BENTHIS

Deliverable 6.4

Report Management Strategy Evaluation and performance test of the decision-support tool(s)

Due date of deliverable: month 54 (March 2017)
Actual submission date: month 62 (Nov 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:
Gerjan Piet[1], Katrine Soma[2], Sara Bonanomi[3], Pascal Laffargue[4], J. Rasmus Nielsen[5], Emilio Notti[3], Hans Polet[6], Antonello Sala[3], Mustafa Zengin[7], Adriaan Rijnsdorp[1]

(1) Wageningen Marine Research, P.O. Box 68, 1970 AB Ymuiden, the Netherlands
(2) Wageningen Economic Research, the Netherlands
(3) Italian National Research Council, Institute of Marine Sciences, Ancona (Italy)
(4) IFREMER (RBE-EMH) rue de l'Ile d'Yeu , 44311 Nantes Cedex 03
(5) Technical University of Denmark, Kemitorvet Building 201, DK-2800 Lyngby, Denmark
(6) Institute of Agricultural and Fisheries Research, Ankerstraat 1, 8400 Oostende, Belgium
(7) Central Fisheries Research Institute, Kasustu Beldesi, Yomra, 61250, Trabzon, Turkey

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
Piet	1st draft		15 Nov 2017
Soma	additions		23 Nov 2017
All co-authors	comments		27 Nov 2017
Piet	Summary added		28 Nov 2017

SUMMARY

The mobile demersal gears currently applied in the fishery sectors across Europe are known to have a large impact both directly and indirectly on the benthic habitats and communities. There is increasing concern about these impacts and the aim is to reduce these impacts on the wider ecosystem without compromising the ability of the fishery to provide food or maintain a socio-economically viable fishery. This is reflected in the main policy framework, i.e. the Common Fisheries Policy (CFP), which encourages an ecosystem based approach, in which benefits from living aquatic resources are ensured 'while the direct and indirect impacts of fishing operations on marine ecosystems are low and not detrimental to the future functioning, diversity and integrity of those ecosystems'. To that end the CFP proposes a new general framework to manage EU fisheries aimed at achieving sustainability objectives across all three pillars of sustainability, i.e. ecological, economic and social. The CFP also stresses that to ensure good governance, appropriate involvement of stakeholders is needed to implement measures.

Therefore in these regional evaluations of the management measures considered in the BENTHIS project we use stakeholder preferences on ecological, economic and social criteria to assess the performance of these management measures against those criteria. For this we applied multi-criteria decision analysis (MCDA), a set of formal approaches which seek to take explicit account of multiple criteria in helping decision-makers explore decisions. Different stakeholder perspectives were ascertained by distinguishing between three stakeholder groups: Fishers, Civil society (NGOs) and Government.

This evaluation showed that the different stakeholder groups value the criteria differently. Overall fishers value the social criteria highest and the ecological criteria lowest whereas civil society and the government value the ecological criteria highest and the economic lowest but with each with different relative weightings.

This was reflected in the preferred management measures in each regional assessment where different stakeholder groups assessed the performance of a management measure differently. In the Baltic sea fishers and government all stakeholders agreed that the Nephrops short sweeps performed least while Nephrops creels/trawls as applied in the Danish or Swedish fishery came out as best with minor differences between the stakeholder groups. In the Bay of Biscay there was a clear preference for a change from trawling to Nephrops pots by all stakeholders not affiliated to the fishery whereas the fishers themselves were somewhat undecided. In the Mediterranean the stakeholders from civil society and government preferred the change from trawling to targeted trapping in specific areas/seasons whereas the fishers preferred the change from traditional to novel otterboards. Finally in the North sea civil society had a strong preference for the application of a Habitat Credit System while fishers and government preferred the pulse trawl replacing tickler chain beam trawl.

This exercise confirms that an explicit consideration of stakeholder perspectives is important when considering the implementation of management measures and that a balanced representation of the relevant stakeholder groups is an important requirement for participatory processes to inform decision-making.

TABLE OF CONTENTS

INTRODUCTION

The mobile demersal gears currently applied in the fishery sectors across Europe are known to have a large impact both directly and indirectly on the benthic habitats and communities (e.g. (Bergman and van Santbrink, 2000; Kaiser et al., 2016; Piet et al., 2000). Direct impacts include direct change in population dynamic parameters such as mortality, growth, reproduction, distribution, density, and abundance patterns of target and bycatch fish and shellfish species as well as benthic invertebrate communities and habitats. Also direct impacts involves physical impacts, i.e. abrasion, on the benthic habitats and its physical structures. Indirect impacts include derived changes in species or food web interactions, long term changes caused by changed water turbidity and sedimentation, e.g. long term influence on recruitment, nursery and feeding habitats, etc. The indirect impacts also involves discards in relation to changes in food web interactions in high discard areas caused by fishery. There is increasing concern about these impacts and the aim is to reduce these impacts on the wider ecosystem without compromising the ability of the fishery to provide food or maintain a socio-economically viable fishery.

This is reflected in the main policy framework, i.e. the Common Fisheries Policy (CFP), which encourages an ecosystem based approach, in which benefits from living aquatic resources are ensured 'while the direct and indirect impacts of fishing operations on marine ecosystems are low and not detrimental to the future functioning, diversity and integrity of those ecosystems' (EC, 2008; EC, 2013). Correspondingly, the CFP proposes a new general framework to manage EU fisheries, focusing on multiannual plans as a main tool to plan and define management goals for fish stocks, functioning as a roadmap for achieving sustainability objectives to preserve marine biological resources (EC, 2013). The CFP stresses that to ensure good governance, appropriate involvement of stakeholders is needed to implement measures (EC, 2013). Still, the CFP remains unclear about how to possibly incorporate specific conservation measures and objectives in practice.

Even though extensive information and data have been sampled, compiled and elaborated lately, e.g. in relation to distribution and intensity of fishery with high spatial and temporal resolution (Hintzen et al., 2012; Eigaard et al., 2017; Rijnsdorp et al., 2016), which are critically important for policy making that instructs or facilitates choices for specific gears, such policy making also depends on human preferences; i.e. on what are considered relatively more important or relevant options. It has for instance been shown that the beam trawling on the benthic megafauna has raised concerns among the public, at least in the Netherlands (Groeneveld, 2010). Still, it remains unclear what exactly the societal concerns are, for whom and in which location.

In order to deal with these societal concerns, several management measures are considered to mitigate fishing impacts on the seabed habitats. Besides the quality of the data sampled on the stocks, habitats and ecosystems through monitoring, the stakeholder incentives/acceptance and perceptions of those measures are likely to influence compliance to the measures when and if implemented, and thus, eventually the future status of the seabed habitats.

Decision-making in fisheries management is complex and involves uncertainty, multiple objectives and multiple stakeholders. Objectives may be conflicting, and there can be disagreement between stakeholders who are involved in the decision-making process. Decision support tools can lead to a greater understanding of different stakeholder positions and thus increase awareness of the issues involved and the root of any conflict. The application of decision support tools may structure discussions, improve communication among stakeholders and lead to additional insight on possible solutions to the issues. This may increase stakeholder buy-in to the decision as the decision process is more transparent and thus the decision more easily defended, and provides a documented basis for possible modifications of the decision in the future (Jarre et al., 2010). The main reason for employing tools for decision support is that the decision process remains structured, transparent and documented, and that there is scope for better decisions in this way.

Multi-criteria decision analysis (MCDA) is a set of formal approaches which seek to take explicit account of multiple criteria in helping decision-makers explore decisions (Goodwin and Wright, 2004). They also allow to document, in a structured manner, the way a decision was reached and in this way make the decision process transparent. In MCDA, a decision problem typically is broken down into a set of smaller problems

that are easier to address, and a formal mechanism is then applied for integrating the results of the partial problems to develop a course of action to address the overarching issue.
Against this background, this deliverable applies stakeholder perceptions about societal objectives to determine what should be the preferred fisheries management measures in order to achieve these societal goals. In doing this we explicitly consider all three pillars of sustainability, i.e. the ecological, social and economic, that should be achieved simultaneously. To that end a questionnaire survey was conducted within the Benthis project, the intention is to identify stakeholder preferences of fishermen, fisher representatives, other private companies, civil society, government, science, and others, across different EU marine regional seas. Europe including; the Black Sea, the Mediterranean, the Baltic Sea and the North Sea. This exercise is a formal way of integrating stakeholder preferences towards defining what are the most appropriate management measures for a sustainable exploitation of the benthic ecosystem.

MATERIAL & METHODS

The method is based on a multi-criteria approach, including an initial problem structuring phase generating a set of alternative management measures and a set of criteria representing societal objectives, followed by a phase with assessments by means of stakeholder priorities (Soma, 2010; Ramos et al., 2015) (See Table 1).

Table 1. Step-wise description of the multi-criteria approach to select the preferred management measures to achieve the societal objectives identified in the BENTHIS project. This approach is applied for each regional sea for which the required information is available.

<table>
<tr><th>Stakeholder perspectives</th><th>Management measures</th></tr>
<tr><td>Identify relevant stakeholders;</td><td>Identify the innovative management measures</td></tr>
<tr><td>Identify relevant options and arrange them into hierarchies distinguishing stakeholder groups</td><td>Assess their performance against relevant societal objectives</td></tr>
<tr><td>Design questionnaire survey with pairwise comparisons based on options in the hierarchies;</td><td rowspan="2">Translate the narrative of their performance into scores where best=highest score, worst=lowest score.</td></tr>
<tr><td>Estimate relative importance for each stakeholder group for each option.</td></tr>
<tr><td colspan="2">Combine the stakeholder preferences per criterion with the performance scores against those criteria of the management measures.</td></tr>
</table>

In BENTHIS D6.2 and D6.3 we identified *what* the relevant societal objectives related to the three pillars of sustainability are for four regional seas: Black Sea, the Mediterranean, the Baltic Sea and the North Sea. Presentations of options in hierarchies (Figure 1) facilitate an open and transparent consideration of all relevant aspects and assist by informing and structuring different arguments during a conversation (Soma et al., 2014). Moreover, some option were specified for acceptability. In other words, it was specified what is relevant to consider for enhancing more acceptability to fishery management (Figure 2). Also, mitigation measures were specified (Figure 3).

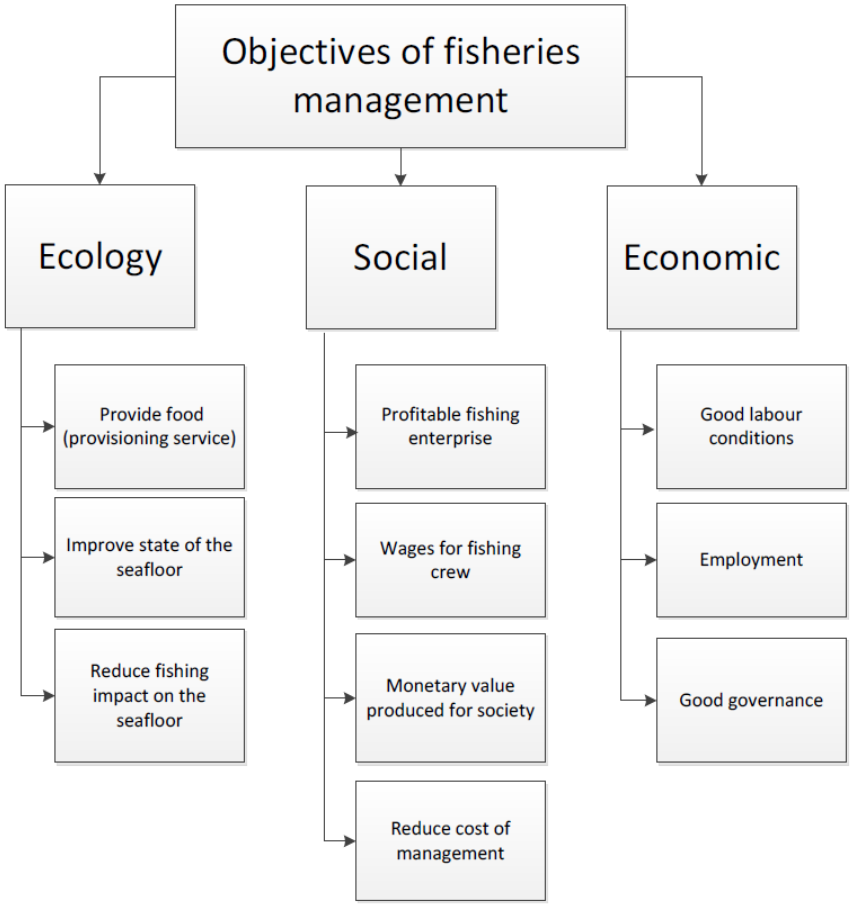

Figure 1. The societal objectives related to the three pillars of sustainability (from BENTHIS D6.3)

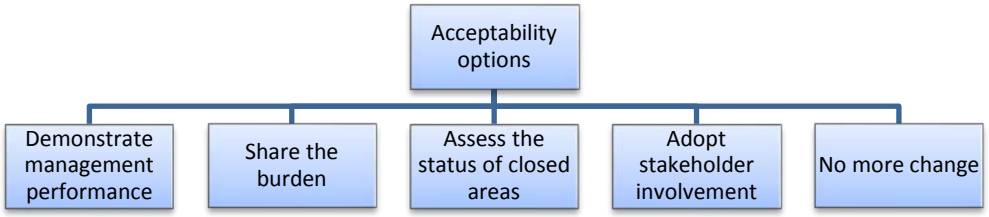

Figure 2. Acceptability options identified for mitigations of benthic impacts of fisheries

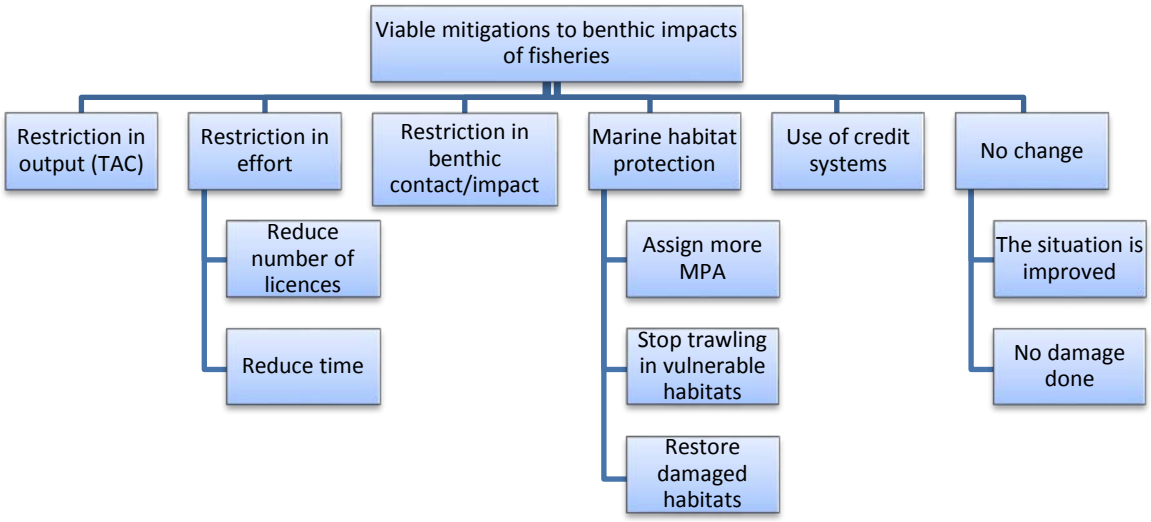

Figure 3. Options of measures identified for viable mitigations to benthic impacts of fisheries

For these societal objectives we obtained the stakeholder perspectives through a questionnaire survey covering a broad range of stakeholders including fishermen, fisher representatives, other private companies, civil society (i.e. NGOs), government and science. This process is described in BENTHIS D6.3 and Soma et. al (submitted). The relative preferences of the societal objectives were established within each sustainability aspect and for the overall preferences per societal objective, the preferences per sustainability aspect were multiplied with the relative preferences within that aspect. The method applied to conduct the questionnaire survey is referred to as a pairwise comparison technique because stakeholders are asked to compare two options at the same time on a scale of importance (Soma, 2003; Saaty, 2004; Sparrevik et al., 2011; Soma et al., 2013; Ramos et al., 2014). See example in Table 2.

Table 2. Example of pairwise comparison of two options at the time on a scale of importance

Good labour conditions																Good governance
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

9= This option is extremely more important than the other
7= This option is much more important than the other
5= This option is more important than the other
3= This option is slightly more important than the other
1= Both options are equally important

Estimates are based on the pairwise comparison technique by means of the eigenvalue methodology (Saaty, 2004). By comparing two options at a time on a semi-quantitative scale, the priorities are spread over the relevant options. This approach is based on the assumption that each interviewee can distribute a total of 100% importance priorities among the different options in a hierarchy. The interviewee can be an individual stakeholder or a representative for a group of stakeholders. The programme Select Survey is used to design the questionnaire and to generate outcomes, the programme DEFINITE is applied for the eigenvalue methodology estimations to find the relative importance of the options specified in the hierarchies in Figures 2 and 3 as well as Appendix 1 (Janssen, 2001; Saaty, 2004; Ramos et al., 2014), while an Excel worksheet is used for designing the figures/ tables showing the relative importance of stakeholder preferences.

For each of the management measures that were tested in the BENTHIS case studies (see BENTHIS D7.1, d7.2; Table 3) their performance was assessed against the same societal objectives for which the stakeholder perspectives were obtained. MCDA was used to combine the stakeholder preferences with the outcome of the performance assessment to determine the preferred management measures. In the

analysis we contrast the perspectives of the fishers (including fisher representatives), civil society (i.e. NGOs), and government as this represents how the different perspectives could result in different selections of the most appropriate management measures. For those regions for which both the stakeholder preferences as well as the assessment of the performance of the management measures are available, i.e. Baltic sea, Mediterranean and North sea, we were able to do a truly regional MCDA, for the Bay of Biscay for which the stakeholder preferences were not available we applied the average across all stakeholders and assumed this was sufficiently representative for that region.

Table 3. Management measures per region and their codes. More detail provided in Annex1.

Region	Management measure	Code
Baltic Sea	Application of Nephrops creels/trawls in DK fishery	BSA
	Application of Nephrops creels/trawls In Swedish fishery	BSB
	Application of Nephrops short sweeps	BSC
Bay of Biscay	Changing from traditional to "Jumper" otterboards	BOBA
	Changing from trawling to Nephrops pot	BOBB
Mediterranean Sea	changing from traditional to novel otterboards	MSA
	changing from trawling to targeted trapping in specific areas/seasons	MSB
North Sea	Pulse replacing tickler chain beam trawl	NSA
	Pulse trawl replacing tradition beam trawl in shrimp fishery	NSB
	Application of a Habitat credit System	NSC

RESULTS

For each region the stakeholder preferences are given for both the broad sustainability objectives, i.e. ecological, economic and social (Table 4), as well as the more detailed societal objectives (Table 5). It is striking that in all regions there is a clear difference between on the one hand civil society and government with a strong preference for the ecological sustainability and the fishers with an almost equal preference for all aspects of sustainability.

Table 4. Stakeholder preferences per region for each of the sustainability objectives. The average is based on those three regions. The number of stakeholders per region and societal group (F=Fishers, C=Civil society (NGOs) and G=Government) that returned the questionnaire is provided.

Sustainability criteria	Baltic Sea			Mediterranean Sea			North Sea			Average		
	F	C	G	F	C	G	F	C	G	F	C	G
Ecological	0.44	0.78	0.69	0.32	0.63	0.55	0.24	0.75	0.48	0.29	0.72	0.56
Economic	0.11	0.06	0.10	0.31	0.10	0.13	0.35	0.08	0.16	0.31	0.08	0.13
Social	0.44	0.17	0.21	0.38	0.27	0.32	0.42	0.17	0.36	0.40	0.20	0.30
Number	2	2	4	14	3	6	15	6	5	31	11	15

Table 5. Stakeholder preferences per region and societal group (F=Fishers, C=Civil society (NGOs) and G=Government) for each of the societal objectives within the sustainability aspects. The average is based on weighted preferences from those three regions. that returned the questionnaire is provided.

	Societal objectives	Baltic Sea			Mediterranean Sea			North Sea			Average		
		F	C	G	F	C	G	F	C	G	F	C	G
Ecological	Provide food	0.25	0.05	0.15	0.59	0.12	0.11	0.63	0.06	0.30	0.59	0.07	0.18
	Low fishing impact on the seafloor	0.08	0.73	0.29	0.26	0.35	0.24	0.14	0.66	0.13	0.19	0.59	0.22
	Improve state of the seafloor	0.68	0.22	0.56	0.15	0.53	0.66	0.24	0.28	0.57	0.23	0.34	0.60
Economic	Profitable fishing enterprises	0.08	0.06	0.12	0.33	0.05	0.07	0.21	0.05	0.13	0.25	0.05	0.10
	Wages for fishing crew	0.11	0.44	0.12	0.23	0.40	0.24	0.20	0.17	0.10	0.21	0.28	0.16
	Monetary value produced for society	0.09	0.16	0.31	0.10	0.29	0.25	0.22	0.27	0.36	0.16	0.25	0.30
	Low management costs	0.50	0.06	0.15	0.18	0.03	0.15	0.13	0.09	0.10	0.17	0.07	0.13
	Fair distribution of costs and benefits	0.22	0.27	0.31	0.16	0.23	0.30	0.25	0.42	0.31	0.21	0.34	0.31
Social	Good labour conditions	0.42	0.62	0.23	0.54	0.59	0.32	0.47	0.21	0.55	0.50	0.39	0.37
	Employment	0.13	0.13	0.21	0.26	0.27	0.09	0.23	0.09	0.20	0.24	0.14	0.16
	Good governance	0.46	0.26	0.57	0.20	0.14	0.60	0.30	0.70	0.25	0.26	0.47	0.47

The stakeholder preferences within each of the aspects of sustainability are given in Table 5. This shows that overall within the ecological aspect the fishers give a higher weighting to the food provisioning objective while the other stakeholder groups are more concerned with the conservation of the seafloor with the distinction that the civil society primarily aims to reduce fishing impact whereas the government aims to achieve a good status of the seafloor. Within the economic aspect we observe again a marked difference between the fishers and the wider society (i.e. NGOs and government) where the former prefer a "profitable fishing enterprise" whereas the latter is more concerned with a "Fair distribution of costs and benefits". This is also observed within the social aspect where the fishers show a preference for "Good labour conditions" as opposed to wider society preferring "Good governance".
For each region the performance of the management measures was assessed against the societal objectives. The narratives can be found in Annex 1. The narratives were translated in scores per region given in Table 6. The societal objective "Improve the state of the seafloor" was assessed differently in some regions. For example in the Baltic Sea there was no difference in performance of the management measures because this aspect was not measured in the case study. This is a much stricter interpretation than in other regions where a more lenient interpretation was applied assuming that if the impact of fishing is reduced over time an improved state of the seafloor should be achieved.

Table 6. Scores of each management measure per region (for explanation codes see table mm1). Best=highest score, Worst=lowest score, if there is no difference the scores were averaged. The MCDA outcome is based on the summed weighted scores. Based on this we indicated what is considered the best (green) and worst (red) management measure per region.

Societal objectives	Baltic Sea			Bay of Biscay		Mediterranean Sea		North Sea		
	BSA	BSB	BSC	BOBA	BOBB	MSA	MSB	NSA	NSB	NSC
Provide food	1	2.5	2.5	2	1	2	1	2	3	1
Reduce fishing impact on the seafloor	2.5	2.5	1	1	2	1	2	2	1	3
Improve state of the seafloor	2.5	2.5	1	1	2	1	2	2	1	3
Profitable fishing enterprises	3	1	2	1.5	1.5	2	1	3	1	2
Wages for fishing crew	3	1	2	2	1	2	1	3	1	2
Monetary value produced for society	3	1	2	2	1	2	1	1	2	3
Reduce cost of management	3	1	2	1.5	1.5	1.5	1.5	2.5	2.5	1
Fair distribution of impacts	2	2	2	1	2	2	1	2	1	3
Good labour conditions	1.5	1.5	3	1	2	1	2	3	2	1
Employment	2	2	2	2	1	2	1	2	2	2
Good governance	2	2	2	2	1	1	2	2	2	1
Outcome MCDA per societal group										
Fisherman	2.05	2.04	1.90	1.52	1.48	1.55	1.45	2.29	1.85	1.74
Civil society	2.32	2.29	1.39	1.26	1.74	1.48	1.53	2.04	1.30	2.55
Government	2.23	2.25	1.52	1.35	1.65	1.27	1.73	2.18	1.73	1.99

In the Baltic Sea the strictest interpretation of the analysis where the "state of the seafloor" criterion is not assessed (see Annex 1) shows that BSC would be the preferred management measure according to the fishers. In contrast civil society and government would prefer the other two management measures, i.e. BSA and BSB. However, if the reduced fishing impact on the seafloor would indeed result in an improved state of the seafloor, all societal groups would agree on an about equal preference for the management measures BSA and BSB but with minor differences between the societal groups. This difference is mainly caused by the different performances in relation to the food provisioning objectives (i.e. "provide food") versus the seafloor conservation objectives (i.e. "Reduce fishing impact on the seafloor" and "Improve state of the seafloor"). These differences in performance are also observed in the other regions causing different preferences between the societal groups.

Comparing the core objectives at the most general level (Figure 1); ecological objectives (green), social objectives (red) and economic objectives (blue), they score overall high, with the civil societies in the Baltic Sea and the North Sea providing extremely high priorities to the ecological objectives (Figure 4). This finding is based on preferences of selected stakeholder groups; fishermen, civil society and government, within the four regions Black sea, Baltic Sea, Mediterranean Sea and the North Sea. The government in the North Sea provides relatively high priority to the social objectives, and the fishermen in the North Sea give a lot more priorities to the economic and social objectives than most others. The economic objectives get relatively low priorities overall, although compared with the other stakeholders, the civil societies in the Black Sea, as well as by the fishermen in the North Sea and the Mediterranean Sea provide some more priorities to economic objectives.

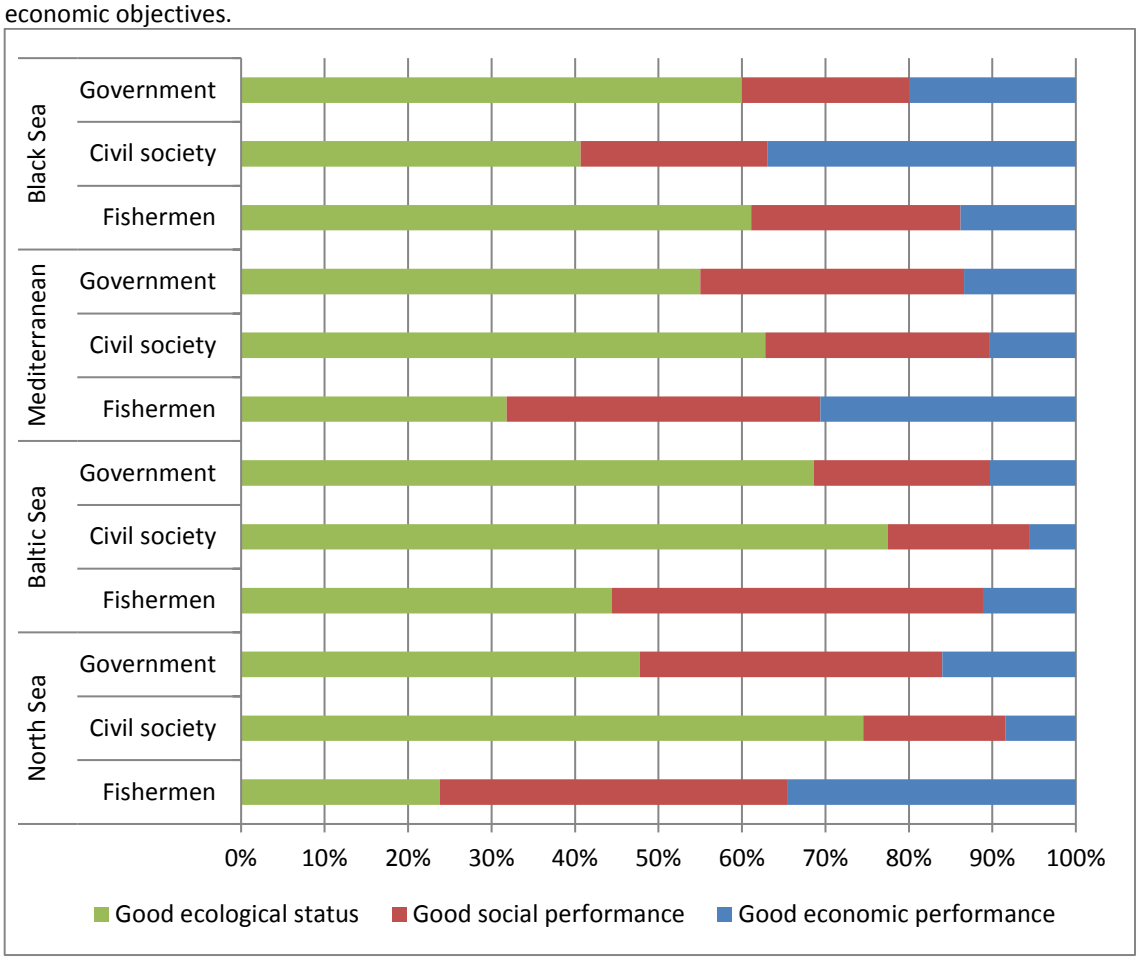

Figure 4. Preferences for sustainability objectives identified for mitigation of benthic impacts of fisheries across regions and selected stakeholders

Also comparing the acceptability options (Figure 2), the preferences differ across stakeholders in different regions (Figure 5). For instance, the fishermen in the Mediterranean and the Black Sea give highest priority to the 'demonstrate management performance' option, whereas in the Baltic Sea and the North Sea, they are most favourable to 'adopt stakeholder involvement'. 'Self-regulation' is an option which by most stakeholders get little priority, but the fishermen in the Black Sea, Mediterranean Sea and the North Sea, as well as governmental officers in the North Sea, give higher priority to this option. 'Share the burden' is a highly prioritised option by Black Sea civil society and Mediterranean governmental officers, but less so to the others. 'Adopt stakeholder involvement' is highly prioritised across most stakeholders, however, the government in the North Sea and civil societies in the Black Sea and the Mediterranean give low priorities to this option. The civil societies and fishermen in the Baltic Sea and the North Sea give very low priorities to 'demonstrate management performance' but their governmental officers as well as most other stakeholders give high priority to this option. The option 'assess the status of closed areas' is highly

prioritised by civil society in the Mediterranean and the Baltic Sea government, as well as to all three stakeholder groups in the North Sea.

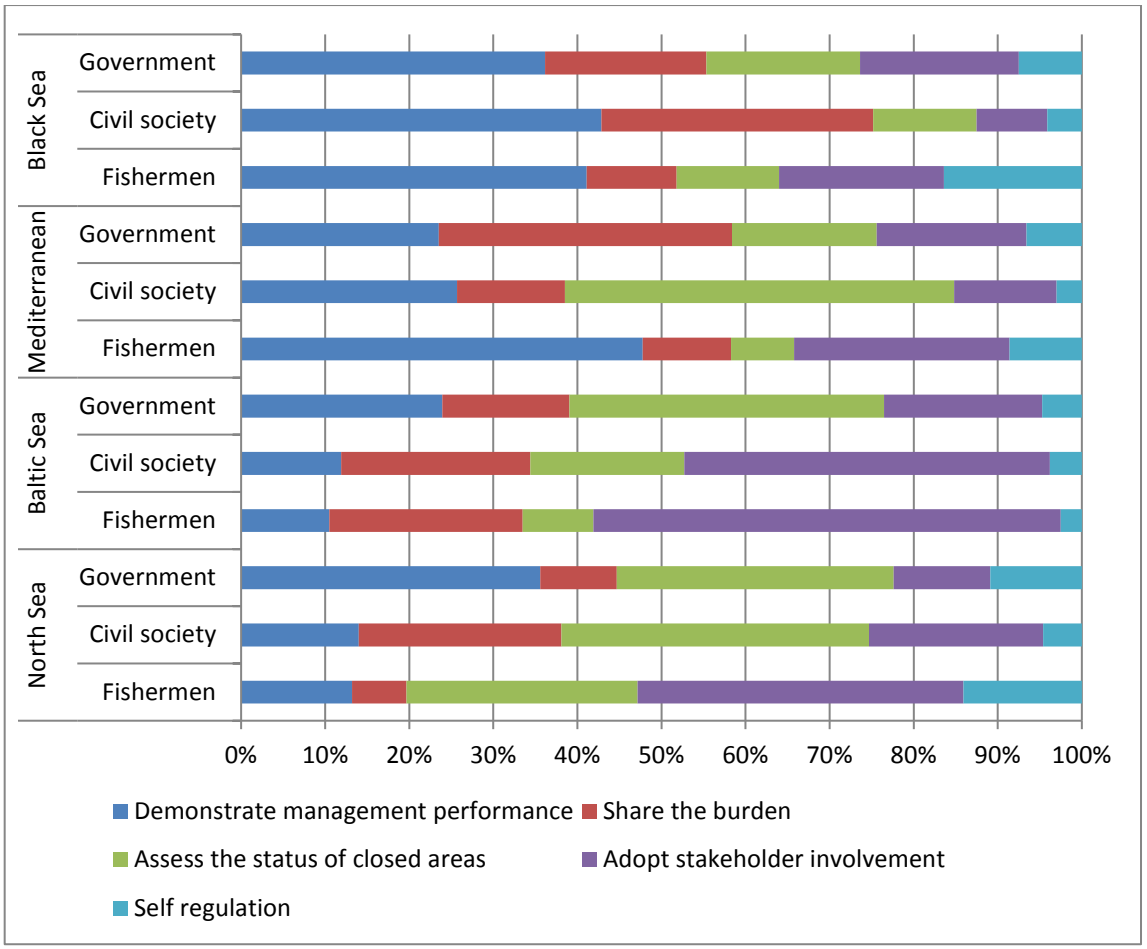

Figure 5. Preferences for acceptable options for mitigations of benthic impacts of fisheries across regions and selected stakeholders

The mitigation measures in Figure 3 have been judged by stakeholders and these results are shown in Figure 6. Still, given the responses, it is evident that 'restriction in output i.e. fishing quotas (TAC)' scores around 10% in all regions and countries, and a little less in Belgium. The 'restriction in efforts' option gets the highest priorities by all stakeholders in the Mediterranean Sea, but also some by the governments in the Black Sea and the North Sea. The 'restriction in benthic contact/impact' gets high priorities by almost all stakeholders, except fishermen in the North Sea and the Mediterranean Sea. Comparing priorities for 'implementation of marine ecosystem measures' across stakeholders, the civil societies in the North Sea and the Black Sea, as well as the government in the Baltic Sea and the fishermen in the Mediterranean, give extremely high priorities to this option. 'The use of sea floor quota system' gets some priorities by fishermen in the Baltic Sea and the North Sea, and also by civil society in the Baltic Sea and in the Black Sea. Only fishermen in the Black Sea and the Mediterranean Sea put this option extremely low. Fishermen in the North Sea, the Black Sea and the Mediterranean Sea are favourable to 'no change in management', which contrast with all the other stakeholder groups who put this option the very lowest.

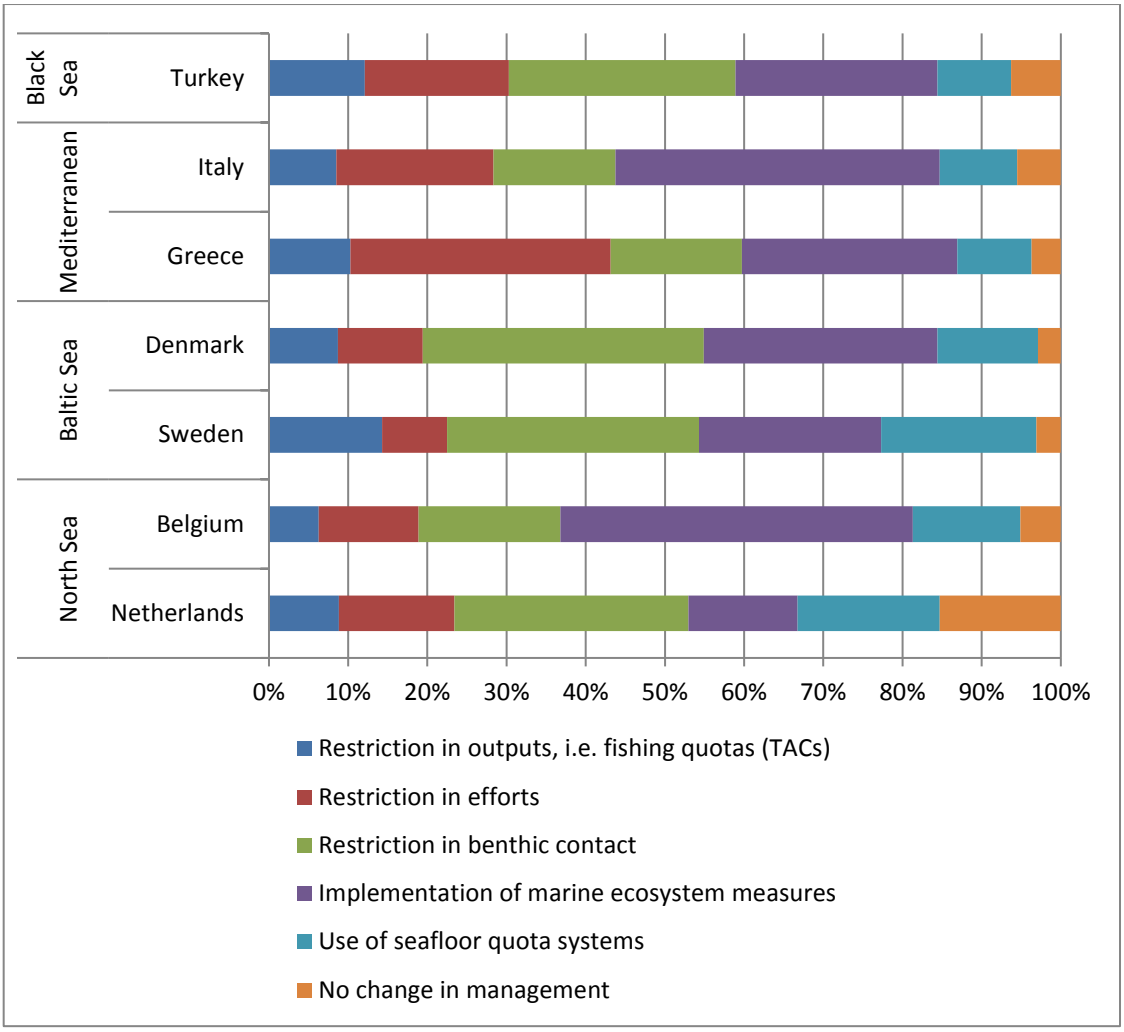

Figure 6. Preferences across core countries and regions for viable mitigation measures to benthic impacts of fisheries

DISCUSSION

Stakeholder preference investigations can aid in the processes of co-management. The application of pairwise comparison as a methodological approach to assign stakeholder preferences has been applied in other studies (Soma, 2003, 2010; Sparrevik et al., 2011; Soma et al., 2013; Ramos et al., 2014). The pairwise comparison for identifying stakeholder preferences in fisheries management can; a) contribute as an additional multiple knowledge dimension to existing scientific based information considered in policy making, b) ensure transparent treatment of the different preferences, in which diversity is made visible in a series of figures, c) contribute to identifying most urgent issues for management of activities with benthic impacts in specific contexts, and d) give the opportunity to include norms about what is more important to enhance acceptability of management of activities with benthic impacts.

It should be noted though, that outcomes of this study are only indicative and cannot be used to value certain policy strategies above others. This is because statistical representation cannot be claimed, and extents of inconsistencies exist across responses. The results are valuable for knowing where more attention should be given in further research or decision making processes. Actually, the method is just as much an demonstration and implementation of a process oriented tool as it is about suggesting solutions. Moreover, stakeholders contributing with information to inform about their preferences is complementary to for instance expert based information about indicators and figures.

This exercise shows that an explicit consideration of stakeholder perspectives is important when considering the implementation of management measures. In all regions the different preferences between

the societal groups would result in the selection of different management measures. Especially striking is that fishers and the wider society (here represented by civil society, i.e. NGOs and the government) are often diametrically opposed. In terms of the broad sustainability aspects the fishers primarily focus on the social aspect where wider society is more concerned about the ecological aspect. This not only applies to the sustainability aspects but also within each of these sustainability aspects we observe a similar divide. This implies that whenever decisions need to be taken that requires stakeholder involvement, such as the implementation of ecosystem-based management measures, a balance representation of the relevant stakeholder groups is an important requirement.

The importance of participatory processes has increased in natural resources governance and in EBM in particular since stakeholder participation is viewed as a key element of EBM (Flannery and Cinneide, 2012; Linke and Jentoft, 2013; Pomeroy and Douvere, 2008). However, participatory processes need to be well designed (Rockmann et al., 2015), because if handled badly, they can result in counterproductive negative consequences (e.g. erosion of trust between partners and end of cooperation (Reed et al., 2009). The main motivations for(increased)stakeholder involvement and participatory processes are well-known: Participation can strengthen democratic cultures and processes, bring additional knowledge and values into decision-making in order to make better decisions, provide greater legitimacy, increase trust, enhance compliance, and reduce the intensity of conflict. An improved overall process quality can result in increased management efficiency, equity, sustainability, reduction of administration and enforcement costs, making the management not only more legitimate, salient, credible, (Rockmann et al., 2015) but also enforceable and realistic (Christie, 2011; Reed, 2008; Tallis et al., 2010; Young et al., 2013).

REFERENCES

Bergman, M. J. N., and van Santbrink, J. W. 2000. Fishing mortality of populations of megafauna in sandy sediments. *In* Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues, pp. 49-68. Ed. by M. J. Kaiser, and S. J. de Groot. Blackwell Science, Oxford.

Christie, P. 2011. Creating space for interdisciplinary marine and coastal research: five dilemmas and suggested resolutions. Environmental Conservation, 38: 172-186.

EC. 2008. The role of the CFP in implementing an ecosystem approach to marine management. SEC(2008) 449.

EC 2013. Regulation (EU) on the Common Fishery Policy. Official Journal of the European Union, L354: 1–40.

Eigaard, O. R., Bastardie, F., Hintzen, N. T., Buhl-Mortensen, L., Buhl-Mortensen, P., Catarino, R., Dinesen, G. E., et al. 2017. The footprint of bottom trawling in European waters: distribution, intensity, and seabed integrity. ICES Journal of Marine Science, 74: 847-865.

Flannery, W., and Cinneide, M. O. 2012. Deriving Lessons Relating to Marine Spatial Planning from Canada's Eastern Scotian Shelf Integrated Management Initiative. Journal of Environmental Policy & Planning, 14: 97-117.

Goodwin, P., and Wright, G. 2004. Decision analysis for management judgment. Third edition. John Wiley and Sons, Chichester, UK. 477 p.

Groeneveld, R. A. 2010. Framing and Training to Induce Preference Learning in Choice Experiments. Marine Resource Economics, 25: 233-245.

Hintzen, N. T., Bastardie, F., Beare, D., Piet, G. J., Ulrich, C., Deporte, N., Egekvist, J., et al. 2012. VMStools: Open-source software for the processing, analysis and visualisation of fisheries logbook and VMS data. Fisheries Research, 115: 31-43.

Janssen, R. 2001. On the Use of Multi-Criteria Analysis in Environmental Impact Assessment in The Netherlands. Journal of Multi-Criteria Decision Analysis, 10: 101–109

Jarre, A., Rochet, M.-J., and Spedicato, M. T. 2010. Decision support tools in fisheries management: A review as research background for the possible inclusion of multiple indicators into fisheries management. IMAGE deliverable 4. Appendix 1: 25.

Kaiser, M. J., Hilborn, R., Jennings, S., Amaroso, R., Andersen, M., Balliet, K., Barratt, E., et al. 2016. Prioritization of knowledge-needs to achieve best practices for bottom trawling in relation to seabed habitats. Fish and Fisheries, 17: 637-663.

Linke, S., and Jentoft, S. 2013. A communicative turnaround: Shifting the burden of proof in European fisheries governance. Marine Policy, 38: 337-345.

Piet, G. J., Rijnsdorp, A. D., Bergman, M. J. N., van Santbrink, J. W., Craeymeersch, J., and Buijs, J. 2000. A quantitative evaluation of the impact of beam trawling on benthic fauna in the southern North Sea. ICES Journal of Marine Science, 57: 1332-1339.

Pomeroy, R., and Douvere, F. 2008. The engagement of stakeholders in the marine spatial planning process. Marine Policy, 32: 816-822.

Ramos, J., Soma, K., Bergh, O., Schulze, T., Gimpel, A., Stelzenmuller, V., Makinen, T., et al. 2015. Multiple interests across European coastal waters: the importance of a common language. ICES Journal of Marine Science, 72: 720-731.

Reed, M. S. 2008. Stakeholder participation for environmental management: A literature review. Biological Conservation, 141: 2417-2431.

Reed, M. S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Prell, C., et al. 2009. Who's in and why? A typology of stakeholder analysis methods for natural resource management. Journal of Environmental Management, 90: 1933-1949.

Rijnsdorp, A. D., Bastardie, F., Bolam, S. G., Buhl-Mortensen, L., Eigaard, O. R., Hamon, K. G., Hiddink, J. G., et al. 2016. Towards a framework for the quantitative assessment of trawling impact on the seabed and benthic ecosystem. ICES Journal of Marine Science, 73: 127-138.

Rockmann, C., van Leeuwen, J., Goldsborough, D., Kraan, M., and Piet, G. 2015. The interaction triangle as a tool for understanding stakeholder interactions in marine ecosystem based management. Marine Policy, 52: 155-162.

Saaty, T. L. 2004. Decision making – the Analytic Hierarchy and Network Processes (AHP/ANP). Journal of Systems of Science and Systems of Engineering, 13: 1–35.

Soma, K. 2003. How to involve stakeholders in fisheries management — a country case study in Trinidad and Tobago. Marine Policy, 27: 47–58.

Sparrevik, M., Ellen, G. J., and Duijn, M. 2011. Evaluation of factors affecting stakeholder risk perception of contaminated sediment disposal in Oslo harbor. Environmental Science and Technology, 45: 118–124

Soma, K. 2010. Framing Participation with Multicriterion Evaluations to Support the Management of Complex Environmental Issues. Environmental Policy and Governance, 20: 89-106.

Soma, K., Ramos, J., Bergh, O., Schulze, T., van Oostenbrugge, H., van Duijn, A. P., Kopke, K., et al. 2014. The "mapping out" approach: effectiveness of marine spatial management options in European coastal waters. ICES Journal of Marine Science, 71: 2630-2642.

Tallis, H., Levin, P. S., Ruckelshaus, M., Lester, S. E., McLeod, K. L., Fluharty, D. L., and Halpern, B. S. 2010. The many faces of ecosystem-based management: Making the process work today in real places. Marine Policy, 34: 340-348.

Young, J. C., Jordan, A., Searle, K. R., Butler, A., Chapman, D. S., Simmons, P., and Watt, A. D. 2013. Does stakeholder involvement really benefit biodiversity conservation? Biological Conservation, 158: 359-370.

ANNEX 1. REGIONAL ASSESSMENTS OF THE PERFORMANCE OF MANAGEMENT MEASURES

Table: Synthesis results Baltic Sea case study

Sustainability dimension	Objective	*Management measure* Nephrops creels/trawls in DK fishery (vessels < 12 m with 2 crew members) (D7.9)	Nephrops creels/trawls In Swedish fishery (Hornborg et al. 2016)	Nephrops short sweeps (D7.9)
Ecologic	Provide food	Ca. 30% reduction. Catch/food provision is assessed to be reduced for a scenario with a fixed fleet size. This is because creeling is more sensitive to weather conditions and is estimated to have only 150 yearly fishing days compared to 216 days for trawlers.	Assumed 0% change. Catch/food provision is assumed unchanged based on the scenario setting of unchanged Nephrops catches/TAC, but it can be inferred from the analysis that due to discard reductions the total landings of Nephrops may increase without causing further fishing mortality.	0% change. Initial analyses of sea trials indicate unchanged catch rates for main target species.
	Reduce fishing impact on the seafloor	Ca. 95 % reduction. Based on estimates from analyses of the Swedish fisheries (Hornborg et al. 2016). It should be noted that this reduction reflects Swedish water habitats, fleet structure and fishing patterns.	Ca. 95 % reduction. The area impact of creels is estimated to be between 0.003 and 1.3 km^2/ton catch and for trawls between 21 and 40 km^2/ton in the Swedish fishing areas, which implies a potential reduction of the trawled area of more than 90%	Ca. 25% reduction. Sensor data from sea trials demonstrated a 25% reduction in door spread from shortening the sweeps
	Improve state of the seafloor	Not measured but benthic invertebrate biomass is assumed to increase based on the estimated reduction in area impacted per kg catch	Not measured but benthic invertebrate biomass is assumed to increase based on the estimated reduction in area impacted per kg catch	Not measured but assumed to increase based on the reduction in gear footprint size
Economic	Profitable fishing enterprises	On a daily basis the profitability of creeling is estimated to be higher (a ca. 30 % increase). On a yearly	Average creel-Nephrops price from 1998-2013 was 132SEK/kg and 108 SEK/kg for trawl-	Since the catch rates and gear costs and labour demands are unchanged, we estimate profitability

		basis the profitability of creeling is estimated to be lower (ca. 10% reduction) due to fewer fishing days.	Nephrops price. Disregarding potential cost differences between creel and trawl fishery this implies room for an increase of ca. 20 % in profitability.	to be unchanged as well
	Wages for fishing crew	Potential for ca. 30% increase on a daily basis Decrease of ca. 10% on a yearly basis given the higher number of annual fishing days for trawlers	Based on the potential ca. 20% increase in profitability there should also be potential for an increase in wages with up to ca. 20%	Unchanged
	Monetary value produced for society	For the catch sector (ignoring the processing sector) there is a ca. 10% reduction in monetary value produced for society because of fewer yearly fishing days of creelers.	For the catch sector (ignoring the processing sector) there is potentially a ca. 20% gain in monetary value produced for society	Unchanged
	Reduce cost of management	Unchanged or potentially reduced. Because of reduced monitoring requirements due to higher selectivity and less by-catch/discard in creels	Unchanged or potentially reduced. Because of reduced monitoring requirements due to higher selectivity and less by-catch/discard in creels	Unchanged
Social	Fair distribution of impacts	Unchanged	Unchanged	Unchanged
	Good labour conditions	It is in general more time consuming and labour demanding to catch the same amount of Nephrops with creels compared to trawls.	It is in general more time consuming and labour demanding to catch the same amount of Nephrops with creels compared to trawls.	Unchanged in that deployment of the gear change (shortening of sweeps) does not require any additional work load.
	Employment	Unchanged	Unchanged	Unchanged
	Good governance	Unchanged	Unchanged	Unchanged to slightly improved, as fishermen seem to be positive about the measure.

Table: Synthesis results Bay of Biscay case study

Sustainability dimension	Objective	A – changing from traditional to "Jumper" otterboards	B– changing from trawling to Nephrops pot
Ecologic	Provide food	No change	Loss in catches diversity as compared to trawlers (especially commercial fish species)
	Reduce fishing impact on the seafloor	Amount of re-suspended sediment highly reduced and limited depth of sediment reworking. Swept area slightly lowered (minus otterboards shoes).	High decrease of swept area and sediment reworking level.
	Improve state of the seafloor	Potentially Reduced impacts for infauna but low effect on epifauna.	Very high selectivity and promote fishing ground heterogeneity and epifauna biomass. However, high densities of pots could induce significant impacts.
Economic	Profitable fishing enterprises	Reduction in running costs (i.e. fuel saving) increase directly profitability. Investment costs needed to adapt rigging and system to control gear parameters.	High landing prices related to the size and quality of the products. Reduction of variables costs (lower fuel consumption, low maintenance and repair costs). However investment costs would be high for non-specialized vessels.
	Wages for fishing crew	Salaries could be increased thanks to a reduction in running costs (indirect effect).	More variable, depending on catch.
	Monetary value produced for society	Increased benefit to society by increased profitability	Monetary value locally very important
	Reduce cost of management	No change	No change
Social	Fair distribution of impacts	*No change*	Better distribution of benefits (lower scale enterprise) but mostly kept in the local area.
	Good labour conditions	*No change for the crew but need more attention by the skipper to control fishing gear parameters*	Nephrops pots are light gears easy to work with and risk lowered
	Employment	*No change*	Lower scale enterprise (smaller fishing vessels and reduced number of crew members).
	Good governance	*No change*	High spatial conflicts with trawlers. High dependence of catches level on Nephrops population structure

[1]Note: By lifting the doors off the bottom, the capture efficiency of the gear was guaranteed by two additional chains of 250 kg each, inserted just behind the backstrops. The idea is that the traditional demersal otterboards are replaced with two chains that keep the bridle ends down, while a pair of semi-pelagic otterboards are towed ahead of the chains and clear of the ground to provide spread. This approach to bottom trawling relies entirely on hydrodynamic force to open the gear, eliminating the ground shearing force and seabed impact.

[2]Note: The main results show that it is possible to design new otterboards with up to 15-20% less fuel consumption and up to 40% more door spread.

[3]Note: the trapping experiments were not successful in terms of catch and thus profitability. This may be due to the state of stocks in the trawl areas where the trapping took place (also could be season, area, mesh size). However, we know that traps are used, in areas closed to trawling, at a close to artisanal level. We have filled the table more based on our experience with other project data from those areas.

Table: Synthesis results Mediterranean Sea case study

Sustainability dimension	Objective	Management measure A – changing from traditional to novel otterboards	B	C – changing from trawling to targeted trapping in specific areas/seasons[3]
Ecologic	Provide food	No effect on total catch and species composition.		Targeted food provided with large decrease in overall catch, from multi-targets to 1 target species plus minor bycatch. More selective to the correct size of targeted catch, thus less discarding.
	Reduce fishing impact on the seafloor	Traditional doors dig deeper into the sediment, making furrows up to 10-15 cm deep. Semi-pelagic otterboards annul this impact on the seafloor, even though the footprint was not reduced because of the compensation chain[1]. Note that this is not supposed to be a driver for the innovation.		Approx. 99.9 % decrease in swept area with very large decrease in impact
	Improve state of the seafloor	Equal swept area/seabed impacted area and decrease in the seabed penetration of the doors lead to a moderate improvement in the state of the seafloor		Increased local heterogeneity and biomass, at least 100% increase in macrofauna.
Economic	Profitable fishing enterprises	Reduction in running costs (i.e. fuel saving[2]) increase directly profitability.		The fishery would be close to artisanal level, profit is very low.
	Wages for fishing crew	Salaries could be increased thanks to a reduction in running costs (indirect effect).		Wages are low and continuously variable, depending on catch and costs. It would act more like a family business.
	Monetary value produced for society	Increased benefit to society by increased profitability.		Monetary value is low, bit locally very important as it mostly stays in the local community.
	Reduce cost of management	No change. Despite the novel otterboards might be part of some regulated features or technical measures, costs of management will not be minimized.		Trap fisheries are under-enforced and managed only by some technical measures. No change however, would be foreseen so management costs would not change.

Social	Fair distribution of impacts	*No change.*		Less fair distribution as less people benefit, but all the benefits are kept in the local area.
	Good labour conditions	*No change*		Small scale fishery has better labour conditions usually family or friends – compared to trawler with foreign crews under harsh conditions
	Employment	*No change.*		Less jobs overall, but employment is very local and fishing stays in the community.
	Good governance	*No change.*		If they understand the measure, there should be good compliance.

[1]Note: By lifting the doors off the bottom, the capture efficiency of the gear was guaranteed by two additional chains of 250 kg each, inserted just behind the backstrops. The idea is that the traditional demersal otterboards are replaced with two chains that keep the bridle ends down, while a pair of semi-pelagic otterboards are towed ahead of the chains and clear of the ground to provide spread. This approach to bottom trawling relies entirely on hydrodynamic force to open the gear, eliminating the ground shearing force and seabed impact.

[2]Note: The main results show that it is possible to design new otterboards with up to 15-20% less fuel consumption and up to 40% more door spread.

[3]Note: the trapping experiments were not successful in terms of catch and thus profitability. This may be due to the state of stocks in the trawl areas where the trapping took place (also could be season, area, mesh size). However, we know that traps are used, in areas closed to trawling, at a close to artisanal level. We have filled the table more based on our experience with other project data from those areas.

Table: Synthesis results North Sea case study

Sustainability dimension	Objective	*Management measure* NL pulse replacing tickler chain beam trawl	Pulse trawl replacing tradition beam trawl in shrimp fishery	Habitat credit French demersal fishery eastern English Channel
Ecologic	Provide food	Landings of the fishery has remained the same as these are controlled by quota / TAC. Reduction of discards of commercial fish, due to the improved species selectivity, is expected to positively affect the productivity of these stocks	Shrimp landings per vessel may increase as catch efficiency expected to be higher if applied in traditional trawl. Higher catching efficiency can be traded off to improve selectivity, which is the principle of Hovercran. Reduction of discards of commercial flatfish will positively affect the productivity of these stocks	Minimal loss of landings and revenue as vessels are still able to reallocate their effort to less vulnerable fishing grounds while allowing the fishery to catch their catch quota and maintain their revenue. Only if reduced extremely, habitat credits may constrain fishing activities to levels that prevent the fisheries to uptake the catch quota of the target species
	Reduce fishing impact on the seafloor	Footprint ~25% lower due to lower towing speed. Impact (PD2) reduced by >50% due to lower footprint and lower penetration depth. Bycatch of benthic invertebrates reduced substantially.	Bycatch reduced by 50-75%. Depending on the groundgear configuration, the bottom contact and impact of seafloor will be reduced. Impact of traditional beam trawl is relatively mild.	Habitat credits will reduce the benthic impacts of the trawl fisheries
	Improve state of the seafloor	The lower impact is expected to result in an increase in the state of the seafloor	State of seafloor will increase in proportion to reduced bottom contact	State of seafloor will increase in proportion to reduced bottom contact
Economic	Profitable fishing enterprises	Economic profitability has increased.	Profitability will likely reduce because of investment cost, during depreciation period. Higher landings may negatively impact ex-vessel price of shrimps if improved selectivity is not a goal.	Profitability likely to be reduced slightly. Effects case specific. Reduction due to higher competition among vessels in core fishing grounds.
	Wages for fishing crew	Wages are a fixed share of the revenue and has increased	Wages will reduce during depreciation period.	Profitability will be reduced slightly

	Monetary value produced for society	Landings of the fishery has remained the same as these are controlled by quota / TAC.	Landings may increase or public image of fishery may improve due to more environment friendly fishing.	May increase as public image of fishery improves due to more environment friendly fishing.
	Reduce cost of management	Pulse trawling is currently conducted under a temporary derogation.	Pulse trawling is currently conducted under a temporary derogation.	Administration of habitat credits and its enforcement will increase management cost
Social	Fair distribution of impacts	Profits are restricted to a selection of fishers who have granted the temporary derogation.	Social benefits may be restricted to innovative fishers that may outcompete others.	No change. Some fishers may lose access to fishing grounds and face increased competition from other vessels
	Good labour conditions	Labour conditions have improved because of lower maintenance and lower bycatch volume (shorter processing time of a tow).	Potential shorter sorting time of the catch, if improved selectivity is a goal.	unknown
	Employment	Unchanged	Slight increase for pulse gear manufacturer.	unchanged
	Good governance	Unchanged	Unchanged	Compliance may be jeopardised. Habitat credits may be incorporated in MSC certification