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SUMMARY

In the BENTHIS project we distinguished different levels of decision-making for which Decision Support Tools (DSTs) can be developed. One is at the level of the fisher where the actual fishing activity involves a vast array of decisions that not only determine the composition and size of the catch but also the fishing impact on the seafloor. The other is at the level of the fisheries manager where the decision-making 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.

Two different decision-support tools are presented here:

(1) Seafloor Impact Risk Reduction (SIRR) aimed to reduce the impact of fishing on the seafloor through a change in the behaviour of the fisher. This also has the potential to be developed into a management tool.
(2) Multi-Criteria Analysis (MCA) for the evaluation of management strategies taking stakeholder preferences into account.

The SIRR is based on an ecological risk assessment which, in line with the requirements of the DPSIR framework often applied for Ecosystem-Based Fisheries Management (EBFM), can cover both the pressure caused by fishing, as well as the degree to which the seafloor and its benthic community are impacted. The DST aims to achieve a reduction of the risk that the seafloor is impacted through a change in behaviour of the fishers. This change in behaviour should be accomplished by providing the fishers with a detailed spatial map showing the areas where seafloor integrity is closest to the policy goal of "Good Ecological Status"(GES) and hence the risk that the seafloor is impacted is highest, together with an incentive to avoid those areas. Various fisheries credit systems exist which have shown considerable potential for incentivizing changes towards achieving management goals that improve the environmental performance of fisheries. However, incentivizing a reduction of fishing impact on the seafloor can only be achieved if this does not reduce their catch opportunities. To that end we studied the relationship between the status of the seafloor (i.e. seafloor integrity, SI) and the fishing impact on the seafloor (i.e. uptake of Seafloor Integrity Quota, SIQ) with the catch opportunities reflected in four metrics that capture the catch opportunities of the fleet and its performance in terms of its catch efficiency in relation to swept area or seafloor impact. This showed that the highest efficiencies are achieved in the areas with the lowest SI and thus least SIQ uptake confirming the potential of the SIRR as a tool that reduces the fishing impact on the seafloor.

In the second part of this report, we present a quantitative tool which evaluates the impact of fisheries on the benthic ecosystem taking stakeholder input into account. Making the stakeholder preferences explicit can lead to a greater understanding of different stakeholder positions and thus increase awareness of the issues involved and the root of any conflict. It is proposed that the mult-criteria analysis is based on the Analytical Hierarchy Process. The value that stakeholders' attach to objectives of fisheries management is calculated using pair-wise comparison. The tool is designed to be used by case-study leaders.

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1 INTRODUCTION

In the BENTHIS project we distinguished different levels of decision-making for which Decision Support Tools (DSTs) can be developed. One is at the level of the fisher where the actual fishing activity involves a vast array of decisions that not only determine the composition and size of the catch but also the fishing impact on the seafloor. The other is at the level of the fisheries manager where the decision-making 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.

1.1 Two different decision-support tools in BENTHIS

BENTHIS aims to prepare two different decision-support tools (DST). These DST have different objectives, different target-groups and a different position in the project (see Table 1.1). This deliverable reports on the methodological development of both these DST.

Table 1.1: Two Decision support tools in BENTHIS

DST	**Seafloor Impact Risk Reduction (SIRR)**	**Multi-criteria analysis (MCA)**
Objective	In collaboration with some of the SMEs we aim to develop a decision-support tool that provides information that helps fishers take account of their impact on the seafloor when deciding to fish in a particular area or not. The performance of this tool will be assessed using the VMS data generated as part of the project.	The MCA will assist by structuring discussions and improving communication among stakeholders, leading to additional insight on possible solutions to the issues in a more transparent manner, as well as providing a documented basis for possible modifications of the decision in the future
Target group	Fisher	Stakeholders involved in fisheries management
Position in the project	Methodological development First results available	Methodological development To be applied by case-study leaders

2 DST 1: A RISK-BASED APPROACH FOR ECOSYSTEM-BASED MANAGEMENT AIMED AT CONSERVING SEAFLOOR INTEGRITY

2.1 Introduction

Fishing is known to be the main human activity affecting marine ecosystems and this occurs through several different pressures (Jennings and Kaiser, 1998; EEA, 2015). By the nature of the activity the main pressure is probably biological disturbance through the catch of target-, but also non-target, species. However an increasing body of evidence is pointing towards the significant adverse impacts of another pressure, i.e. physical damage of the seafloor and its benthic community, that is the result of those fishing activities targeting bottom dwelling fish species, which comprise about 23% of the global fisheries yield (FAO, 2009). While extensive fisheries management measures are in place to mitigate the biological disturbance to sustainable levels, e.g. through reductions in fishing effort or catch quota, this is still rather piecemeal in case of physical damage as implementation of MPAs is fraught with ecological, economic, and social problems (Agardy et al., 2003; Kaiser, 2005). In EU waters this is now changing with the introduction of the Marine Strategy Framework Directive (MSFD) of which one objective states that "Seafloor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected" (EC, 2008b). In order to achieve "Good Environmental Status" (GES), the ultimate goal of the MSFD, two criteria need to be considered, i.e. "Physical damage, having regard to substrate characteristics" and "Condition of benthic community".

Although it is widely accepted that Ecosystem-Based Fisheries Management (EBFM) is required to mitigate the adverse effects of fishing on the ecosystem (Browman and Stergiou, 2004a; Hall and Mainprize, 2004) this mostly involves fishing mortality affecting the commercial (shell)fish stocks while another important effect of fishing, i.e. physical damage to the seafloor and its associated benthic community (Botsford et al., 1997; Pikitch et al., 2004), is often ignored. Physical damage is interpreted as encompassing more specific pressures such as "abrasion" and "changes in siltation" (EC, 2008) affecting the physical habitat but also "death or injury by collision" which may affect the associated benthic invertebrates but is usually considered under "other physical disturbance" (OSPAR, 2014).

Three assessment methodologies for fisheries management in relation to seafloor integrity are distinguished by (Fock et al., 2011), i.e. pressure-state-response (PSR) models aiming at indicator-based management concepts (Greenstreet et al., 2009; Link et al., 2010; Rochet and Rice, 2005), process-based ecological risk assessment (ERA) models able to treat uncertainty in data and processes (Fock, 2011(Landis and Wiegers, 1997; Hayes and Landis, 2004)), and score-based impact or vulnerability models preferably useful for broad scale assessments due to the wide range of impacts analysed and the many ecosystem components covered ((Ban et al., 2010; Stelzenmuller et al., 2010; Halpern et al., 2008)). PSR models ((OECD, 1993)) and its extended form (DPSIR) are considered state-of-the-art for integrated marine assessments and policy advice in Europe (EEA, 2015). In both the ERA and the PSR framework, the link between pressure and ecosystem component is treated differently (Fock et al., 2011). In the PSR framework, the state indicator relevant for policy and used to generate the management response is a direct consequence of the pressure. But due to a number of caveats, e.g. a pressure-state relationship that is absent or poorly understood, the state indicator has limited operational properties (Fock et al., 2011). In the ERA this is resolved by introducing risk as an operational property that is fully reactive to the pressure, but also linked to the ecosystem state. In addition, risk as it is used in ERAs should allow the quantification of impact such that mitigation or management measures can be included and the risk acceptance in society is reflected in the operational management objectives (Stelzenmuller et al., 2015). (Stelzenmuller et al., 2010) defined impact as a function of the vulnerability of ecosystem components and the likelihood of occurrence and magnitude of a pressure. The vulnerability of an ecosystem component, in turn, was defined by exposure and sensitivity to a pressure as well as its recovery potential ((De Lange et al., 2010)). The sensitivity to a pressure is due to structural properties, functions, or trophic relations of the ecosystem component while recovery depends on population recovery, resilience, positive feedback loops, and adaption ((Tyler-Walters et al., 2001; Hope, 2006) Halpern et al., 2008).

This study thus presents an ERA which, in line with the requirements of the DPSIR framework often applied for EBFM, can cover both the pressure caused by fishing, as well as the degree to which the seafloor and its benthic community are impacted. The ERA was used to assess the status of the two MSFD criteria for seafloor integrity against GES, and develop a management approach aimed at reducing fishing pressure on the seafloor. This approach is also aligned with the concept of habitat vulnerability where a habitat is considered to be vulnerable when it is exposed to a pressure (from human activity) to which it is sensitive (Tyler-Walters et al., 2001). The degree to which the feature is vulnerable is dependent on the degree of sensitivity and the level of exposure to the pressure. Sensitivity is defined as the degree to which a species or habitat responds to a particular pressure, taking into consideration the resistance (tolerance) of a habitat or species to a pressure and the time it would take to recover (resilience) (Tillin et al., 2006).

The MSFD requires for an assessment of status against GES the specification of a boundary (or threshold value) between an acceptable and an unacceptable condition (EC, 2011). For the setting of GES boundary values in this status assessment we followed the conclusion in (Rice et al., 2012) that GES cannot be defined exclusively as “pristine Environmental Status” but rather as the status when impacts of all uses are sustainable. Therefore our risk assessment specifies two boundaries which capture those perspectives and are aligned with the two GES criteria. The first, and least stringent, GES boundary which applies to the Physical damage criterion is based on the sustainability criterion and requires the level of fishing disturbance to be below the recovery capacity of the benthic community. The second GES boundary is based on the assumption that seafloor integrity is not compromised in an unfished situation. This implies, obviously, that the part of a habitat which is unfished is in GES but also that those parts of the habitat that were previously fished but left undisturbed for a period longer than the recovery time of that habitat, are in GES. (Hiddink et al., 2006) used the proportion of an area where benthic invertebrate biomass or production was more than 90% of their pristine levels as an indicator of state and the proportion of the area where trawling frequency prevents reaching these 90% of pristine levels as the pressure indicator. Splitting the study area into small grid cells on which these boundaries can be applied is therefore a requirement to evaluate the two aspects of GES taking account of the variability in fishing patterns across the study area, Aggregation across grid cells will then give an overall assessment of seafloor status . Based on the OSPAR 'Texel-Faial' criteria less than 15% of the total area of the habitat should be lost or damaged in terms of its "specific structures and functions, including typical species" (OSPAR, 2011). Under the EU Habitats Directive a habitat is classed as 'Unfavourable-Bad' if more than 25% of the extent of the habitat is damaged (EC, 2006).

Fisheries credit systems show considerable potential for incentivizing changes towards achieving management goals that improve the environmental performance of fisheries, by supplementing rather than replacing existing management approaches (Van Riel et al., 2015). This contribution to ecosystem-based management aimed at conserving seafloor integrity involves a fisheries credit system where behavioural credits (Van Riel et al., 2015) are applied based on the assumption that the behaviour of fishers can be influenced through incentives aimed at reducing their fishing impact on the seafloor. An example of such a fisheries credit system is the real-time incentives (RTI) fisheries management approach proposed by (Kraak et al., 2012) as a potential contribution to the development of adaptive and ecosystem-based fisheries management (EBFM). This approach goes beyond the management of the abundance and fishing mortality of single commercial species and includes mixed-fisheries and multispecies interactions as well as the effects on the wider ecosystem. The approach is implemented through quotas of fishing-impact credits through tariffs. The basis of the approach is that the area would be divided up into grid cells, each with a certain "cost" applied to fishing in that cell. Fishers would then "pay" these costs in RTIs from their individual RTI account, allocated at the start of the management period, e.g. year. The costs, or tariffs (e.g. in RTIs per day), associated with fishing in each of the cells would be shown on colour-coded tariff maps. Using these maps, fishers are then free to fish when and where they choose as long as their RTI credit lasts; they would not be allowed to exceed their RTI quota once they have exhausted it. The approach allows a shift from top–down regulation (Daw and Gray, 2005) towards strengthened stakeholder participation in fisheries governance, as reflected in the Green Paper (EC, 2009) of the European Commission (EC) on the new Common Fisheries Policy (CFP; (EC, 2013)). An essential part of the approach is that through simulations the tariffs can be related to the levels of risk of under- and overshooting the various targets or objectives; these risk levels can be set explicitly by managers in a transparent way (reflecting societal choices). The approach is adaptive: if it fails to deliver some stated aim or objective on a particular time-scale, the tariffs can be adjusted up or down, for example, at annual time-scales (Kraak et al., 2012). This paper introduces an application of a fisheries credit system which, in contrast to the RTI approach aimed at reducing the fishing impact on the wider ecosystem, specifically aims at the seafloor habitats and their benthic invertebrate communities, but without affecting the catch opportunities (Lambert et al., 2014). Similar to the existing management using catch quota to mitigate the fishing pressure on the stocks this application uses quota to reduce the footprint of fishing on the seafloor. We therefore propose Seafloor Integrity Quota (SIQ) for this application of a fisheries credit system toward the achievement of the Marine Strategy Framework Directive (MSFD) objective on sea-floor integrity (EC, 2008b). The risk-based approach will be used to calculate fishing impact on the seafloor and assess the performance of the fishery in terms of its efficiency expressed as catch or revenue per amount of physical damage. Only if this efficiency is shown to vary depending on behaviour of the fishers is there scope for this management tool based on behavioural credits to be used as part of EBM to reduce the fishing disturbance of the seafloor.

2.2 Material and methods

This risk-based approach for EBFM aimed at conserving seafloor integrity is based on an assessment of the risk that seafloor integrity is compromised which is calculated based on the Risk concepts of Exposure and Effect. This study is based on the North sea, one of the few European marine regions for which all the information required for such an approach is available, i.e. a basin-wide coverage of a seafloor habitat map (based on EUSeaMap) distinguishing the main (EUNIS level 3) habitats and annual fishing intensity maps (period 2010-2012) at appropriate spatial scale covering, and distinguishing, all the main fleet segments that disturb the seafloor. For the spatial scale we applied grid cells of 1x1 minute (approximately 2 km^2), the temporal scale was annual but other spatio-temporal scales may be applied.
The method follows the DPSIR (Drivers, Pressures, State, Impacts and Response) analytical framework often applied for EBM (Atkins et al., 2011; Knights et al., 2013) and specifically EBFM (Martins et al., 2012) but applies an ERA to estimate Pressure, State, Impact and propose a management Response. The operational property, i.e. the risk that seafloor integrity is compromised, is closely aligned to the aim of the main EU policy framework, the Marine Strategy Framework Directive (MSFD) requiring seafloor integrity to be in Good Environmental Status (GES). The risk that seafloor integrity is compromised is based on our knowledge of the exposure of the seafloor to fishing pressure and an understanding of the effect fishing has on the state of the seafloor. The management response is based on a fisheries credit system that applies SIQ to mitigate fishing impact on the seafloor.

2.2.1 DPSIR: State expressed as Seafloor integrity

For the main EU policy framework, i.e. the Marine Strategy Framework Directive (MSFD) the state of the seafloor is captured by the phrase seafloor integrity and quality is expressed in relation to Good Environmental Status (GES). In this study the state of the seafloor, i.e. seafloor integrity ($Si_{g,t}$), at some point in space (grid cell g) and time (t) is determined by the combined effect of a recovery rate (RR) and a physical damage rate, based on Instantaneous Effect (IE) and (historic) fishing intensity FI (see Table 1 and Figure 1). The state of the seafloor $Si_{g,t}$, can therefore be estimated as an equilibrium value (Figure 2), which is essentially a fraction of carrying capacity K, using the following formula:

$$SI_{g,t} = K_g - \left(\frac{1-\left(1-IE_g\right)^{HFI_{g,t}}}{RR_g}\right)K_g$$

$$\overline{SI_t} = \frac{\sum_{g\in[1,G]} SI_{g,t}}{G}$$

Where HFI is the historic fishing intensity over the long term and the parameters RR and the IE are determined by the gear-habitat combination (Table 1). For pragmatic reasons (i.e. data availability) this “long term” will need to be based on the period for which data are available, i.e. one year in this study, in order to allow the consistent calculation of SIQ (see below) in two of the three years for which data were available. Thus, even though in this study $HFI_{g,t}$ is effectively equal to $FI_{g,t-1}$ we chose to use $HFI_{g,t}$ as longer periods can be used if more data are available.

Our interpretation of seafloor integrity based on IE and RR is therefore clearly tied, albeit loosely, to the concepts of respectively resistance and resilience in the definition of sensitivity by (Tillin et al., 2010). Therefore we assume that the sensitivity of the seafloor (or specific habitat) to fishing pressure (Piet et al., 2007; Hiddink et al., 2007) at some point in time follows from the state of the seafloor which is determined by the type of habitat and previous fishing disturbance. If fishing intensity in a particular year and grid cell is at a (gear- and habitat-specific) level that would result in the equilibrium value that characterizes seafloor integrity because it matches the recovery rate, there will be no (further) impact on the seafloor in that grid cell and fishing can be considered sustainable. Over the entire marine region this can also be achieved after aggregation across grid cells if the recovery in some (often unfished) grid cells matches the (further) impact in other grid cells that are fished.

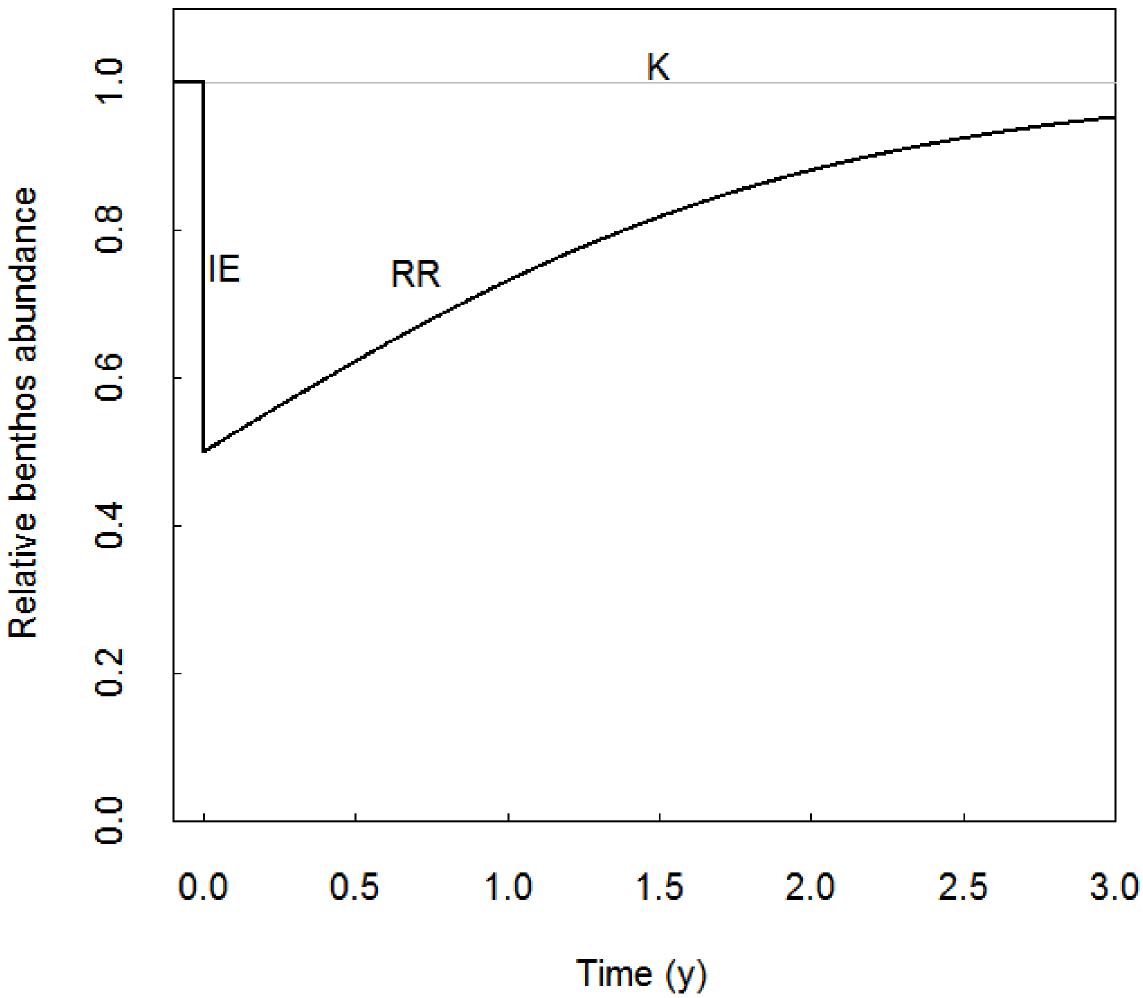

Figure 1. Schematic of the parameters defining the logistic recovery rate. *d* is the instantaneous effect (IE) caused by trawling, *r* is recovery rate (RR), *K* is the carrying capacity, here defined as the before or control density/biomass and set to 1 for all analyses.

To determine if seafloor integrity is compromised because policy targets are not met, we apply the (EC, 2006) criterion that there should be "no significant deterioration in quality or pressures threatening" where the last part, i.e. "no pressures threatening", links to our first GES boundary and the first part, i.e. "no significant deterioration in quality", links to our second GES boundary. Figure 2 shows how these two criteria are related because if applied consistently over the long term a specific pressure (i.e. type of gear fished at a specific trawling frequency) will result in a specific deterioration in quality (dependent on the habitat). Table 1 shows how the concept of significant deterioration (i.e. 80%, 90% or 95%), determines which trawling frequencies can be considered "threatening". For example in biogenic habitat any pressure is "threatening" independent of what "significant deterioration in quality" is allowed because there is no recovery. In the most common habitat in the North sea, i.e. Sublittoral sand covering almost 60% of the area, a 95% threshold would allow a patch to be fished once every 7 years (frequency < 0.14) before it would be considered "threatening". In contrast, in case of the application of an ottertrawl (OT) in a gravel habitat, this same 95% deterioration in quality threshold would determine any fishing intensity <2.66 yr^{-1} as not "threatening".

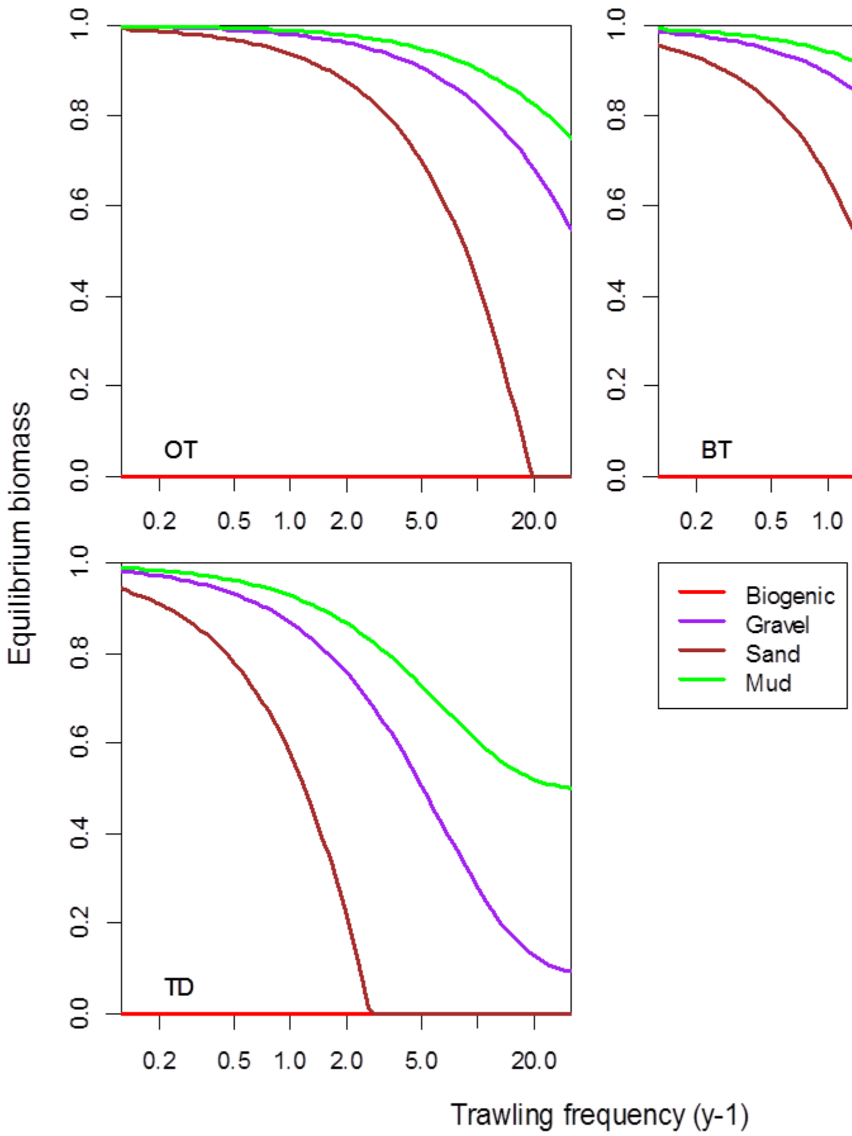

Figure 2. A risk-based measure of seafloor integrity reflecting habitat sensitivity (=Equilibrium biomass, i.e. total biomass of the benthic community relative to that at carrying capacity) at different trawling intensities for three trawling gears (OT=Otter trawl, BT=Beam trawl and TD=Dredge) and four habitats.

2.2.2 DPSIR: Fishing pressure affecting the seafloor

Fishing pressure affecting the seafloor (i.e. Physical Damage) is usually expressed as the extent of surface area that is threatened by those segments of the fleet that use towed fishing gears and the literature distinguishes several potential indicators that capture this (Piet and Hintzen, 2012; Fock et al., 2011; Rijnsdorp et al., In press). It is also well established that bottom trawling is patchy and that this patchiness needs to be taken into account to assess the impact of trawling on the benthic ecosystem (Rijnsdorp et al., 1998; Lee et al., 2010a; Ellis et al., 2014). Therefore all of these indicators involve the calculation of a surface area that is considered threatened based on estimates of fishing intensity per grid cell, for example: the surface area disturbed by fishing (i.e. summation of all grid cells in which trawling was recorded), surface area disturbed more than a specific threshold (e.g. frequency > 1 yr^{-1}) or the surface area of the most intensively trawled grid cells (e.g. encompassing 90% of the annual fishing effort).

Our calculation of fishing intensity was based on the hourly swept area, i.e. footprint, as calculated by Eigaard et al. (2015) for all major European fishing gears distinguishing between surface impact only and one where both surface and subsurface are impacted. While this allows a distinction between these different aspects of the seafloor when estimating risk our estimation makes no distinction including both surface and subsurface.

2.2.3 DPSIR: Fishing impact on the seafloor

In this study the impact (*IM*) due to physical damage is expressed as the difference in *SI* caused by the annual *IE* calculated per grid cell *g* in year *t* after which it is averaged across all grid cells in the marine region according to the following formula:

$$IM_{g,t} = SI_{g,t} - SI_{g,t-1}$$
$$\overline{IM_t} = \frac{\sum_{g \in [1,G]} IM_{g,t}}{G}$$

Where SI_g is the total species abundance in grid cell *g* and IE_g is the instantaneous effect expressed as a proportional loss in total species abundance (Table 1 and Figure 1) per encounter of the gear and the habitat. The average *IM* of the entire grid is calculated as the sum of all *IM*'s per grid cell *g* divided by the total number of grid cells *G*.

Fishing pressure and impact can also be calculated for a specified subset of the fishing activity, e.g. a particular fleet segment, fishing vessel or trip, in order to guide EBM aimed at reducing the fishing pressure and/or impact on the seafloor. This partial fishing pressure then reflects the relative contribution of this subset, i.e. fleet segment, fishing vessel or trip, to the overall damage rate.

2.2.4 DPSIR: Management response

Footprint management is based on the risk that seafloor integrity is compromised (similar to the risk of overshooting the intended catch levels or undershooting fishing mortality rates in Kraak et al., 2012) and how fishing activity contributes to this. This risk is calculated based on Exposure and Effect and translated into SIQ of which the annual uptake (per vessel, per trip) can be recorded and management measures can be implemented to reduce this uptake.

The exposure of the seafloor (or any specific habitat) to fishing is determined by the number of grid cells exposed to fishing but without any consideration of the intensity. This is therefore identical to the "Proportion of the surface area fished" considered by the EU Data Collection Framework (EC, 2008a) as a potential indicator for fishing pressure. Piet et al. (2012) calculated the indicator for the Dutch EEZ in the North sea, period 2001-2010, this study covers the entire North Sea and information on fishing effort was available for the period 2010-2012.

The effect in each grid cell depends on the instantaneous effect (*IE*), the state of the seafloor (reflected in the *SI*) and the recovery potential of the habitat (reflected in the *RR*) and is expressed as the time to recover from that impact (Figure 3). The SIQ can thus be calculated as the summation across grid cells of the time to recover from this impact according to:

$$SIQ_t = \sum_{g \in [1,G]} (\ln\left(\frac{\frac{\left(1-IE_g\right)^{FI_{g,t}}}{SI_g} - \left(1-IE_g\right)^{FI_{g,t}}}{1 - \left(1-IE_g\right)^{FI_{g,t}}}\right) / -RR_g)$$

In this study we explore the potential of footprint management to decrease the fishing impact on the seafloor (reflected in a lower SIQ uptake) through incentives that change the behaviour of fishers. This, however, can only succeed if this change in behaviour does not reduce their catch opportunities. Therefore we assessed the performance of the fishing fleet in terms of catch opportunities relative to seafloor impact using several metrics: catch (kg), revenue (€), catch per swept area, and catch per SIQ uptake where the latter two are the most informative as they reflect the efficiency of achieving these catches (or actually landings as recorded in the logbooks) in relation to the fishing impact on the seafloor. To that end we assigned catches to VMS pings that were associated with fishing, evaluated separately by ship and trip. Swept area (km^2) per grid cell was calculated as the time interval between VMS pings that are positioned within a specific grid cell times gear width (Eigaard, 2015) and instantaneous speed recorded at each VMS ping. RPUE was calculated from CPUE by multiplying catches to their species-specific average monthly price. For each trip the total trip catch was obtained from logbooks and revenue calculated from those catches and records of market value per species.

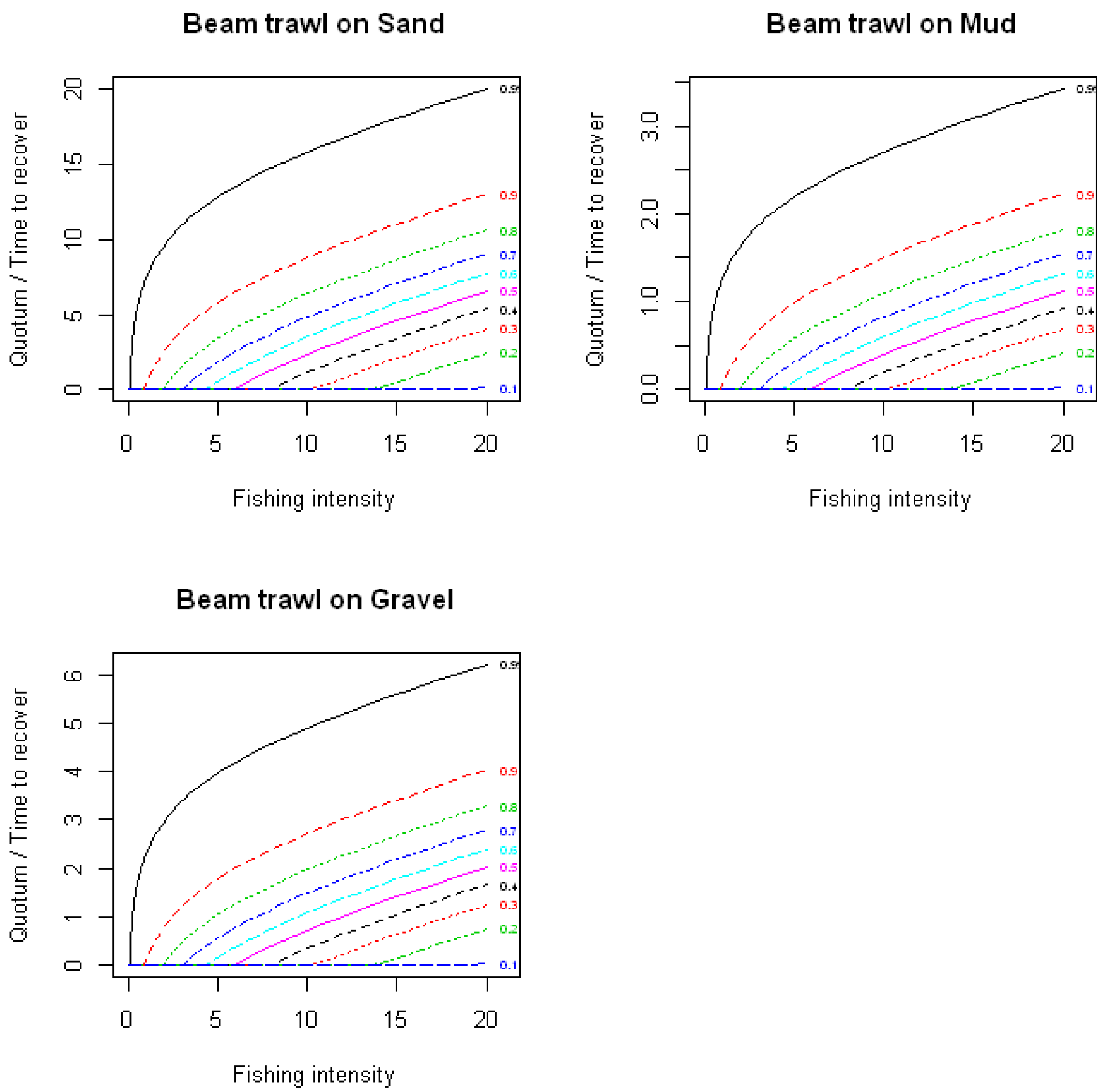

Figure 3. Quota uptake expressed as time to recover in relation to fishing intensity and at different seafloor integrity (SI) values varying from very bad (0.1) to untrawled/fully recovered (0.99).

2.3 Results

Based on the Dutch bottom-fishing fleet in the North sea period 2010-2012 (~300 vessels, ~14.000 trips, ~30.000.000 kWDays) we estimated the state of each grid cell, i.e. seafloor integrity, which determines its sensitivity to fishing and hence the impact that a specific level of fishing intensity will have. For each grid cell with known seafloor integrity we calculated four metrics that capture the catch opportunities of the fleet and its performance in terms of its catch efficiency in relation to swept area or seafloor impact (Figure 4). Both catches and revenue show a similar decreasing trend with decreasing seafloor integrity across all SI categories except for the grid cells with lowest seafloor integrity. This is probably because effort (i.e. swept area) is low as the catch per swept area shows the highest efficiency in those grid cells.

Catch per SIQ uptake could not be calculated for the SI categories ≤ 0.4 as the SIQ uptake equals 0 in those grid cells preventing calculation of the ratio. The remaining grid cells show a huge significant decline (note the logarithmic scale) of the catch efficiency in relation to seafloor impact expressed as SIQ uptake. Most grid cells are relatively undisturbed with more grid cells in the risk categories 0.6 and up (together making up >95%) than in the most heavily perturbed grid cells with lowest seafloor integrity (≈3%).

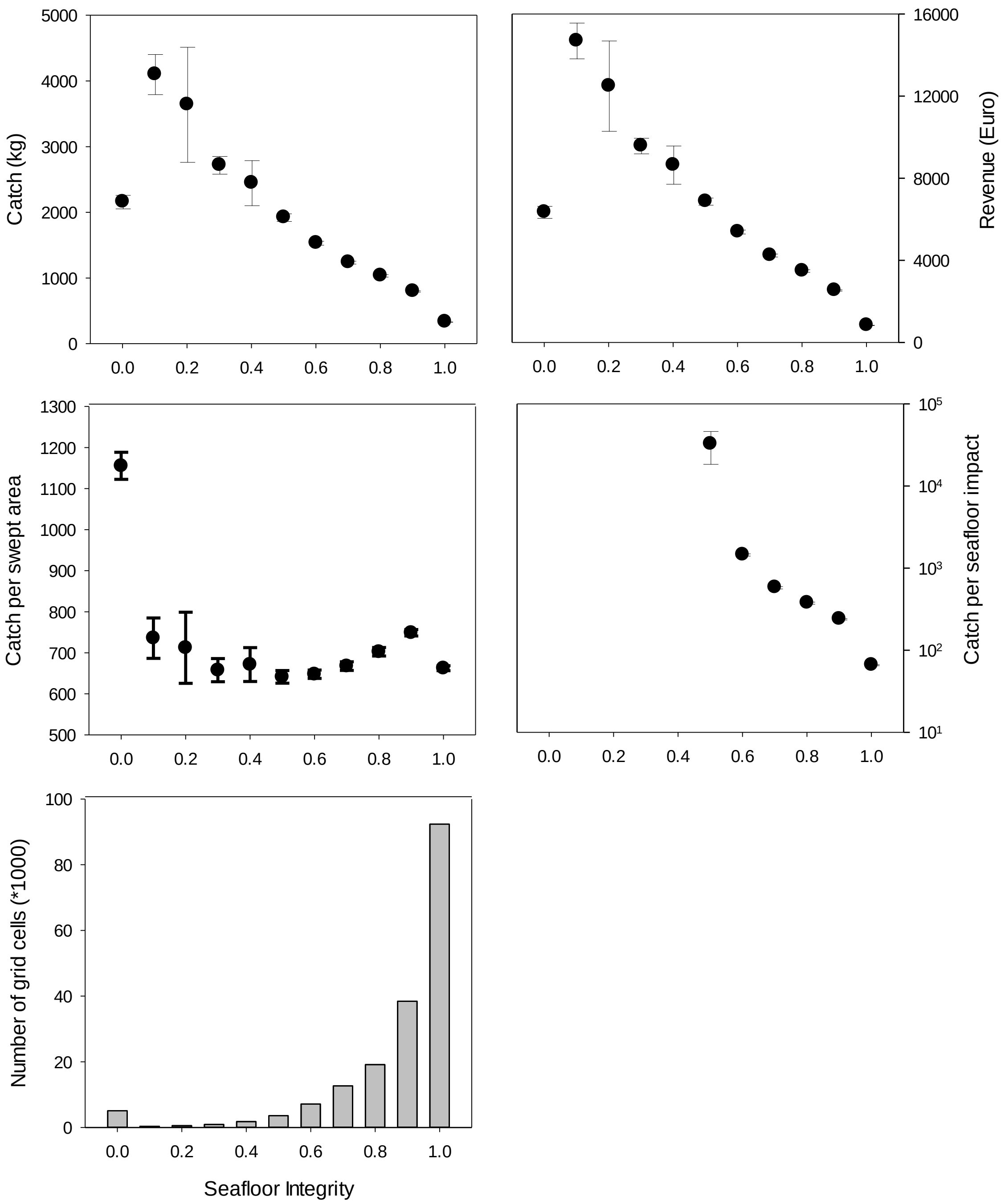

Figure 4. Catch opportunities per grid cell with specified seafloor integrity. Shown are average and 95% confidence limits of the Catch, Revenue and catch efficiencies in relation to fishing effort (i.e. catch/swept area) and seafloor impact (i.e. catch/SIQ uptake). The number of gridcells per category is shown below.

For the two main segments of the Dutch fleet, i.e. small (engine power <221 kW, 13351 trips) and large beam trawlers (engine power ≥221 kW, 6757 trips) we calculated the relationship between the total uptake of SIQ representing the contribution of each trip to the risk that seafloor integrity is compromised and four metrics that may represent the performance of that segment of the fleet: catch (kg), revenue (€), catch per swept area, and catch per SIQ uptake (Figure 5). This shows, not surprisingly, that both the amount of fish landed and the revenue increases with the total uptake of SIQ. What is more relevant in terms of performance in relation to the conservation of seafloor integrity is that both metrics of catch efficiency in relation to (potential) seafloor impact show decreasing trends, considerably more so for the catch per SIQ uptake. This shows that the decision to opt for a more conservative strategy, i.e. low SIQ uptake, improves the performance in terms of both catch per swept area and catch per SIQ uptake. For example this increased catch efficiency implies that a shift well within the observed range of total SIQ uptake per trip from 1 to 10 for the small beam trawlers results in a damage reduction by factor 7.4. Thus the same amount of catch requires a factor 7.4 less time to recover. Or inversely 7.4 times more catch can be obtained for the same amount of seafloor damage. For the large beam trawlers a similar but slightly lower reduction by factor 4.3 was observed for a shift from 10 to 100 total SIQ uptake per trip.

Interestingly there is a marked difference in performance between the two segments depending on the metric. The large beam trawlers perform worse than the small beam trawlers in terms of catch per swept area but considerably better in terms of catch per SIQ uptake.

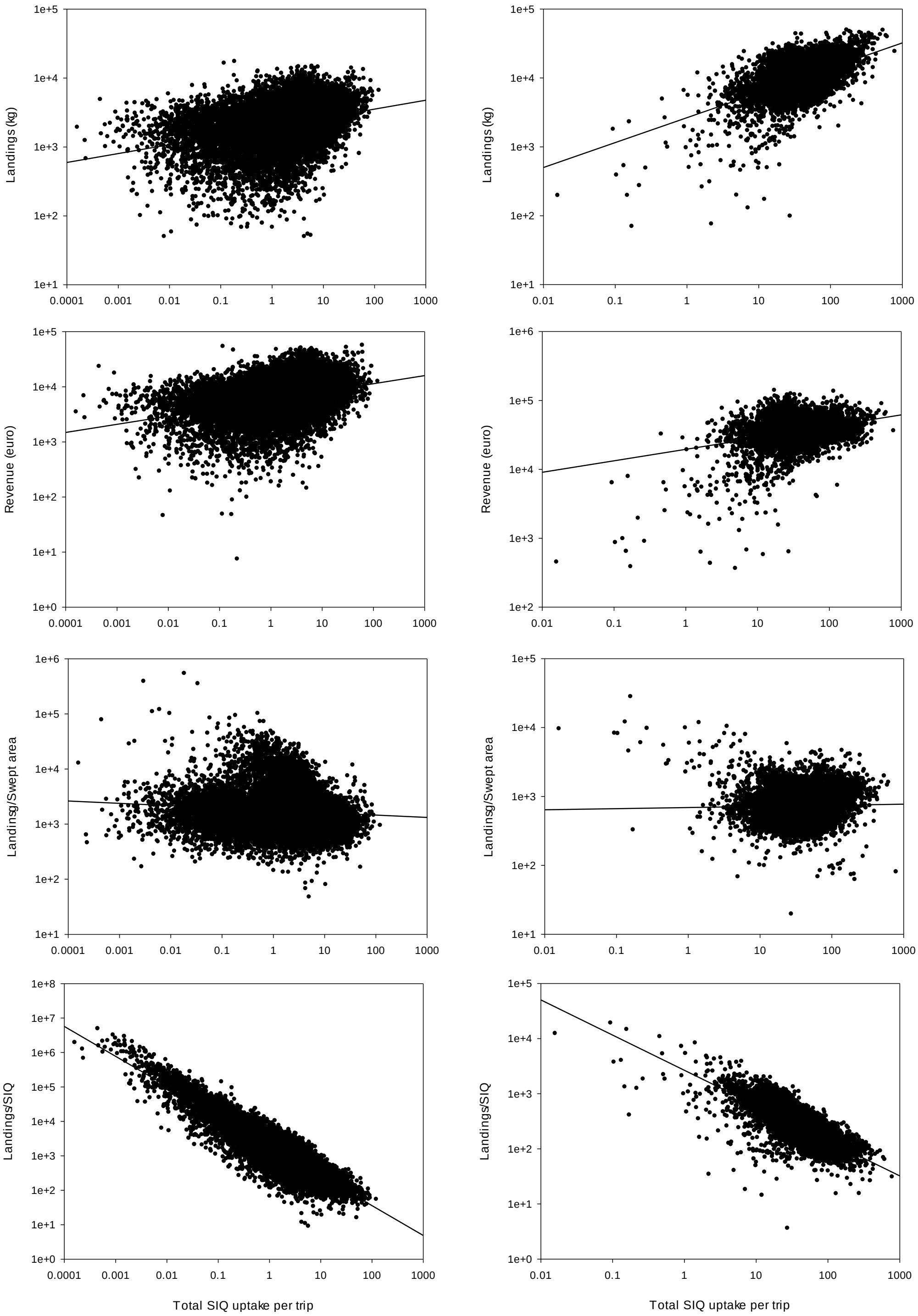

Figure 5. Relationship between the total damage per trip expressed as uptake of SIQ and four catch opportunity metrics, i.e. landings (kg), revenue (€), landings per swept area, and landings per SIQ uptake. that may represent the performance of the two main sectors of the Dutch fishing fleet: small beam trawlers (so-called euro-cutters with engine power <221 kW, left) and large beam trawlers (engine power ≥221 kW, right).

2.4 Discussion

This application of a risk-based approach provides the framework to assess both the state of the seafloor and the main pressure, i.e. physical damage, through which fishing impacts that seafloor. This risk is based on the exposure to fishing pressure and sensitivity of the seafloor and translated into so-called SeaFloor Integrity Quota (SIQ) which are at the basis of a potential management response, i.e. footprint management. Foot print management aims to mitigate the impact on the seafloor through a change in behaviour of the fishers where they avoid relatively undisturbed areas (with high risk and thus high SIQ uptake), fishing mostly in areas that have a history of disturbance and therefore contribute less to the risk that overall seafloor integrity is compromised (and hence low SIQ uptake). This change in behaviour, however, can only be achieved if it does not negatively affect their catch opportunities. This was tested using several metrics reflecting the performance of the fishing fleet in terms of catch (or revenue) efficiency in relation to swept area or seafloor impact showing that the decision to adopt a more conservative strategy results in a significant improvement of the catch efficiency. Hence the expectation that footprint management has potential to reduce fishing impact on the seafloor and can contribute to the conservation of seafloor integrity.

While marine protected areas (MPAs) are the obvious choice in ecosystem-based management to protect the seafloor (Roberts et al., 2001; Browman and Stergiou, 2004b), footprint management can certainly contribute to the achievement of conservation goals without one of the main problems of the implementation of MPAs, i.e. the displacement of effort (Dinmore et al., 2003; Kaiser, 2005), as this concentrates fishing activity rather than displaces it. The concentration of fishing into intensively fished areas, but with relatively high catch efficiencies, leaving nearby patches unfished should result in an increased recovery as it enhances recolonization rates (Lambert et al., 2014) but without short-term negative socio-economic impacts (Richardson et al., 2006) through the loss of or increased travelling time to fishing grounds, and decreased overall catches (Jones, 2001) and as such probably compares to partially protected marine areas as a more viable management strategy (Sciberras et al., 2015).
Implementation of MPAs is often difficult as fishers usually have negative attitudes towards MPAs, especially when implemented for the purpose of conservation rather than for fishery management (Pita et al., 2011). Behavioural credit systems incentivize fishers to gradually change their fishing behaviour to more sustainable fishing methods (Van Riel et al., 2015) and thereby avoid the resistance and lack of compliance often associated with the implementation of MPAs (Agardy et al., 2003). In our observation of the behaviour of the fishers we found a gradient from more “conservative” trips visiting mostly (or exclusively) areas that were also fished last year resulting in relatively high catch efficiencies to more “explorative” trips visiting new grounds and hence lower efficiencies (see figure 4). Implementing SIQ as part of a behavioural fishery credit system is therefore likely to stimulate fishers to gradually change toward more conservative trips without much of the resistance invoked by MPAs.

The observation that the catch per swept area is highest in the areas with low SIQ uptake because they were recently trawled fits with the notion of fishermen that bottom trawling ‘‘farms the sea’’ (Rijnsdorp and Van Beek 1991). The idea behind this is that ploughing the seabed with bottom trawls increases the production of the small benthos that flatfish feed on by removing the large fauna that small benthos compete with over food and space. The higher production of the preferred food should then result in the aggregation of flatfish in the patches trawled in the previous year which because of that also has a lower seafloor integrity and thus conservation value. Evidence for such aggregations has also been found for Atlantic cod (Gadus morhua) and haddock (Melanogrammus aeglefinus) in the North Sea ((Blanchard et al., 2005; Hiddink et al., 2005)).

This risk-based approach is flexible with regard to the choice of indicators or thresholds. In this study we used benthic invertebrate abundance as the indicator for seafloor integrity and assess the consequences of applying different thresholds (i.e. 80%, 90% or 95%). For an assessment of fishing impact on seafloor integrity (Hiddink et al., 2006) used benthic invertebrate biomass or production as indicator of state and the trawling frequencies that prevent achieving a 90% of pristine level threshold as indicator of pressure which was adopted by (Fock et al., 2011) in his disturbance indicator based on the ratio of recovery to mortality. In contrast (van Denderen et al., 2014) used species richness and Rijnsdorp et al (in press) used longevity as indicators for the status of the benthic community. While our choice of total abundance Similar to (Hiddink et al., 2006) and (Fock et al., 2011) is probably the best option given the information available the aim should be to develop more sensitive indicators to reflect the impact of fishing on the seafloor and its benthic community. One possible way forward would be to develop a more sensitive indicator by selecting only the most sensitive species and/or traits (Rijnsdorp et al., In press). These traits could be selected based on their potential relationship to the two aspects that determine risk, i.e. Exposure and Effect. For Exposure the traits to consider should involve e.g. their position in relation to the surface where epibenthic invertebrates are more sensitive than deep-burrowing infauna. For Effect the candidate traits could include morphology where fragile species are more sensitive. As the recovery potential of a species also determines sensitivity in this assessment traits capturing the life-history characteristics and/or recolonizing ability could also be considered, where e.g. sessile species with high longevity (sensu (Rijnsdorp et al., In press) are more sensitive. Application of a more sensitive indicator will result in a more precautionary assessment and management.

This risk-based approach provides the framework that would allow an assessment of the status of the seafloor, i.e. seafloor integrity, in relation to the two MSFD criteria for GES, i.e. (1) "Physical damage, having regard to substrate characteristics" and (2) "Condition of benthic community" and has shown that these two criteria are inter-related. As such, and according to the ERA requirements, risk is indeed the operational property that is fully reactive to the pressure, but also linked to the ecosystem state (Fock et al., 2011). However, in order to fulfil another ERA requirement, i.e. to allow the quantification of impact to guide management (Fock et al., 2011) a distinction between an acceptable (i.e. GES) from an unacceptable condition (EC, 2011) needs to be established for both GES criteria. This requires political and scientific choices on the setting of boundaries (or thresholds) and development on what should be considered the most appropriate indicator to measure "seafloor integrity". The following considerations apply:

- Before any boundaries can be established political choices need to be made on what is considered "unacceptable". For the 2nd GES criterion this is linked to how much uncertainty is allowed before deterioration becomes "significant" and a habitat would be considered "damaged". If we accept that the two GES criteria are inter-related it emerges that any choice on the boundaries for the 2nd criterion also determines the boundaries for the 1st GES criterion (see our table 1 and figure 2). The existing indicators for the 1st GES criterion (Piet and Hintzen, 2012) describe the level of physical damage in terms of the reduction in the surface area that is undisturbed which implies that the occurrence of any pressure is considered significant which our study now shows would only apply in case of biogenic habitat or if any deterioration of quality would be considered unacceptable. While this interpretation would make sense from a precautionary perspective, it would effectively imply that risk is based on exposure only as any effect already results in the maximum level of risk. The 90% threshold applied in (Hiddink et al., 2006) was chosen arbitrarily and considering the trawling frequencies found to be sustainable in this study at that threshold (see table 1) a more precautionary threshold (95% or even 99%) is probably appropriate.
- The choice of indicator for seafloor integrity is linked (or should be) to the criterion to assess the risk that seafloor integrity is compromised (see above) and follows from the criteria for selecting indicators proposed by (Rice and Rochet, 2005) which include sensitivity, specificity, and responsiveness in relation to the pressure (i.e. physical damage) that compromises the achievement of the policy objectives. This risk-based approach fulfils this requirement as it clearly links the two aspects of seafloor integrity according to the MSFD, i.e. "Physical damage" and "Condition of benthic community".
- A scientific choice (but mostly determined by data availability) that would affect the outcome of the assessment is the length of the time-period when determining the historic fishing intensity (*HFI*). (Piet and Hintzen, 2012) showed that the pooling of trawl tracks over longer time periods up to 10 years may reduce the proportion of the habitat unfished by half. As the disturbance of an untrawled (i.e. SI=0.99) sandy habitat by beam trawl at an intensity of approximately 2.3 yr^{-1} already results in a recovery time of 10 years (see figure 3) these are probably appropriate time-periods to consider when estimating the *HFI*. The application of such time-periods for *HFI* will probably result in a decreased seafloor integrity and hence reduced uptake of SIQ.

Application of this tool as part of results-based adaptive management aimed at achieving policy targets and objectives in relation to seafloor integrity would require monitoring of SIQ uptake as well as an assessment of seafloor integrity. This would allow the annual setting of the total amount of SIQs in relation to the aims and progress toward achieving the objectives on the state of the seafloor as specified in e.g. the MSFD Descriptor on seafloor integrity. As long as the objectives are not achieved in a specific MSFD (sub-)region, the total SIQs for the next year in that (sub-)region should be set at or below those of the last year. The SIQs therefore fit in the proposed RTI approach in that they are truly adaptive and can be updated based on fishery-dependent information. The proposed SIQ approach, however, differs from the RTI approach in terms of its spatio-temporal scale. Pertaining to the spatial scale the appropriate spatial resolution for SIQs probably needs to be higher than that for RTIs based on CPUE data (Kraak et al., 2014). Also, and in relation to that, the proposed real-time update (e.g. weekly) of the tariffs as proposed by Kraak et al. (2012) is not feasible and an annual update similar to that of catch quota is probably more realistic given the nature of the data-collection process and issues processing the international data.

Thus, the risk-based approach developed and applied in this study is aligned with the most common assessment methodologies for fisheries management, i.e. PSR/DPSIR and ERA (Fock et al., 2011; Stelzenmuller et al., 2015), revealing potential for alternative EBFM measures involving fisheries credit systems (Van Riel et al., 2015) that may contribute to the conservation of the seafloor with only minor consequences on fishing industries' capacity to provide seafood.

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3 DST 2: Development of a decision-support tool for management evaluation

3.1 Introduction

BENTHIS studies the fishing impact on the benthic ecosystem and starts from the observation that benthic ecosystems provide important ecosystem services. There is concern about the negative effects of trawling the seafloor. Yet knowledge claims are contested; there is no uniformly recognized point of view. Environmental NGO's emphasize that trawling destroys habitats, negatively effects the integrity of the seafloor and has a negative impact on the productivity of the system (and thus yields of fishermen). Representatives of the fishing community have a different perspective and argue that, based on their experience in the field and knowledge, trawling can have positive effects on the productiveness of the ecosystem, and that species are able to protect themselves to, or recover quickly, from trawling. Science is not (yet) in a position to bring this uncertainty to an end, not only because scientific knowledge on benthic impacts are not systematically studied, but also because the knowledge claims of science are contested themselves.

3.1.1 Objective

In this context of uncertainty and contesting knowledge claims there is a need to develop quantitative tools to assess the impact of fisheries on the benthic ecosystem and at the same time collaborate with the fishing industry to develop innovative technologies and new management approaches to reduce the impact on benthic ecosystems. Like other problems of governing fisheries, the problem of managing the benthic impacts of fisheries can be described as a "wicked problem" (Jentoft and Chuenpagdee 2009). These are multi-faceted problems; there is not one perfect solution. There are conflicting values at stake; not all stakeholders find the same things equally important. A management measure will impact on the different stakeholders in different ways. Wicked problems are not restricted to fisheries governance. For example, environmental governance and land-use policies are in many ways comparable. These also face complex problems, with multiple actors and multiple knowledge claims, particularly in cases where ecological and societal complexities are mixed up (Wittmer et al, 2006).

A range of methodologies are available that can be used to structure problems and determine which solutions are best to solve wicked problems. Multi-criteria analysis is one of those categories of tools thatcan be used. It is commonly argued that participation is required to involve stakeholders in the decision-making process, to get better decisions, and to gain support and legitimacy for eventual decisions. The objective of this working paper is to develop the approach to participatory multi-criteria analysis that fits within the BENTHIS project.

3.1.2 Methodology

In this chapter, we take the following steps to develop an appropriate approach for participatory MCA for the BENTHIS project:

- Review of DOW and sharpening the objectives and expectations of the MCA
- Analysis of theoretical literature on different forms of MCA
    - Review of case-studies where P-MCA was used, to identify lessons learned
    - Reviewing literature that describes evaluation and selection of tools for MCA
- Selection of MCA that suits the needs of BENTHIS
- Development of indicators to be used in the MCA
- Development of a questionnaire to be used in the BENTHIS project
- Guideliness for implementation of the MCA

3.1.3 Definitions and abbreviations

When it comes to discussion on decision support tools, multi-criteria analysis and the like, the risk of semantic confusion is never far away. Different techniques and methodologies have different names, even if the differences in practice are negligible.

In this working paper, we use the term multi-criteria analysis (MCA) and participatory multi-criteria analysis (P-MCA) to refer to the methodologies at large (thus including all varieties). As will become clear in subsequent chapters, there is a range of instruments and approaches that fall under MCA. For example, deliberative workshops or IMA are approaches for MCA. Within such an approach, there are formal decision rules that describe how data is processed to come to recommendation.
The following abbreviations are used:

- AHP: analytical hierarchy process
- DST: decision support tools
- MCA: Multi-criteria analysis
- P-MCA: participatory multi-criteria analysis
- MCDM: multiple criteria decision making

3.2 Objective of MCA in BENTHIS

Below, the relevant text passage from the DOW that describes the work under WT6.2. Underlines are added to illustrate key phrases.

> 6.2 Development of decision-support tool(s)
> Lead: LEI; Contributors: IMARES, IFREMER, DTU-Aqua, SME's
> 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 (DST) 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 actual fishing activity also involves a vast array of decisions that not only determine the composition and size of the catch but also the impact fishing has on the seafloor. Analysis of VMS data has shown that some fishers always return to the same positions whereas others display a more explorative behaviour. This can be captured by calculating the footprint these fishing strategies have on the seafloor where the former should have a smaller footprint than the latter. In collaboration with some of the SMEs we aim to develop a decision-support tool that provides information that helps fishers take account of their impact on the seafloor when deciding to fish in a particular area or not. The performance of this tool will be assessed using the VMS data generated as part of the project.
> An <u>appropriate multicriteria analysis (MCA) will be developed as DST</u>. MCA is a set of formal approaches which seek to take explicit account of multiple criteria (ecological, economic and social) in helping decision-makers explore decisions (Goodwin and Wright, 2004). <u>They also allow to document, in a structured manner, the way a decision is reached and in this way make the decision process transparent</u>. In MCA, a decision problem typically is broken down into a set of smaller problems that are easier to address.
> The MCA will assist by <u>structuring discussions and improving communication among stakeholders</u>, leading to additional insight on possible solutions to the issues in a more transparent manner, as well as providing a documented basis for possible modifications of the decision in the future (Soma 2010). This should, if carefully implemented, <u>increase legitimacy</u> of the decision-making process, making the final decision understandable to affected people (Jarre et al. 2010). After an initial problem structuring phase generating a set of <u>alternative management options</u> (with input from 6.1) and a <u>set of criteria</u>, the following steps will involve various methods of <u>assessing stakeholder priorities</u>. The relevant priorities on the identified criteria will be assigned by stakeholders (e.g. policy, industry, NGO) by email or in-depth interview. As these priorities may lead to different preferences of the policy options, they will explicitly be considered when informing the decision makers. The development of this tool will be based on experiences in previous EU-funded projects (e.g. COEXIST and MEFEPO). The MCA methodology developed will be applied in the regional case studies (WP7) in collaboration with the SMEs and other stakeholders.

The following key passages in the DOW for WT6.2 were highlighted:

- An appropriate multi-criteria analysis (MCA) will be developed as DST.
- They also allow to document, in a structured manner, the way a decision is reached and in this way make the decision process transparent.
- The MCA will assist by structuring discussions and improving communication among stakeholders.
- This should, if carefully implemented, increase legitimacy of the decision-making process,
- After an initial problem structuring phase generating a set of alternative management options (with input from 6.1)

- and a set of criteria, the following steps will involve various methods of assessing stakeholder priorities.

These highlights points towards a number of key concepts. First, “decision”. The text suggest that the MCA should result in a “decision”. The DOW of WT6.3 provides a clue what this decision should be about: the outcome of the MCA will be used to put a weighting on the different indicators so that as a result of the management strategy evaluation (in WT6.3) we will obtain a selection of the preferred management scenario’s to achieve the policy objectives of relevant marine directives”. This suggest the “decision” to be reached in 6.2 is not a decision for a management option per se, but rather a description of the stakeholders preferences for the proposed management options. Secondly, we see various references to what the process of doing MCA should result in: transparency, structure, communication and legitimacy. These notions will be considered back in the theoretical background and the review of MCA tools.

3.3 Literature review

The notion of Decision Support Tools (DST) refers to a wide range of instrument that can be used to make informed decisions. These range from economic models to serious games, but can also include simpler checklists and the like.

To deal with complex problems, the 'traditional' solution was to have expert panels feed in the facts and have democratically elected representatives reflect these facts on the basis of public values and make informed decisions, the so-called de*cisionistic model of communication* (Renn 2006). This model of decision-making has reached its limits when it comes to complex, multi-facetted problems.

Wittmer et al (2006) argue that environmental conflicts are characterised by combination of two types of complexities: ecological and societal. Ecological complexities follow from the complexity of the system, questions of impact and causation that give rise to different plausible hypothesis, the mix of scientific and idiosyncratic knowledge and uncertainty. Societal complexities stem from the fact that many of the concerned are not persons who can influence the decisions and that some of the concerned are actors who might impede the implementation of a decision.

The combination of participation and multi-criteria decision aid promises potential to improve the resolution of environmental conflicts: processes supported by both strategies offer possibilities to deal with ignorance and uncertainty, and can be structured in a way to include stakeholders and be comprehensible for outsiders (Wittmer, Rauschmayer et al. 2006).

Renn (2006) described different objectives of participatory decision making:

- Needed to define the role and relevance of systematic (scientifically derived) and idiosyncratic (derived from experience and familiarity with local conditions) knowledge for making choices that affect large populations
- To find the most appropriate way to deal with uncertainty in environmental decision making and to set efficient and fair trade-offs between potential over- and under- protection in the face of uncertain outcomes.
- To address the wider concerns of the affected people and the public at large.

When it comes to decision making in the context of these complexities, new criteria for good decision making are identified: the process should facilitate the legitimate selection of appropriate instruments for the resolution of environmental conflicts. This already points towards two main reasons for a participatory approach MCA: a functional argument and an ethical-normative argument.

The ethical-normative foundation of P-MCA is the belief that involvement of different stakeholders in evaluation of a multi-facetted problem is worthwhile in itself. The plea for participatory approaches is often founded on the work of Habermas (1984) who defined his theory of communication action to describe the conditions under which just decision making should take place. Ethical-normative arguments are for exampl esovereignty, equity and political equality. A high degree of transparency seems to be the most promising measure to achieve effective and legitimate conflict resolution procedures in the face of doubts on representativeness (O'Neill 2001). This requires involvement of stakeholders or the general public in decision making process and is further augmented by a structured process which is comprehensible for non-participants.

If done successfully, participation and deliberation can results in many desirable products and accomplishments: enhance understanding, generate new options, decrease hostility and aggressive attitudes among the participants, explore new problem framing, enlighten legal policy makers, produce competent, fair and optimised solution packages, facilitate consensus, tolerated consensus and compromise.

Renn (2006) emphasizes that the benefits of participation are not reached by simply organising a common platform for mutual exchange of ideas, arguments and concerns does not suffice in order to assure fair and competent results (Renn 2006). Discursive processes need a structure that assures the integration of technical expertise, regulatory requirements, and public values (Renn 2006).

3.3.1 Evaluation and selection of instrument

Various authors have addressed the question how to select to most appropriate instrument for MCA, sometimes directly related to fisheries management, sometimes not. Wittmer et al. (2006) describe how to select an instrument to be applied in environmental conflict resolution. To this end, they formulate criteria, and apply them to numerous methodologies. An overview of the criteria is provided in table 3.1

Table 3.1 criteria for selection of instruments for environmental conflict resolution

Dimension	Criteria
Information management	Coping with complexity
	Integrating different types of knowledge
	Coping with uncertainty
Legitimacy	Accountability (someone held accountable for the decision and is it clear who?
	Inclusions/representation (all relevant interest represented)
	Transparency of rules and assumptions to insiders and outsiders
Social dynamics	Respect/relationship
	Changing behaviour, changing perspectives/learning
	Agency/empowerment
	Facilitate convergence or illustrate diversity

Costs	Cost-effectiveness
	Cost of the method
	Decision failure costs

Rauschmayer and Wittmer (2006) evaluates various participatory methods for environmental conflict resolution, based on the criteria developed in continues upon the criteria formulated by Wittmer et al (2006) All of these methods are some sort of multi-criteria analysis. The paper then evaluates the different methodologies on the criteria defined by Wittmer and thereby describes which instrument is most appropriate, dependent on the objectives of the project (see Table 3.2

Table 3.2 Evaluation of different particpatory methodologies

Method	Stakeholders	Description
Mediated modelling	Stakeholder groups	Stakeholder collaborate in the development of a simulation model about a specific problem
Consensus conference	General public	Dialogue open to the public, between lay people and experts. Stretching over 3-4 days. Ca. 15 citizens. Ca 12-15 experts
Participatory multi-criteria decision support IMA	Stakeholder groups	Integrated Methodological Approach including problem analysis and scenario derivation, indicator and criteria selection and impact analysis. Evaluation using cost-benefit and multi-criteria analysis in participatory context
Multi-criteria analysis in deliberative workshops	General public	To gain in-depth understanding of the public's perspective. On several successive weekends, 2 day workshops are held.
Cooperative discourse	Stakeholder groups and general public	Three consecutive steps. 1. Identification and selection of concerns and evaluative criteria 2. Identify impacts and measure impacts and consequences related to the different policy options 3. Finally a discourse with randomly selected citizens is conducted
Mediation	Stakeholder groups	Allows for direct involvement of those most affected by decision, often behind closed doors
Non-participatory multi criteria analysis	None	Use multi-criteria analysis, usual steps, but without participation of stakeholders

The paper by Mackinson et al (2011) is relevant as it emphasizes the difference between science-society and politics-society interaction. This is illustrated in the case of fisheries. Engaging stakeholders in research is different. Different rationale: principal desired outcome is to improve the scientific data and knowledge required for management and governance. Key difference is absence of a political agenda (Mackinson, Wilson et al. 2011).

3.3.2 Case-studies that use participatory MCA

Methodologies for participatory approaches to multi-criteria analysis are applied in a number of studies, related to fisheries governance or environmental management at large. The objective of this chapter is to review some of these studies and learn from them when designing a P-MCA approach for BENTHIS.

Soma (2003) published her study on the involvement of stakeholders in fisheries management in Trinidad and Tobago. The objective was to show how the analytical hierarchy process (AHP) methodology can be applied to prepare and facilitate the process of change which the fisheries sector and its stakeholders face (Soma 2003).

The background is the observation that sustainable development and responsible development might not always match when it comes to e.g. fisheries. If restrictions are needed for limiting access to fish resources, the two might conflict, particularly in the short term. Soma argues that in order to facilitate sustainable and responsible development as well as to involve stakeholders in fisheries management, tools like the multi-criteria decision-support tool can be used to assist decision-makers. AHP is one of those tools, it was applied in the shrimp fishery sector in Trinidad and Tobago in order to show how it works and to identify strengths and weaknesses of such a tool. The AHP application process consisted of four steps (1) to develop a hierarchy of interrelated decision-elements describing the problem. Stakeholders were involved in this, (2) performing pairwise comparisons on the decision-elements using a nine-point weighting scale to generate the input data, (3) computing the relative weights of the decision-elements and (4) determining the most prioritised objectives, criteria and management options.

Mardle et al (Mardle, Pascoe et al. 2004) report on their study where they used AHP to identify priorities in fisheries management in the English Channel. This study illustrates how a tree of key objectives can be prepared for evaluation by stakeholders. Using pairwise comparison, the authors have established the aggregated preferences for “natural” groups (fishermen, civil society, etc). The result of pairwise comparison are the relative weights attached to the different objectives (hierarchy of objectives). The authors conclude that with the multiple, often conflicting objectives of fisheries management, determining the importance of objectives in the process is key to developing appropriate strategies .

Renn (2006) provides a practical example for participatory deliberation titled the model of co-operative discourse. This model is based on many practical experiences, which share the following three consecutive steps:

1. Identification and selection of concerns and evaluate criteria. Asking all relevant stakeholders to reveal their values and criteria for judging different option. To elicit the values and criteria for such a list, the technique of value-tree analysis has proven helpful.
2. Identification and measurement of impacts and consequences related to different policy options. Evaluation criteria from value tree are operationalised and transformed into indicators by the research team or an external expert group.
3. Conducting a discourse with randomly selected citizens as jurors and representatives of interest groups as witnesses.

Various different formal decision tools are used in this process. Value tree analysis is used to structure the elicited values, criteria and corresponding attributes in a hierarchy. Multi-attribute utility theory is used for elicitation of the values, criteria, and attributes and assignment of relative weights to the different value dimensions. Final holistic judgement is not the result of this exercise but based on holistic judgement of individuals and/or groups. Some examples of application of this methodology are provided. These are generally time-consuming (25 citizens panel, 200 randomly selected individuals etc) and costly (examples between $800.000 and $1.2 million) process. Renn therefore concludes that this is a valuable approach but others and less costly alternatives are presents as well.

Soma (2010) describes the use of participatory MCA in Norway. The underlying argument was that an appropriate decision support tool can deal with multidimensionality by ensuring transparent and legitimate decision making processes (Soma 2010). Whereas MCA has been suggested as suitable decision support when environmental management issues must take into account multiple dimensions and goals, the MCA can be extended by combining them with participatory processes to also take into account value-complexities. The communicative rationality concept developed by Habermas has provided an important theoretical foundation to the dialogue as a means to deal with complex management issues and is practised in deliberative processes with citizens. It translates into what is called a co-operative discourse on decision-making. This is strong when it comes to legitimacy because of the involvement of different people in the different roles, it may be less strong with respect to transparency. From a deliberative policy perspective, it may be less logical that interest groups and experts can reach agreements after group interactions.

Soma therefore designed an approach that combines MCA with participatory processes to increase transparency. The MCA had the objective to decide on coastal zone management decisions. The main new aspect in this study includes the integration of the roles of interest groups, experts and citizens with the MCE aspects of relevance to participatory processes. In other words: MCA is seen as a rather technocratic thing, but it can be improved by acknowledging that different actors have differing roles and value, and giving this a place in the process. This process identifies three groups of actors: (1) interest groups, (2), experts, (3) citizens.

The steps taken are:

1. Facilitator selects people to participate
2. Interest groups and experts identifying an impact matrix with alternatives, criteria and scores
3. Citizens finding the most important aspects during deliberative processes and obtaining weights on a set of criteria with technical support from the experts
4. Facilitator summarizing and reporting the main findings on the basis of the interest-group, citizen and expert contributions.

Soma (2010) formulates lessons learned. It is appropriate to keep the identified interest and concerns in their original form throughout the process. Interest group participation tends to favour short-term consideration, citizens participation in long-term considerations about protecting environmental values taking future generations into account. Possibilities for transparent treatment of information increases by the arrangement of information into an impact matrix, consisting of criteria, alternatives and scoring, during and after the participatory process. The methods, structures, assumptions, information treatments and the involvement strategies could explicitly be communicated to all parties in an easy manner. Main challenge of applying a method based on appropriate assumption in a practical situation are related to resource and time constraints for all participants.

Pita et al (2010) focus on fisheries management. Background statement is that public participation is key to good governance. General agreement that failure to include the major stakeholders in meaningful decision making is one of the causes of the current crisis in world fisheries and a weakness of the fisheries management process (1093)(Pita, Pierce et al. 2010). Innes et al (2010) theor problem definition in this paper is relevant for BENTHIS: impact of demersal fisheries on the ecosystem and development of alternative gears. Modifying gears comes at a costs to the industry. Determining an optimal gear combination to minimise habitat damage and bycatch at least cost to the industry requires some common measure of environmental damage.

The objective of this study is to develop a means of comparing the relative value of a change in habitat damage with a change in the level of bycatch. The study uses the Analytical Hierarchy Process (AHP) to clarify and prioritise considerations in achieving a goal, to determine the relative significance stakeholder groups attach to differing impact reductions. AHP is one of several multi-criteria decision making techniques, provides a relatively simple yet powerful means of deriving individuals' preference for one attribute over another.(Innes and Pascoe 2010). Three basic principles (Saaty, 1994): decomposition, comparative judgement and hierarchic composition/synthesis of priorities

In this study, the following steps were taken (Innes et al, 2010):

1. Develop a hierarchy of factors important in that decision (Ad 1: a hierarchy of impacts was developed: in-situ impacts and bycatch)
2. Survey the associated participants to elicit judgement based on pairwise comparison on the identified criteria (Ad 2: construct database of respondents, let them do pairwise comparison)
3. Calculate the individual's relative weights to the factors under consideration (Ad 3: calculate relative weight (eigenvalue). Use Expert Choice software)
4. Determine homogeneous group weights

3.4 Design of MCA for BENTHIS

3.4.1 Criteria for the approach in BENTHIS

What is the appropriate methodology depends on the objectives. In selecting an instrument for BENTHIS, the following points are considered important:

- The instrument does not have to lead to a decision, the results are used to inform decision-makers
- The approach should address different categories of stakeholders with the aim to elicit stakeholders opinions
- Democratic legitimacy is less of an issue at this stage; the purpose is to get stakeholder preferences on the table and integrate them
- The approach should be able to tackle a complex problem.
- The approach should be transparent and results of the approach should be understandable for different stakeholders categories.

This means the approach suggested by Renn (2006) Pita (2010) and Soma (2010) are not directly applicable; they include decision-makers in the process and end up with a final decision. The P-MCA in BENTHIS is more science-driven. We seek a way to match scientific results with the preferences of stakeholders. The gap we aim to bridge is that between science and stakeholders at large. The findings of the P-MCA are linked with the results from the other WPs to formulate recommendations for policy-makers. This is more in line with the approach taken by Soma in her 2003 study and Innes et al (2010). Referring back to the criteria provides by Wittmer et al (2006), we can describe the importance of these criteria for the BENTHIS project (Table 3.3)

Table 3.3 Criteria for multi-criteria analysis and BENTHIS

Dimension	Criteria	Relevance for BENTHIS	Argument
Information management	Coping with complexity	++	BENTHIS tackles a complex issue
	Integrating different types of knowledge	++	Different opinions of stakeholders
	Coping with uncertainty	++	Uncertainty present
Legitimacy	Accountability (someone held accountable for the decision and is it clear who?	-	No decision needs to be made
	Inclusions/representation (all relevant interest represented)	+	Different stakeholders present
	Transparency of rules and assumptions to insiders and outsiders	+	Outcome should convince decision makers
Social dynamics	Respect/relationship	+	Process is relevant, continued commitment

	Changing behaviour, changing perspectives/learning	+/-	No direct behavioural change foreseen
	Agency/empowerment	-	Not an objective
	Facilitate convergence or illustrate diversity	++	Of different stakeholder views
Costs	Cost-effectiveness	++	Particularly for respondents
	Cost of the method	+	Budget is limited but available
	Decision failure costs	+/-	No 'final' political decision is made.

Matching these BENTHIS demands with the evaluation of Rauschmayer et al (2006), it shows that the approach they call Integrated Methodological Approach (IMA) is the most suitable approach for the BENTHIS project as a whole.

This approach to evaluation combines benefit–cost analysis, multi-criteria analysis, and participatory elements on the basis of scientific modelling (Horsch et al., 2001; Klauer et al., forthcoming). IMA focuses on improving competence and fairness of decision-making (Webler, 1995). The competence improvement is attained through the broadening of the knowledge base through participation of stakeholders, the inclusion and processing of complex data generated by scientific models, and the explicit consideration of uncertainties. A decision support following the IMA approach can be described by a sequence of four major steps, all including participatory elements that are crucial to grant minimum standards of competence and fairness in decision-making:

- problem analysis and scenario derivation,
- indicator and criteria selection,
- impact analysis via modelling or other effect estimation methods,
- evaluation using benefit–cost and multi-criteria analyses in a participatory context.

The BENTHIS project as a whole includes all these steps. This particular deliverable is concerned with aspects (2) and (4): it describes which indicators are selected in the project and describes the methodology to attach give weights to these indicators by means of a multi-criteria analysis.

WT6.2 contributes to participatory MCA, as part of an IMA-based for BENTHIS. It is aimed at eliciting different preferences and views on different management measures, this information can be used in decision-making. It requires involvement of all relevant stakeholder categories: fishermen, civil society, government. The management measures from WT6.1 are evaluated on various criteria.

The Analytical Hierarchy Proces is considered to most appropriate instrument to elicit stakeholder preferences. AHP is aimed at deriving ratio scales by means of paired comparisons and allows some small inconsistency in judgment. A full AHP analysis includes the following steps

1. Define objective: select best management measure

2. Structure elements in criteria, subcriteria and alternatives: triple P → but still complex (comparing buying a gadget e.g. color). Subcriteria = colors, memory space = criteria
3. Pairwise comparison of elements in each group
4. Calculate weighting and consistency ratio: Compute normalized Eigen value and Eigen vectors
5. Evaluate alternatives according weighting
6. Get ranking

3.4.2 Identification of relevant objectives

We aim to compare different management options on benthic fisheries. Management objectives can have varying objectives. Stakeholders involved in, and affected by, the management options attach different importance to these objectives. In line with the Triple Bottom Line of sustainability, we identify three categories of objectives: ecology (planet), economy (profit) and social (people). To evaluate the performance of management options on each of these objectives, it is necessary to “translate” objectives into indicators.

Regarding social objectives, we know that social objectives are important; fishermen pursue more objectives that only maximum profit-making (Coulthard, 2012). These are often mentioned in policy making but hardly ever made explicit (Symes & Phillipson, 2009). There are various reasons for this, among them neo-liberal tendency to subsume social objectives under economic objectives (Symes & Phillipson, 2009). If that line if followed, social objectives are close to economic indicators, for example wage, employment etc. Note that is done in various studies (Seung & Zhang, 2011; Avadí & Fréon, 2015). As argued by others, there is a broad set of other social indicators that could be used here (Pascoe et al., 2014) including for example social capital and networks.

In conjunction with the project partners, I was decided that the objectives selected should be able to:

- Highlight differences between the management scenario’s
- Inter-dependence of indicator should be avoided
- It should be possible to say something about performance of management scenario’s on indicators (either quantitative or qualitative)

There are two ‘levels’ of objectives to evaluate in the AHP. On a general level, we wish to elicit relative weights between the objectives ‘ecology’, ‘economy’ and ‘social’. On a more detailed level, a the following of objectives were selected as relevant for the evaluation of management scenario’s in BENTHIS (see Figure 3.1; Table 3.4)

Figure 3.1 Tree of objectives

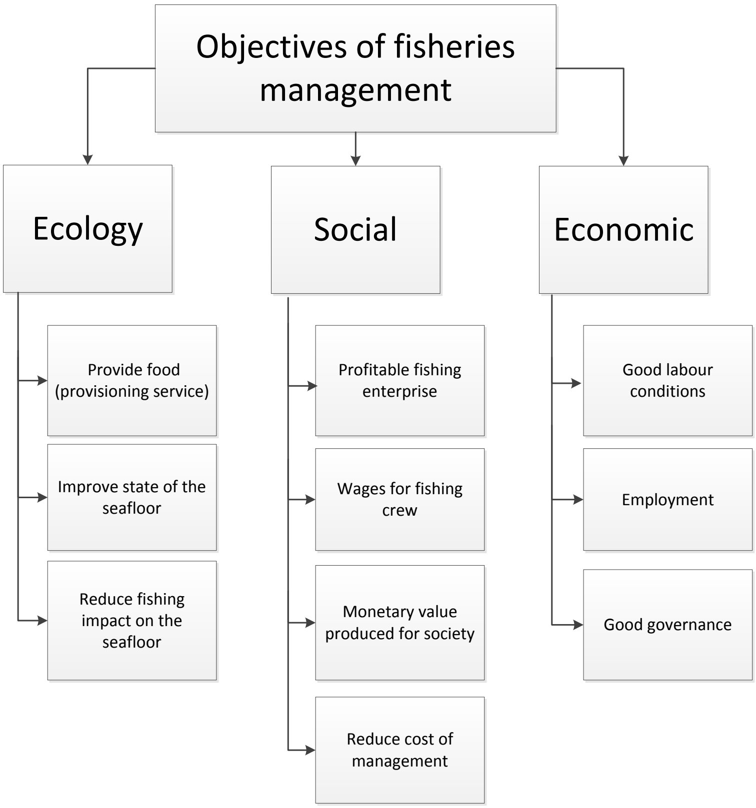

Table 3.4 Objectives

Objective	Why it is important
Provide food	Seafood is healthy and an important source of nutrition. It is important that people can consume seafood from fisheries.
Reduce fishing impact on the seafloor	Fishing causes mortality and damage to benthic communities. It can harm natural habitats, alter food-web dynamics and compromise the ability of the seafloor to deliver its ecosystem services.
Improve state of the seafloor	The seafloor hosts a wide variety of organisms and is an important source of biodiversity. The seafloor provides important ecosystem services, i.e. bio-remediation or carbon sequestration.
Profitable fishing enterprises	Fishing is a business activity and it is important that this activity is profitable from a business perspective.
Wages for fishing crew	It is important that the crew on board of fishing vessels receives a fair remuneration.
Monetary value produced for society	Society as a whole benefits from healthy businesses and that total gross value added is maximized.
Reduce cost of management	Regulations can come with extra control and enforcement measures. The cost of management should be minimized.
Fair distribution of impacts	It is important that cost and benefits of fisheries are distributed fairly, to avoid that only a few people benefit from the seas resources.
Good labour conditions	It is important that the fishermen can work safely under good labour conditions, including appropriate safety measures and working hours.
Employment	The more jobs provided by fisheries to the communities, the better.
Good governance	It is important that management measures are accepted by the fisheries. This will possibly lead to higher compliance rates.

3.4.3 Questionnaire for AHP

Based on the objectives identified by the BENTHIS project partners, the questionnaire was designed (see Annex 1) This questionnaire is programmed in SelectSurvey and can be send out to the identified stakeholders by email. All returned questionnaires are centrally collected for further processing.

Note that the pair-wise comparison are randomized when the participants fill-in the questionnaire.

3.4.4 Application of AHP

The methodology developed can now be used in the various case-studies. This concluding paragraph describes the steps to be taken and the results that can be expected. The following five steps can be distinguished

1. Translation of the questionnaire into the most appropriate language
2. Identification of the stakeholders by the case-study leaders
3. Send out link to the questionnaire on SelectSurvey
4. Collecting and processing returned surveys
5. Evaluation of management scenario's based on relative weights

3.4.4.1 Translation of the questionnaire

For the different case-studies, the questionnaire has to be translated in the most appropriate languages. Translation should be done by native speakers. DLO will prepare a separate online questionnaire for each of the languages.

3.4.4.2 Identification of stakeholders

The case-study leaders need to identify the most relevant stakeholders to whom the questionnaire will be send. A point of concern is possible overrepresentation of particular stakeholders. To counter this, it is suggested to sample after receiving the questionnaires. We need to be sure that the respondents honestly state which category they belong to and explain/pay attention to non-response

3.4.4.3 Send out link to the questionnaire on SelectSurvey

This should be done by the case-study leaders to ensure recognition and response of the stakeholders.

3.4.4.4 Collecting and processing returned surveys

When stakeholders fill the questionnaire, results are collected by DLO via Select Survey. After close of the response period (to be determined with the case-study leader), answers are analysed and processed. This analysis results in relative weights to each of the objectives, per stakeholder category.

3.4.4.5 Evaluation of management scenario's based on relative weights

After calculating the relative weights attached to the objectives, the management scenarios are ready for evaluation. This requires modelling and evaluation of the objective; we need to know how a scenario performs on each of the objectives. This can be a quantitative of qualitative score as different scores can be standardised. The final evaluation of management scenarios results from the scores multiplied by weights.

3.5 References

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