Dutch government put in lobbying with the European Union to get a derogation, the Dutch government showed that it was a good idea to invest in the pulse technique. It was a trustworthy technique.

The first period lasts from 2004-2010 when initially one commercial vessel was testing the technique (pilot), and at the end of the period in total 22 fishers switched to pulse. The second wave took place in 2011 when another 22 licenses were granted. The third wave was in 2014 when the number of experimental licences was expanded to 10% of the Dutch cutter fleet, a total of 84 cutters (Scherders, 2016).

2.2 Economic performances

Simple static analysis was performed on some of the cases to compare the economic viability of the alternative gears using the SENSECO model (see Deliverables 5.2 and 7.9, this project). These results have been used to explore economic performances of an alternative gear compared to the traditional gears subject to different external factors (such as fuel price).

This among other include Cost-Benefit-Analyses (CBA) and fishing efficiency analyses of the passive Nephrops creel gears in the Baltic Sea (Kattegat) compared to the existing commercial otter board trawl fishery targeting Nephrops and flatfish in the area where efficiency across different vessel size classes and crew member classes were investigated.

2.3 Interviews

This report builds on the retrospective case study method with a focus on fishers. Semi-structured interviews have been performed with fishers in different countries to investigate drivers behind the investment decisions of fishers. The main characteristic of semi-structured interviews is that the “interviewer knows what topics and questions need to be covered but the information derived from the interviews can vary between participants” (Miles and Gilbert 2005 cited by Scherders 2016). This is because the interviewer has the flexibility to adapt questions thereby taking into account the expertise and experience of the respondent.

The main aim of the interviews was to reconstruct (timeline) the whole decision process that took place before the fisher decided to switch gears. We wanted to know who were involved in the decision, how fishers knew about the gear, how knowledge was transferred, and how it was financially arranged. We also wanted to know if there were fishers who wanted to switch back if they would have the chance.
In all cases, interviews were performed (Table1.3), for most the example interview provided by LEI-DLO (annex 2) was used as such or adapted.

Table 1.3 Interviews list in different cases

Country	Number of interviews	Performed by	Region	case
Netherlands	17	Wageningen Economic Research	North Sea	Beam trawl to pulse fishery
Belgium	8	ILVO	North Sea	Beam trawl to alternatives
Italy	20	CNR	Central Adriatic	Otterboards (midwater pair trawls, beamtrawls & hydraulic dredges)
Turkey	42	CFRI, Marmara University	Black Sea	Beam trawl and bottom trawl
Denmark & Sweden	12	DTU Aqua & SLU	Baltic Sea	Creels as an alternative to trawls

Denmark	10	DTU Aqua	Baltic Sea	Nephrops-trawls with shorter sweeps
Denmark	2	DTU Aqua	Baltic Sea	Light mussel dredge
France	8	IFREMER	Bay of Biscay	Nephrops fishery in the Bay of Biscay

Baltic Sea

Open interviews were conducted with relevant fishers (SMEs in the project) and gear manufacturers (producing the gears for the sea trials) and the Danish Fishery Association (DF) on two occasions; the first interviews were made during the first regional stakeholder event (RSE1) and the next interviews during the following collaborative work with producing and testing the selected gear-technological innovations and alternatives. At the first RSE the interviews focused on identifying a list of potential gear innovations and alternatives, which was then refined by critically addressing the incentive structures and potential bottlenecks for the future implementation of these. The next interviews were conducted with the same persons either during the planning or execution of the studies of the four selected innovations. The second round of interviews also addressed incentive structures and potential bottlenecks, but now with focus on the four tested innovations and based on the additional knowledge and experience obtained by the interviewees. In addition to the interviews then DTU Aqua scientists under the BENTHIS project participated in the sea trials testing the different gear innovations in the Baltic Sea case study, and here the innovations, their design and performance was thoroughly discussed and commonly evaluated. Furthermore, the discussions during the sea trials between the SMEs (fishery representatives) and the DTU Aqua scientists also resulted in adjustments to the right gear settings and practical fishing procedures to make the gear innovations perform optimally.

Bay of Biscay

Semi-structured interviews were conducted with 3 nephrops bottom trawlers operating the test with alternative jumpers boards and potters using nephrops traps as complementary metiers. Those interviews were reported in D7.9. In addition 5 non directed interviews on investment in selective devices have been organised with key stakeholders to complement and triangulate documentary sources.

Black Sea

A qualitative approach was used for the analysis of the drivers of innovation: fourteen fishers have been interviewed during individual deep, face-to-face, interviews collecting evidence from about 5% of the total vessels of the SSA fleet. The fishers interviewed use two main types of fishing gears: Beam trawl (7), bottom trawl (7).

Main target species is sea snail in beam trawl (algarna) and red mullet and whiting in bottom trawl. The fishers interviewed were aged from 28-69 years (average 43.5 years), vessel length from 9-32.3m (average 15.79m), vessel engine power from 64-1293HP (343.9HP), vessel aged from 3-33 years (average 14.7 years) determined. Yet, innovative gears are not practically used in SSA. But, experimental studies have been done with innovative gears, results were presented to fishers in third regional stakeholder event (RSE3) in May 2016. During the RSE3 the investment questionnaire form was used with stakeholders and a summary of the responses is given TableA.2 in annex 3.

It can be said that fishers generally share similar opinion. Fishers stated that financial problems are the most important reason for not changing fishing gears. It is also clear from the responses given by fishers that lack of using innovative gear and technical knowledge about fishing techniques are influential in fishers's decision about not to change current gear.

Mediterranean Sea - Central Adriatic

A qualitative approach was used for the analysis of the drivers of innovation: twenty fishers operating in Central Adriatic have been interviewed during individual deep, face-to-face, interviews collecting evidence from about a fifth of the total vessels of the Ancona fleet. The semi-structured questionnaire prepared by

LEI (annex 2) was supplemented with additional questions designed to bring out the individual life stories of fishers, the characteristics of their business and their needs in terms of training. Two types of questionnaires were proposed with different questions based on whether or not the fisher being interviewed had recently implemented sustainable innovations.

The questions were designed to investigate the reasons and the most important factors in choosing or refusing sustainable innovations. Other key stakeholders have been interviewed to better understand the characteristics, the actors, the relationships within the local fishery sector as well as the working mechanisms of the whole supply chain. All interviews were recorded, transcribed and then analyzed by the working group. Transcripts were reduced and corrected in team as suggested in Bertrand et al., 1992 and Krueger, 1994. The analysis was made by means of reading frame improved in an iterative manner during the analysis of the transcripts, as suggested by Dawson et al., 1993.

The people interviewed were owners and skippers aged from 20 to 65 years, they all have a wide experience of fishing that comes also from a long family tradition in fishery. Fishing activities mostly are run as a family business employing, formally or informally, relatives in several jobs such as sailors, fish sellers or helping in gears maintenance activities.

The fishers interviewed use three main types of fishing gears: otterboards (14), beam trawls (1), midwater pair trawlers (3), and hydraulic dredges (2). The differences in the various types of fishing technologies are reflected also in the different needs for investments in fishing equipment, in the fishers' perception of how the sector is managed, as well as of the role of regulations and restrictions and in their propensity toward innovation. The answers show that fishers share very similar opinions, especially for what concerns the management and the regulation of the sector, the perception of environmental problems and the future of the industry. All those factors are able to influence their propensity to invest in new sustainable gears.

About half of the fishers interviewed had implemented innovative gears (9 over 20). The innovations implemented are: (4) plastic AR Grilli otterboards for bottom trawling aimed to reduce the consumption of fuel and the impact on the sea bottom; (2) 50-mm meshes to reduce catches of juvenile fishes; (2) plastic nets to reduce drag and fuel consumption; and an engine with greater energy efficiency.

The age of the boats, ranging from 7 to 35 years, did not seem to affect the decision to innovate.

<u>North Sea</u>

The Belgium case

Semi-structured open interviews were conducted with eight vessel owners of the Belgian fleet in the period January-March 2016. The initial questions were based on the questionnaire prepared by LEI (annex 2), with some adjustments and additions relevant to the Belgian context. Interviews with these fishers focused on the adoption of alternatives to the beam trawl, such as otter trawl, Aqua Planning Gear, Sumwing and Ecoroll beam. The pulse trawl is barely used in Belgium. Therefore, fishers were asked about their stance towards this technique. Thematic analysis was used to improve our understanding of elements behind gear choice (Howitt, 2012; Braun & Clarke, 2006). An advantage of thematic analysis as a research tool is its flexibility and accessibility. It can also provide rich and detailed, but complex account of data (Braun & Clarke, 2006). We identified a number of potential drivers behind gear decisions (economic, regulatory, social, environmental and governance) and used it as our framework throughout the interviews. Patterns within the data – themes - were then identified using a semantic approach. Identification of these themes is based on researcher judgement which remains necessary. Braun & Clarke, 2006 state "*A theme captures something important about the data in relation to the research question, and represents some level of patterned response or meaning within the data set"*. The analysis consists of a recursive process that develops over time, where transcribed material was reread and coded a number of times in order to identify key factors in gear choice.

The Dutch case

Semi-structured interviews were held in 2014 with 9 Dutch fishers that had switched to the pulse technique. In 2016 (February-April) another round of interviews was done with 7 different Dutch fishers. The fishers selected for the interviews were fishers that switched in different years. The purpose of this was to see if different factors played a role in different time periods. The first round of interviews was used to get an idea of the possible factors that played a role with the decision to switch. In the second round of interviews we were able to go more in depth, as we already got some vital information. In the second round of interviews the social practices theory was used as a framework. In the social practice theory, as the name already indicates, practices are taken as the main unit of analysis. Practices are shaped by routines, shared habits, technique and competence. The social practices theory adds materials, technologies and products to the theory (Scherders, 2016).

2.4 Model

As pointed out by Nøstbakken et al. (2011), predicting investment in fisheries is very difficult. One of the reasons explaining the lack of empirical models on investment in fisheries is the lack of available data. In BENTHIS, one of the goal was to better understand the investment in alternative and innovative gears. During the course of the project it became clear that most of the alternative gears tested would not be adopted at all or by only a few fishers, preventing any quantitative estimation of the importance of the parameters of the different investment factors. One notable exception is the Dutch pulse fishery for flatfish. Since the beginning of the project, the utilisation of electric trawls in the Dutch sole fishery has doubled from 42 to 84 licences.

An investment model was therefore applied on the Dutch flatfish fishery where fishers have massively invested and switched to pulse trawls. The method and results are shown in annex 4.

3 LESSONS LEARNED ON KEY FACTORS

3.1 Economic drivers

3.1.1 Profitability

In all case studies, profitability has been identified as a determining factor to adopt an alternative gears. Even if an increase of profitability is not always necessary (a small loss of profitability can be compensated by other factors), profit is important for the economic viability of the fisheries.

<u>Baltic</u>
A bio-economic study using Cost-Benefit-Analysis methodology to investigate the economic incentives and the of a potentials in a possible Danish creel fishery for Nephrops (D7.9) demonstrated that the potential profit decreases with increasing vessel size, but increases with the number of crew members on-board. Overall the results showed that a Danish creel fishery may potentially be profitable for small vessels with two crew-members, depending on factors such as number of creels fished, number of yearly fishing days, Nephrops price, fuel costs, gear costs, and auction costs. The qualitative interviews confirmed that profitability in a Danish creel fishery is highly dependent on keeping (fuel) expenses low (e.g. fishing from harbors close to the fishing area and adjusting engine size). Furthermore creel-fishing was perceived as more sensitive to weather conditions than trawl-fishing and extra price for live lobsters was assessed to be essential as economic buffer. In Sweden, a profitable creel fishery for Nephrops already exists, likely facilitated to some extent by the prevalence of larger, rocky non-trawlable areas in Swedish waters of Kattegat and by designated non-trawling zones in Kattegat. A desk-based study of three Swedish fisheries for Nephrops in the Kattegat–Skagerrak (creel, mixed trawling and grid-trawling) showed that allocation of a larger quota share to creels would significantly reduce seafloor pressure without jeopardizing the profitability of the Nephrops fleet.

The trial fishery with a Nephrops trawl with reduced sweep lengths demonstrated that it was possible to maintain the same catch rates of Nephrops, cod, plaice, sole and haddock, indicating that the profitability in the fishery is also kept. However, changes in energy efficiency and profitability between use of standard and short sweep lengths has not yet been analyzed. But the interviewed fishers were very positive to the use of shorter sweeps as is does not increase labor and ease in the fishery (just taking two sweeps of 15 off to reduce the sweep length from 45 fathoms to 15 fathoms). Also, they were positive to the catch efficiency in the fishery using shorter sweep length. The fishers very much recommend further trials and experiments to further document the efficiency in using shorter sweep length. In relation to benthic impacts the potentially changed trawl door impact on the seabed when using shorter sweep lengths compared to standard sweep length should also be further tested according to the fishers (in agreement with the DTU Aqua and SLU Aqua scientists) participating in the trial fisheries with shorter sweeps in the Baltic Sea.

Sea trials with a light-weight mussel dredge versus a standard dredge demonstrated similar or higher catch rates and significantly reduced sediment catch and drag resistance, indicating a reduction in energy transfer to the seabed (and likely a reduction in fuel consumption and costs). These results add credibility to the light dredge as a profitable alternative to the standard dredge, and the dredge is also currently implemented (by area-specific legislation) in parts of the Danish blue mussel fishery. In the interviews some mussel fishers, however, questioned the potential reduction in overall benthic impact because of individual variations in ground gear mounting, vessel movements, etc. Instead they pointed to smart fishing with advanced pre-harvest monitoring techniques (e.g. side-scan sonar) as a more promising way to increase profitability and reduce effort, seabed pressure and discards in the mussel fishery. The latter has accordingly been investigated in the Baltic Case Study. Since this extensive sub-case-study work and sea-trials by use of side-scan-sonars and video-cameras searching for blue mussels instead of conducting trial fishery to reduce effort and accordingly benthic impacts from search fishery is not reported here as it does not involve bio-economic analyses.

Bay of Biscay

For smaller vessels, in particular those fishing in the South of the Bay of Biscay, previous assessments indicated that 80 mm mesh size in the codend was economically unsustainable as a result of the loss of other commercial species. Since square mesh panels are relatively inexpensive, technically simple to fit in the trawl and benefit from a positive image based on the hake square mesh panel experience, this selectivity option was logically retained by those vessels.

The sorting grids remain hardly used by any Nephrops trawler of the Bay of Biscay. Although sorting grids, in particular those placed in the bottom of the trawl are, according to research results, the most effective selectivity device for sorting Nephrops in the trawl, adoption by fishers is undermined by the potential complexity of the device compared to other, and by its fast wearing in particular when used on hard bottom. In addition, this device is found by fisher organisations to be costly (between 450 € and 1 000 € each, with a minimum of four grids required) and to wear out fast. One might hypothesize that the small gain in landings was not sufficient to compensate for the extra costs generated by the frequent replacement of a costly device. However, since sorting grids are perceived as the most effective selectivity device for sorting Nephrops in the trawl, research projects over the last 15 years consistently tried to improve the mechanism through identification of the best adapted material and design for increased robustness and easier handling, in particular for fitting in the drawl drums upon trawl hauling and trawl shooting.

Black Sea

The modified beam trawl has lower CPUE but higher ex-vessel price than traditional beam trawl. The average resulting income of the modified beam trawl is lower than the income of the traditional one. This result will make the fishers unwilling to use the modified gear. Fishers expectation is that the ban on sea snail fishing, which is prohibited by the beam trawl during the summer season (particularly June and July) hampers the investment in the innovative gears. They would require the removal of the ban by the use of a modified net (sliding and wireless beam trawl net). Their greatest expectation is that they want to lift the ban on summer fishing. Because in this period, the catch rates are the highest. Pot which is the other alternative for vessel, has not shown satisfactory results for commercial fishing (catch rates are too low). For this reason, fishers do not prefer this fishing gear. In the case of work carried out with 4 different types of fishing gear on bottom trawl net, in terms of selectivity the square and T90 meshed net fishing gear red mullet and whiting has been found preferable for sustainable fishing. The efficiency of fishing has been low with this new gear mesh size fishing. For this reason, fishers have not adopted the recommended gear mesh size openness in the trawl codend.

Mediterranean Sea - Central Adriatic

Profitability of the innovative gears is also one of the main drivers in the Central Adriatic. The fishers interviewed have declared that maintenance costs are key factor in investment decisions. After fuel costs they decide whether to invest or not in a new gear if this is able to reduce the whole upkeep cost of ship. They look also at the upkeep cost of the new equipment itself.

North Sea

The Belgium case

The interviewed fishers seemed concerned with increasing their income. Different strategies were mentioned to improve their efficiency and ultimately earn more. For some catching less was not the first option, rather catching the same amount but increasing their CPUE and reducing their costs.

"My motivation for all the changes that I have made are simply to try and catch more. Don't get me wrong, I look at the period that we are away. Say if I fish for one hour and I earn 1000 euro while another fished for 10 hours and earned 9000 euro, the other has more than me in total, but in the end I have more than him because I earned 1000 euro in only one hour. That is my motivation as long as I can do it." (personal interview with fisher, Belgium 2016)

"It needs to be a win-win situation. If it results in catching less, you should not do it, but if it is possible with the same catch and less wear and tear or less fuel consumption etc, then immediately." (personal interview with fisher, Belgium 2016)

It seemed to be a recurrent view in all interviews that reducing fuel consumption on a trip level (as opposed to decreasing the number of days at sea) came together with a lower catch. Therefore, while many measures were taken to reduce fuel consumption on a trip basis, some of these measures were abandoned again following the decreasing fuel prices to increase the catch. Another view was also observed, namely that although reducing fuel consumption may mean catching less, it may also lead to better fish prices. *"The benefits no longer outweighed the disadvantages to reduce the fuel consumption compared to the revenue."* (personal interview with fisher, Belgium 2016)

The Dutch case

In the Dutch flatfish fishery, fishing with pulse trawls is much profitable than to fish with traditional beam trawls (about short term profitability is 1.5 times higher). The pulse trawl is much better at catching the high value sole than traditional beam trawls, increasing the value of the catch and has lower fuel costs decreasing the costs of fishing. The return on investment for the pulse trawl is about 25%, way above long term interest rates for the Netherlands in the early 2010's (at about 3%, OECD, 2016). This means that it is more profitable for fishers to invest in such a gear than to place the money on "safe" investments.

3.1.2 Change in fuel price

Baltic

In the case of creels as an alternative to trawling for Nephrops, changes (increases) in fuel prices were informed by the interviewees as a potential key driver of any gear shifts. A study of the Swedish fisheries have shown that for similar vessel sizes, the fuel cost share of variable costs is double for trawling compared with creeling for Nephrops (Bengtsberg, 2010) and low energy efficiency has also been demonstrated for the Danish trawl fishery for Nephrops in Kattegat of the Baltic Sea (Bastardie et al., 2013). A reduction in fuel consumption and efficiency was expected from using creels and using shorter sweeps compared to standard Nephrops trawling, as well as in the use of light mussel dredges instead of standard dredges.

Bay of Biscay

Increasing fuel prices had detrimental impacts on the economic profitability of fishing fleets. Fuel consumption reduction has been one of the key objectives in technological adaptations developed all over the last 15 years. The adaptations focused on the reduction of the drag generated by trawl doors and netting surface which altogether represent at least 80% of total drag, with 20% for trawl doors and 60% for netting surface (Khaled and Priour, 2010). New models of trawl doors of smaller size providing similar trawl opening have been adopted by the fleet, and fishers used larger mesh sizes in trawl wings and back.

Black Sea

The modified beam trawl saves fuel cost (about 10%). The average fuel costs saving per day at sea amounts to about 10 euro. Saving on energy consumption is the most important result in the gear trials which also provided an advantage in negotiation with the fishers for the adoption of the modified gears. Although the modified beam trawl does not provide a great advantage in fuel consumption, this result from innovative gear is positively regarded as fuel cost constitutes the largest share of the fisheries operating costs. Despite this, the fishers expectation is the opening of the summer season fishing, which is entirely forbidden and fishing yield highest.

The increasing of fuel prices had important impacts on the economic profitability of fishing fleets in SSA. The use of innovative beam trawl showed a reduction of the average fuel consumption per day at sea. On average it was 12,05 Lt per day less than with the use of conventional beam trawl all the periods considered, corresponding to a daily fuel consumption difference of 10% less than the average consumption per day at sea of the periods with the traditional beam trawl.

Using the average price of fuel (0,8591€) of the entire considered period (2014) it was appraised the daily saving of fuel per day at sea in unit of euro in the amount of 10,35€ per day at sea. This amount multiplied by the average days at sea of the period (135 days at sea) carried out the value of the annual savings in fuel costs using the innovative beam trawl in the amount of 1397,54€ per year of fishing activity. This is the most important argument the gear trials could provide in favour of adoption of the modified gears (Zengin et al., 2016).

Mediterranean Sea - Central Adriatic

Fishers who had implemented sustainable innovations in the previous years said that one of their main motivations for doing so was high fuel prices. After they had a clear idea that the new gear would not worsen their fishing activities, they would choose the gear improving their profits. As stated by most of them the principal beneficial effects of the fishing innovation they look at is fuel savings.

North Sea

The Belgium case

In all interviews with Belgian vessel owners a recurrent theme was the necessity to make a change following the fuel crisis. The rapidly increasing fuel prices between 2004 and 2008 led to severe economic losses. All interviewed vessel owners adopted some alternative to the traditional beam trawl after this period. Early responses included the reduction of steaming time and towing speed. Some fishers also reduced the weight of their gears (e.g., by using a shorter beam). This was followed by investments in new gears such as Sumwing and Ecoroll beam. In 2010, many fishers also invested in a new engine, nozzle and propeller.

“Indeed, there were some who remained conservative and said they would not change. But if it really comes to that point, it is no longer possible [not to change]. If you have a system that is too expensive, then you can no longer survive.” (personal interview with fisher, Belgium 2016)

“In the past, the idea was always faster and heavier delivers more fish. If you never have to stop and think about it, if you never have problems, why change? But of course in 2007 and 2008 it was a necessity. Everyone saw that they could not afford it anymore. That you were always running in red. 40% even 50% fuel costs. Then you better remain on the docks.” (personal interview with fisher, Belgium 2016)

Most of the vessel owners recall the high fuel prices as the main reason for changing their fishing behaviour and some stated to have since reduced their yearly fuel consumption by 50%. In hindsight, a couple of fishers stated that the fuel crisis triggered the Belgian fishing sector to change, and that things have changed for the better. Now that fuel prices have decreased again, there seems to be no wish to go back. However,

some fishers stated that lower fuel prices have given them the opportunity to try out new fishing grounds or to experiment with larger fishing gears and faster towing speeds, in order to increase their profits.
"The company would have gone bankrupt, nobody could afford it. However, in hindsight it is better for everyone, the environment and the fish stocks. Because of it we probably catch a little less fish, but if we all catch less, prices might improve and you have less costs. (…) It was really a bad evolution, only going larger and heavier. (…) The high fuel price was the main reason that we had to work on fuel consumption, let's be honest about this. But in hindsight, this was a good thing, I think. And we learned to deal with it. Before, we didn't realise this, it was a habit. Indeed, it didn't cost a thing." (personal interview with fisher, Belgium 2016)
Although pulse trawling is a more fuel efficient gear in comparison to the traditional beam trawl, it was not adopted in the Belgian fleet. A belief among interviewed Belgian vessel owners existed that the pulse was largely responsible for the higher resilience of the Dutch fleet in the period following the fuel crisis. On the other hand, the Belgian fleet initially had lower fuel consumption values in comparison, so the effect of switching to the pulse trawl may not have been as striking for the Belgian fleet as it was for the Dutch fleet.
"If the Dutch would not have been allowed to fish electrically, there would be no more Dutch fleet. Those guys were at 8000-9000 litres of fuel per day, so that was not profitable anymore." (personal interview with fisher, Belgium 2016)

The Dutch case
For many pulse fishers that switched in 2010/2011 it was important that a new technique lowered the fuel costs, as these costs had been increasing enormously, making the fishery non-profitable. The first results of the pulse trawlers were financially positive. These results were shared on many occasions leading to a change in the attitude of the fishers (Haasnoot, 2015). In addition, a catch comparison was done between two pulse trawl vessels, and a traditional beam trawl. Results showed a positive performance of the pulse compared to the beam trawl in terms of fuel consumption, costs, and catches (ibid).

Unsurprisingly, the fuel price has a great impact on the short term profitability of pulse and traditional beam trawls. However the impact of changing fuel price is greater for beam-trawl than for pulse. The pulse activity is more resilient to fuel price variations as it is less sensitive to fuel costs.

3.1.3 Access to funding

Black Sea
In Turkey, fishers have difficulties getting loans from banks. Especially the fishers are unable to meet the collateral requirements of the banks. For this reason, very few fishers borrow from investment banks. Generally, large-scale fishers benefit from these loans. Since 2004, the government has been providing fishers fuel without excise duty (in Turkish abbr. ÖTV). Not only fishing vessels, but all marine vessels benefit from tax exemption on fuel at different rates. The maximum fuel quantity exempted from duty that can be used annually is defined based on the power of the boat.

Mediterranean Sea - Central Adriatic
A further element affecting the choice to innovate, for both those who implemented a sustainable innovation and those who did not, was the availability of subsidies and public incentives for innovation. Public funding to sustain part of the costs of the innovation or presence of subsidies and incentives have been claimed a discriminating factor in whether to invest in sustainable gears or not. They could be in form of direct payments or tax reliefs. Fishers who said that they had not made any technological improvement stated that they would have if public incentives had been available.

North Sea

The Belgium case

The interviewed Belgian fishers stated that there was an overall lack of capital within the Belgian fishing industry to implement the changes they aspired. These changes included flyshooting, pulse fishing and twin-rigging with all-round fishing vessels that can easily switch between fishing methods. They named the construction of new vessels as a requirement to sustain a profitable Belgian fishing sector in the future.

"In my opinion the entire sector needs to change. Alternatives to the beam trawl exist, but Belgian vessels are not equipped for flyshooting or pulse fishing. Construction of new fishing vessels is needed in the near future." (personal interview with fisher, Belgium 2016).

Fishers stated that obtaining a loan from the bank was particularly difficult during and soon after the fuel crisis, but that banks were still disinclined to hand out loans at the time of the interviews.

"You just can't find the starting capital. The banks are very reluctant with regards to investments in the fishing sector. The loans are still difficult to obtain." (personal interview with fisher, Belgium 2016)

"The fishery has been very negatively perceived over the last… at least by the banks." (personal interview with fisher, Belgium 2016)

This created a downward spiral in which many businesses went bankrupt. The interviewed fishers were amongst those that survived and stated that they did so thanks to financial support. Subsidies for engine replacement came timely. In 2010, the government ran a large-scale campaign in which they subsidized 60% of investments in lighter engines in order to reduce engine power and fuel consumption. The more profitable businesses were able to experiment with the construction of new gears, for which some of them also received subsidies (e.g. Sumwing).

The Dutch case

In order to cover the investment costs for the pulse technique fishers needed to access funding, either through banks, subsidies, or with private capital. Some early adopters have received a subsidy to stimulate them to switch to the pulse, but most fishers had to fund their investment through a loan from the bank. It was clear that the banks wanted to stimulate the fishers towards sustainability. In 2011 a 'Think Tank' of the ING published a report in which they stated that from then onwards they would only invest in fishing techniques that are not damaging the environment (Visserijnieuws, 2011).

"The bank pushed us, because in their opinion we were not innovative enough. That is how it all started in 2010." (personal interview with fisher, 2015).

3.2 Technical drivers

3.2.1 Functionality/workability of the new gear

Baltic:

A substantial redirection of effort (from trawls to creels) would of course have social and economic implications for the fishers currently involved in traditional trawl fisheries, and among other it will have to be examined if the fish quotas may still be caught. Another bottleneck for the traditional trawlers to make the transition to creeling is the high investment costs in terms of new gears and deck equipment (potentially a new vessel) combined with the risk-increase related to the implementation of new technology in terms of more uncertain catches, costs and income.

Bay of Biscay

From fishers perspective, using 80 mm mesh size is the simplest technical option. Fishers regularly have to change their codend when it is worn-out and can therefore easily increase the mesh size at no extra cost to comply with regulatory requirements. For larger fishing vessels fishing in deep waters (100 m +), the 80 mm codend reduces Nephrops discards without significant catch losses of other species.

The separator panel trialed in the early 90's and again recently (Redresse project) is considered as potentially interesting to separate Nephrops from other fish in the codend. Given their benthic behavior, Nephrops would go in the lower part of the trawl bag while fish species would go in the upper part. The interest is twofold : i) Nephrops are not crushed by other species while in the codend, with higher quality of catches as a result, and ii) specific mesh size can be fitted in the lower part of the bag to improve Nephrops selectivity with minimal effects on catches of other fish species. According to fishers associations, separator panels may not be adapted to the Nephrops fishery. One reason is that the device is complex to fit in the trawl, and cannot be repaired at sea in case of problem. Another reason is that separator panels increase the workload upon gear hauling since fishers have two sets of two bags to process instead of one set of two bags in the case of a twin trawl without separator panel. From fisheries technologists perspective, fitting stable separator panel in trawls with low vertical opening, such as twin trawls, is challenging.

According to information available, Nephrops fishing with traps remains a marginal activity deployed by vessels specialised on trap fishing for other crustaceans (crabs, lobsters), mostly as a seasonal complement. Fishers representatives met do not anticipate further development of this fishing technique for Nephrops in relation with its uncertain economic viability and the increased workload it would generate for fishers which would have to haul hundreds of traps to reach levels of income aligned with income generated by trawl catches. Besides, the spatial interactions with trawlers in the Grande Vasière do not enable the extension of the trap activity that is only limited to canyons and untrawled area. A recovering of the Nephrops population structure towards larger individuals would also be a condition to ensure higher yields for traps and thus higher economic viability (see also D7.9).

Mediterranean Sea - Central Adriatic

How the new gear works is one of the principal drivers of investment decision for fishers, they principally aim to gain improvement of their fishing activities in terms of quantity and quality of fish through innovation. Fishers unanimously claimed that the principal element in investing or not is the technical performance of the gear maintaining at the same time the same attitude of the gear to catch fish. At least the new gear configuration must to be equal in catching capacity compared to the previous equipment. Maintenance costs are secondary elements in the decision process. Most of fishers stated that they believe in "what they see on the vessel deck rather than on economic calculus, if a gear do not catch as the old one they would not invest in it".

North Sea:

The Belgium case

In the Belgian fleet, fishing ground characteristics greatly contribute to gear choice within the same fishery. Some gears are more adapted to rocky environments, while others work better on sandy soils. For instance, Sumwing does not perform well when there are too many rocks.

"We cannot fish in the stones with the Sumwing. On the other hand, with the Ecoroll beam it is possible, it uses chain mats." (personal interview with fisher, Belgium 2016)

Sumwing is therefore adapted to certain fishing grounds in the North Sea, in the Bristol Channel (VIIfg) and the Bay of Biscay, but cannot cover all fishing grounds where Belgium has sole quota. Sole is the most important target species for the entire Belgian fleet and contributes largely to fishing income and thus profitability. This makes fishers vulnerable to quota changes for sole and explains why sole quota decreases are a sensitive subject.

"Sole needs to be included in your catch to assure your revenue. You need to stay profitable because exploiting a vessel costs a gigantic amount of money." (personal interview with fisher, Belgium 2016)

The Dutch case

The pulse fishing gear is much lighter than the traditional beam trawl, because the traditional tickler chains, which were used to startle the fish, are not applied anymore. The pulse technique works with electrodes that generate an electric pulse. 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 cited by Haasnoot, 2015). This makes the gear lighter. In addition, the speed of the vessel could also be reduced, making the pulse technique a less energy consuming technique.
The pioneer pulse fishers (before 2014) experienced a lot of technological problems, including: broken modules, failures in the system, short-circuits and broken electricity cables, which needed to be fixed every week. “The pioneers needed to develop skills and knowledge to overcome these problems.” (Scherders, 2016).
Besides the advantage of less energy consumption, there are two other important advantages of the pulse technique. The first one is the access to new fishing ground. These are mainly areas with
softer ground were previously avoided by beam trawl fishers. Second, a different proportion in the target species is found, as more sole can be caught with the pulse technique, whereas with the beam trawl more plaice was caught (Turenhout et al, 2016). Sole has a higher market value than plaice.

3.3 Regulatory drivers

3.3.1 Access to quota

Baltic:
For the Swedish Nephrops fishery it has been assessed that allocation of a larger quota share to creels would significantly enhance fishing with this gear type in Sweden, thereby reducing pressure on the seabed and the Nephrops stock (Hornborg et al. 2016). A substantial redirection of how quotas are allocated between gear types would have social and economic implications for fishers currently involved in Swedish Nephrops trawl fisheries, and it needs to be examined if the fish quotas may still be caught given the changes. Among Swedish creelers, there is also a concern for overcrowding if the creel fishery is allowed to expand substantially without new areas being made available/exclusive for this gear type. This may affect prices on creel caught Nephrops (e.g. live Nephrops). In Denmark the Nephrops fishery is managed through an Individual Transferable Quota system, which makes it less straightforward to favour alternative gears through quota access management.

North Sea:
The Belgian case
Reducing the quota of the target species (sole in this case) could be a driver to change target species and consequently gears, if the prices are favourable enough to remain profitable.
“The choice to change to a twinrig can be substantiated by the development that the quota are decreasing each year. Our current target species is sole. Each year we receive less for our target species. If half of one’s returns come from sole catch, that means something. So if they remove half of one’s sole quota, then you simply cannot get by. So I have to, and I’ve seen that sepia is doing well on the market.” (personal interview with fisher, Belgium 2016)

The Dutch case
The catch composition of the pulse and traditional beam-trawls are different and the pulse is much better at catching sole (the high value species of the assemblage). Switching to pulse implies that one had to have access to sole quota through ownership or through renting sole quota. The quota lease prices for sole quota have increased dramatically since 2014 after the second set of 42 pulse permits were made available (multiplied by 4 in a year). Although the TAC decreased between 2013 and 2014, it does not alone explain the increase in demand as such variation in TAC was already observed in the past without significantly affecting the quota lease price. The specialisation of the pulse fishers for sole mainly drove the rise on the quota lease market.

3.3.2 Technical limitations

Bay of Biscay

Early 2000, poor status of Hake stocks in European waters, and in particular in the Bay of Biscay triggered adoption of EU specific additional technical measure in 2001 involving increased mesh sizes for access to Nephrops fishing zones.

In November 2000, ICES indicated that the stock of hake in ICES sub-areas III, IV, V, VI and VII and ICES divisions VIII a, b, d, e was at serious risk of collapse, triggering an immediate requirement to reduce catches of juvenile hake. As a first response, the European Commission mandated in 2001 a mandatory increase of mesh size from 70 mm to 100 mm[3] for any demersal towed net. From the Bay of Biscay fishers perspective, the mesh size increase was viewed as economically unsustainable, triggering research into alternative technical measures aiming at avoiding undersized hake while targeting Nephrops. Based on the results of the ASCGG research programme, French fishers successfully submitted fitting of a 100 mm square mesh panel in the top trawl extension as a derogation to use of 100 mm mesh in the codend. The derogation became official in 2006 at National level as a condition attached to the national Nephrops license and in Community law through Reg (EC) 51/2006[4].

Devices developed for Nephrops and hake selectivity were transposed in the National legislation as a condition associated with the Nephrops fishing authorisation created in 2004.

The first selectivity device imposed was a square mesh panel fitted in the top of panel of the trawl to improve hake selectivity based on the results of the ASCGG programme. Incorporated into National and EU legislation as from 2005, the square mesh panel is an approved alternative to the use of 100 mm mesh size in the codend mandated by EU legislation. In 2016, the hake square mesh panel remained an obligation for all Bay of Biscay Nephrops license holders.

Concerning Nephrops selectivity, the option adopted by the National Committee for Fisheries has been to leave to fishers the choice between different selectivity devices, instead of imposing a one size fits all selectivity solution. Therefore, as from 2008, Bay of Biscay Nephrops license holders were given the choice of fitting one or several of the selectivity devices listed below, in addition to the mandatory hake square mesh panel:

1. A square 60 mm mesh panel in the bottom of trawl extension
2. A sorting grid with 13 mm bar spacing placed either across the upper side (inverted grid) or the lower side (regular grid) of trawl extension
3. A codend with 80 mm mesh size, instead of the legal 70 mm mesh size
4. As from 2011, the option of using a square 60 mm mesh cylinder in trawl extension was added as an additional option

The different options available are depicted in the figure below.

[3] Commission Regulation (EC) No 1162/2001 of 14 June 2001 establishing measures for the recovery of the stock of hake in ICES sub-areas III, IV, V, VI and VII and ICES divisions VIII a, b, d, e and associated conditions for the control of activities of fishing vessels. OJ L 159, 15.6.2001, p. 4–9

[4] Council Regulation (EC) No 51/2006 of 22 December 2005 fixing for 2006 the fishing opportunities and associated conditions for certain fish stocks and groups of fish stocks, applicable in Community waters and, for Community vessels, in waters where catch limitations are required. OJ L 16, 20.1.2006, p. 1–183

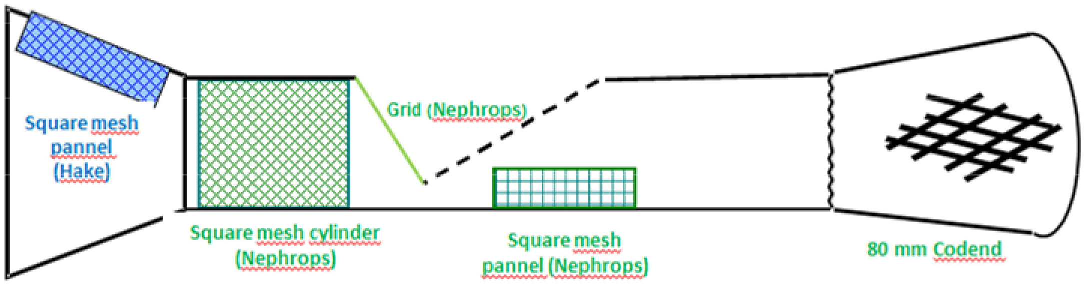

Figure 2 : Schematic representation of mandatory selectivity devices imposed as a condition for Nephrops license by the French law (arrêté du 9 décembre 2011).
Note : the so-called inverted grid is shown in the graph. Grid in lower part of the trawl is also acceptable from a legal perspective
Source : Rimaud (2015)

Selectivity devices 1 to 3 above was successfully tested between 2006 and 2008 by the "Selectivité Pêche Langoustine" research project and assessed as effective by the fishers community. Selectivity device 4 was added to the option list in 2011 mainly on the basis of Chalutec programme.

According to information available based on Nephrops license submissions, about 75% of the Bay of Biscay trawler fleet selected the 80 mm mesh size codend option in 2016. The remaining 25% selected the Nephrops bottom square mesh panel while using the legal 70 mm mesh size in the codend.

Some of devices developed in the Bay of Biscay nephrops fishery were adopted while others remained unused. The main reasons for not adopting Square mesh cylinders in the trawl extension considered by the National legislation can be explained by the fact that i) identification of this selectivity device is more recent than the other, and ii) scientific trials have not been explained to fishers as other selectivity devices could have been after being tried and assessed.

<u>Black Sea</u>
The general management criteria announced by General Directorate of Fisheries every two years concern all fishing methods. They are described for both bottom trawl and beam trawl in the Turkish Black Sea:

I-Bottom trawl (whiting and red mullet fisheries):

(1) Area closures: Bottom trawls is prohibited along waters a) between Sinop city, İnceburun (42° 05.959' N-34° 56.695' E) and Samsun city, Yakakent, Çayağzı Cape (41° 41.040' N-35° 25.193' E), b) between Ordu city, Unye; Taskana Cape (41° 08.725' N-37° 17.531' E) and Georgia border, c) between Ereğli Baba Cape (41° 17.342' N-31° 23.937' E) and Bartın city, Amasra, Tekke Cape (41° 43.485' N-32° 19.258' E) in 2 miles from land. Furthermore, in open areas it is prohibited to make any fishery within 3 miles from land.
(2) Time closures: In open areas, fishery is prohibited between 15 April-15 September.
(3) Mesh size limitations: The mesh size should not be lower than 40 mm.
(4) Minimum legal catch size: For whiting minimum legal size (total length) is 13 cm and for red mullet 11 cm.

II-Beam trawl (Rapa whelk fisheries):

In Turkey, MFAL (Ministry of Food, Agriculture and Livestock) implemented some limitations to the fishery of Rapa whelk by yearly circulars which can be mentioned under three items. The first was the fishing method that permits scuba diving in the western part while dredges (mesh size as minimum 40 mm) are allowed in the eastern part including Samsun Shelf Area. The second was about fishing period. Scuba diving was allowed throughout all year, but dredges are banned between 1 May and 30 August. In addition, fishing at night was also banned. The third one is about

the area limitations such as closure of a zone 500 m from the coast. Actually, these limitations never came into use and illegal fisheries increased in following years. The possible reasons for illegal fisheries may be considered as:
(1) The Rapa whelk migrates to the coastal zone to reproduce in summer months (5-15 m depths) and the illegal fishery increases especially in this period due to abundance. Also gear efficiency resulted in higher catches. The Rapa whelk population moves to deep water in autumn when the temperature lowers and so the decrease of the catch in this legal period compels the fisher to practice illegal activities.
(2) The meat yield reaches its highest percentage in summer and market prices get higher. In the legal period (autumn) the condition of Rapa whelk declines. So the processing plants are reluctant to pay high prices.
(3) In this legal period the artisanal fishers harvesting Rapa whelk leave the dredges and focus on bonito fishing which is more profitable.
(4) Except for the banned period some of the small scale fisher work as a crew in large vessels (trawls and purse seines). After the closure of the fishing season for the large vessels, they seek a profit from Rapa whelk and fish during the illegal season

<u>Mediterranean Sea - Central Adriatic</u>
Government regulations for environmental sustainability through "command and control" policies appears as the most important factor of investment decision. Regulations and policies are followed by fishers even if the innovation implementation involves loss of income. Fishers declared to be scared of controls and fines, so they prefer to conform with new technical requirements instead of incurring penalty payments, fishing license suspension or ship blocks. An example is the case of EU Regulation no.1967/2006, which imposed various restrictions on gear to protect fish stocks, among others the use of nets with larger meshes. This resulted in substantial economic losses for fishers in terms of catches and sales, but the regulation was followed by all the fishers of the fleet.

<u>North Sea</u>
The Dutch case
In 1988 the European Union (EU) put a ban on electric fishing. As a result, all research and development of electric fishing gears was halted until the EU granted an experimental license. In 2006 a derogation was granted by the EU for 5% of the beam trawl fleet (Haasnoot et al, 2016). In December 2010 in total 42 licenses were granted to the Netherlands (Scherders, 2016). In 2014 another 42 licenses were granted, however these licenses had a restriction: they were not allowed to fish above fish a latitude of 55°N (Haasnoot, 2015). At present, the pulse gear is still officially forbidden in EU waters and used under derogation.

3.3.3 Effort restriction

<u>North Sea</u>:
The Belgian case
Another regulatory driver in the Belgian fleet is linked to effort restrictions. Currently for the large fleet segment, a vessel is only permitted to spend 160 days in the North Sea and VIId, which has implications for gear choice.
“You cannot fish all year round with Sumwing, that’s the problem. (…) We tried it some years, but had to think of something else. It was a disaster, totally unprofitable.” (personal interview with fisher, Belgium 2016)
Pulse trawling is currently only permitted in the southern North Sea. This may be a bottleneck for the adoption of this gear as a vessel would only be able to fish 160 days a year with the pulse trawl. Quota and effort are allocated at the vessel level, meaning that a company with two vessels cannot decide to fish all

year round with pulse in the North Sea with one vessel. One of the interviewed vessel owners explicitly stated that allowing pulse trawling in the Western waters and testing its performance on these grounds was a prerequisite to introducing the pulse in Belgium and stated it would not be profitable to only use the pulse in the North Sea.

“[about allowing pulse trawling in the western waters] I think that it is a very important condition because it is a large investment. It is still about 350.000 euro. (…) The investment is too large, I think that you will need to fish with it all year round. We are restricted in our sea days in the North Sea, we only have 160 sea days. We are limited in our quota. We need to fish everywhere that is why the western waters need to be added.” (personal interview with fisher, Belgium 2016)

As previously mentioned, most interviewed fishers made statements that can be interpreted as an attempt to increase their CPUE in order to become more efficient and ultimately increase their income. In this regard, one fisher specifically stated that given his quota, he would not mind to lower his number of days at sea. He even mentioned the pulse as a possible means of achieving this. As a result he would spend less while catching the same amount. However, there is still a large difference between intention and action.

“It would be nice if our returns would remain the same, with a fuel consumption like we have now and with the pulse trawl that should be possible. So the same yearly returns, but a lot less days.” (personal interview with fisher, Belgium 2016)

“I cannot catch more fish, I am restricted by my quota. Now we make 270 sea days in a year. What if we could reduce that to 220 days with about the same fuel consumption? Then we are also on the right tracks I think. (…) I have a quota, whether I fish this with the mats and a beam or I fish this electrically, I can only fish my quota. So then I will try to fish it in a shorter period of time. ” (personal interview with fisher, Belgium 2016)

3.3.4 Landing obligation

In 2011, the publication by the European Commission[5] of the main outline of the forthcoming reform of the CFP introduced the discard ban subsequently included in the reformed CFP, known as the landing obligation.

The willingness of the European Commission to take measure to reduce discards was first tabled in 2007. In 2011, the European Commission announced the landmark initiative of discard prohibition to be included under the next CFP with consideration of certain exemptions.

<u>Baltic:</u>

The traditional otter trawl fishery for Nephrops in Skagerrak-Kattegat has substantial discards compared to many other fisheries (Kelleher, 2005) and logically the enforcement of the EU landing obligation in this area in 2016 should stimulate the fishery towards adopting gear-technologies and alternatives with improved selectivity such as creels or grid-trawls. However, it was very evident from the interviews that the fishing industry is highly sceptical towards the feasibility and practicalities of this particular measure, which no doubt renders it less efficient as a driver of gear innovations. The discards of Nephrops in the area has, however, decreased with the introduction of the new minimum landing size of Nephrops in 2015 in the area which is now more in alignment with the mesh sizes used in the fishery.

<u>Bay of Biscay</u>

The measure encouraged continuation of research on selectivity while triggering investigations on the survival rate of discarded Nephrops to explore possible exemptions. Based on findings of earlier research projects (Charuau et al., 1982), it was assessed that Nephrops could qualify for an exemption for high survival rate. A dedicated research project (*Surtine* associating AGLIA and IFREMER) was deployed, and

[5] COM(2011) 425 final - 2011/0195 (COD)

provided interim results that supported a temporary exemption of the landing obligation for undersized Nephrops for 2016, renewed for 2017[6].

North Sea:

The Belgian case

All Belgian vessel owners interviewed had a negative perception towards the landing obligation. They expressed their misbelief that this regulation was becoming a reality. There seemed to be a lot of confusion between cause and consequence. Generally they did acknowledge the goal of the regulation, but could not understand the means currently in place to achieve it. Interviewed fishers presented this as their greatest concern for the future and the majority presented themselves as being very discouraged, even desperate, with regards to taking on the challenge. Rather than stating non-compliance they expressed a tendency to give up.

"[about the implementation of the discard ban] Then I quit, I will not partake in doing crazy things. Then things will shut down and it won't be my concerns any longer. That's how bad it is. By all means, I do want to invest in the company but such crazy things… They are asking for something we cannot do." (personal interview with fisher, Belgium 2016)

"I am very afraid of the discard ban. That's a terrible measure. Everyone says so. What do they want to achieve with it? I do not understand that they could have voted this. It's political and as a result everyone is in deep trouble." (personal interview with fisher, Belgium 2016)

"Then that's the end of the fishery, I will not be part of it" (personal interview with fisher, Belgium 2016)

"you mustn't forget, you go to sea to earn something and not to bring water to the sea. Look, some fisheries can more easily apply selective fishing than ours. It is not possible to fish more selective because you lose sole… Sole is like an eel, it's slippery and flexible, but plaice gets stuck by the spine" (personal interview with fisher, Belgium 2016)

"For some species it is not possible. Especially not in a mixed fishery like we practice, it is a lost cause. We fish on the bottom, there are 30 to 40 species swimming round there." (personal interview with fisher, Belgium 2016)

The Dutch case

The LO is affecting the Dutch pelagic freezer trawlers and the demersal cutter fleet. For pelagic fisheries it is already in place since January 2015. The LO for the demersal fleet became effective in January 2016 (De Vos et al, 2016). The Dutch fishers were against the landing obligation, and in September 2013 the resistance in the demersal fishing sector had become so large, that meetings about the landing obligation were temporarily put on hold. After that the Ministry of Economic Affairs announced to invest 4.5 million euro in pilot projects, and proposals for de minimis and other exemptions were discussed. This lowered a bit the resistance (de Vos et al, 2015). While there is still largely disbelief that the LO will be implemented in practice, fishers have been looking into improving selectivity, but most count on exemptions to be granted on high survivability.

3.3.5 Specific areas

Baltic:

In the Swedish Nephrops fishery a set of gear-specific area closures have been important in the development of fisheries with alternative, more selective gears. Creel and grid-trawl fishers exploit roughly the same areas closer to the coast, i.e. areas where ordinary trawling is not allowed, however, creeling and grid-trawling may not exploit the same fishing grounds simultaneously due to incompatibility of the fishing

[6] Commission Delegated Regulation (EU) 2016/2374 of 12 October 2016 establishing a discard plan for certain demersal fisheries in South-Western waters. OJ L 352, 23.12.2016, p. 33–38

methods. The number of creel fishers and their effort increased when the area closed to traditional trawling was expanded in 2004 (Hornborg et al. 2016). Also in the Danish blue mussel fishery gear-specific area closures has facilitated the implementation of an alternative, light mussel dredge, which is the only gear type allowed for fishing blue mussels in the Danish Natura 2000 areas. The light mussel dredge has been demonstrated to have less seafloor impact than the traditional mussel dredge (Frandsen et al. 2015).

3.3.6 Penalties

Bay of Biscay
In 2005, France was ordered by European Court of Justice[7] to pay a fine of 77 million € for failure to enforce landing / marketing prohibition of undersized hake between 1984 and 1987. Tighter enforcement of the marketing prohibition of undersized hake ultimately killed their market. It deprived fishers from the incentive to keep catching this species, which underpinned selectivity improvements as foregone catches were not accompanied by foregone income.

3.4 Social drivers

3.4.1 Behaviour towards risk

Mediterranean Sea - Central Adriatic
The main aspects causing the non-implementation of sustainable technologies were: the "traditionalism" of the fishers and their family culture not inclined to innovations. It is strictly related to investment risks of the new technology in terms of catches, economic losses and lower income; high investment costs; and opportunities to amortize such costs. The time elapsing between the initial need to change and the actual decision to buy new gear depended on the fishers's own propensity to change, which does not appear strictly related to age, but has to do with the culture of the fishers and their life experiences. Also curiosity and discussions with colleagues and family members seems to influence these factors. Some fishers decided to buy innovative gear after direct contacts with the gear manufacturers, who gave them a chance to test the new equipment before purchase.

North Sea
The Dutch case
Econometric analysis of the Dutch investment data (annex 4) showed that people are more likely to invest if they have previously invested in new technology. Results suggest that the investment mind-set is even more important than expected gain in profitability in determining whether a fisher will make investment. It is difficult to then identify what this mind-set is associated with, it could be that those fishers are more likely to take risk or that they value the long-term viability of their company (which necessitate regular investment) more than others or simply that the innovative gears require regular investment.

3.4.2 Role of crew

Baltic:
With respect to social and economic implications for fishers currently involved in Swedish Nephrops trawl fisheries then there is a concern whether the level of employment (occupation) and wages can be maintained at the same level if introducing more creel fishery and accordingly reducing the trawl fishery in certain areas. As written above, there is also among Swedish creelers a concern for overcrowding if the

[7] Judgment of the Court (Grand Chamber) of 12 July 2005. Commission of the European Communities v French Republic. Case C-304/02

creel fishery is allowed to expand substantially without new areas being made exclusively available for this gear type. This may affect prices on creel caught Nephrops (e.g. live Nephrops).

Black Sea

Fishing in the rapa fishery is very important for the local community. Today, more than 45% of the population living on the Samsun coastal settlements has actively been involved in Rapa fisheries. Especially when the population abundance is high in the coastal waters in summer months (May-July period), fishers try all illegal ways to harvest Rapa although the fishing season is officially closed. During the intensive fishing season for industrial fisheries in late autumn and winter seasons, Rapa fishers mostly work as crew in the trawl and purse seine vessels. And after 4-5 month's, they continue their own Rapa fisheries again. Some are involved in small scale coastal fisheries; catch bonito and blue fish in September-October, shad and mullet in January, February and March, and turbot in April, May and October. It is fairly common among owners of small boats (up to 10 m) to combine work on one's own boat, typically during sea snail and bonito seasons, with work as crew on trawlers or purse seiners during winter (Zengin et al, 2016). Of the fishers interviewed for this research, 10.4% are working both on their own boat and also as a crew during the previous fishing season. 28.6% of the fishers had extra income from activities other than fishing, especially of farming (17.2%), but some were also seasonal workers (5.2%) or civil servants/tradesmen (3.8%).

North Sea

The Belgian case

Interviewed Belgian vessel owners expressed that adopting a new gear would not succeed without the full support of the skipper. Furthermore, several Belgian vessel owners stated that with the full implementation of the discard ban, the workload would increase to a point that it would not be feasible for the crew to sort all the fish. Wages in Belgium are high, but finding crew members remains a challenge. Reducing the workload could therefore potentially be a driver behind gear choice.

"The crew will simply not want to do it. It is the end of the fishery. People will not want to sail anymore. (…) They already have to work 16 hours a day. Try telling someone that they will need to work 22 hours a day… Or you can get twice as many crew members earning half as much. The vessel owner won't be able to afford it otherwise. I can pay 6 people, but not 12. I can pay 12 people half of what I pay them now. What is currently the main driver to go out at sea? Earning well of course. It's hard work. It is already tough enough to find crew members, even if they earn a lot." (personal interview with fisher, Belgium 2016)

The Dutch case

The remuneration system in the Dutch fisheries is based on shares. Crew members receive a fixed share of the value of landings minus a number of operating costs of which fuel costs represent the largest part. This means that if the value of landings increases (through prices or volume of landings) or if the fuel costs decrease, the wage of the crew increases. Using pulse trawl instead of conventional beam trawl decreases the fuel consumption by 46% (Turenhout et al. 2016) resulting in higher salaries for the crew. During interviews we got anecdotal evidence that some crew members switched from conventional beam trawlers to a pulse trawlers, compelling the conventional beam trawlers to invest in pulse trawls to retain their crew (Scherders, 2016).

3.4.3 Role of social network

Mediterranean Sea - Central Adriatic

A key factor to boost innovation was the peer-to-peer comparison with colleagues who had already tried a new technology. Generally, the fishers based their evaluation on both implementation costs and opportunities to save money from a reduction in fuel consumption and gear maintenance costs. A most important aspect in the decision to innovate was that the new gear would ensure at least the same catch capacity as the previous one. Furthermore, the fishers also considered the labor costs required to learn how to use the new equipment. Fishers seems to measure and reduce all the aforementioned elements of risk by comparing and looking at the effects of new gears implementation on colleagues.

North Sea

The Belgium case

The Belgian fishing community has been severely reduced in the past decades, leading to a situation where everyone more or less knows each other. Therefore choices made are generally noticed by peers.

"In the sector, everyone knows each other and we talk about it [gear choice]. I think it is good. We need to move forward in life. If something is really good, everyone will start using it." (personal interview with fisher, Belgium 2016)

This is likely to have played a part in the perception towards the pulse trawl together with a perceived competitive pressure from the Dutch fleet. The pulse trawl was initially well received. However, after the introduction and rapid growth of the Dutch pulse fishery in the North Sea in 2011, the opinion of Belgian fishers changed. The negative perception that pulse fishing caused widespread fish mortality and other damage was generally accepted, despite the lack of scientific evidence. This was followed by a media campaign against pulse fishing. Consequently, the Belgian Producers Organisation (PO) gave a negative advice on the introduction of the pulse trawl in Belgium and thus pulse fishing remained limited to scientific experiments. It took until August 2015 before the PO changed their opinion.

During the interviews, opinions related to the pulse were divided. Some were open to the idea and would be curious to try it if the conditions were more favourable, while others were convinced that it was a terrible development as it was too efficient. They stated to be worried about depleting the fish stocks (a perception that seemed to be widespread, not only among interviewed vessel owners).

The Dutch case

In the Dutch fishing sector local trust and social networks have always played a very important role in information exchange and innovation processes of fishers (De Vos and Mol, 2010). In 2008 the government set up Study Groups of fishers to stimulate innovation, sustainability and knowledge exchange. In total thirteen study groups were formed, of which the pulse group was one. It consisted of five fishers who can be considered the pioneers of the pulse fishery. Demonstration days were organised on board of the cutters of pioneers. Spending a day on board resulted in the sharing of knowledge and meanings among fishers regarding the pulse trawl. Meanings changed, and this contributed to more fishers/owners switching to pulse fisheries (e.g. followers) (Scherders, 2016).

Many fishers also exchanged knowledge within their own group and family, and they heard their success stories. Another important network are the crew members. Crew members sometimes switch from one company to another or someone that worked previously as a crew member then started to work for his family company. Positive experiences with the pulse technique taken on board other vessels were later used in the decision making process of the new company.

The important role of social networks, and trust became clear when one of the leading fishing companies had registered to make the change from the beam trawl technique towards the pulse trawl technique in 2011. Soon after thereafter more vessel owners followed (Haasnoot, 2015).

3.4.4 Future for the company

Mediterranean Sea - Central Adriatic

Other important element of decision is the vision about the future of their business and the whole fishing sector, which directly influence professional motivation. Some fishers who were tired of working, childless and with no opportunities to leave the market showed low propensity to innovate. Whereas fishers with successor in their business and positive feeling on their business trend showed higher propensity to innovate.

<u>North Sea</u>

The Dutch case

Also in the Netherlands there is a direct link with the future of the business, and the willingness to innovate. With the rise of the fuel prices fishers started to worry about the continuation of the fishing company. As fuel consumption is much lower in pulse fisheries, many fishers decided to switch. In that way they were able to continue the fishing company. "Continuation of the fishing company is an important personal aspect that pushed transition towards the pulse trawl because due to high fuel prices a future with the beam trawl was not possible anymore." (Scherders, 2016).

3.5 Governance

3.5.1 Government support

<u>Mediterranean Sea - Central Adriatic</u>

A further element affecting the choice to innovate, for both those who implemented a sustainable innovation and those who did not, was the availability of subsidies and public incentives for innovation. Public funding to sustain part of the costs of the innovation or presence of subsidies and incentives have been claimed as discriminating factor in whether invest in sustainable gears or not . They could be in form of direct payments or tax reliefs. Fishers who said that they had not made any technological improvement stated that they would have reversed that decision if public incentives had been available.

<u>North Sea</u>

The Belgian case

In Belgium, subsidies were granted for investments in certain gears such as Sumwing and Ecoroll beam. Fishers take pride in the gear adaptations (in some cases even new gears) that they developed to reduce bycatch (e.g., the 'Flemish panel', 120mm release panel for roundfish) or save fuel (e.g., Ecoroll beam, aqua planning gear). In many cases fishers were aided by the Foundation for Sustainable Fisheries Development (SDVO), which subsidized the testing and implementation of newly developed gears. ILVO also played an important role in testing the gears and assessing their impact. Some successful adaptations were then institutionalized and enforced by the Department of Agriculture and Fisheries. A recent example is the implementation of the Flemish panel (a 3 m long 120 mm mesh patch in front of the codend extension piece) for the entire fleet to reduce the bycatch of undersized sole.

The Dutch case

In the Netherlands, innovation and sustainable fishing is stimulated through bottom up governance structures. Decentralisation already started in 1993 with the introduction of a co-management system. In 2005 decentralisation was explicitly mentioned as a policy of the Ministry of Agriculture. The aim was to stimulate innovation and a sustainable fisheries together with the industry (de Vos, 2011).

3.5.2 Framework encouraging innovation

<u>Bay of Biscay</u>

Since the early 2000's the various research projects focusing on improving the selectivity of the Bay of Biscay Nephrops trawlers (see annex 1) have often also involved the fishing industry itself and some outputs of research findings on Nephrops trawl selectivity have been adopted by fishers and transposed in National legislation as a condition associated with the Nephrops fishing authorisation created in 2004.

<u>North Sea</u>

The Belgian case

In Belgium, innovation towards more sustainable fishing is stimulated through several new governance structures that combine bottom-up with top-down approaches. In 2011, an agreement for the promotion of a sustainable Belgian fishing sector was signed by the fishers' producer organization (*De Rederscentrale*), an environmental NGO (Natuurpunt), the Flemish Department of Agriculture and Fisheries and the Institute for Agricultural and Fisheries Research (ILVO). The aim was to initiate the transition of the Belgian fishery towards sustainability. In "Vistraject", the partners defined their vision for a transition towards the sustainability of the fishery (economically, socially and ecologically). Goals and actions were defined to bring the fishery to a desired level of sustainability by 2020 (De Snijder et al., 2015). The follow-up of the pulse trawl and support for research was included. In the VALDUVIS project, a tool was developed to assess and monitor the sustainability of the Belgian fishery, based on trip-based sustainability assessments (Kinds et al., 2016). These initiatives provided a context for discussions between fishers, researchers, policy makers and market players. The actions within this framework constitute an interesting mix of top-down and bottom-up approaches.

The Dutch case

Several governance arrangements were set up in order to stimulate innovation and a sustainable fisheries. In 2005 both a Task Force Sustainable Fisheries, and a Steering Group for Pulse Fisheries were set up. The latter consisted of the Ministry and the representatives of the fishing industry, being the FFA and the Dutch Fishers' Federation (DFF). This steering group supervised and guided the pulse pilot project (Haasnoot, 2015). In 2007 a Fisheries Innovation Platform was established, which financially supported innovation projects in which various stakeholders were simulated to work together towards sustainable fisheries. In 2008 Study Groups for Fishers were set up, among which one study group focused on pulse fishers. Also gear developers participated in this group.

3.6 Environmental drivers

3.6.1 Sustainability

<u>Bay of Biscay</u>

In 2009, the "Grenelle de la Mer" led to commitments of the fishing industry to mitigate environmental impacts of fishing activities, including discard reduction and impacts of fishing gears on the broader environment[8]; and to engage in concerted management strategies.

The Grenelle de la Mer was an initiative promoted by the newly elected government to promote conservation of biodiversity. The fishing industry was part of the debate and committed to define and adopt measures to reduce the impact of fishing on the environment. Selectivity improvements were part of this initiative, and other projects emerged to reduce the impacts of trawl doors on the bottom while supporting as much as possible energy savings. In addition, the Grenelle de la Mer included a commitment of the fishing industry to engage in co-management of the Bay of Biscay fisheries through involvement of stakeholders, including the civil society represented by environmental NGOs. According to persons met, the co-management initiative did not produce sensible results, but underpinned the need for fishers to better communicate on their management strategy of the Bay of Biscay stocks.

<u>Mediterranean Sea - Central Adriatic</u>

The last factor taken into consideration by fishers when deciding to innovate was the presence of beneficial effects on the environment. It appears to give added value to the choice of implementing new technologies

[8] Commitment 18 of the Ocean roundtable (Grenelle de la Mer) Anonym (2009) Le Livre Bleu des Engagements du Grenelle de la Mer. République française. 71 p.

but it is not fundamental in the investment decision. Most of the fisher declare themselves as being environmental friendly, but they claim to have more interest on their business rather than on sustainability. They would invest in an innovation which reduces the impact on the environment only if it would be economically efficient and valuable for them.

North Sea

The Belgian case

Environmental drivers were not directly identified as such in the Belgian fishery. However, public opinion with regards to environmental issues did matter. Furthermore, fishers did acknowledge that the fuel crisis indirectly led them to be more conscious about environmental and ecological matters.

3.6.2 Better selectivity

Bay of Biscay

The willingness of fishers to avoid catches of undersized individuals has always been a driving force to improve selectivity. Catches of undersized fish or otherwise non-marketable species during trawling operations represent an additional sorting workload upon catch retrieval on deck. Responsible fishers also perceive unwanted catches as a waste of resources in a context of poor status of stocks potentially jeopardising the future of the fishery[9] .

Efforts to improve trawl selectivity date back from the early 80s in the Bay of Biscay, with some experiments focused on separator panels and sorting grids. However, until 2004, the fishery was poorly organised and the almost open-access regime prevented adoption of collective solutions while encouraging race for fish in a context of low fuel price. The situation changed in 2004. Conscious of the need to better manage the Bay of Biscay trawl fishery, the fishers unilaterally adopted through their National Committee a licensing scheme for the Nephrops fishery with the creation of a Special Fishing Permit mandatory for all vessels catching more than 20 tonnes of Nephrops per year or 200 kg in any one day. The number of licenses was restricted to a maximum of 250 vessels. In parallel, a special Committee (Commission langoustine) was created with a mandate to propose specific management measures potentially enforceable to vessels holding a Nephrops license.

From 2005 to 2007 established NGO WWF showed interest in the Nephrops fishery in the Bay of Biscay and triggered fishers to demonstrate good management practices for the public, with promotion of selectivity efforts as part of a wider programme on sustainability of French fisheries (WWF, 2006), triggered for a willingness.

North Sea

Other (although less relevant) developments that stimulated the transition to pulse in the Dutch flatfish fishery were: the increasing need for selectivity, and more environmentally friendly fishing techniques (i.e. less bottom disturbance), the related closure of areas for the traditional beam trawl, and the landing obligation.

4 CASE STUDY SYNTHESIS

In BENTHIS we have investigated the reduction of bottom impact through several ways amongst which technological adjustments of towed bottom-contact gears. The effect of different adjustments and innovations can be found in other deliverables. Here we focused on the following step, namely reasons behind the adoption of those technological innovation by the fishery and is it possible to enhance or hamper the uptake of technology. We interviewed fishers in 5 fisheries around Europe (covering the Black Sea, Bay of Biscay, Baltic Sea, Adriatic Sea and North Sea). In most fisheries, the uptake of innovative technology did

[9] Perception reflected by all stakeholders met

not (yet) happen or began. Only in the Dutch flatfish fishery is the pulse trawl now widely operated since its massive adoption during the BENTHIS project. The synthesis of the investment decision per case study is found below:

Baltic Sea

In the Swedish nephrops fishery, creels or traps have been used for many years. The use of creels in the Danish part of the fishery as an alternative to otter-trawls was investigated in BENTHIS. While creeling could be economically profitable for the smaller vessels due to the decrease of fuel costs it seems that the larger vessels could not efficiently transition. The investment to adapt vessels from trawl to creel would be too important. There are also concerns about the impact of additional creelers on the current creel fishery. Currently, they fish in reserved areas where trawling is banned. If fishing effort increased, new areas should be made available to avoid overcrowding. In addition, nephrops caught with creel receive a premium price for their quality and fishers are afraid that the price would decrease if the supply of creel nephrops was to increase dramatically.

Bay of Biscay

A number of gear adjustments have been tested in the Bay of Biscay nephrops fishery in order to improve selectivity. Most of the gear innovations have been developed in projects funded nationally or at the EU level together with scientists, gear technologists and the fishing industry. While some adaptations were theoretically promising, fishers did not select them because they implied high maintenance costs or were impossible to repair at sea. The first step towards more selective gears was made when tighter controls of the market of undersized hake basically voided the value of juveniles. From that point onward it became more efficient to avoid those small fish that could not be sold but increased labour costs when caught and that would improve the state of the stock if left to grow. On the path to better selectivity, fishers value sustainability more and more and they have signed agreements to continue to reduce the impact of fishing.

Black Sea

All interviewed fishers have a common opinion on preservation and sustainability of fish stocks and benthic structures and would be open to use innovative fishing gear. Their most important problem is that it is currently difficult to be economically viable while operating legally. The fish prices are too low compared to the operating costs and the loss of income incurred with innovative gears would not be compensated by the lower fuel consumption. To maintain a sufficient revenue, fishers have to work long hours. They pointed out that if they earned a sufficient income, they could reduce their time at sea and subsequently the impact on the benthos would decrease too.

Fishers are aware that the illegal fishing practices (fishing at night and fishing during the closed season in summer) are threatening the sustainability of the stock and the viability of the fishery. They would prefer fishing to be open part of summer (June or July) with tighter controls and punishments during the prohibited period. In the current situation, if they are caught they have to pay the fines affecting their revenue and they end up fishing even more to compensate. Partly allowing summer fishing would allow them to be economically viable while decreasing the impact of fishing. However there is a lack of trust from the senior management-bureaucrats (decision-making mechanism) responsible for fisheries management in the General Directorate of Fisheries and Aquaculture. Since the central government does not believe that the fishers would decrease their fishing they choose to ban the summer fishing altogether even though this ban does not prevent illegal fishing.

In this context, innovative gears are not perceived as a solution to end overfishing and decrease the impact on the benthos.

Mediterranean Sea - Central Adriatic

Most of the fishers interviewed have a strong sense of responsibility and environmental sensitiveness. They feel themselves active and important actors in the management of the Adriatic sea and its resources. They are concerned that their activity undermine fisheries stocks and cause impacts on the seabed ecosystem. The fishers who implemented more innovative technologies were happy with their choice, due to lower fuel and maintenance costs and improvements in the quality of catches. None of them said that they would go back to the previous technology. The main drivers of innovation appeared to be very similar among fishers. Essentially key factors in investment decision were found to be the high costs, taxations, regulations and the improvement of fishing activity.

Following the answers given by respondents during the investigation the drivers of switching towards sustainable fishing equipment seems to be in this order:

1. legal obligations and controls;
2. technical (knowhow on the new gear and necessity of training for use) or economic performance of the new equipment (equal catches capacity compared with the previous gear);
3. cost saving in fuel (fuel consumption);
4. presence of subsidies and incentives (availability and/or amount of public financial support);
5. cost savings in maintenance (maintenance costs);
6. risk propensity (personal attitude towards risk) and inclination for innovation or traditionalism of the fisher (cultural attitude towards innovation or tradition; innovative vs conservative);
7. comparisons with colleagues (innovation success stories of other fishing enterprises);
8. work motivations and perception about the future of the company and/or the sector (profitability of the enterprise; type of ownership; succession or not; age of the vessel; vision of the sector; optimistic vs pessimistic, not depending on age of the fishing enterprise owner);
9. environmental sustainability of technology innovation.

<u>North Sea</u>:

The Belgian case

Overall, the Belgian fishing fleet was not profitable between 2008-2014 (STECF 2016). However, things seem to be improving in more recent years. This was stated by several fishers in the interviews. The rising fuel prices in the late 2000's was an important drive for changing fishing behaviour and investing in alternative fishing techniques in Belgium. Both small adjustments and larger investments were made and some initiatives were subsidized. Between 2010 and 2012 subsidies for Sumwing were given to 16 vessels (there were 83 vessels in the Belgian fleet by the end of 2012). However, the pulse trawl was not adopted. In 2014 a single license was given to a commercial vessel for the use of a shrimp pulse trawl. Opinions about pulse trawling are now gradually changing.

While the fuel crisis was the largest worry of the past, interviewed Belgian vessel owners expressed the discard ban as their greatest concern for the future. Rather than stating non-compliance they expressed a tendency to give up. Fishers fear the discard ban will have a large impact on their profitability as the revenue from these previously discarded fish will be low while their processing comes with extra costs (storing, icing, labour). Additional crew costs can emerge as a result of an increased workload (Batsleer 2016). In the Netherlands this may lead to lower wages as in many fisheries it is a fixed share of the net revenue. In Belgium this may also lead to lower wages as the crew receives a fixed percentage of the gross value of landings. However, a minimum wage system is in place. Despite current high wages in Belgium, finding crew members is already a challenge. The profession may become less attractive with the foreseen increased workload. Therefore, adapting fishing strategies such as changing effort allocation or finding more selective gear can be part of the solution, which is what the discard ban intends to achieve. However, until now there is no ready-made solution for the Belgian case and developing potential alternative gears takes time.

The Dutch case

In the Dutch flatfish fishery the pulse trawl has rapidly been replacing the traditional beam trawl. The adoption of the pulse trawl in the fishery has been a long process (Haasnoot et al, 2016) but once the gear was found to be both functional and economically performant, the pioneers who developed the gear still needed to convince the other fishers. This was a very important step where the information sharing and demonstration of the use of the innovative gear in the fishery happened thanks to the financial support of the Dutch government. Knowledge sharing and the role of social network were the drivers of the uptake of the gear once development was successfully completed.

5 CONCLUSION

In this study, we have identified a number of factors influencing the investment decision in the context of gear change to protect the Benthos. The importance of those factors varies, while some appear to be necessary to envisage a wide uptake of the alternative gears, some are merely facilitating and accelerating the uptake. It should be kept in mind that we have only been looking here at bottom contact gears in this project and some factors may be less important in other types of fishery.

Necessary drivers to invest in alternative gears include factors intrinsic to the gear use ensuring that operating the gear is not only economically viable for all involved but also practically possible; access to funds to purchase the gear and possibly adapt the vessel; and access to the fishery.

Economic profitability largely driven by fuel prices
In all case studies, economic profitability of innovative gears was deemed an important factor in the decision to invest. The need to replace highly fuel-dependent gears such as beam trawls or otter-trawls has been particularly felt since the early 2000's when the fuel price steadily increased and especially in 2008 when it doubled in a year (Poos et al. 2013). The influence of fuel prices is twofold: 1) high prices lead to economically unviable fisheries and 2) high volatility in prices means large variations in crew remuneration (when linked to costs) and company profit. The relatively low and stable fuel prices observed since 2014 have therefore probably slowed down the investment in innovative gears is some of the fisheries. One can wonder how appropriate are the tax exemptions on fuel that most EU countries and Turkey apply on fisheries as they probably slow the innovation towards less fuel intensive gears.

High revenues remain important
Improving the profitability through lower operating and maintenance costs can happen at the cost of a (slight) reduction in catch and revenue. The decrease of landings and revenue is difficult to accept for fishers for whom the volume of landings remain a factor on which they evaluate the success of a fishing trip and compare with other fishers, even if the overall profitability is improved. When the decrease in landings is compensated by higher prices (e.g. because the quality of the catch is higher with traps than with trawls) the loss of volume is better accepted.

Crew is affected by the gear choice of the owner on several levels
While the economic performance of the gear and its sensitivity to fuel price is important for crews salaries working in a share-based remuneration system, gears also affect the working conditions of fishers on-board. Different gears are operated differently and can be more or less labour intensive while i) setting the gear, ii) retrieving the catch, iii) sorting/processing the catch, iv) repairing/maintaining the gear itself. All those factors need to be taken into account to make sure the gear gets accepted by the crew who ultimately has to use it. In some of the fisheries investigated, retaining qualified crew is already a struggle and was identified as a factor influencing the decision.

*Having access to a fishery fitting the alternative gear is key**
Encouraging alternative gears should be thought in relation to other management measures. In the case studies investigated, several type of accesses were identified as crucial for the successful adoption of gears. In the case of gear change from trawl to traps, specific areas where only trapping is allowed were identified as essential. For fleets active in several areas or metiers, it was also indispensable that the fishers could use the innovative gear for a large part of their activity. Unfortunately, in the case of the Belgian fleet where effort and quota is allocated individually but not tradable, investing in a pricy device such as pulse that can only be operated in the southern North Sea becomes economically unprofitable. In case of tradable quota, adjustment will happen only if the alternative gear is more economically profitable than the traditional one, in case of national quota, management choices can be made to reserve quota for specific, more sustainable

gears. In the case of innovative gears recently developed, the legal status of the gear can be an additional limiting factor that requires rapid adjustments to allow its use.

*Access to funds needed to invest**

Whether through loans or subsidies, funds to invest in alternative gears are necessary but can be particularly difficult to access given the financial position of many fisheries a few years ago during the fuel crisis. For existing gears, business cases can more easily be made based on available data to get loans from banks. It can be more difficult to build a business case for innovative gears, this is where independent trials in partnership with scientific institutes and subsidies can help.

The above-mentioned factors are all required to improve uptake of alternative gears with lower benthic impacts, but other factors can also be very important to trigger or facilitate the process. The sharing of information in professional and personal networks was identified as a key factor driving innovation. Regulations can also stimulate the development and uptake of alternative gears. The perceived sustainability of alternative fishing technique is becoming increasingly important and while the mind-set of vessel owners is difficult to influence, innovative mind-set with future perspectives for their company is essential to gear uptake.

*Information sharing and trials facilitate uptake**

Social networks, professional and personal have been proved to be efficient vectors of information. While in some cases, knowledge circulate easily and efficiently in the network it is also possible to stimulate exchanges as was the case of the innovation platforms funded by the Dutch government. In this context, fishers could exchange with colleagues but also approach gear manufacturers, scientists and decision makers. Pioneers showed the practical utilisation of the pulse trawls to other fishers who could then ask all their questions. Similarly, in Italy, fishers who could try gears with the manufacturers subsequently adopted the gear.

*The effect of top-down regulations can either stimulate the development of innovation or have no effect at all**

In the project we saw examples of top down regulations that stimulated transition to alternative gears (in the case of the stricter regulation on marketing undersized hake in the Bay of Biscay) while other regulations, such as the landing obligation in the EU or the summer closure of the rapa fishery in Turkey seem to have a limited effect. In the cases when regulation does not seem to have the desired impact, fishers seem to think that the measure is not applicable without them going bankrupt. Some Belgian fishers expressed that they would rather give up than try to adapt. Effectively in such cases, fishers perceive that they don't have a choice and when the regulation is full of exemptions, like for the landing obligation, fishers feel like to can never be implemented. To improve the acceptability of measures, involving the fishing industry in designing the measures would be beneficial.

Perceived sustainability is valued by fishers but not a driver of investment decision

Sustainability is becoming increasingly important in society as a whole. In that context, fishers also value the sustainability of their activity more and more. However, while it is currently an "added bonus" to alternative gears, increased sustainability does not necessarily translate in improved prices or better access to market and was not identified as a key factor in this study.

*Fishers mind-set may be the most important driver**

In the preliminary results of the econometric analysis it seems that once fishers had invested in the pulse trawl, they were more likely to invest. While an innovative mind-set is probably difficult to induce in individuals, it is possible to stimulate innovation in groups (e.g. the Fisheries innovation platforms in the Dutch fishery). Additionally, fishers who wanted to pass on their company to the next generation were more inclined to invest in new technology and look into the future.
Many factors were identified as influencing the investment decision in alternative gears. Some are necessary, others merely facilitating uptake but many (marked *) can be influenced by policy. Policy

measures likely to influence this kind of behaviour are measures promoting co-management and knowledge transfer, also in some cases top-down measures can be effective.

6 REFERENCES

Bastardie, F., Nielsen, J. R., Andersen, B. S., and Eigaard, O. R. 2013. Integrating individual trip planning in energy efficiency - building decision tree models for Danish fisheries. Fisheries Research, 143: 119–130.

Batsleer J. (2016). Fleet dynamics in a changing policy environment. PhD thesis, Wageningen University. pp 172.

Batsleer J., Rijnsdorp A.D., Hamon K.G., Overzee H.M.J., Poos J.J. 2016. Mixed fisheries management: is the ban on discarding likely to promote more selective and fuel efficient fishing in the Dutch flatfish fishery? Fisheries Research 174: 118-128.

Bengtsberg, R. 2010. Kartläggning av energianvändning och energieffektiviserande atgärder inom svensk fiskesektor 2007. Underlagsrapport för fiskesektorn inom uppdraget om energikartläggning av de areella näringarna, regeringsbeslut Jo2009/1596 (Assessment of the energy use and energy saving measures in the Swedish fishing sector in 2007. Swedish Board of Fisheries report. (in Swedish).

Bertrand, J.T., Brown, J.E. e Ward, V.M., 1992, “Techniques for Analyzing Focus Group Data”, in Evaluation Review, XVI (2), pp. 198-209.

Bjørndal, T., and J.M. Conrad. 1987. Capital Dynamics in the North Sea Herring Fishery. Marine Resource Economics 4:63–74.

Bockstael, N.E., and J.J. Opaluch. 1983. Discrete Modelling of Supply Response under Uncertainty: The Case of the Fishery. Journal of Environmental Economics and Management 10:125–37.

Bockstael, N.E., and J.J. Opaluch. 1984. Behavioral Modeling and Fisheries Management. Marine Resource Economics 1:105–15.

Braun, V. & Clarke, V. 2006. Using thematic analysis in psychology. Qualitative Research in Psychology, 3 (2). pp. 77-101. Available from: http://eprints.uwe.ac.uk/11735

Charuau, A., Morizur, Y., & Rivoalen, J. J. 1982. Survival of discarded Nephrops norvegicus in the Bay of Biscay and in the Celtic Sea. ICES CM 1982/B, 13.

Dawson, S., Manderson, L. e Tallo, V.L., 1993, A Manual for the Use of Focus Group, International Nutritional Foundation for Developing Countries (INFDC), Boston.

De Snijder, N., Brouckaert, E., Hansen, K., Heyman, J., Polet, H. & Welvaert, M. 2014. Vistraject: Duurzaamheidstraject voor de Belgische visserijsector. Devriendt Printing, Koekelare. pp 131. Available online http://lv.vlaanderen.be/sites/default/files/attachments/vistraject-rapport.pdf

De Vos, B.I, Mol, A.P.J. 2010. Changing trust relations within the Dutch fishing industry: The case of National Study Groups. Marine Policy , Vol. 34.

De Vos, B.I. 2011. Trust and New Forms of Governance. Doctoral Thesis, Wageningen University.

De Vos, B. I., Döring, R., Aranda, M., Buisman, F. C., Frangoudes, K., Goti, L., ... & Vasilakopoulos, P. 2016. New modes of fisheries governance: implementation of the landing obligation in four European countries. Marine Policy, 64, 1-8.

Ferraris, M. and Pagliarino, E. 2014 Real Option Theory and Application to the Fishery Industry: A survey of the literature. Working paper CNR-CERIS, N.08/2014. 34p

Frandsen R, Eigaard OR, Poulsen LK, Tørring DB, Stage B, Lisbjerg D, Dolmer P. 2015. Reducing the impact of blue mussel (Mytilus edulis) dredging on the ecosystem in shallow water soft bottom areas. Aquatic Conservation : Marine and Freshwater Ecosystems. 25(2):162-173.

Haasnoot, T. 2015 . 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. Wageningen University.

Haasnoot, T., M. Kraan and S. R. Bush, 2016. "Fishing gear transitions: lessons from the Dutch flatfish pulse trawl." Ices Journal of Marine Science 73(4): 1235-1243.

Halpern BS, Walbridge S, Selkoe KA, Kappel CV, Micheli F, D'Agrosa C, Bruno JF, et al. 2008. A global map of human impact on marine ecosystems. Science, 319: 948-952.

Hornborg, S., Ulmestrand, M., Sköld, M., Jonsson, P., Valentinsson, D., Eigaard, O.R., Feekings, J.P., Nielsen, J.R., Bastardie, F., and Lövgren, J. 2016. New policies may call for new approaches: the case of the Swedish Norway lobster (Nephrops norvegicus) fisheries in the Kattegat and Skagerrak. ICES J. Mar. Sci. 73 (7): 1806-1814. doi:10.1093/icesjms/fsw153.

Howitt, D. 2012. Introduction to Qualitative Methods in Psychology. Pearson Education Limited. ISBN-13: 978-0273770060. pp 576

Jackson JBC, Kirby MX, Berger WH, Bjorndal KA, Botsford LW, Bourque BJ, Bradbury RH, et al. 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science, 293: 629-638.

Kelleher, K. 2005. Discards in The World's Marine Fisheries: An Update. FAO Fisheries Technical Paper No. 470. ISN 10429-9345. Food and Agriculture Organization of the United Nations, Rome.

Khaled, R., & Priour, D. 2010. Numerical method for energy optimisation of bottom trawl. In First International Symposium on Fishing Vessel Energy Efficiency, Vigo, Spain.

Kinds, A., Sys, K., Schotte, L., Mondelaers, K. & Polet, H. 2016. VALDUVIS: An innovative approach to assess the sustainability of fishing activities. Fisheries Research. 182, 158–171. doi:10.1016/j.fishres.2015.10.027

Knudsen S, Zengin, M, Kocak, M. H. 2010. Identifying drivers for fishing pressure. A multidisciplinary study of trawl and sea snail fisheries in Samsun, Black Sea coast of Turkey. Ocean and Coastal Management; 53: 252-269.

Krueger, R.A., 1993, "Quality Control in Focus Group Research", in Morgan, D.L. (ed.), Successful Focus Group. Advancing the Syte of Art, Sage, London, pp. 65-85.

Marchal, P., Andersen, B., Caillart, B., Eigaard, O., Guyader, O., Hovgaard, H., ... & Santurtún, M. 2007. Impact of technological creep on fishing effort and fishing mortality, for a selection of European fleets. ICES Journal of Marine Science, 64(1), 192-209.

Mellibovsky F, Prat J, Notti E, Sala A, 2015. Testing otter board hydrodynamic performances in wind tunnel facilities. Ocean Engineering, 104: 52-62.

Nøstbakken, L., Thebaud, O., & Sørensen, L. C. 2011. Investment behaviour and capacity adjustment in fisheries: a survey of the literature. Marine Resource Economics, 26(2), 95-117.

Poos, J. J., Turenhout, M. N., AE van Oostenbrugge, H., & Rijnsdorp, A. D. 2013. Adaptive response of beam trawl fishers to rising fuel cost. ICES Journal of Marine Science, 70(3), 675-684.

Scherders, V. 2016. Understanding gear transitions in the Dutch cutter fleet from a social practice theory. Master Thesis. Wageningen University.

STECF, Scientific Technical and Economic Committee for Fisheries 2016. The 2016 Annual Economic Report on the EU Fishing Fleet (STECF-16-07). Publications Office of the European Union, Luxembourg, ISBN 978-92-79-64633-1; doi:10.2788/842673

Turenhout, M., Zaalmink, B.W., Strietman, W.J, Hamon K.G. 2016. Pulse fisheries in the Netherlands. Wageningen Economic Research Report 2016-104.

Zengin, M., 2011. Samsun Trol Balıkçılığının Geçmişteki İzleri, 13-16 Ekim 2011, Samsun Sempozyumu, Bildiriler Kitabı, Samsun, 18 s (in Turkish).

Zengin, M., Gümüş, A., Düzgüneş, E., Uzmanoğlu, S., 2016. An important small-scale fishery targeting rapa whelk along the Southern Black Sea Coast (Samsun province, Turkey); The social, economic and ecological effects. “Building a future for sustainable small-scale fisheries in the Mediterranean and the Black Sea”, Algiers, Algeria, 7–9 March 2016. Regional Conference, Proceeding Book. FAO, General Fisheries Commission for the Mediterranean. http://www.fao.org/gfcm/meetings /ssfconference2016/en/.

Zengin, M., Gümüş, A., Van, A., Süer, S., Rüzgar, M., Kaykaç, H., Akpınar, İ.Ö., Tosunoğlu, Z., Düzbastılar, O., Uzmanoğlu, S., Ceyhan, V., Osma, R., Çelik, T., Ulukan, U., Başçınar, S.N., 2016. Report on technological innovations and management scenario’s, BENTHIS deliverable 7.9 Black Sea case study, 124-176.

ANNEXES

ANNEX 1 OVERVIEW OF THE RESEARCH PROGRAMS AIMING AT IMPROVING SELECTIVITY OF BAY OF BISCAY NEPHROPS TRAWLERS SINCE 2002

Table A.1 Summary of the main research programs that have been implemented since the early 2000 with objective to improve selectivity of Bay of Biscay Nephrops trawlers.

Programme	Main objectives / main results
ASCGG 2002-2004 Technical partners CNPMEM (lead) IFREMER	Project focused on the reduction of Nephrops and hake by-catches in the bottom trawl fishery of the Bay of Biscay Three main selective devices trialed: Square mesh panel fitted in the top panel of the trawl Sorting grid across trawl extension Large mesh panels in trawl wings and top panel Main findings : Square mesh panel fitted in the top panel of the trawl proved successful to avoid catches of undersized hakes while minimising losses of commercial sizes. Sorting grids showed some potential to reduce Nephrops by-catches but further research was needed to improve their effectiveness, their resistance and their adaptation to trawl drums Large mesh panels in trawl wings and top panel showed some effectiveness to avoid undersized hakes. However, undersized individuals of other species were still retained, and catches of commercial Nephrops decreased. Source : CNPMEM (2004)
NECESSITY 2004-2007 IMARES (NL - lead) IFREMER + 21 other EU research institutes EU funding (FP6)	International research project focused on reduction of by-catches in the Nephrops fisheries and cetaceans mortality in pelagic fisheries. Concerning Nephrops fisheries of the Bay of Biscay, two main selectivity devices trialled: Sorting grids with tests on adequate location in trawl extension, bar spacing and grid material Square mesh panel fit in the sides on the extension (lateral position) Main findings : A 13 mm bar spacing sorting grid is effective to reduce Nephrops by-catches without losses of commercial sizes “Lateral” square mesh panels proved to be effective to avoid catches of other species, but commercial losses on Nephrops Source : Van Marlen (2008)
Sélectivité Pêche Langoustine 2006-2008	The project focused on improvement of trawl Nephrops selectivity through new models of deformable sorting grids and square mesh panel fitted on the bottom of the trawl. The project also evaluated the effects of a codend mesh size increase from 70 t0 80 mm. Main findings

Technical partners AGLIA (lead) IFREMER CNPMEM	Square 60 mm mesh panel fitted on the bottom of the trawl supports escapement of undersized Nephrops New design and material of sorting grids showed improved performances compared to the models trialed under ASCGG. However, sorting grids show signs of accelerated wearing when used on hard bottoms Results of experiments have been submitted to STECF in 2007 to support validation of bottom square mesh panels and new grids which could have been considered as infringing technical measures regulations from a legal perspective. Source: Guigue (2007)
CHALUTEC 2009-2011 Technical partners AGLIA (lead) IFREMER CNPMEM	The project aimed at trialing a square mesh cylinder fitted in trawl extension and a sorting grid fitted on top panel (known as *inverted grid)* as opposed to other sorting grids fitted on bottom panel. Main findings: Square mesh cylinders have similar performances than other selectivity devices on Nephrops and better results on hake Inverted grid showed good results on Nephrops and hake selectivity, with increased performances on hake compared to regular grids. However, technical problems arose in relation with adaptation to trawl drums and resistance of grid bars. Source : Figarede and Delamare (2011a)
PRESPO 2009-2011 Technical partners AGLIA (lead) IFREMER	Project focused on improvement of resistance of square mesh panels fit in the top panel and improvement of survival of discarded Nephrops. In parallel, PRESPO trialed deployment of Nephrops traps as an alternative / complement to Nephrops trawling. Concerning square mesh panels, the project trialed : Strengthened square mesh panel using dyneema twine Strengthened square mesh panel with a polyurethane coating Concerning Nephrops survival, the project aimed at measuring survival rate and at designing equipments to improve survival rate Main findings square mesh panel: Dyneema twine effective compared to other twines with improved resistance to distortion. However, dyneema twine generated mesh obstruction issues Polyurethane coating was effective to reduce deformation but tended to disappear after a few trips due to abrasion. Polyurethane is also potentially hazardous for health. Nephrops survival rate: Survival rate is improved when fishers use a sorting table equipped with a discharge chute to release discarded Nephrops as and when they are sorted Nephrops traps Variable average yield around 100 g / trap, mostly large Nephrops Economic study indicates that trap activity could be viable for small vessels utilising traps as main gear Likely high spatial interactions with trawlers competing for the same species resulting in losses of traps Source : Figarede and Delamare (2011b), Figarède and Bigot (2011)
REDRESSE	The project trials three selectivity devices :

2015- ongoing AGLIA (lead) IFREMER CNPMEM 1 000 000 €	A separator panel Square mesh panels fitted on top or bottom panels, or in cylinder in trawl extension T90 mesh Improved models of foldable sorting grids to be fitted in the lower side of trawl extension (as opposed to inverted grids developed under Chalutec project - see above). Preliminary findings : Dispersive buoy associated with square mesh panel : low result Reduction of number of mesh in codend circumference : may prove effective but need to assess impacts on commercial catches Separator panel : promising results but need to be refined T90 (55 mm) : promising results when fitted in trawl extension (too many losses if fitted in codend) but need to assess impacts on commercial catches Foldable sorting grids appear to be well suited for trawl drums while producing good selectivity results. However wearing issue still encountered. Source: AGLIA (2015)
JUMPER 2013-2014 CNPMEM (lead) IFREMER MORGERE IMP	Project objective was to design a trawl door that would minimise interactions with the bottom while contributing to energy savings. Main findings The new developed trawl door proved to be effective, but needed fine tuning to work properly under different conditions Interactions with the bottom appeared to be minimised, but additional research is needed to have some metrics Energy saving component of the project not developed in the final report Source: Vincent et al. (2015)

Annex 2 Interviews

Factors that influence the switch to different (more sustainable) fishing gear

Questions to be asked to fishers that have switched
Name:
Company:
Previous fishing gear and target species:
New fishing gear and target species:

1. You recently changed fishing gear, why did you choose this gear?
2. In what year did you make the switch?
3. Why this year, what had changed?
4. Had you been thinking for a long time to switch?
5. How long, and why haven't you made the switch before?

6. Can you please indicate for each of the following factors whether or not they have played a role in your switch to a different fishing gear?

- A family member/neighbour or friend has bought the same gear
- You received a subsidy for the switch
- Your fuel costs were too high
- You wanted to target different species
- You were not allowed anymore (or will not be in the future) to fish with the old technique in certain areas
- You received a loan through the bank or somewhere else
- Buyers request fish caught with the new technique
- You will receive a higher price for your fish
- You will receive a certificate (which one?)
- Upcoming regulations, such as the landing obligation

7. Are there factors that played a role, which were not mentioned in the list above? If yes, can you please indicate these?
8. Are you satisfied with the new gear? What are the advantages?
9. If not, what are the disadvantages.
10. Do you want to switch back, and can that be easily done?
11. Do you catch less unwanted by-catch?

ANNEX 3 SUMMARY OF RESPONSES TO INTERVIEWS IN THE TURKISH CASE

Table A.2 Responses to be asked to fishers that have not made the switch

Statements	Beam trawl	Bottom trawl
Advantages of the current gear	No advantage (%14.29) More captured (%35.71	No advantage (%28.57) More captured (%21.43
Disadvantages of the current gear	No disadvantages (%42.86) More fuel cost (%7.14)	No disadvantages (%21.43) Codend (14.29) More non-target captured (%7.14) Big mesh size (%7.14)
Satisfied with your current fishing gear	Yes (%50)	Yes (%21.42) No (%28.58)
Switching to a different fishing technique	No (%35.71) Yes, it did not succeed. (%14.29)	No (%21.43) Yes (%28.57)
What is stopping you?	Current gear is best (%28.57) More fuel cost (%21.43)	Regulations (%35.71) Nothing (%14.29)
Factors play a role in your decision not to switch,	Costs (%21.43) Lack of experience or knowledge (%14.29) Catch less fish (%14.29)	Costs (%21.43) Lack of experience or knowledge (%21.43) Regulations (%7.14) Catch less fish (%7.14) Do not see a future for your company (%7.14) Do not have access to funding (%7.14)
Familiar with other fishers that have switched	Yes, they did not success (%35.71) No (%14.29)	No (%35.71) No response 8%14.29)
What needs to be changed in order for you to make the switch	Financial supports (%50)	Policy regulations (%35.71) Financial support (%7.14) Authorities must listen to the fishers (%7.14)

ANNEX 4 INVESTMENT MODEL FOR THE DUTCH PULSE FISHERY FOR SOLE

We used Dutch data to estimate a model clarifying whether an exogenous preference parameter for pulse fishing influence investments in the Dutch sole fishery. We estimated three different basic models given by:

$$I_{it} = a + b * PS + \sum_{j=1}^{n} c_j x_{ijt} + e_i \qquad \text{(basic model 1)} \quad (1)$$

$$I_{it} = a + b * PS + \sum_{j=1}^{n} c_j x_{ijt} + \sum_{j=1}^{n} d_j PS * x_{ijt} + e_i \qquad \text{(basic model 2)} \quad (2)$$

$$I_{it} = a + b * PS + \sum_{j=1}^{n} c_j x_{ijt} + \sum_{j=1}^{n} f_j x_{ijt-1} + e_i \qquad \text{(basic model 3)} \quad (3)$$

where *a, b,* c_j, d_j and f_j are estimated parameters, x_{ijt} are explanatory variables and e_i is a random error term. The main purpose of this study is to investigate whether an exogenous preference parameter for pulse fishery influence investments and this explains why we include results from all three basic models. Let us, therefore, begin by discussing the three models. In basic model 1 we assume that the pulse dummy (PS) only affect the constant term and that there is no lags on the explanatory variables. No lags is consistent with a situation where both the capital stock and the fish stock is in a steady-state equilibrium. In basic model 2 we extend basic model 1 to include the possibility that PS affects the estimated coefficients of the explanatory variables by incorporating interactions between the pulse dummy and x_{ijt}. Finally, in basic model 3 we extend basic model 1 to allow for lagged values of the explanatory variables implying we are not assuming a steady-state equilibrium. We only include one lag in the model but we allow for lags on all parameters and variables.

We estimate (1), (2) and (3) by using both the price and quantity of all fish species caught and the price and quantity of sole alone. Furthermore, for the selected explanatory variables we use both $x_{ijt} = y_{ijt}$ and $x_{ijt} = \ln y_{ijt}$. Thus, for each model we estimate an investment function by using both a linear and a logarithmic approximation on the right hand side. Finally, because we want to investigate whether an exogenous preference parameter influence investments, it is important to control for random vessel-specific effects and fixed firm-specific effects and this is possible because we have a panel dataset. For this reason we estimate (1), (2) and (3) in three different ways. First, we estimate the models directly by using ordinary least square (OLS) and these model estimations are labelled Pooled. Second, we estimate a random effect model where vessel specific random variation is taken into account and these models are labelled Random. Third, we allow for firm-specific correlation between the random variables and the explanatory variables by estimating a fixed effect model that is Within. Now we preform various tests of the three models. We test whether there are random firm specific effects by comparing Pooled and Random. This is done by an RE test for which we report the p-value. We also investigate whether there are firm-specific fixed effect and this is done by comparing Pooled with Within throughout a p-value for an FE test. Finally, by using the p-value for a Hausman test we can compare Random and Within.

Let us, finally, discuss the choice of the explanatory variables we include in the models and here we relate the discussion in basic model 1 from above. Now it is useful to distinguish between three issues. First, we estimate an investment function directly and of course this may imply problems with heterogeneity. It is, therefore, natural to discuss whether the variable input used by a vessel, the physical capital stock and the fish stocks shall be included in the model. Regarding the capital stock it is natural to include this variable because it is closely related to the investment throughout the dynamic capital constraint and capital stocks have a positive influence on the investments. With respect to variable input we must expect that there is low variation in the variable input over the data period and between the vessels and the same holds for the fish stock. Therefore, excluding these variables seems reasonable despite the endogeneity problems. In discussing the estimation results below the average price and catch amount is taken to be a measure for the profit while the quota price and size of the quota captures the quota market. The interest rate measures the capital gain from the fishing activity. Finally, it is useful to correct the estimated equations for the

influence of other explanatory variables. Here Jensen et al (2012)[10] finds that the construction year for the vessel is important so we include this variable. We would expect that a lower construction year (an older vessel) imply higher investments. Furthermore, Nøstbakken (2012)[11] finds that the size of the vessel is important for investments. In this study we use the tonnage as a measure for the size of the vessel and we believe that a higher tonnage imply higher investments.
The results are presented in the tables below. The main finding is that the pulse dummy explains most of the investment. This could be summarised as people investing in pulse are in an investing mindset and no other economic variable has more importance than that.

Basic model 1
Table 1: A traditional specification with the price and quantity of all species
Table 2: A logarithmic specification with the price and quantity of all species
Table 3: A traditional specification with the price and quantity of sole
Table 4: A logarithmic specification with the price and quantity of sole

Basic model 2
Table 5: A traditional specification with the price and quantity of all species
Table 6: A logarithmic specification with the price and quantity of all species
Table 7: A traditional specification with the price and quantity of sole
Table 8: A logarithmic specification with the price and quantity of sole

Basic model 3
Table 9: A traditional specification with the price and quantity of all species
Table 10: A logarithmic specification with the price and quantity of all species
Table 11: A traditional specification with the price and quantity of sole
Table 12: A logarithmic specification with the price and quantity of sole

[10] Jensen, F., Andersen, J., & Jensen, C. L. (2012). Investment behaviour in individual nontransferable quota systems. Applied Economics, 44(8), 969-978.

[11] Nøstbakken, L. (2012). Investment drivers in a fishery with tradable quotas. Land Economics, 88(2), 400-424.

Table 1: A traditional specification with the price and quantity of all species

	Dependent variable:		
	Total investment (1000 Euro)		
	Pooled	Random	Within
	(1)	(2)	(3)
Pulse dummy	59.596***	57.645***	124.020***
	(15.090)	(14.646)	(29.889)
Construction year	0.045	0.049	-4.471
	(0.351)	(0.325)	(5.156)
Vessel tonnage	171.506**	154.493**	1,580.924***
	(74.603)	(63.299)	(370.215)
Catch amount (tonnes)	-0.115*	-0.100*	-0.471
	(0.067)	(0.056)	(0.413)
Avg. price of fish (Euro/Kg)	-12.657	-11.895	-23.631
	(12.033)	(11.205)	(21.626)
Capital stock (1000 Euro)	0.0003	0.001	-0.053
	(0.011)	(0.010)	(0.066)
Interest rate (percent)	0.0003	0.0003	-0.003
	(0.001)	(0.001)	(0.002)
Quota amount (tonnes)	0.070	0.075*	-0.536
	(0.046)	(0.043)	(0.390)
Quota price (Euro/Kg)	1.014	1.022	8.026
	(6.061)	(5.890)	(5.426)
Constant	-31.497	-43.982	
	(678.361)	(629.256)	
RE test (p-value)	0.09	-	-
Hausman test (p-value)	-	0.00	-
FE test (p-value	-	-	0.00
Observations	385	385	385
R^2	0.094	0.100	0.194

Note: "Pooled" denotes OLS estimation based on pooled data, "Random" denotes the random effects model and "Within" denotes the fixed effects model. Robust standard errors in parenthesis. *p<0.1; **p<0.05; ***p<0.01. "RE test" is the Breusch-Pagan Lagrange Multiplier test for random effects. The (Durbin-Wu-) Hausman test compares the Random effects and the fixed effects model and "FE test" is an F test for the presence of fixed effects.

Table 2: A logarithmic specification with the price and quantity of all species

	Dependent variable:		
	log of Total investment		
	Pooled	Random	Within
	(1)	(2)	(3)
Pulse dummy	0.757***	0.738***	1.079***
	(0.230)	(0.224)	(0.378)
Construction year	0.004	0.004	-0.079
	(0.009)	(0.008)	(0.054)
Log of Vessel tonnage	0.134	0.114	4.811***
	(0.207)	(0.198)	(0.844)
Log of Catch amount	0.491**	0.515**	-0.070
	(0.232)	(0.226)	(0.730)
Log of avg. price of fish	0.673**	0.682**	0.614
	(0.342)	(0.333)	(0.678)
log of Capital stock	-0.040	-0.040	-0.134
	(0.131)	(0.127)	(0.506)
Interest rate (percent)	0.00000	0.00000	0.00003
	(0.00002)	(0.00002)	(0.00003)
Log of Quota amount	-0.030	-0.030	-0.127
	(0.045)	(0.044)	(0.106)
Log of Quota price	0.078	0.050	0.760*
	(0.142)	(0.134)	(0.394)
Constant	-8.430	-8.928	
	(16.414)	(15.921)	
RE test (p-value)	0.04	-	-
Hausman test (p-value)	-	0.24	-
FE test (p-value	-	-	0.78
Observations	385	385	385
R^2	0.199	0.242	0.078
Note:	*p<0.1; **p<0.05; ***p<0.01		

Table 3: A traditional specification with the price and quantity of sole

	Dependent variable:		
	Total investment (1000 Euro)		
	Pooled	Random	Within
	(1)	(2)	(3)
Pulse dummy	101.381***	93.117***	156.265***
	(19.649)	(19.640)	(25.904)
Construction year	0.340	0.430	-7.060**
	(0.583)	(0.565)	(2.852)
Vessel tonnage	231.519***	218.298***	1,112.568**
	(54.505)	(51.350)	(471.171)
Sole catch amount (tonnes)	-0.839***	-0.763***	-1.556***
	(0.276)	(0.266)	(0.538)
Avg. price of sole (Euro/Kg)	3.205	2.790	5.230
	(2.839)	(2.823)	(3.288)
Capital stock (1000 Euro)	-0.005	-0.006	0.057*
	(0.012)	(0.012)	(0.035)
Interest rate (percent)	-0.0001	-0.0001	-0.0004
	(0.001)	(0.001)	(0.001)
Sole quota amount (tonnes)	0.195	0.196	-0.099
	(0.325)	(0.329)	(0.333)
Sole quota price (Euro/Kg)	-1.183	-1.194	-0.601
	(1.063)	(1.080)	(1.015)
Constant	-686.203	-857.098	
	(1,138.391)	(1,099.063)	
RE test (p-value)	0.12	-	-
Hausman test (p-value)	-	0.29	-
FE test (p-value	-	-	0.82
Observations	310	310	310
R^2	0.096	0.105	0.094
Note:	*p<0.1; **p<0.05; ***p<0.01		

Table 4: A logarithmic specification with the price and quantity of sole

	Dependent variable:		
	Log of total investment		
	Pooled	Random	Within
	(1)	(2)	(3)
Pulse dummy	0.845***	0.813***	1.238***
	(0.211)	(0.205)	(0.397)
Construction year	0.019	0.020	-0.075
	(0.013)	(0.012)	(0.065)
Log of vessel tonnage	0.531***	0.522***	4.420***
	(0.158)	(0.152)	(0.822)
Log of sole catch amount	0.030	0.032	-0.049
	(0.034)	(0.032)	(0.147)
Log of avg. price of sole	1.372***	1.374***	1.799***
	(0.492)	(0.490)	(0.538)
Log of capital stock	-0.112	-0.131	0.054
	(0.142)	(0.140)	(0.685)
Interest rate (percent)	0.00000	0.00000	0.00004
	(0.00002)	(0.00002)	(0.00004)
Log of sole quota amount	-0.078	-0.074	-0.091
	(0.061)	(0.058)	(0.136)
Log of sole quota price	0.073	0.078	0.010
	(0.163)	(0.162)	(0.272)
Constant	-36.174	-39.328	
	(24.848)	(24.525)	
RE test (p-value)	0.06	-	-
Hausman test (p-value)	-	0.69	-
FE test (p-value	-	-	0.79
Observations	310	310	310
R^2	0.216	0.253	0.099
Note:	*p<0.1; **p<0.05; ***p<0.01		

Table 5: A traditional specification with the price and quantity of all species

	Dependent variable:		
	Total investment (1000 Euro)		
	Pooled	Random	Within
	(1)	(2)	(3)
Pulse dummy	8,688.629	8,391.809	7,908.788
	(6,331.546)	(6,185.695)	(12,394.490)
Construction year	0.494	0.475	-8.313
	(0.333)	(0.305)	(6.840)
Vessel tonnage	173.393*	160.504*	945.606**
	(99.091)	(83.228)	(392.161)
Catch amount (tonnes)	-0.085	-0.064	-0.694
	(0.097)	(0.078)	(0.641)
Avg. price of fish (Euro/Kg)	-12.555	-11.230	-30.344
	(13.120)	(12.189)	(24.885)
Capital stock (1000 Euro)	-0.022*	-0.021*	-0.053
	(0.013)	(0.012)	(0.071)
Interest rate (percent)	-0.001	-0.001	-0.002
	(0.001)	(0.001)	(0.003)
Quota amount (tonnes)	0.087	0.076	-0.031
	(0.093)	(0.086)	(0.375)
Quota price (Euro/Kg)	5.220	5.051	4.945
	(4.134)	(4.048)	(4.713)
Pulse dummy * construction year	-4.291	-4.139	-4.074
	(3.189)	(3.114)	(6.270)
Pulse dummy * vessel tonnage	-50.160	-43.229	-295.863
	(182.669)	(171.814)	(543.521)
Pulse dummy * catch amount	-0.075	-0.091	0.593
	(0.159)	(0.146)	(0.604)
Pulse dummy * avg. price of fish	4.400	3.197	33.147
	(38.770)	(37.121)	(41.978)
Pulse dummy * capital stock	0.094***	0.090***	0.123**
	(0.036)	(0.035)	(0.062)
Pulse dummy * interest rate	0.002	0.002	0.0003
	(0.004)	(0.003)	(0.005)
Pulse dummy * quota amount	-0.061	-0.039	-0.701
	(0.188)	(0.180)	(0.537)
Pulse dummy * quota price	-18.687	-19.215	28.710**
	(33.405)	(32.677)	(14.457)

Constant	-944.067	-911.881	
	(633.202)	(582.510)	
RE test (p-value)	0.1.0	-	-
Hausman test (p-value)	-	0.00	-
FE test (p-value	-	-	0.00
Observations	385	385	385
R^2	0.125	0.131	0.272
Note:	$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$		

Table 6: A logarithmic specification with the price and quantity of all species

	Dependent variable:		
	log of Total investment		
	Pooled	Random	Within
	(1)	(2)	(3)
Pulse dummy	-89.909	-90.359	40.389
	(98.069)	(98.545)	(172.376)
Construction year	0.005	0.005	-0.153**
	(0.009)	(0.008)	(0.068)
Log of Vessel tonnage	0.057	0.060	3.788***
	(0.249)	(0.243)	(0.822)
Log of Catch amount	0.675***	0.668***	0.479
	(0.253)	(0.251)	(0.823)
Log of avg. price of fish	1.046***	1.042***	1.085
	(0.364)	(0.360)	(0.677)
log of Capital stock	-0.180	-0.168	-0.355
	(0.164)	(0.162)	(0.519)
Interest rate (percent)	-0.00002	-0.00002	0.00003
	(0.00002)	(0.00002)	(0.00002)
Log of Quota amount	-0.028	-0.029	-0.102
	(0.049)	(0.048)	(0.115)
Log of Quota price	0.012	-0.0001	0.178
	(0.216)	(0.208)	(0.347)
Pulse dummy * log of construction year	0.052	0.052	-0.017
	(0.052)	(0.052)	(0.091)
Pulse dummy * log of vessel tonnage	1.094	1.030	1.088
	(0.859)	(0.844)	(1.323)
Pulse dummy * log of catch amount	-1.711	-1.588	-2.273*
	(1.105)	(1.096)	(1.351)
Pulse dummy * log of avg. price of fish	-2.729**	-2.637**	-3.879***
	(1.161)	(1.151)	(1.308)
Pulse dummy * log of capital stock	0.130	0.088	1.104
	(0.463)	(0.458)	(0.712)
Pulse dummy * log of interest rate	0.0001**	0.0001**	0.00004
	(0.00005)	(0.00004)	(0.0001)
Pulse dummy * log of quota amount	0.114	0.131	0.055
	(0.215)	(0.209)	(0.189)
Pulse dummy * log of quota price	0.214	0.213	4.431***
	(0.363)	(0.345)	(0.820)

Constant	-11.586	-11.446	
	(16.751)	(16.505)	
RE test (p-value)	0.11	-	-
Hausman test (p-value)	-	0.00	-
FE test (p-value	-	-	0.19
Observations	385	385	385
R^2	0.231	0.257	0.173
Note:	*p<0.1; **p<0.05; ***p<0.01		

Table 7: A traditional specification with the price and quantity of sole

	Dependent variable:		
	Total investment (1000 Euro)		
	Pooled	Random	Within
	(1)	(2)	(3)
Pulse dummy	-42.900	-22.156	-1,511.850
	(7,260.050)	(7,102.476)	(9,769.215)
Construction year	0.747	0.770	-7.247
	(0.543)	(0.547)	(5.530)
Vessel tonnage	226.149***	212.553***	111.151
	(69.622)	(62.786)	(601.990)
Sole catch amount (tonnes)	-0.764*	-0.709*	-3.417*
	(0.436)	(0.418)	(1.771)
Avg. price of sole (Euro/Kg)	-0.435	-0.739	0.894
	(2.168)	(2.272)	(2.367)
Capital stock (1000 Euro)	-0.025*	-0.025*	0.061
	(0.013)	(0.014)	(0.044)
Interest rate (percent)	-0.001	-0.001	-0.0003
	(0.001)	(0.001)	(0.001)
Sole quota amount (tonnes)	0.379	0.393	0.061
	(0.404)	(0.421)	(0.287)
Sole quota price (Euro/Kg)	0.433	0.329	1.367
	(1.060)	(1.083)	(1.135)
Pulse dummy * construction year	-0.084	-0.103	0.736
	(3.631)	(3.552)	(4.933)
Pulse dummy * vessel tonnage	-153.729	-137.843	-591.880
	(179.019)	(172.113)	(443.884)
Pulse dummy * sole catch amount	0.763	0.730	3.150*
	(0.792)	(0.761)	(1.910)
Pulse dummy * avg. price of sole	39.670*	40.338*	29.020
	(22.793)	(22.600)	(21.155)
Pulse dummy * capital stock	0.054	0.050	0.111**
	(0.037)	(0.037)	(0.046)
Pulse dummy * interest rate	-0.002	-0.002	-0.004
	(0.004)	(0.004)	(0.006)
Pulse dummy * sole quota amount	-1.297	-1.282	-2.204**
	(0.963)	(0.965)	(1.056)
Pulse dummy * sole quota price	-4.735	-4.543	-4.705
	(3.184)	(3.170)	(3.344)

Constant	-1,465.239	-1,506.869	
	(1,058.887)	(1,063.420)	
RE test (p-value)	0.13	-	-
Hausman test (p-value)	-	0.41	-
FE test (p-value	-	-	0.74
Observations	310	310	310
R^2	0.139	0.144	0.154
Note:	$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$		

Table 8: A logarithmic specification with the price and quantity of sole

	Dependent variable:		
	Log of total investment		
	Pooled	Random	Within
	(1)	(2)	(3)
Pulse dummy	-128.545	-128.063	68.891
	(107.600)	(108.379)	(218.552)
Construction year	0.016	0.017	-0.068
	(0.013)	(0.013)	(0.080)
Log of vessel tonnage	0.725***	0.722***	3.786***
	(0.194)	(0.191)	(1.272)
Log of sole catch amount	0.032	0.033	0.037
	(0.033)	(0.032)	(0.146)
Log of avg. price of sole	0.829	0.835	1.273**
	(0.522)	(0.518)	(0.621)
Log of capital stock	-0.295*	-0.296*	-0.438
	(0.179)	(0.177)	(0.667)
Interest rate (percent)	-0.00002	-0.00002	0.00002
	(0.00002)	(0.00002)	(0.00003)
Log of sole quota amount	-0.076	-0.075	-0.073
	(0.068)	(0.067)	(0.141)
Log of sole quota price	0.090	0.090	-0.001
	(0.256)	(0.254)	(0.300)
Pulse dummy * log of construction year	0.064	0.064	-0.038
	(0.056)	(0.056)	(0.113)
Pulse dummy * log of vessel tonnage	0.196	0.195	0.924
	(0.636)	(0.628)	(1.052)
Pulse dummy * log of sole catch amount	-0.702***	-0.695**	-0.973***
	(0.270)	(0.272)	(0.325)
Pulse dummy * log of avg. price of sole	2.091	2.084	1.382
	(1.593)	(1.597)	(1.579)
Pulse dummy * log of capital stock	0.081	0.048	1.369
	(0.483)	(0.484)	(0.978)
Pulse dummy * log of interest rate	0.0001	0.0001	0.0001
	(0.0001)	(0.0001)	(0.0001)
Pulse dummy * log of sole quota amount	0.111	0.122	-0.170
	(0.149)	(0.147)	(0.190)
Pulse dummy * log of sole quota price	-0.199	-0.195	0.257
	(0.355)	(0.351)	(0.579)

Constant	-28.194	-29.397	
	(25.539)	(25.438)	
RE test (p-value)	0.13	-	-
Hausman test (p-value)	-	0.49	-
FE test (p-value	-	-	0.66
Observations	310	310	310
R^2	0.258	0.276	0.169
Note:	*p<0.1; **p<0.05; ***p<0.01		

Table 9: A traditional specification with the price and quantity of all species

	Dependent variable:		
	Total investment (1000 Euro)		
	Pooled	Random	Within
	(1)	(2)	(3)
Pulse dummy	56.644***	52.084***	82.471***
	(14.484)	(13.746)	(22.588)
Construction year	0.011	0.058	-3.674
	(0.290)	(0.277)	(4.775)
Vessel tonnage	92.201**	102.476**	1,033.028***
	(46.507)	(45.997)	(347.690)
Catch amount (tonnes)	-0.026	-0.027	-0.048
	(0.033)	(0.032)	(0.086)
Avg. price of fish (Euro/Kg)	-6.652	-7.254	-5.096
	(6.031)	(6.007)	(8.523)
Capital stock (1000 Euro)	0.104	0.082	0.490
	(0.141)	(0.138)	(0.307)
Lagged capital stock	-0.093	-0.074	-0.471
	(0.130)	(0.127)	(0.314)
Interest rate (percent)	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)
Lagged Interest rate	-0.001	-0.001	-0.002*
	(0.001)	(0.001)	(0.001)
Quota amount (tonnes)	-0.192*	-0.176	-0.742***
	(0.116)	(0.112)	(0.280)
Lagged quota amount	0.239*	0.222*	0.641**
	(0.137)	(0.129)	(0.276)
Quota price (Euro/Kg)	-1.159	-1.398	-1.399
	(2.217)	(2.224)	(4.382)
Lagged Quota price	5.721**	5.734***	7.416**
	(2.282)	(2.186)	(2.986)
Constant	-12.370	-102.636	
	(574.309)	(550.849)	
RE test (p-value)	0.13	-	-
Hausman test (p-value)	-	0.11	-
FE test (p-value	-	-	0.78
Observations	268	268	268
R^2	0.201	0.257	0.167
Note:	*p<0.1; **p<0.05; ***p<0.01		

Table 10: A logarithmic specification with the price and quantity of all species

	Dependent variable:		
	log of Total investment		
	Pooled	Random	Within
	(1)	(2)	(3)
Pulse dummy	0.490*	0.496*	0.799**
	(0.259)	(0.262)	(0.400)
Construction year	0.009	0.008	-0.098
	(0.011)	(0.011)	(0.062)
Log of vessel tonnage	0.033	0.024	3.198***
	(0.220)	(0.222)	(1.223)
Log of catch amount	0.612**	0.612**	0.513
	(0.262)	(0.263)	(0.841)
Log of avg. price of fish	0.871**	0.879**	1.109
	(0.421)	(0.424)	(0.782)
log of capital stock	-1.574	-1.495	0.444
	(1.052)	(1.062)	(1.406)
Lagged log of Capital stock	1.443	1.365	-0.491
	(1.006)	(1.016)	(1.396)
Interest rate (percent)	0.00001	0.00001	0.00004
	(0.00002)	(0.00002)	(0.00005)
Lagged interest rate	-0.00003	-0.00003	-0.0001***
	(0.00002)	(0.00002)	(0.00002)
Log of quota amount	-0.197***	-0.197***	-0.155
	(0.067)	(0.067)	(0.127)
Lagged log of quota amount	0.153**	0.157**	0.316***
	(0.064)	(0.064)	(0.077)
Log of quota price	-0.440	-0.436	0.051
	(0.350)	(0.351)	(0.605)
Lagged log of quota price	0.695**	0.708**	1.316***
	(0.349)	(0.352)	(0.507)
Constant	-18.210	-17.981	
	(20.667)	(20.757)	
RE test (p-value)	0.60	-	-
Hausman test (p-value)	-	0.60	-
FE test (p-value	-	-	0.43
Observations	268	268	268
R^2	0.214	0.202	0.106
Note:	*p<0.1; **p<0.05; ***p<0.01		

Table 11: A traditional specification with the price and quantity of sole

	Dependent variable:		
	log of Total investment		
	Pooled	Random	Within
	(1)	(2)	(3)
Pulse dummy	0.490*	0.496*	0.799**
	(0.259)	(0.262)	(0.400)
Construction year	0.009	0.008	-0.098
	(0.011)	(0.011)	(0.062)
Log of vessel tonnage	0.033	0.024	3.198***
	(0.220)	(0.222)	(1.223)
Log of catch amount	0.612**	0.612**	0.513
	(0.262)	(0.263)	(0.841)
Log of avg. price of fish	0.871**	0.879**	1.109
	(0.421)	(0.424)	(0.782)
log of capital stock	-1.574	-1.495	0.444
	(1.052)	(1.062)	(1.406)
Lagged log of Capital stock	1.443	1.365	-0.491
	(1.006)	(1.016)	(1.396)
Interest rate (percent)	0.00001	0.00001	0.00004
	(0.00002)	(0.00002)	(0.00005)
Lagged interest rate	-0.00003	-0.00003	-0.0001***
	(0.00002)	(0.00002)	(0.00002)
Log of quota amount	-0.197***	-0.197***	-0.155
	(0.067)	(0.067)	(0.127)
Lagged log of quota amount	0.153**	0.157**	0.316***
	(0.064)	(0.064)	(0.077)
Log of quota price	-0.440	-0.436	0.051
	(0.350)	(0.351)	(0.605)
Lagged log of quota price	0.695**	0.708**	1.316***
	(0.349)	(0.352)	(0.507)
Constant	-18.210	-17.981	
	(20.667)	(20.757)	
RE test (p-value)	0.60	-	-
Hausman test (p-value)	-	0.60	-
FE test (p-value	-	-	0.43
Observations	268	268	268
R^2	0.214	0.202	0.106
Note:	*p<0.1; **p<0.05; ***p<0.01		

Table 12: A logarithmic specification with the price and quantity of sole

	Dependent variable:		
	log of Total investment		
	Pooled	Random	Within
	(1)	(2)	(3)
Pulse dummy	0.490*	0.496*	0.799**
	(0.259)	(0.262)	(0.400)
Construction year	0.009	0.008	-0.098
	(0.011)	(0.011)	(0.062)
Log of vessel tonnage	0.033	0.024	3.198***
	(0.220)	(0.222)	(1.223)
Log of catch amount	0.612**	0.612**	0.513
	(0.262)	(0.263)	(0.841)
Log of avg. price of fish	0.871**	0.879**	1.109
	(0.421)	(0.424)	(0.782)
log of capital stock	-1.574	-1.495	0.444
	(1.052)	(1.062)	(1.406)
Lagged log of Capital stock	1.443	1.365	-0.491
	(1.006)	(1.016)	(1.396)
Interest rate (percent)	0.00001	0.00001	0.00004
	(0.00002)	(0.00002)	(0.00005)
Lagged interest rate	-0.00003	-0.00003	-0.0001***
	(0.00002)	(0.00002)	(0.00002)
Log of quota amount	-0.197***	-0.197***	-0.155
	(0.067)	(0.067)	(0.127)
Lagged log of quota amount	0.153**	0.157**	0.316***
	(0.064)	(0.064)	(0.077)
Log of quota price	-0.440	-0.436	0.051
	(0.350)	(0.351)	(0.605)
Lagged log of quota price	0.695**	0.708**	1.316***
	(0.349)	(0.352)	(0.507)
Constant	-18.210	-17.981	
	(20.667)	(20.757)	
RE test (p-value)	0.60	-	-
Hausman test (p-value)	-	0.60	-
FE test (p-value	-	-	0.43
Observations	268	268	268
R^2	0.214	0.202	0.106
Note:	*p<0.1; **p<0.05; ***p<0.01		