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AN INTEGRATED IMPACT ASSESSMENT OF TRAMMEL NET AND BEAM TRAWL FISHERIES

WAKO-II

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SCIENCE FOR A SUSTAINABLE DEVELOPMENT
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North Sea

FINAL REPORT

AN INTEGRATED IMPACT ASSESSMENT OF TRAMMEL NET AND BEAM TRAWL FISHERIES

SD/NS/08A

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D/2012/1191/2
Published in 2012 by the Belgian Science Policy Office
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Depestele J, Courtens W., Degraer S., Haelters J., Hostens K., Houziaux J-S., Merckx B., Polet H., Rabaut M., Stienen E.W.M., Vandendriessche S., Verfaillie E. & Vincx M. ***An integrated impact assessment of trammel net and beam trawl fisheries "WAKO II"*** - Final Report. Brussels : Belgian Science Policy Office 2012 – 233 p (Research Programme Science for a Sustainable Development)

TABLE OF CONTENT

SUMMARY 5

1. INTRODUCTION 11

2. PARTIM I: QUANTIFICATION OF MAJOR PRESSURES FROM TRAMMEL NET AND BEAM TRAWL FISHERIES FOR THE BELGIAN PART OF THE NORTH SEA 13

2.1 Effects of trammel net and beam trawl fishery on endofauna 13

2.2 Effects of trammel net and beam trawl fishery on epifauna 19

2.3 Effects of trammel net and beam trawl fishery on fish 30

2.4 Effects of trammel net and beam trawl fishery on seabirds 42

2.5 Effects of trammel net and beam trawl fishery on marine mammals 53

3. PARTIM II: SENSITIVITY ASSESSMENT AS A TOOL FOR SPATIAL AND TEMPORAL GEAR-BASED FISHERIES MANAGEMENT 59

3.1 Where marlin's sensitivity assessment approach meets and does not meet the WAKO-II needs: identifying problems and prospecting solutions 59

3.2 A protocol for sensitivity assessment of fishing techniques 73

3.3 Species selection and distribution in the BPNS 83

3.4 Case studies to validate the applicability of the sensitivity assessment protocol 92

4. DISTRIBUTION OF FISHING EFFORT IN THE BELGIAN PART OF THE NORTH SEA 97

5. CONCLUSIONS 107

6. POLICY SUPPORT 109

7. DISSEMINATION AND VALORISATION 111

8. PUBLICATIONS 113

9. ACKNOWLEDGEMENTS 115

10. REFERENCES 117

Annex 1: COPY OF THE PUBLICATIONS 143

Annex 2: MINUTES OF THE FOLLOW-UP COMMITTEE MEETINGS 146

Annex 3: Length-weight relationships in the southern North Sea 148

Annex 4: Length-frequency distributions of fish species 152

Annex 5: Selectivity ogives for sole, plaice, cod, and whiting 158

Annex 6: Selection of species for tests on gravel bed communities of the BPNS 159

Annex 7: High resolution maps of modeled spatial distribution based on presence of the selected macro- and epibenthic species. 165

Annex 8: Pressure effects of beam trawling and trammel netting and scoring principles... 192

Annex 9: Demographic attributes for recoverability: scoring principles 217

Annex 10: Uncertainty analysis for the effects of direct biological pressures for benthic invertebrates and demersal fish... 220

Annex 12: scores for demographic attributes of benthic invertebrates, demersal fish, seabirds and marine mammals 232

SUMMARY

A. Context

There is widespread agreement on the critiques to the Common Fisheries Policy (CFP) and fishing impacts on the marine ecosystem, e.g. low fish stocks, loss of biodiversity and high levels of discarding. Aspirations for a better protection of marine ecosystems are now formally set out in the Marine Strategy Framework Directive (MSFD) (2008/56/EC) and are under way through the reform of the CFP (COM, 2011: 425). The Belgian marine fisheries fleet is dominated by beam trawlers. Beam trawling can experience considerable pressure from the latest EU legislation, as this fishery is clearly questioned for its ecological effects (e.g. discarding). One example is the need for fisheries measures in Natura 2000 sites, which is likely to impact the Dutch beam trawlers for instance in the proposed Natura2000 sites in the Netherlands. Similar measures are likely to be discussed in the short-term for the BPNS to fulfill the requirements from the Habitats (92/43/EEC) and Birds Directive (79/409/EEC). Passive fisheries, such as trammel net fishery, can be prompted as an alternative gear for the Belgian flatfish-directed beam trawl fleet.

The former WAKO-I project explored the state-of-the-art knowledge on beam trawl and trammel net effects in the Belgian Part of the North Sea. The project served as stepping stone in the exploration of multi-disciplinary research and compiling expertise from biological-ecological and fisheries science. WAKO-II builded upon this base and bridged projects, that were exclusively focused on fundamental ecosystem research with fisheries projects (such as those financed through the European Fisheries Fund). From this basis, WAKO-II aimed at making progress in developing an integrated assessment tool, which can scientifically underpin policies that reconcile the interests of both the marine environment and fisheries. To be effective in the CFP, such a tool should be at the level of the fisheries management unit. Metiers can be a practical unit for management, which is why the selected case-study of the two Belgian fishing metiers serves as a proper example. To take ecosystem-based considerations effectively onboard, the tool also needed to be set in the context of risk analysis.

The WAKO-II project therefore focused on the development of a risk/sensitivity assessment of the effects of beam trawl and trammel net fishery. As WAKO-I concluded that our scientific knowledge on especially trammel netting is limited, partim I of the WAKO-II project focused on filling parts of the knowledge gaps. Partim II is set up around the development of an appropriate assessment tool, given the need for ecosystem-based management decisions despite incomplete knowledge. The development of the tool has been demonstrated with selected examples from the divergent effects of both fisheries. These examples as well as the link with the actual fishing efforts at the BPNS explored the potential for the application of risk/sensitivity assessment as a tool for spatial and temporal planning and evaluation of fisheries.

B. Objectives

The key objectives of the WAKO-II project were (1) to fill out knowledge gaps in our understanding of trammel net and beam effects in the BPNS and (2) to set up an actual integrative approach to assess ecosystem effects of fishing effects.

C. Conclusions

Filling out data gaps in short-term, direct effects of beam trawl and trammel net fishery in the BPNS

The effects investigated were short-term and direct, as these are more easily related to a specific fishing métier and as the focus was a relative comparison of effects of these métiers in order to guide managers on the potential of managing fishing gears to achieve ecosystem-based management objectives. The selected short-term effects were (1) endofaunal mortality from passage of a fishing gear (tow path mortality), mortality from the catching process for (2) epifauna and (3) commercial fish species, (4) seabirds interactions and (5) marine mammals bycatch.

(1) Tow path mortality is only relevant to beam trawling, but quantitative data only exist with sufficient quality for muddy sand and sandy sediments. Suggestions have been made for gravel beds and proxies are presented for biogenic reefs. Biological traits should assist further analysis and preliminary suggestions of traits needed for establishing a relationship with mortality were identified. (2) The discards of epifaunal invertebrates and non-commercial fish were quantified and compared for trammel net and beam trawl fishery. An univariate approach was developed and trialed. Multivariate approaches indicated the larger total number of individuals and of species discarded in beam trawl than trammel net fishery. (3) The commercial fish discard rates were high for a range of species, with high total discards of beam trawls, because of their highly mixed character. The high variability in discards was partially explained for some species, but data limitations suggest to be cautious in interpretation. The same uncertainties hold true for the fleet discard estimates. (4) These estimates suggest that, even if only a limited part of the discards would be consumed by seabirds, the mean seabird population in the BPNS can still be supported from it. In the breeding season however, there might be a deficit in energetic input from discards, taking factors as distance to the breeding colony in Zeebrugge into account. The effects were demonstrated for scavenging seabirds, but potential effects to rarer and non-scavenging species could be anticipated. (5) Seabird and marine mammal bycatch was investigated through a number of approaches (strandings data, questionnaires, independent observers and fishermen cooperation) and suggest a potential danger for diving seabird and harbor porpoises. More efforts are needed though to get a clearer picture here and our positive experiences with fishermen's cooperation could be an important basis.

Filling out the gaps, identified in WAKO-I was an important achievement, but this short-term project could obviously not accomplish a quantification of all fishing pressures of beam trawling and trammel netting and further detailed investigations are required.

Development of an integrated assessment approach for ecosystem effects of fisheries

The first WAKO project was mainly focused on the evaluation of distinct effects of trammel net and beam trawl fishery. Some of the identified gaps were resolved in the first part of the WAKO-II project. This project aimed also add the development of an approach to evaluated the effects in an integrated approach. The MarLIN sensitivity assessment was identified as a developing tool, which might serve our purpose. An international workshop was held to discuss the challenges that we were facing to meet our objective, i.e. to be suited for the relative comparison of fishing métiers, and to be spatially and temporally explicit. There were ten challenges identified and solutions were discussed. The challenges were (1) key and important species definition and selection, (2) baseline conditions, (3) 'unquantifiable' species, (4) intraspecific sensitivity, (5) pressure selection, (6) bench marking, (7) qualification or quantification, (8) spatio-temporal dynamics, (9) confidence of the assessment and (10) sensitivity assessment in practice. The challenges lead to conceptual discussion which was further developed with a range of other 'sensitivity' or risk assessment approaches. None of the proposed methodologies fully served the WAKO-purpose and therefore a hybrid methodology was built upon the existing experiences of peer-reviewed assessment methodologies. These were fine-tuned to a pragmatic approach and the development of a protocol which is easily applicable, transparent, repeatable, reliable and meaningful to managers. The protocol involves a roadmap for sensitivity/risk assessment, a scoping phase, and specificities on species selection, pressures selection and scoring, recoverability scoring and the determination of a sensitivity index which is represented spatially and temporally by sensitivity/risk maps. As such, the method urged for a species selection and distribution component in the BPNS, which was also part of the project.

The protocol was applied to certain key species for a range of pressures, but its full application and interpretation to the BPNS-ecosystem and implications for management could not be aimed for within this 2-year project. The developed methodology nevertheless has the potential to guide management and make suggestions for spatial and temporal planning of fishing techniques. Its application should also be linked with actual fishing effort to evaluate the current fisheries management. Preliminary investigations on fishing effort distributions were made and are meant to initiate further investigations.

D. Contribution of the project in a context of scientific support to a sustainable development policy

The UN Food and Agriculture Organisation (FAO) describes sustainable fisheries within the Ecosystem Approach to Fisheries as the planning, development and management of fisheries in such a way that it meets the present needs without compromising the ability of future generations to meet their own needs. Traditionally the three pillars which contribute to this concept are socially, economically and ecologically inspired. The latter, sometimes referred to as 'ecological sustainability', is the focus of the WAKO-II project.

The ecological costs of beam trawl and trammel net fisheries are an important question within the move towards more sustainable fisheries. Up till now, this ecological pillar for a sustainable development of fisheries is only limitedly investigated for the Belgian Part of the North Sea (BPNS). The need to manage fisheries to overcome the problem of overexploitation and collapse of fish stocks has long been recognized. More recently there has also been the appreciation that in order to have healthy fish stocks (amongst other ecosystem services) a healthy supporting ecosystem is needed. Its health is at risk from a range of human actions, including fisheries. Fisheries kill and remove the target species but also cause mortality and injury to other species, alter habitats and interfere with ecological processes such as nutrient and carbon cycles. The move to the ecosystem based approach to fisheries management has gained momentum. The multiple uses of marine resources have been acknowledged to take account of ecosystem considerations and the recommendations from numerous international agreements, conferences and summits held on the subject. Fisheries clearly are a key human factor in determining the quality of the marine environment, also for the BPNS. Some of the strategies and policies for an ecosystem approach to fisheries and a good environmental status of the marine environment, are: (1) Common Fisheries Policy, (2) OSPAR-convention, (3) Marine Strategy Framework Directive, (4) Bergen declaration, (5) Bonn Convention, (6) Convention on Biological Diversity, (7) Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS), (8) the Habitat and Bird Directive and (9) the EU 2020 biodiversity Strategy.

Beam trawl fishery has been questioned from both economic and ecological perspectives. Alternatives are being looked upon through technical modifications and alternative fishing gear. One of those alternatives is trammel net fisheries, a passive fishery with a good economic potential, due to reduced dependency on volatile fuel prices. Before the WAKO-II project, its ecological effects were only limitedly quantified in the BPNS.

WAKO-II made considerable progress in resolving these knowledge gaps. WAKO-II also developed a tool to integrate our knowledge of ecosystem effects and set up a sensitivity/risk assessment methodology. The application of this methodology was exemplified in a few case studies for a range of ecosystem components. This showed the potential to assist spatial and temporal planning of fishing techniques in the BPNS, which would allow to balance the ecological effects of both fisheries. The tool can be applied with a variety of objectives in mind: (1) mitigating ecosystem effects, (2) reducing economic losses (through discards) and/or (3) meeting legislative requirements. The latter is of growing interest as mitigation measures for marine protected areas in the Belgian Natura 2000 network are to be developed in the near future. A combination of the sensitivity/risk assessment tool with socio-economic factors will lead to improved sustainability.

E. Keywords

beam trawl; ecological risk assessment; ecosystem approach to fisheries management; North Sea; sensitivity; trammel net

1. INTRODUCTION

There is widespread agreement on the critiques to the Common Fisheries Policy (CFP) and fishing impacts on the marine ecosystem, e.g. low fish stocks, loss of biodiversity and high levels of discarding. Aspirations for a better protection of marine ecosystems are now formally set out in the Marine Strategy Framework Directive (MSFD) (2008/56/EC) (Cotter, 2010) and are under way through the reform of the CFP (COM, 2011: 425). The Belgian marine fisheries fleet is dominated by beam trawlers. Beam trawling can experience considerable pressure from the latest EU legislation, as this fishery is clearly questioned for its ecological effects (e.g. discarding). One example is the need for fisheries measures in Natura 2000 sites, which is likely to impact the Dutch beam trawlers for instance in the proposed Natura2000 sites in the Netherlands (ICES, 2011b). Similar measures are likely to be discussed in the short-term for the BPNS to fulfill the requirements from the Habitats (92/43/EEC) and Birds Directive (79/409/EEC). Passive fisheries, such as trammel net fishery, can be prompted as alternative for the flatfish-directed beam trawl fleet. The former WAKO-I project (Depestele *et al.*, 2008) explored the state-of-the-art knowledge on beam trawl and trammel net effects in the Belgian Part of the North Sea. The project served as stepping stone in the exploration of multi-disciplinary research and compiling expertise from biological-ecological and fisheries science. WAKO-II builded upon this base and bridged projects, that were exclusively focused on fundamental ecosystem research with fisheries projects (such as those financed through the European Fisheries Fund). From this basis, WAKO-II aimed at making progress in developing an integrated assessment tool, which can scientifically underpin policies that reconcile the interests of both the marine environment and fisheries. To be effective in the CFP, such a tool should be at the level of the fisheries management unit (Fock, 2011a). Metiers can be a practical unit for management, (Marchal, 2008), which is why the selected case-study of the two Belgian fishing metiers serves as a proper example. To take ecosystem-based considerations effectively onboard, the tool also needed to be set in the context of risk analysis (Smith *et al.*, 2007; Hilborn, 2011).

The WAKO-II project therefore focused on the development of a risk/sensitivity assessment of the effects of beam trawl and trammel net fishery. As WAKO-I concluded that our scientific knowledge on especially trammel netting is limited, partim I of the WAKO-II project focused on filling parts of the knowledge gaps. Partim II is set up around the development of an appropriate assessment tool, given the need for ecosystem-based management decisions despite incomplete knowledge. The development of the tool has been demonstrated with selected examples from the divergent effects of both fisheries. These examples as well as the link with the actual fishing efforts at the BPNS explored the potential for the application of risk/sensitivity assessment as a tool for spatial and temporal planning and evaluation of fisheries.

2. PARTIM I: QUANTIFICATION OF MAJOR PRESSURES FROM TRAMMEL NET AND BEAM TRAWL FISHERIES FOR THE BELGIAN PART OF THE NORTH SEA

2.1 Effects of trammel net and beam trawl fishery on endofauna

Jochen Depestele, Marijn Rabaut and Magda Vincx

Introduction

Fisheries' impact on benthic invertebrates can be assessed in several ways, e.g. short-term versus long-term, direct versus indirect, from species level (e.g. abundance or biomass) to community level (e.g. species composition, production, etc.). The WAKO-II approach focuses on the changes in abundances of individual species populations. Beam trawl fisheries induce these changes through tow path and catch mortality, whereas trammel net fisheries can only account for catch mortality. Due to the nature of its catching process tow path mortality is considered negligible in the latter. The catching efficiency of beam trawls for benthic invertebrates ranges from zero (endofauna or small epifauna) over 10% (e.g. *Liocarcinus holsatus*) to exceptional higher values for large epifaunal specimen (Lindeboom and de Groot, 1998).

The generic effects of beam trawl fisheries on benthic invertebrates, endo- and epifaunal, have been extensively documented in literature, see Depestele *et al*. (2008a) and Polet and Depestele (2010) for an overview. However, a clear-cut conclusion stays out (Løkkeborg, 2005). Two approaches are up to this day used for the investigation of the effects of trawling on benthic invertebrates (Reiss *et al*., 2009).

The first approach describes the differences in impact by comparing "fishing grounds" with different levels of fishing effort. The advantage of this method is the full inclusion of all interactions in the ecosystem (e.g. proliferation of scavengers). However, the disadvantages are the difficulties in attributing a certain effect neither to fishing nor to a specific fishing métier, in comparison to other human activities or natural disturbances. To disentangle the direct effects of beam trawling specifically, the data used have their origins in experimental fishing studies with an Before-After-Control-Impact (BACI) design. These have focused on the immediate short-term effects of the passage of a fishing gear. The "total" mortality caused by the passage of a beam trawl is caused by the mortality of organisms left dead in the tow path (tow path mortality) and organisms caught and discarded, partly dead (catch mortality). Tow path mortality has been analyzed in 2 meta-analysis (Collie *et al*., 2000; Kaiser *et al*., 2006). The WAKO-project has revised the database and extended it with unpublished data (Depestele *et al*., 2008a). The advantage of this approach is that guidance can be offered for inducing changes of the interactions between the fishing gear and marine featurs by e.g. gear modifications. The disentanglement of this information also allows its valorization in sensitivity assessments (Partim II).

Material and methods

Tow path mortality is assessed in the WAKO-database, of which the set-up is described in detail in the WAKO-I project (Depestele *et al*., 2008a). All data records where the samples after trawling are taken after 24hours are removed from the analysis. Only records with density changes are taken into account, i.e. no biomasses. The sediment has been classified by median grain size and sediment silt content, as these parameters have proven to be important environmental parameters to predict the occurrence of (macro)benthos (Van Hoey *et al.*, 2004; Verfaillie, 2008). Other sediment than sand and muddy sand did not occur. This implies that the tow path mortality can only be realistically predicted if these parameters apply, which is the case for the rather "near coastal" habitats, but not for the gravelly areas (Figure 2.1.1), nor for biogenic reefs.

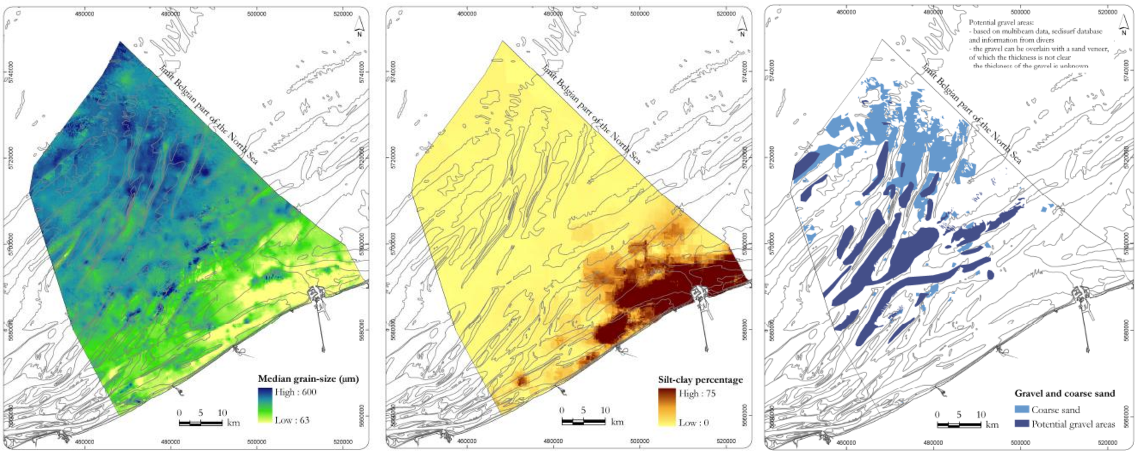

Figure 2.1.1: Median grain size of the sand fraction (left), silt-clay percentage (middle) and gravel/coarse sand in the BPNS (Modified from Verfaillie, 2008)

The densities before and after trawling are transformed to a response variable (Kaiser *et al.*, 2006):

Change in density = $(D_a - D_b) / D_b$

where D_a is the density after trawling ($n*m^{-2}$) and D_b is the density before trawling ($n*m^{-2}$). The database includes a range of species, but is not exhaustive:

- Beam trawl data from the WAKO-database are limited to mud, muddy sand and sandy sediments. A recent study extends these results for biogenic reefs ("*Lanice conchilega*", Rabaut, 2009), whereas for gravel habitat only qualitative information exits (Houziaux *et al*., 2005).
- A range of species, typically rare species are not mentioned, which is most likely due to their limited occurrences in the BACI-experiments.

For species were no data exist on tow path mortality, predictions could be made on biological traits. This idea was explored in van Marlen *et al.* (2010). The probability of mortality initially assumed that all species that encounter a gear component are killed (or removed). The model is unique in its approach, but needs further analysis to fully have predictive power (Robinson L.A., pers. comm.). The probability of mortality, given encounter is based on flexibility and fragility. In this chapter, crisp biological traits are derived from the MarLIN-website (www.marlin.ac.uk/biotic) and related to the mortality estimates from the COST-IMPACT-database (Kaiser *et al.*, 2006). Univariate, non-parametric analyses indicate the importance of the biological traits for tow path mortality in mud, muddy sand and sandy sediments. The biological traits tested were (1) fragility: fragile, intermediate or robust; (2) flexibility: none (<10 degrees), some (10-45 degrees) or high (>45 degrees); (3) size: very small (<1cm), small (1-2cm), medium (3-10cm), large (11-20cm) or very large (>20cm) and habit: attached, burrow dwelling, tubiculous or free living.

Results and discussion

The tow path mortality "WAKO-database" contains a total of 763 records (6 studies), of which 68 are in muddy sand with tickler chain beam trawl and 51 and 644 in sand with respectively chain mat and tickler chains. Some of the genera included are *Abra*, *Aphrodita*, *Asterias*, *Callianassa*, *Dosinia*, *Ebalia*, *Echinocardium*, *Enchelyopus*, *Ensis*, *Gari*, *Glycera*, *Hiatella*, *Mactra*, *Magelona*, *Moerella*, *Mysella*, *Mysia*, *Nephtys*, *Nereis*, *Notomastus*, *Nucula*, *Owenia*, *Pagurus*, *Palaemon*, *Pectinaria*, *Phoronida*, *Phyllodoce* , *Scoloplos*, *Sigalion*, *Spiophanes*, *Spisula*, *Tellimya*, *Thia*, *Thracia*, *Trachinus*, *Tunicates*, *Turitella* and *Urothoe spp*. Kruskal Wallis tests revealed a significant higher reduction in density in muddy sand substrate ($chi^2(1)=8.53$, $p < 0.01$). The differences between 4m chain mat and 4m tickler chain beam trawls were nearly significant in sandy habitats ($chi^2(1)=3.39$, $p=0.0658$). Similarly, the differences between length of the beam trawl was not apparent for tickler chain beam trawls ($chi^2(1)=3.39$, $p=0.0502$). Data are largely based on the IMPACT-I, IMPACT-II and predecessor studies. Therefore it is not surprising to find similar results as in Lindeboom and de Groot (1998). The responses of individual species differ greatly. The COST-IMPACT database (Kaiser *et al.*, 2006) and the WAKO-database indicate a similar decrease in densities of respectively 47.45% and 56.23% (mean of 26 records) for *Enchinocardium sp.*, which clearly demonstrates its high probability of mortality. However, some difficulties arise. For instance, values for the response variable vary from a mean reduction of 62 (+/-16)% for 4 records of *Spisula subtruncata* in the COST-IMPACT database (Kaiser *et al.*, 2006) to reduction between minimum 5% and maximum 60% in the WAKO-database with a mean of 24.85 (+/-35)% (13 records).

This excludes one records with a density increase. *Abra alba* is another species which has been recorded in various treatments. The COST-IMPACT database comprises 3 records with mean reduction in density of 26 (+/-25)%. The WAKO-database mentions 11 records varying from nearly no reduction in density to a complete depletion (mean reduction = 30 (+/-65)%. The high variability in tow path mortality is clearly an issue of concern. The causes could be related to:

- Mobile, scavenging species might migrate in the tow path before sampling (Bergman, pers. comm.).
- The number of sampling replicates might be insufficient to sample representatively.
- The sampling gear might be insufficient for the species investigated, e.g. sampling deep burrowing fauna with a 3m small meshed beam trawl?
- Burrowing fauna might become exposed after a commercial beam trawl passed by and therefore, it might be sampled in higher number after trawling than before trawling.
- Organisms might be moved in or out of the trawl path (Robinson, L.A., pers. comm.), which might be an issue of concern in some experimental set-ups.

Sampling issues are further discussed in the Marine Pollution Bulletin (Løkkeborg, 2005; Gray *et al*., 2006; Sheppard, 2006; Gray *et al*., 2007a; Gray *et al*., 2007b; Løkkeborg, 2007; Valdimarrson, 2007). Nevertheless the occurring difficulties for individual species, generic trends have been observed (Kaiser *et al.*, 2006). In order to focus on a finer scale of detail however, it is advised to investigate thoroughly whether the response variable is appropriate for assessment usage or not. These species assessment might therefore look into similar trends from for instance otter trawling, dredging and/or potentially other mobile gears. Investigating the variation in densities before and after trawling might be another possibility, if this information is provided at all in the original research articles. Parallels with effects on analogous species, or with effects on the species' genera or family will be used here. The changes in densities for scoring the tow path mortality in this project (see PARTIM II) are largely based on Kaiser *et al.* (2006) (Table 2.1.1).

Table 2.1.1: changes in densities ((D_{after} - D_{before}) / D_{before}) from beam trawling (based on the COST-IMPACT database, Kaiser *et al.*, 2006)

Taxon	Changes in density (%)	Taxon	Changes in density (%)
Ophiuridae	-65.938	Echinoidea	-12.445
Spisula spp.	-62	*Mysella spp.*	-6
Phyllodoce spp.	-42.38	*Mysella spp.*	-6
Nephthys spp.	-24.445	Spionida	-3.7
Scoloplos spp.	-26	glyceridae	74.525
Abra spp.	-26		

Given the difficulties above, the preliminary investigation of biological traits and their predictive power for tow path mortality estimation was based on the COST-IMPACT database, including both otter trawls and beam trawls. There were 150 records for which "all" biological traits could be retrieved (49 taxa). Only 10 taxa were detected for both fishing gears, potentially due to the fact that 58 otter trawl records originated from mud substrate; 10 from sand; and resp. 44 and 38 beam trawl records from muddy sand and sand. The generic effect of beam trawling was significantly higher than for otter trawling ($\chi^2(1)=6.89$, $p < 0.01$), indicating that the intensity of disturbance is higher, even though most species records for otter trawls were taken from mud substrate, where penetration depths of gear components are deeper (van Marlen *et al.*, 2010). In sandy habitat, the reduction in species densities is even more pronounced for beam trawling in comparison to otter trawling ($\chi^2(1)=6.19$, $p < 0.05$). Kruskal Wallis tests (Table 2.1.2) indicated the high significance of flexibility for tow path mortality (Figure 2.1.2). Size was not selected, whereas habit was important but not significant and fragility was envisaged both important and significant.

Table 2.1.2: changes in densities ((D_{after} - D_{before}) / D_{before}) from beam trawling (based on the COST-IMPACT database, Kaiser *et al.*, 2006)

Biological trait	χ^2	d.f.	P-value
Flexibility	**16.35**	**2**	**<0.001**
Size	2.72	4	0.60
Habit	6.88	3	0.04
Fragility	**6.46**	**1**	**<0.05**

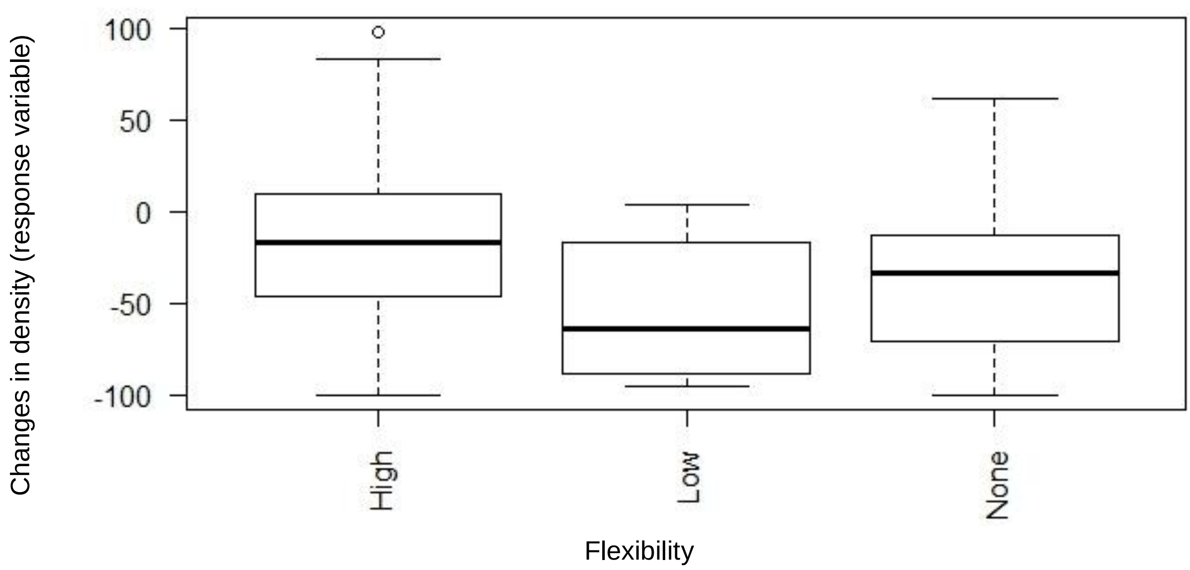

Figure 2.1.2: Boxplot indicating the effect of flexibility on changes in density after the passage of a "generic" bottom trawl (outliers are removed)

This analysis indicates that the traits which are proposed for the estimation of probability of mortality might serve their purpose (van Marlen *et al.*, 2010). The scope of this project, as well as the complexity of the experiments and gear-species interactions did not allow the extension of the model from the DEGREE-project. Instead, the COST-IMPACT database was used to indicate which biological traits are important in potential predictions of tow path mortality.

The univariate analyses do not account for potential interactions between traits, and their discriminative power is also compromised by the crisp classes. Fuzzy classification (Bremner *et al.*, 2006) might be a way forward if interactions can be taken into account. If a species can escape trawling (low encounterability) through its mobility or burrowing capacities, than its fragility is of no importance. On the other hand might its flexibility be a major factor in its resistance, even though the species is incapable of escapement of the gear. Which and how many traits, their availability and how they are accounted for (crisp versus fuzzy), is of major importance in the potential prediction of tow path mortality, but needs further investigations. For species that do not have an estimate of tow path mortality, their traits might nevertheless assist judging its tow path mortality. This analysis shows the importance of flexibility and fragility as a basis for expert judgements.

The mortality in biogenic habitats is significant for some species, closely associated with *Lanice conchilega* as well as for some other co-occurring species. The densities of opportunistic species increased significantly shortly after beam trawl passage (Rabaut, 2009). Houziaux *et al*.. (2005) declare that beam trawling accounts for local changes in benthic biodiversity of gravel habitats. The impact of beam trawls in these areas is not demonstrated at species level. *Ostrea edulis* and *Alcyonium digitatum*, are species which are assumed to suffer short- and long-term mortalities (Houziaux *et al*., 2005). Interpretation of these results must be cautiously executed, as the baseline "pre-impacted" state is largely different between the studies in biogenic, sandy and muddy sand habitats and the study in gravel areas. This is due to the nature of the experiments and the availability of data.

Conclusion

Tow path mortality is considered negligible for trammel net fishery due to the nature of its capture process. Beam trawling has intense contact with the seafloor, leading to high mortality rates for certain species. The effect is habitat-specific, but quantitative data only exist for muddy sand and sand habitats. Suggestions have been made for gravel beds and proxies are presented for biogenic reefs.

For species where data are lacking, biological traits could assist expert judgements. Model predictions are envisaged, but up to this day not available. Flexibility and fragility are demonstrated as being important. The insignificance of other traits could not be proven, as their predictive power might increase when interactions are accounted for.

2.2 Effects of trammel net and beam trawl fishery on epifauna

Jochen Depestele, Steven Degraer, Kris Hostens, Hans Polet, Sofie Vandendriessche, Els Verfaillie and Magda Vincx

Introduction

The previous chapter focuses on tow path mortality as a major source of benthic mortality for beam trawls. Here, we focus on the part that is caught, especially the non-commercial species. Commercial fish species are dealt with in chapter 2.3 (p30), as they require a different approach. Catch mortality of non-commercial species consists of the amount being caught and the chances they have to establish themselves again after being discarded. The latter is dependent on the survival chances from the catching process, catch handling to the re-establishment in its "new" environment. The amount being caught is the basis for comparison here.

The catch or discards per unit of effort is generally a firm basis for evaluation of discards (e.g. Bergmann *et al.*, 2002; Enever *et al.*, 2007; Gonçalves *et al.*, 2007). Measuring gill net fishing effort by soaking time or net length for instance is challenging, due to the combination of a complex mix of net characteristics, soaking time, net length, etc (Zydelis *et al.*, 2009). However, this metric is difficult to compare with beam trawl effort, generally expressed as fishing hours, swept area or another unit related to its active nature. Direct discard comparisons of an active and a passive fishing technique, e.g. beam trawl and trammel nets, is rather challenging. As zoned fishery management (e.g. Blyth *et al.*, 2002; 2004) is a feasible, alternative for evaluating the benthic effects, but this possibility was not available.

Therefore, two tasks were taken to evaluate the effects of beam trawl and trammel netting on epifauna:

(1) A methodology was developed that allows direct comparison of trammel net and beam trawl discards by standardizing discard per target species and taking the density of the discard species into account: discard number analysis

(2) Discards of trammel net and beam trawl fishery were compared after standardization by target species: discard composition analysis

Material and methods

Discard number analysis

This approach is univariate and intends to compare the number of specimen of a particular species that is discarded. The developed concept (see results) was tested with commercial catch data from beam trawl and trammel net fisheries, and from available density estimates in areas where these commercial catches originated from. These different data sources were available from the Belgian Part of the North Sea and the Outer Thames area in the UK.

The Outer Thames Estuary is a broad easterly-facing embayment lying offshore of south-east England on the south-western margin of the North Sea. Offshore lies the southern North Sea, which is bounded in the east by The Netherlands and Belgium. The Outer Thames study area is mainly characterized by sandbank systems consisting of fine to medium sand (especially in the Western Zone), and gullies and flats of sandy gravel and gravelly sand. The sandbanks of the Central Zone overlie a flat platform which is also characterized by several elongate depressions. The principal epifaunal assemblage found in the study area, in terms of spatial coverage across the Outer Thames Estuary REC, is an assemblage characterized by brown and pink shrimps (*Crangon* sp. and *Pandalus* sp.), echinoderms (*Ophiura albida* and *Psammechinus miliaris*) and crabs (*Liocarcinus holsatus*) that are common to the shallow waters of the southern North Sea. This assemblage showed no specific distribution pattern and did not appear to relate to any specific sediment type or habitat preference. Differences between trawl samples could mainly be attributed to aggregations of shrimps, in particular *Pandalina brevirostris*, *Pandalus montagui* and *Crangonidae*.

Similar to the Outer Thames area, the BPNS is characterized by series of parallel sublittoral sandbank systems. The sediment composition is mainly sandy, with varying mud contents, going to coarser sediments in the offshore regions. A study of epibenthos and demersal fish assemblages (De Backer *et al.*, 2010) revealed a coastal to offshore gradient reflected in five distinct communities (3 coastal and 2 offshore).

The coastal assemblages mainly differed in the occurrence and densities of *Ophiura ophiura*, *Ophiura albida*, *Crangon crangon*, *Liocarcinus holsatus* and *Nassarius reticulates*. Within the offshore samples, two subgroups were defined based on varying densities of *C. crangon*, *Echiichthys vipera* and *O. albida*.

The data sources included were:

1. Discard data from commercial trammel net catches (chapter 2.3, p.30)
2. Discard data from beam trawl catches aboard RV Belgica and a commercial beam trawler (e.g. Depestele *et al.*, 2008a), with commercial net configuration (4m beam trawls with chain mat configuration and 80mm cod end).
3. Density estimates from shrimp trawl sampling campaigns with RV Zeeleeuw, spatially and temporally concurrent with discard samplings aboard trammel net fishing vessels (http://www.vliz.be/vmdcdata/midas/cruise.php?showcruise=1)
4. Density estimates from semestral monitoring data gathered with a shrimp trawl aboard RV Belgica, spatially and temporally independent from discard samplings aboard trammel net fishing vessels (e.g. Van Hoey *et al.*, 2009a; De Backer *et al.*, 2010). Density estimates from the Outer Thames area available from the MALSF (REC) survey 2007 gathered with a 2m scientific epibenthos trawl (Anon., 2009a).

Species were selected based on the following criteria, if (1) not of commercial interest (except for *Cancer pagurus*), (2) not colonial, (3) present in commercial beam trawl samples and density estimates AND in commercial trammel net samples and density estimates and (4) minimum 2 data points for beam trawl and for trammel nets. The study on the Outer Thames area was based on a limited number of samples (20) taken during a single sampling campaign, while the BPNS characterization was based on samples from 80 stations sampled during 9 campaigns spread over 5 years. Consequently, the resolution of the BPNS study was much higher and more samples were available as density estimates in the current study. For the selection of density estimates, samples in a 10km radius from commercial catches were selected in the Outer Thames area. Since more samples and replicates were available per epibenthos assemblage in the BPNS, a 5 km radius was used for selection of density estimates in the vicinity of commercial catches. Per region and quarter, density estimates per species were averaged, after which these averages were compared with numbers in commercial catches. For the data from Outer Thames area this resulted in the following selection for commercial beam trawl catches versus density estimates:

- Selection Outer Thames REC data (2007): all scientific epibenthos trawl samples within a radius of 10 km (radius increased if less than 3 replicates within 10 km) of the commercial beam trawl tracks of 2007 or the RV "Belgica" beam trawl tracks of 2007 (divided in western and central zone samples)
- Selection RV Belgica data: all samples within 3 months of REC (November data), and minimum 3 kg of marketable sole within a sample
- Selection commercial beam trawl data: all samples within 3 months of REC (May – June data) and minimum 3 kg of marketable sole within a sample.

There is a discrepancy in sampling period between REC data and the commercial beam trawl data. The first originate from a sampling cruise in August – September 2007 while the latter originate from different sampling cruises in May – June 2007. Consequently, there is a time lag of 3 months between N58 samples and density estimates. The commercial beam trawl and trammel net catches and the density estimates from the BPNS results in:

1. Selection monitoring data of RV Belgica: all scientific epibenthos trawl samples within a radius of 5 km (radius increased if less than 3 replicates within 5 km) of the commercial beam trawl tracks or the trammel net zone, taking into account sampling year and season (time lags between catches and density estimates were maximum 3 months)
2. Selection density estimates RV Zeeleeuw: all samples within a 5 km radius of trammel net position, temporally concurrent with trammel net discard samplings (within a month)
3. Selection of trammel net data: all except samples without replicates and too few density estimates in a 5-10km radius
4. Selection of RV Belgica commercial beam trawl data: all samples with minimum 3 kg of marketable sole within a sample and at least partly within the BPNS.

Discard composition analysis

The comparison of non-commercial discards from beam trawl and trammel net fisheries in the southern North Sea was based on the above mentioned discard data. Discards are expressed per kg marketable sole to enable comparison.

The relationship between the multivariate discard cloud and several predictors was investigated using DISTLM (DISTance Based Linear Models). Our main interest was to distinguish the importance of the gear (beam trawl or trammel net) in relation to the other potential predictors: spatial (longitude and latitude), temporal (month) and environmental: depth, median grain size, silt content.

Median grain size and percentage silt fraction come from Verfaillie *et al.* (2006), respectively Van Lancker *et al.* (2007) for the BPNS. The southern North Sea median grain size and silt fraction were based on Verfaillie *et al.* (2007). DISTLM was carried out to identify the variables with the greatest influence on the variance distribution of the discard community composition. Correlation of predictors was investigated through the Draftsman plot, and variables with a $|r| < 0.85$ would have been excluded. None of the variables were excluded, although , although correlation was high for depth and latitude 0.76 and for median grain size and depth 0.74. The analysis was performed using the Forward selection procedure with Bayesian Information Criterion (BIC). The effects of different variables was visualized using a distance-based ordination (dbRDA) plot of the variation in discard composition, modeled by the predictors in the DISTLM. The dbRDA plots are constrained ordinations of the fitted values from the multivariate regression model. The vectors within the circle show the "effect" of the predictor variables included in the model, the longer the vector from the center the larger the "effect". All analyses were performed within PRIMER v6 with PERMANOVA add-on software (Anderson *et al*. 2008).

Results and discussion

The general idea is to look into the catch efficiency of both an active and a passive fishing method for a certain species. The discards of the commercial gear is compared with the density estimates in the area and time when fishing took place with the commercial gear. Graphically this implies that the density estimate of species X is mapped in the X-axis (n/m²), while the discards of species X, due to commercial fishing, will be presented in the Y-axis as the number discarded per kg of marketable sole (n/kg marketable sole). The discards are presented as a ratio of numbers discarded to kg marketable sole to enable comparison of an active with a passive fishing gear. The X-axis also uses a measure for surface which could be argued not to be efficient for trammel nets. However, we assume that trammel netting takes place in an area of uniform distribution of species X, which is generally expressed as numbers per m². Both, the density estimate of the "sampling beam trawl" and the discard estimate of the commercial gear, are plotted for beam trawls and trammel nets. Ideally, a relationship should indicate the relative effect of discarding of beam trawling with that of trammel netting. The concept was tested for seven species or species groups, that were represented by a sufficient number of samples for beam trawl and trammel net and that had corresponding density estimates: *Asterias rubens*, *Liocarcinus holsatus*, *Cancer pagurus*, *Corystes cassivelaunus*, *Macropodia* sp., *Ophiuroidea* and the group of hermit crabs (*Pagurus*/*Diogenes*). The amount of discarded individuals per kilogram of marketable sole was compared with the estimated local density at the time and place of fishing.

Since the amount of marketable sole per haul (beam trawl) or fleet (trammel net) varied substantially, this factor was taken into account during the interpretation of the results.

The scatter plot of *Asterias rubens* (Figure 2.2.1) shows that the discards (N/kgSOL) in trammel nets was low (<20/kgSOL) at any estimated density. A single high value (1990/kgSOL) was recorded in September 2009 at the BPNS west coast, corresponding with extremely high density estimates of >3000ind/1000m² (outlier not shown in graph). For beam trawl samples, only catches were recorded corresponding with low density estimates. There was a high variation in discards of *A. rubens* from virtually none to 300/kgSOL. In the Thames study area, there was a large variation in the amount of marketable sole per haul (not shown), which had a strong influence on the Y-axis value. On the BPNS, discards of *A. rubens* was relatively high (mean of 107/kgSOL) at low estimated densities and small catches of marketable sole. Similar trends in discards in trammel nets and beam trawl were observed in *Liocarcinus holsatus*, *Ophiura* spp. and *Pagurus*/*Diogenes*. Low numbers per kg marketable sole occurred for trammel netting, even at high local densities, and recorded values for beam trawl were only at low estimated local densities, with a high variation in numbers per kg marketable sole at these low densities. A high variation in total sole catch was observed in the Thames area, which was not the case in the BPNS.

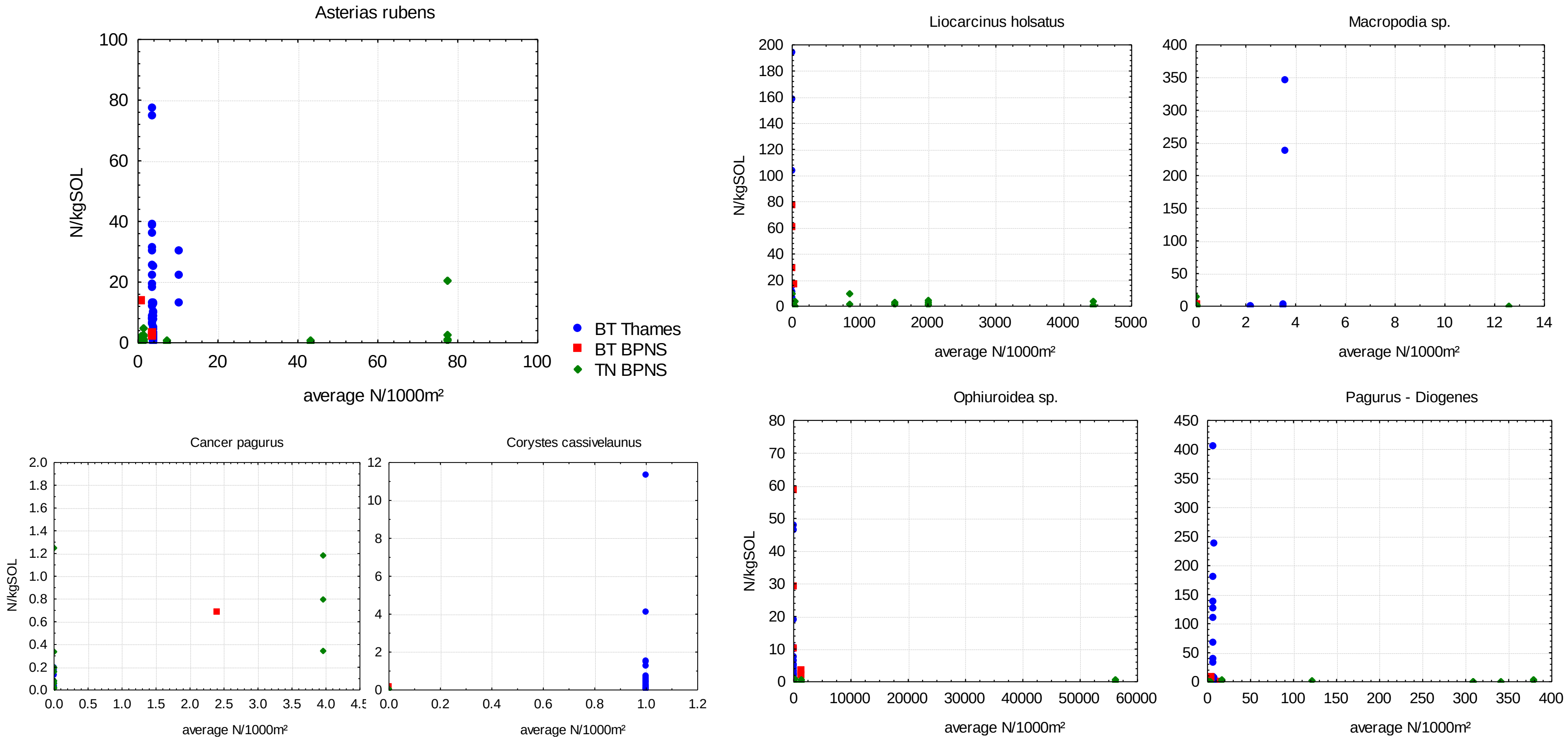

Figure 2.2.1: Scatterplots of density estimates (average N/1000m²) as X-axis and the number of discarded individuals per kg of marketable sole (N/kgSOL) as Y-axis for seven species groups. Colors distinguish between beam trawl data (Thames area: blue, BPNS: red) and trammel net data (green). Extreme values (max 2) in either of the plots were removed.

The differences in discards (N/kgSOL) between trammel nets and beam trawls were largest for *Liocarcinus holsatus* and Ophiuroidea: average numbers per kg of marketable sole were almost 50 times higher in beam trawls for *L. holsatus* and about 100 times higher for Ophiuroidea (Table 2.2.1). A different pattern in the relation between estimated densities and catches (N/kgSOL) was observed for the North Sea crab *Cancer pagurus*. This crab species is caught in commercial beam trawl tows (only 1 data point for the BPNS, but very low values (average of 0.1 ind/kgSOL) in the Thames area) and is rarely observed in epibenthos trawls (cf. density estimates). Individuals are frequently and abundantly observed in hauled trammel nets: up to 129 individuals were counted from a single trammel net fleet. The number of data points, especially for density estimates, is low, so the collection of additional data is necessary to get a clear view of the differences in impact on *C. pagurus* between trammel nets and beam trawls. The same holds true for data on the masked crab *Corystes cassivelaunus* and *Macropodia* spp. Masked crabs were found in high densities in the Thames study area and were found in beam trawl codends in varying numbers, but they were found in discard samples of only two trammel net fleets and in one beam trawl sample at the BPNS (in both cases in very low numbers). *Macropodia* sp. was frequently observed in trammel net samples in low numbers (corresponding with low density estimates). The numbers per kg of marketable sole were similar for beam trawl and trammel net catches at the BPNS, but were particularly high in the Thames study area (Table 2.2.1).

Table 2.2.1: Mean and median numbers, and standard deviations, of bycatch individuals of the 7 discussed species per kg of marketable sole, per study area and per fishing gear (TN = trammel net; BT = beam trawl)

	TN BPNS *Mean (SD)*	**BT BPNS** *Mean (SD)*	**BT Thames** *Mean (SD)*
Liocarcinus holsatus	1.9 (2.4)	88.6 (129.4)	126.5 (279.8)
Asterias rubens	79.0 (389.8)	106.6 (110.0)	18.7 (35.9)
Cancer pagurus	0.5 (0.6)	0.7 (-)	0.1 (0.1)
Macropodia sp.	1.9 (4.6)	1.3 (1.8)	49.1 (116.0)
Ophiura sp.	0.4 (0.4)	98.8 (133.7)	5.1 (10.4)
Pagurus /Diogenes	0.8 (1.2)	4.4 (2.7)	17.9 (47.0)
Corystes cassivelaunus	0.1 (<0.1)	0.2 (-)	0.9 (2.2)

Discard composition analysis

All predictors investigated in the DISTLM Forward-procedure with BIC-criterion were highly significant (P<0.0001) in the marginal tests, except for month (P<0.05). Depth, longitudinal position and gear were selected in the final model (R^2=0.35). The pattern from the DISTLM results are illustrated in Figure 2.2.2. The longitudinal factor was compromised as trammel net samples originated only from the eastern part of the North Sea, where most of the Belgian trammel net fishery takes place (Depestele *et al*., 2008a). The eastern (BPNS) and western (Thames region) part are described have a marked difference between communities (see beginning of this chapter). This would be concurrent with the differences between fish communities in eastern and western part of the North Sea (chapter 2.3, p.30), if epifaunal invertebrates and fish could be considered correlated. The discrepancies between the eastern and western part of the southern North Sea further led to subsequent analysis of the BPNS-data separately.

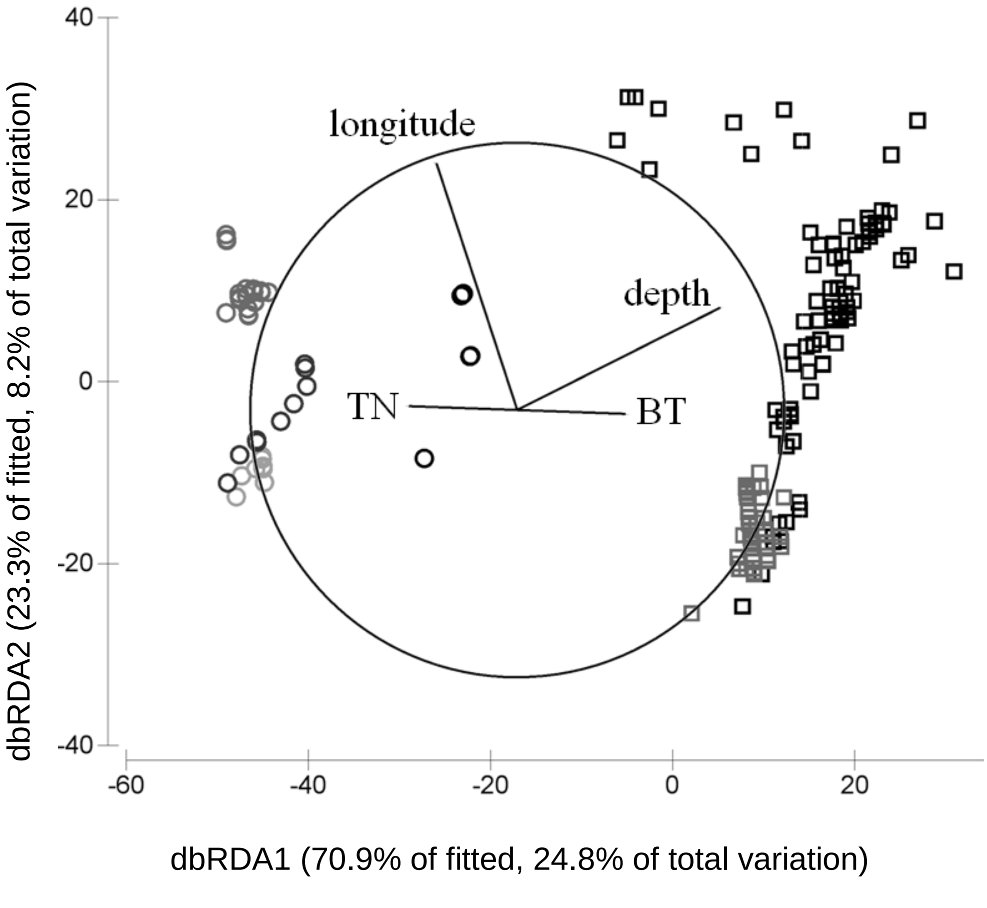

Figure 2.2.2: dbRDA plot, illustrating the DISTLM model of the discard data with environmental and fishery related explanatory factors. The plot is based on Bray-Curtis similarity matrix of square root transformed discard data (numbers per kg marketable sole). Vessels samples codes: four commercial trammel netters (circles), research vessel (black, open squares), commercial beam trawler (grey, open squares) BT: beam trawl, TN: trammel net.

The DISTLM results of the subset of BPNS-data showed that 42.34% of the variation could be explained by the combination of gear, depth, latitude and longitude (Table 2.2.2). Gear explains a high proportion of the variance in the discard composition (19.58%), also after forced inclusion spatial and environmental variables (12.87%). The large explanatory power of gear confirms the large differences between beam trawl and trammel net discard composition.

Table 2.2.2: Test statistics for the DISTLM analyses of non-commercial discards in the Belgian part of the southern North Sea, based on the Forward selection procedure and BIC model selection criterion.

	BIC	SS (trace)	Pseudo-*F*	P-value	Proportion (%)	Residual df
Marginal tests						
latitude	-	10,206	4.07	0.0008	6.78	56
longitude	-	16,824	7.05	0.0001	0.11	56
mgs	-	12,904	5.25	0.0001	8.57	56
sf	-	10,697	4.28	0.0003	7.11	56
depth	-	17,792	7.51	0.0001	0.12	56
month	-	9,552.3	3.79	0.0011	6.35	56
gear	-	29,463	13.63	0.0001	0.20	56
Sequential tests						
+gear	451.45	29,463	13.63	0.0001	19.58	56
+longitude	447.54	15,535	8.10	0.0001	10.32	55
+depth	444.91	11,505	6.61	0.0001	7.64	54
+latitude	444.33	7,218	4.41	0.0001	4.80	53

The differences in trammel net discard composition (analysis without beam trawl data) were explained by spatial position (0.26 explained variation), which ranked first in the final model (R^2=41.73), other predictors were depth and month, respectively explaining 0.10 and 0.51 of the variation (Figure 2.2.3). Longitude was strongly correlated with median grain size (Spearman rank correlation R=-80.69%) and mud content (Spearman rank correlation R=79.11%). The muddy samples along the eastern part of the coast could thus be clearly separated from others.

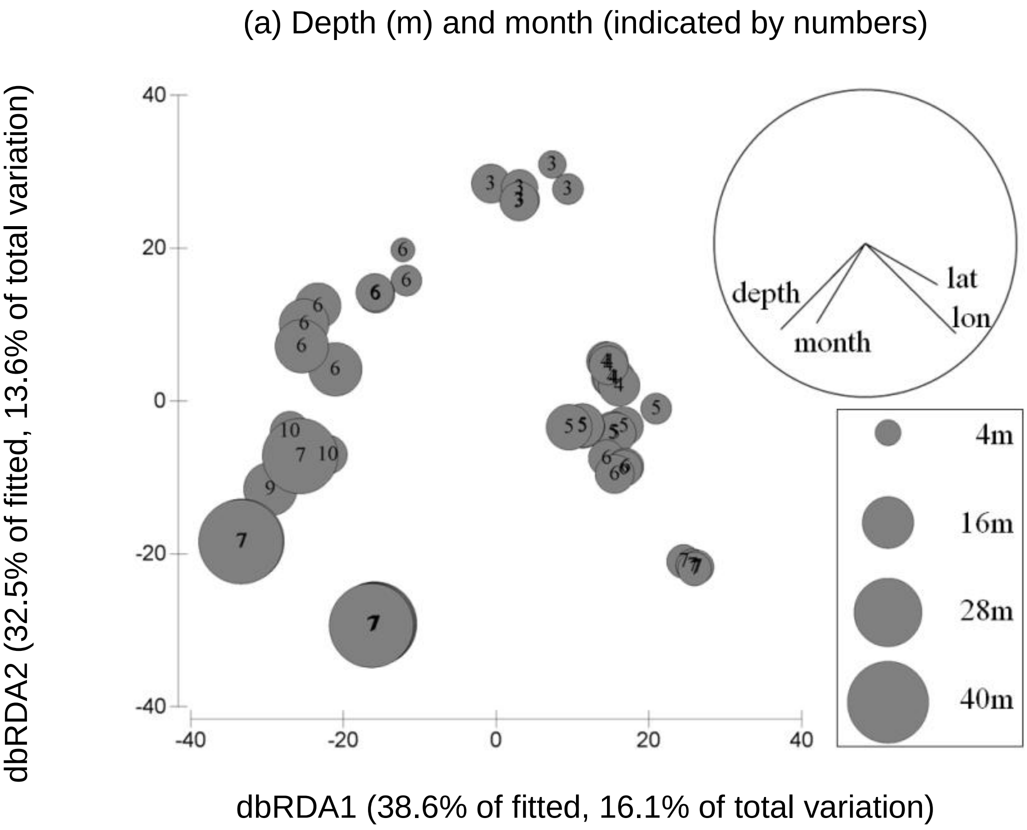

Figure 2.2.3: Bubble plot of trammel net discards (number per kg sole) in the BPNS. Extent of the bubble indicate depth, numbers are months in which sampling took place.

Conclusion

A univariate methodology was developed to compare beam trawl and trammel net discards. This methodology is unique in its applicability for direct discard comparison of beam trawl and trammel net discards. The method is data-hungry, which is a major disadvantage. A relationship between the abundance and discards of non-target species could not be established due to data limitations. Nevertheless, the method suggested for trammel nets that discards of some species (e.g. *Asterias rubens*) do not increase with their abundance, whereas for other species such as *Cancer pagurus* the danger of increasing discard rates with increased abundance does exist. Beam trawl samples suggested that areas with very high abundances of non-target species are avoided and that there is a very high variation in discarding.

The multivariate discard comparison analysis indicates that discard composition of beam trawls and trammel nets differs significantly and to a large extent. Beam trawls catch a higher total number of individuals and catch a wider range of species. The analysis further demonstrates that the variation in discard composition of trammel net fishery is dictated by time of the year and depth. Higher discard rates are found in deeper waters and outside the major fishing season for sole (March-May).

2.3 Effects of trammel net and beam trawl fishery on fish

Jochen Depestele, Wouter Courtens and Hans Polet

Introduction

The objective is finding the gear that is (1) most efficient in landing the target fish species and (2) most promising in achieving "good environmental status" for fish populations (Piet *et al.*,2010) and biodiversity (Cochrane *et al.*, 2010). Two competing approaches to fisheries management could be followed, i.e. whether or not immature fish should be protected. Although arguments exist in favour of the balanced fishing approach (Zhou *et al.*, 2010b, Rochet and Benoît, 2011), of the "spawn-at-least-once" principle and of the combination of the "spawn-at-least-once" principle with the protection of "mega-spawners" (Vasilakopoulos *et al.,* 2011), Rochet *et al.* (2011) argue that neither selective nor nonselective fishing can be said to be generally preferable for biodiversity conservation. This report is nevertheless based on current management regimes, supporting the idea of increased size-selectivity. The validity of the competing approaches are nevertheless acknowledged (Degraer *et al.*, 2010a). Discard rates of sole-targeted trammel net and beam trawl fisheries and their comparison are thus the focus for their potential to serve sustainable fish exploitation. The estimation of the total fisheries discards (all métiers) is also envisaged for the BPNS. These figures serve as an input for the assessment of seabird foraging behavior (chapter 2.4 p.42), together with length-frequency distributions (LFDs) as seabirds feed length-selectively (e.g. Garthe and Scherp, 2003).

Material and methods

Discard rates and length-frequency distributions for flatfish beam trawl fishery

Discard rates of beam trawl fishery could be estimated through fishery dependent data, collected with the EC Data Collection Regulation (DCR; Council Regulation 1543/2000 and Commission Regulations 1639/2001 and 1581/2004). These include the ILVO catch and discard data from commercial vessels, obtained since 2004 in the framework of a programme of onboard observers (Vandemaele *et al*., 2009). The discard rate was defined according to Rochet and Trenkel (2005), as the ratio of the discarded part to the total catch.

The discard rates cannot be calculated for the BPNS as there are only a limited number of hauls registered. Details on sampling, calculation and variability factors can be found in Depestele *et al.* (2011) for sole (*Solea solea*), plaice (*Pleuronectes platessa*), cod (*Gadus morhua*) and whiting (*Merlangius merlangus*). The discard rate for other species was calculated if registered in at least 50 hauls, which was only the case for brill (*Scophthalmus rhombus*) (only 2008) and turbot (*Psetta maxima*) (only 2008). LFDs are determined for species which occur in sensible numbers (ICES, 2004).

The discard rates of commercial fish which were not registered in a sufficient number onboard the commercial fishing trips, were estimated from LFD-data from the RV "Belgica" (50.9 LOA, 765GRT,1154kW engine power). The trials were carried out in 2006-2009 on commercial fishing grounds in the southern North Sea (www.mumm.ac.be). Towing speed was between 3 and 4 knots, hauls were conducted during day or evening times. Additional data were available for gurnards (Triglidae) (175 individuals), rays (Rajidae) (2196 individuals), flounder (*Platichthys flesus*) (200 individuals), dogfish (*Scyliorhinus canicula*) (2856 individuals), dab (*Limanda limanda*) (3871 individuals), bib (*Trisopterus spp.*) (5143 individuals) and lemon sole (*Microstomus kitt*) (979 individuals). The number of individuals by length class is estimated for each hour fishing and averaged over all hauls. The discard rates are based on LFDs and the minimum landings sizes (MLS) for discarding, measured as total length, i.e. from nose to tail. MLS were utile for gurnards (20cm), rays (50cm since 2009), flounder (25cm), dab (23cm), bib (20cm) and lemon sole (25cm). As dogfish does not have a MLS, estimates from other ICES Divisions were used as a proxy. The numbers per length class were converted to a weight allowing the estimation of discarded biomass, needed for its relevancy as a food source for seabirds. The conversion is exemplified in annex 3 for North Sea data on sole, plaice, cod and whiting. The values coincide well with the Fishbase estimates (Froese and Pauly, 2000), which are used for species where discard estimates were based on LFDs and MLS.

Discard rates and length-frequency distributions for sole-targeting trammel net fishery
Discard and landing data have been collected from Belgian commercial trammel net fishery targeting sole within the framework of the WAKO-II project. Fishing trips were randomly selected on the condition that sole was the target species and trammel nets were applied as described in Depestele *et al*. (2008a). Mesh sizes of the inner panel varied between 90 and 100mm and the twine used was monofilament poly-ethylene, multi-monofilament poly-ethylene or multifilament nylon. The fishermen selected fishing grounds in their traditional fishing areas to ensure the highest possible catches, reflecting commercial practice. Trammel nets were usually set in the afternoon or evening before sunset and were hauled the next day before or during sunrise as described in Depestele *et al.* (2006). All fishing trips did not last longer than 24hours, except one that took place over four days. Ongoing observers sampled 16 fishing trips (113.85km net) onboard four different trammel net vessels during 2009 and 2010 in the Belgian Part of the North Sea. The seasonal distribution of fishing trips ought to reflect commercial practice (Figure 2.3.1). Three trips were conducted in the first quarter (20.170km), 8 during the second (38.78km), 6 during the third (44.7km) and two fishing trips in the fourth quarter (10.2km). Fishing trips were the primary sampling unit, fleets the secondary.

A fleet is defined as the combination of net pieces between two flags that mark the nets. Their length varies between 600 and 3600m. Fishermen were asked to collect landed and discarded species in separate boxes per fleet. Observers collected all species (fish and invertebrates) that fell on deck and disentangled invertebrate species. The discarded and landed fish species were weighed onboard and measured to the nearest centimeter below. Benthic invertebrates were collected and analyzed in the lab.

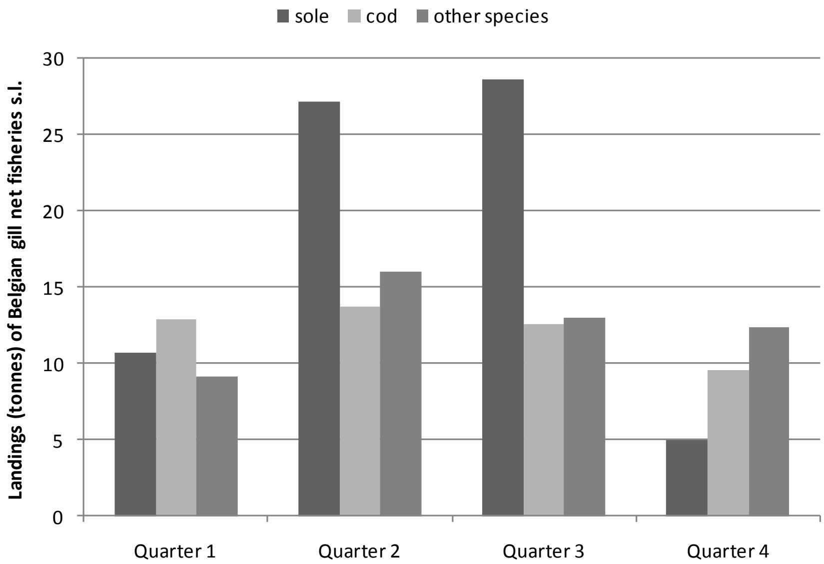

Figure 2.3.1: Seasonal distribution of landings of Belgian gill net fisheries (not métier-based) in ICES rectangle 31F2

The fish species for which LFDs could be estimated from this observer program are cod (449 individuals), flounder (1308 individuals), dab (3403 individuals), plaice (1979 individuals), sole (6513 individuals) and whiting (337 individuals). The number of individuals by length class is standardized to 1000m of net and averaged over all fleets. LFDs are well spread of the quarter, although most sampling effort to place in the second quarter. All species were at least sampled in 30 fleets, accounting for at least 100 individuals per quarter except cod in the first and fourth quarter, flounder in the third and fourth quarter and whiting in the first and third quarter. The discard rates were estimated from formula [2.3.1]. Discard rates are presented for species that were registered in a sufficient number of fleets and numbers.

Total discards in the BPNS

The total discarded biomass serve as a food source for seabirds (chapter 2.4, p.42). Since the latter is focused in the BPNS, discard estimates are needed for this specific zone and therefore all relevant fishing métiers should be accounted for.

The discard rates for sole-targeted trammel netting and for flatfish beam trawling are presented for commercial fish species (above) and non-commercial discard species (chapter 2.2, p.19). Discard rates (or proxies) for other métiers were estimated from literature or selectivity curves. Gutted biomass from landed species were calculated from EC conversion factors (EC, 2009).

The discard estimates were raised from the sampling unit to fleet level using landings data. The raising procedure provides very different results from using effort or trip data as auxiliary variable, and concerns have been presented for each procedure (ICES, 2007), such as the dependence of accurate official landings data on correct reporting by the skippers (Catchpole *et al.*, 2011) and the risk of unrealistically high estimates when landings are small (Stratoudakis *et al*, 1999). Overcoming this lack of guidance on appropriate discard raising procedures is currently being investigated for the Belgian fleet, but results were not available at the time of writing the WAKO-II project (Vandemaele *et al.*, 2009). Landings data were aggregated by quarter and ICES rectangle level for 2006-2008. The BPNS was approximated by ICES rectangles 31F2/3 and 32 F2/3. Belgian landings were based on the database of the Belgian Fisheries Service (Anon., 2007a; Anon., 2008a; Anon., 2009b). The Dutch flatfish beam trawlers play an important role in the fisheries in the BPNS, followed by Belgian trawlers, French fishermen and sporadically English and Danish fishermen (Depestele *et al.*, 2008a). The landings of Dutch and English static gear fisheries in the BPNS is minor in the investigated period (Polet *et al*., 2010; van Hal *et al*., 2010). Dutch landings data from beam trawlers were provided by the Dutch Fisheries Service ("*Ministerie van LNV*") through IMARES. Landings data of French and Danish trammel/gill netters are provided respectively by Ifremer and DTU Aqua. The French fisheries landings were obtained from fish market data registered by the French Fishery Ministry (DPMA) and extracted from "*Harmonie*", the French Fisheries Information System database managed by Ifremer. Landings data were available by gear, ICES rectangle and season. Métier-based discrimination was based on the landings' compositions. All trips where beam trawlers land at least 5% shrimp weight, are considered shrimp beam trawlers. Static gear fisheries are generally more species-selective than bottom trawlers (Marchal, 2008) and vessels tend to combine several fisheries or métiers, e.g. trammel net fisheries for sole, gill net fisheries for cod, hand lining for sea bass, etc. (Guitton *et al*., 2003; Depestele *et al*., 2008a; 2008b). The Belgian static gear vessels in 2006-2008 were also focusing on sole, cod and sea bass. Additionally, experimental trials were carried out in 2008 for turbot with large mesh set-nets and for whelks or cuttlefish with pots (Verhaeghe *et al*., 2008). In order to discriminate the hand lining trips from the trips with gill nets, trips were selected that had at least 50% sea bass in the landings and less than 10% of flatfish, as flatfish are not landed when hand lining for sea bass (Depestele *et al*., 2008b).

From this selection, the trips that might have used hand lines are selected on the basis of the vessel. In 2006-2008 only two commercial fishing vessels were possibly conducting hand lining for sea bass. The remaining fishing trips have been categorized in trips targeting sole with trammel nets if sole comprised at least 15% of the sum of sole, cod and sea bass landings. The other fishing trips are assumed to be targeting cod and/or sea bass. Mostly these fishing vessels fish for cod and/or sea bass, using gill nets with a mesh size between 120 and 170mm (Depestele *et al*., 2008a). The changes in discard patterns were simulated for the replacement of all beam trawling with trammel netting by the assuming that total sole landings remained equal, but the total discards were altered due to changes in catch composition and discard rates.

Results and discussion

Discard rates are estimated from different approaches: long-established and short-term discard-observer programmes (e.g. DCR-observer programme, WAKO-discard observer programme), from cumulative catch curves (e.g. RV "Belgica"-data), from the combination of selectivity ogives and abundance estimates (based on Piet *et al.*, 2009 and Polet *et al.*, 2010) or from literature. None of the methodologies are perfect (e.g. Cotter and Pilling, 2007; Benoît and Allard, 2009). Shortcomings are highlighted throughout the text and are of prime importance in value judgements. Imprecise estimates, inaccuracies and large uncertainties occur throughout all of the methods. Moreover, their usage in a fine-spatial scale, such as the BPNS provokes large difficulties. Nevertheless, discard rates can be indicative and together with selective properties of the fishing gear (annex 5), lead to generic statements on the gear's potential for ecological sustainability.

Discard rates and length-frequency distributions for flatfish beam trawl fishery

Discard rates from the observer programme are only available for a limited number of species. The weight-based discard rates were high to very high for cod (47+-SD 31%, weight-based) and whiting (61+-SD 33%, weight-based) and varied considerably from year to year. Sole and plaice discards were consist over the years, respectively 13+- SD 11% and 27+- SD 21% (weighed-based). Brill and turbot have hardly been discarded in 2008 (resp. 3 out of 157 hauls, and 1 out of 158). The LFDs are presented in annex 4 (modified from Depestele et al., 2011), together with selection ogives (based on Polet *et al.*, 2010).

Even though these data are the best available, interpretation asks for caution. The discard observer program has a low coverage due to a rather small number of observers and large costs (Borges *et al.*, 2004). Therefore discard estimations are generally imprecise and noisy (Dickey-Collas *et al.*, 2007), which is indicated in our case by the high standard deviations (SD).

Moreover, most of the sampled trips originated from the western part of the southern North Sea (see Depestele *et al.*, 2011). These data are expected to be representative for the Belgian beam trawler fleet of southern North Sea, which is managed as one management unit for fish quota. The discard rates are the best available estimates at hand, but the spatial scale might be inappropriate for its evaluation in the BPNS. This hypothesis is supported by the indication of two distinct fish communities in the eastern and western part of the southern North Sea (Ehrich *et al.*, 2009) and potentially by differences in high-grading (discarding of marketable fish) between Dutch and Belgian beam trawlers, which is caused by differences in quota management and market prices (Poos *et al.*, 2010 and Depestele *et al.*, 2011). As these proxies are the only available information, they were nevertheless used as a proxy for discard rates of Belgian beam trawlers in the BPNS. Dutch discard data would result in similar difficulties for estimation in the BPNS (e.g. van Helmond and van Overzee, 2008). Alternative approaches present difficulties on the inclusion of high-grading (e.g. Polet *et al.*, 2010) or are in development, such as self-sampling (Vandemaele *et al.*, 2009; Graham *et al.*, 2011).

For commercial fish species of which discard rates could not be estimated from the observer programme, approximations were made on the basis of data from RV "Belgica". The discard rates were high for bib (51.10 +-SD 29.24%), dab (62.89 +-32.52%), lemon sole (69.92 +- SD 32.87%) and rays (63.53 +- SD 31.24%). This is confirmed for rays by the commercial fishing data, where all recorded rays are discarded. The discards of gurnards (26.71 +-SD 38.80) and flounder (15.64 +-SD 29.96%) were limited. The literature is investigated to enable an indication of discard proportion for dogfish. A "rather similar" species, *Squalus acanthias*, is protected in Norway by a MLS of 70cm, which would imply all dogfish in our database are discarded. Borges *et al.* (2005) report length frequencies of discarded dogfish up to 75cm for beam trawl fisheries in the water around Ireland. This implies as well that all individuals are discarded as the largest individuals reach 65cm in our LFDs. This discard proportion is confirmed by Enever *et al*. (2007), who report 99% discards for dogfish in the English Channel, Western approaches, Celtic and Irish seas. Van Helmond and van Overzee (2008) however, report a discard proportion of 20% by numbers. A MLS of 55cm implies a discard rate of 76% based on LFDs for the Southern North Sea, while a discard rate of 98% is reached when a MLS of 60cm is considered. LFDs are presented in annex 4. The discard rate in numbers is compared with the discard rate of beam trawlers in the ICES subarea VII (Enever *et al*., 2007). The discard rate of gurnards and rays is lower in the estimates of the "MLS-approach" for the southern North Sea as the observations by Enever *et al*. (2007), respectively 19% versus 82% and 64% versus 82%.

The discard rate of lemon sole is higher in the southern North Sea (respectively 77% versus 37%), whereas the discard rate of bib and dab is comparable in both fisheries (respectively 68,1% and 74,9% in the southern North Sea and 75% and 97% in ICES subarea VII). High-grading might occur for bib, dab and gurnards. Discard estimates for lemon sole and rays are not expected to be underestimated.
The discard estimates presented here included all commercial fish species which comprise at least 1% of total landings of 2006-2008. Other commercial fish species landed in less than 1% are *Anarchichas lupus*, *Anguilla anguilla*, herring (*Clupea harengus*), sea bass (*Dicentrarchus labrax*), *Dicologlossa cuneata*, *Hippoglossus hippoglossus*, *Lepidorhombus whiffiagonis*, *Lophius spp*., *Melanogrammus aeglifinus*, *Merluccius merluccius*, ling (*Molva molva*), mullets (*Mullus spp.*), smoothhound (*Mustelus mustelus*), pollack (*Pollachius pollachius*), *Sander lucioperca*, mackerel (*Scomber scombrus*), sprat (*Sprattus sprattus*), spurdog (*Squalus acanthias*), horse mackerel (*Trachurus trachurus*). Their potential discards are not included. Discards of non-commercial species are summarized in chapter 2.2 (p.19).

Discard rates and length-frequency distributions for sole-targeting trammel net fishery
Discard data are only available for a limited number of métiers (Polet *et al*., 2010). Most of them focus sampling effort mainly on discards of trawling (e.g. Borges *et al*., 2005, Enever *et al.*, 2007). This is especially valid for Belgium where most of the fishing fleet consists of bottom trawlers. Therefore, a one-year discard sampling programme was set up in Belgium in conjunction with trammel net fishermen. All four trammel net fishermen cooperated, which strongly reduced potential bias in selecting vessels. Adverse weather, or potential non-random selection of fishing trips was nevertheless a potential remaining source of bias (Catchpole *et al.*, 2011). The observed discard rate, based on weights, are high to very high for dab (55.90 +-SD 44.79%), flounder (57.33 +- SD 47.78%) and plaice (70.23 +-SD 35.07%). The discard rate of sole is very low (2.19 +-SD 3.20%). The discard proportion of all fish species is estimated at 21.9%. Discard rates of cod and whiting have not been calculated, due to the low numbers caught in the fleets. Variability in discarding is high, potentially indicating differences in fishermen's behavior, spatial and temporal characteristics. As in beam trawl fishery, high-grading occurs as well, potentially being a major cause of discarding marketable plaice and dab. This suggests that using selectivity underestimates discard rates for trammel netting, as was the case for beam trawling (Depestele et al., 2011). LFDs are presented in Annex 2, where annex 3 illustrates the differences in selective properties between beam trawls and gill nets for sole, plaice, cod and whiting (Polet *et al.*, 2010). Selectivity of gill nets is presented, as trammel net selectivity is relatively poorly studied (Erzini *et al.*, 2006). Ulleweit *et al.* (2010) evaluated gill nets for sole, which were deployed at the Dutch coast in the southern North Sea.

Gill nets have different characteristics than trammel nets, i.e. the total fleet length set is higher and they are single-walled (Depestele *et al.*, 2006). However, the discard rates ought to be in the same magnitude. Ulleweit *et al*. (2010) reported a mean overall discard rate of 30%, mainly consisting of dab, based on 7 fishing trips. Another source of comparison is the gill and trammel net fishery, fishing for less than 24 hours and using a mesh size of 110mm and below in the Western part of the English Channel. Main target species however include sole, but also pollack, ling and hake. Although this fishery is clearly a mix of different métiers, the discard rates are provided. Discard proportions are zero for sole and cod, whereas all whiting and dab are discarded (Morizur *et al.*, 1996). Polet *et al.* (2010) modeled discard proportions for the North Sea on the basis of selectivity. Their results show discard rates of 93% for plaice, 23% for sole, 16% for cod and 78% for whiting. The latter two discard rates (cod and whiting) will be used for the estimation of total discards in the BPNS. Other species comprising the discards were allis shad (*Alosa alosa*), brill, gurnards, herring, horse mackerel, dogfish spp., mackerel, sardines (*Sardina pilchardus*), sea bass and twaite shad (*Alosa falax*), turbot. Fish species which were landed in 2006-2008, but not sampled during the WAKO-trips: lemon sole, ling, mullet, pollack, smoothhound, and *Salmo trutta*.

Discard rates other fishing métiers

Enever *et al.* (2007, 2009) have estimated a mean discard rate of 36% of fish numbers caught by trammel, tangle and unspecified gill netting in ICES sub-area VII by English and Welsh fishing vessels (28 trips in 2002-2005) and of 47% in the North Sea (14 trips in 2003-2006). Ulleweit *et al.* (2010) specifically discriminate between set nets for sole and cod gill nets. The latter has an overall discard rate of 2%, based on three trips of German fishing vessels in the North Sea. Kindt-Larsen *et al.* (2009) estimated that cod discard rates vary between 0.1% and 12.6% from the fully documented fishery-methodology. Based on landings and selectivity parameters, Piet *et al*. (2009) and Polet *et al*. (2010) estimated that discards for cod are 20%, 72% for haddock (not relevant for the BPNS), 30% for plaice, 2% for sole and 84% for whiting. High-grading is not included in this modeling exercise. These discard rates will nevertheless be used as a proxy in this project. Discard rates of turbot gill net fisheries have, to our knowledge, only been described for the Western part of the English Channel. Discard rates are reported for a soaking time of 2 to 3 days. For cod the discard proportion is 33% in summer and 20% in winter; 2% or 4% for turbot, 20% and 42% for brill, 2% and 42% for dogfish and 65% and 50% for pollack in respectively summer and winter (Morizur *et al*., 1996). Discard rates for sea bass targeted hand lining are assumed negligible.

Discards for shrimp beam trawling are based on Polet (2004) and unpublished data from the ongoing shrimp pulse trawling research (Verschueren *et al.*, 2009). Data from the latter did not include the sieve net selectivity device. Hence, discard data were simulated using (Polet *et al.*, 2004).

Total discards in BPNS

The landings of the four ICES rectangles are the basis for raising to fleet level (Figure 2.3.2). Fleet level discards are presented by fishing gear, and for flatfish beam trawls and sole-targeted trammel nets by major groups for seabird food (Figure 2.3.3).

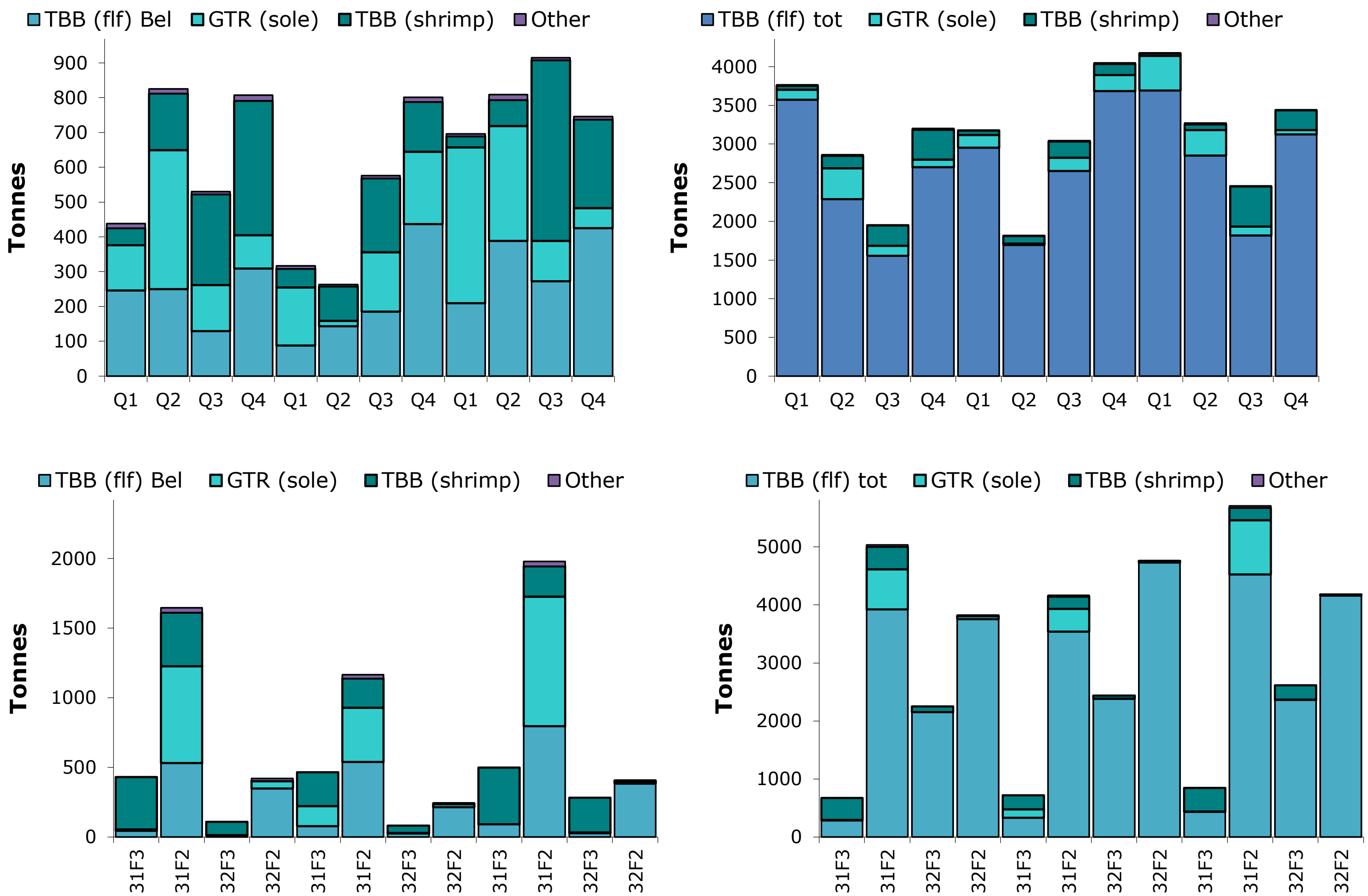

Figure 2.3.2: Landings of flatfish and shrimp beam trawl (TBB flf resp. TBB shrimp), trammel net (GTR sole), and other fisheries for the consecutive years 2006-2008. Left graphs without Dutch beamers.

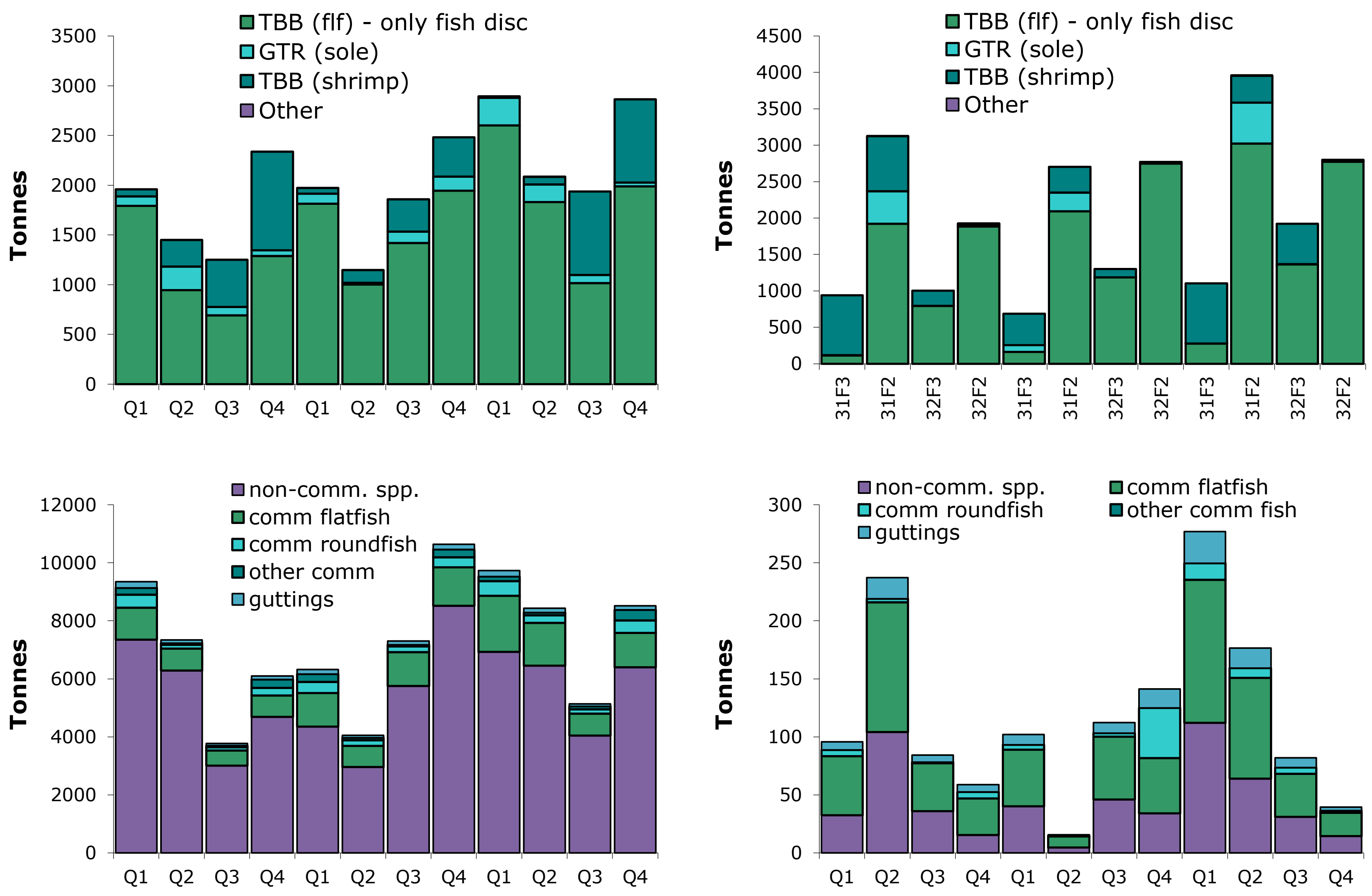

Figure 2.3.3: Discards of flatfish and shrimp (TBB flf resp. TBB shrimp) beam trawl, trammel net (GTR sole), and other fisheries for 2006-2008 (upper graphs). Composition of beam trawl (left below) and trammel (right below) discards.

The landings in four ICES rectangles are dominated by flatfish beam trawlers, especially the Dutch. Shrimp beam trawling takes place closer to the shoreline, partly reflected by the limited landings from 32F2. French gill netters land especially from 31F2, which is presumably but not exclusively originating from outside the BPNS (Depestele *et al.*, 2008a). Foreign VMS-data were not available (chapter 4, p.97), which made it impossible to correctly distinguish between landings from inside and outside the BPNS. If VMS-data would have been available however, there still is the difficulty in discriminating between landings from a fishing trip which took place both inside and outside the BPNS, and the problem of small boats without VMS-obligations. In this chapter, landings and discard data are presented for the whole ICES rectangles. Discard patterns are aligned closely. The discards from shrimp beam trawlers are most apparent in the third and fourth quarters, and are closer to the shoreline. These discards include small individuals, potentially increasing their importance for seabirds. Beam trawl discards are by far the highest in all quarters and ICES rectangles, except for 31F3. Most of the beam trawl discards are dominated by benthic invertebrates, followed by flatfish. Discards of sole-targeting gill netters are considerably lower, and discard categories are more evenly spread. If all sole landings were caught by trammel net fishing instead of beam trawling, the bycatch of cod and dogfish would increase, whereas the landings of bib, brill, dab, flounder, gurnards, lemon sole, plaice, rays, turbot and whiting would decrease. Discard rates follow the same trend as the changes in landings without major differences due to changes in discard rates between the métiers. Sole-targeting trammel netters need to complement this current métier with other, also species-selective métiers. This thinking exercise merely illustrates that static gear fisheries are generally more species-selective than bottom trawlers (Marchal, 2008).

Conclusion

Discard rates are high for a range of flatfish and roundfish species: dab, flounder, plaice, whiting, cod, etc. The size-selectivity for sole is fine-tuned for beam trawls and trammel nets, although the steeper curve for trammel nets was reflected in virtually no sole discards. The total fish discards of beam trawls are higher due to their mixed character, which invokes a larger number of fish species to be discarded.

Key in discarding behavior is not only selectivity, but fishermen's behavior, local fishing grounds (sand banks vs. gullies, Thames estuary vs. BPNS) and other sources of variability. Technical constraints in discard estimation lead to ignorance of these effects, as well as to inducing high uncertainties in the fleet discards. There are many issues to be tackled before realistic discard estimates at fleet level will occur. Nevertheless, the divergent trends in species-selectivity and the impediments of achieving ideal size-selectivity for all species should allow clear guidance for fisheries management, whether selective or non-selective fishing is envisaged.

2.4 Effects of trammel net and beam trawl fishery on seabirds

Wouter Courtens, Nicolas Vanermen, Jochen Depestele and Eric W.M. Stienen

Introduction

In the WAKO-project, several possible impacts of fisheries on seabirds (bycatch of seabirds, disturbance, discards as a food source for seabirds and overfishing) were reviewed. In the WAKO II-project two of these impacts, bycatch and the effects of discard production are analyzed on a more detailed level. Also the consequences of a theoretical shift from beam trawl towards trammel net were studied.

Material and methods

Estimation of bycatch of seabirds

To estimate the bycatch of seabirds in the Belgian part of the North Sea (BPNS), three methods were used. Firstly, direct observations were conducted by observers during 15 commercial fishing trips. These observers noted all details of the bycatch of birds, marine mammals, fish and benthos. As a second approach, fishermen were asked to keep a log for each trip, detailing all bycaught seabirds. These logs were kept by the fishermen of three vessels. A third method was an enquiry of the fishermen of two vessels fishing with gill nets on their general experience with bycatch of seabirds (how many birds and which species are caught, where an when are they caught).

Interactions between discards and seabirds

The aim of this chapter is the estimation of the number of seabirds that can be sustained by discards and offal of fisheries in the BPNS. In order to do so, four questions must be answered:

1) What is the 'average scavenger community' in the BPNS?
2) What is the amount of discards and offal produced by fisheries in the BPNS?
3) What type of discards and offal are consumed by seabirds?
4) What is the energetic need of seabirds and the energetic equivalent of discards?

The 'average scavenging community' of seabirds was derived from the INBO-dataset of seabird counts. This dataset includes standardised counts of seabirds conducted between 1992 and 2011. First, a general assessment of the importance of fisheries for seabirds was made by investigating the degree of association of the different seabird species with fisheries activities. The most important scavenging species in the BPNS were selected and we estimated their populations present in the BPNS This was done for four 'quarters' (Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec), in order to have an overlap with the four quarters used in the discard-calculations.

To compensate for the uneven spatial distribution of some species (some are more abundant near the coast, others prefer areas further at sea), the BPNS was divided in 6x6 km² grid cells. For each grid cell and each period, the geometric mean density of the selected seabird species was calculated, based on count data collected during the period 2003-2010. These densities were extrapolated over the surface of the corresponding grid cells and summed up to estimate the total number of birds present at the BPNS. The amount of discards produced by the beam trawl and trammel net fisheries per quarter in the BPNS was calculated in chapter 2.3 (p.30). Data on the type of discards and offal consumed by seabirds was extracted from the literature since no experimental approach on this in the BPNS was included in the WAKO-II proposal. Also, data on the energetic needs of scavengers and the energetic content of discards were derived from literature. By combining all these data, the importance of bycatch as a food source for seabirds in the BPNS could be calculated. Also the consequences of a theoretical shift from beam trawl dominated fisheries to trammel net fisheries was estimated (see data from chapter 2.3, p.30).

Results

Estimation of by-catch of seabirds

On 15 trips, the on-board observers did not note any bycatch of seabirds in the gill nets. Also, the log of the three fishing vessels did not contain any mention of bycaught seabirds. The inquiry of the captains of two fishing vessels did yield the mention of 'some Cormorants caught every year' in the first case and 'some Cormorants caught in whole career' in the other.

Interaction between discards and seabirds

Of all seabirds counted during the INBO surveys between 1992 and 2009 (n=774.167), 38% was associated with some kind of fishery activity. Since 2003, 15 species of seabird were noted down as being a 'ship-follower' (this is different from being a scavenger). Especially, a high percentage (38-42%) of the larger gull species, i.e. Herring, Lesser and Greater Black-backed Gull, was associated with fisheries activities. Smaller gulls were also frequently noted as ship-followers. Especially Kittiwake (26%) often occurred in association with fishing vessels. Mew Gull (10%), Little Gull (7%) and Black-headed Gull (6%) were less frequently seen behind boats. Of the non-Larids, only Northern Fulmar (25%) and Northern Gannet (9%) were important ship-followers. Other species were only occasionally seen behind fishing vessels. Figure 2.4.1 gives the relative seasonal abundance of seabirds associated with fishing vessels. Obviously, the bulk of the ship-followers belong to only a limited number of species.

Following this, we define the 'average scavenger community in the BPNS' as being composed of 7 common seabird species known to consume fishery waste regularly, being Lesser Black-backed Gull, Herring Gull, Great Black-backed Gull, Kittiwake, Common Gull, Northern Fulmar and Northern Gannet. They make up more than 95% of the total number of ship-followers in all seasons.

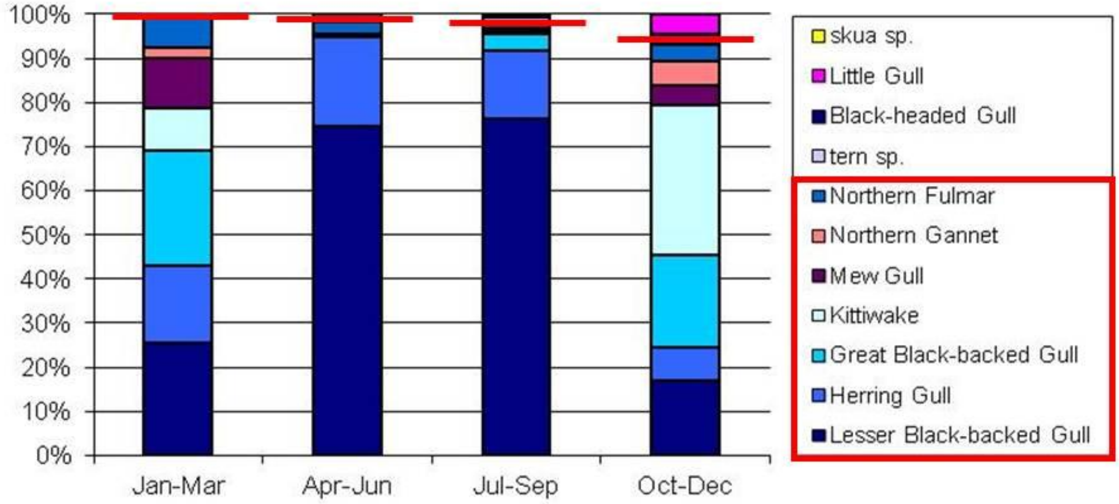

Figure 2.4.1: Seasonal composition of ship-following seabird community in the BPNS between 2003 and 2010. Gulls not identified to species level were omitted

The total population of the 7 common seabird species regularly associated with fisheries activities was calculated for the BPNS based on the standardized seabird counts (Figure 2.4.2). This clearly shows the temporal differences in the numbers of each species present. During autumn, the total population of scavengers was the smallest (around 3000 individuals). In summer, the scavenging population was around 4500 birds and almost entirely made up of Lesser Black-backed and Herring Gull. Both species then breed in a large colony (total number of breeding pairs between 6000 and 7000) in the port of Zeebrugge with smaller numbers elsewhere along the coast. In the two 'winter' periods, many more scavengers were present (7000-9000 individuals) and also the species composition was much more diverse compared to the one during summer months.

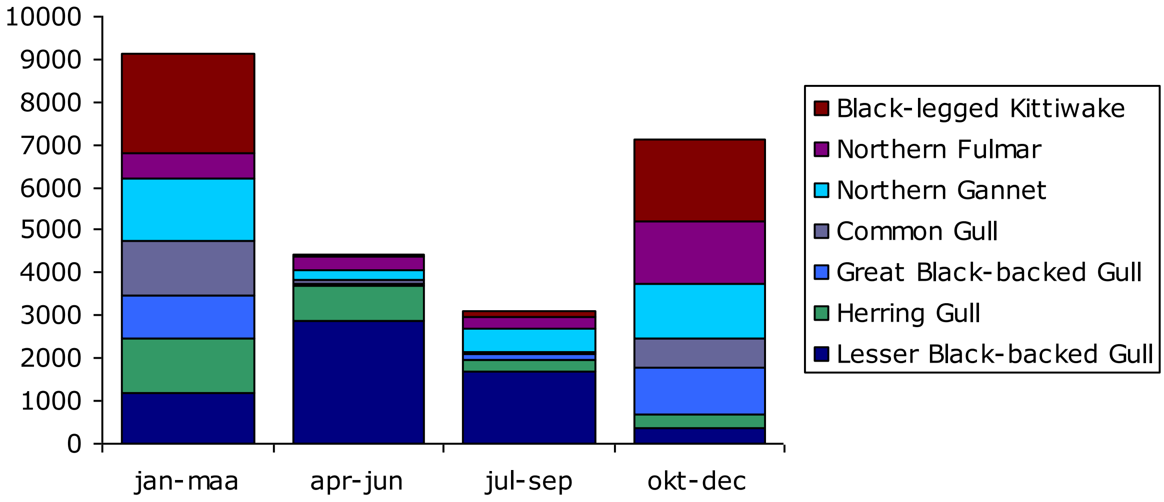

Figure 2.4.2: Total population of 7 scavengers species in the BPNS in 4 periods

Estimation of the amount and energetic value of discards in the BPNS

Total amount/discard percentage/beam trawl and trammel net

The amounts of discards produced was calculated for the 4 ICES-rectangles the BPNS is part of (31F2, 31F3, 32F2 and 32F3) and converted to the total amount for the BPNS by taking into account the ratio of the area of each rectangle inside and outside the BPNS (see also chapter 2.3, p.30). All discards produced by Belgian and Dutch flatfish beam trawl, Belgian shrimp beam trawl, Belgian, Danish and French Sole trammel net and Belgian Cod and Turbot trammel net are included.

Figure 2.4.3 gives an overview per 'season' of the mean amount of discards that was produced in the BPNS by both beam trawl and trammel net fisheries (mean yearly amount for the period 2006-2008). The majority of discarded organic matter (98%) is produced by the beam trawlers (and of these, around 93% by the flatfish beam trawlers) (Figure 2.4.4). Almost all discards from by trammel net fisheries is produced by the sole trammel netting with only minor quantities from Cod or Turbot fisheries.

Table 2.4.1 gives the mean yearly amount of all types of discards produced in the BPNS between 2006 and 2008 (based on calculations in chapter 2.3, p.30). The energetic equivalent of these (Table 2.4.1 and Figure 2.4.5) was calculated based on the calorific values in Garthe *et al*. (1996). Flatfish, roundfish and other fish (mainly Elasmobranchs) all have an energetic equivalent of 4 kJ/g, that of offal (result of the gutting of fishes onboard) is 9 kJ/g. The 'invertebrate' fraction was divided in Crustaceans (3,5 kJ/g), molluscs (1,5 kJ/g), echinoderms (2,0 kJ/g) and other invertebrates (2,8 kJ/g). Due to the nature of the data, also smaller amounts of roundfish, flatfish and Elasmobranchs are included in the 'invertebrate' fraction.

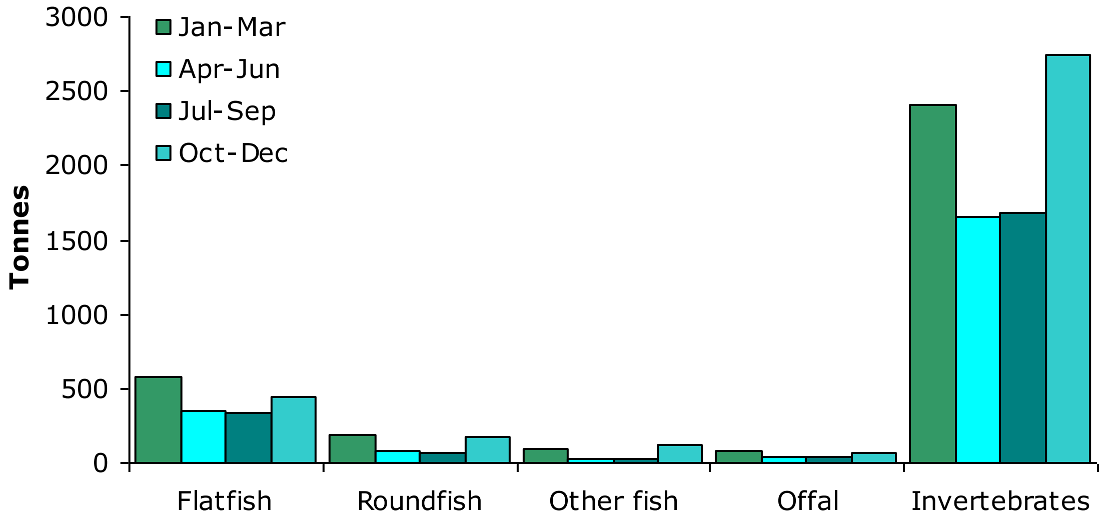

Figure 2.4.3: Mean yearly amount of different categories of discards produced by both beam trawl and trammel net fisheries in 2006-2008 in the BPNS per season

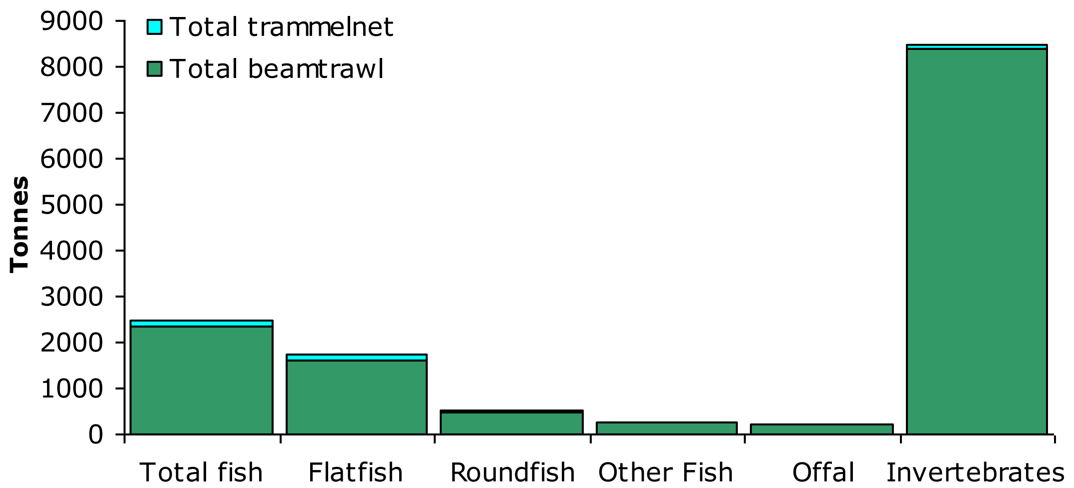

Figure 2.4.4: Mean yearly amount of organic matter discarded by beam trawl and trammel net fisheries during the period 2006-2008

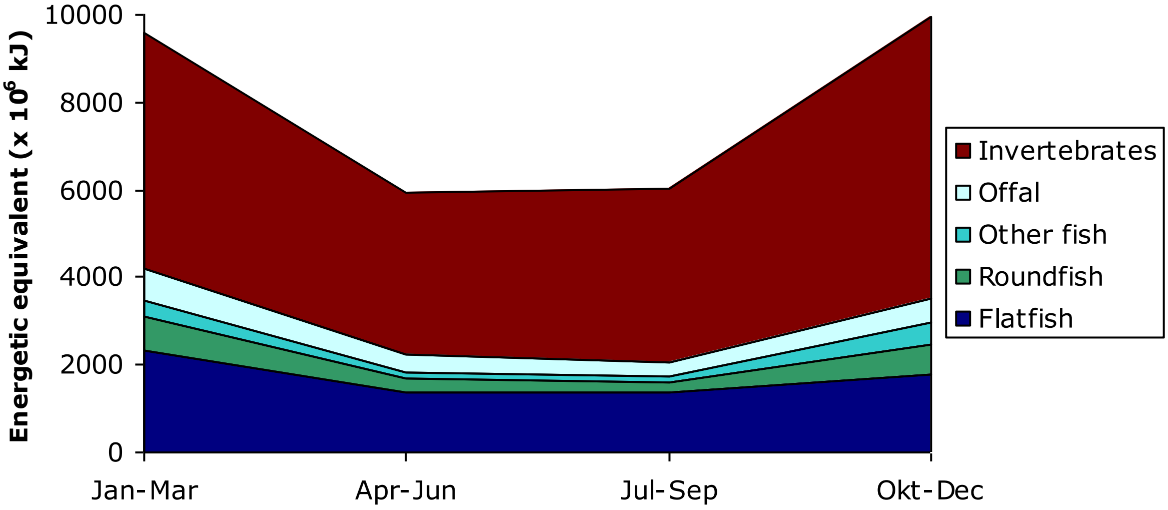

Figure 2.4.5: Energetic equivalent of the different types of discarded material per quarter (in million kJ) in the BPNS

Table 2.4.1: Mean yearly amount of different types of discarded material per quarter (in tonnes) in the BPNS

Quarter	Flatfish	Roundfish	Other fish	Offal	Invertebrates
Jan-Mar	584.7	193.6	88.2	81.2	2407.6
Apr-Jun	347.1	77.8	32.4	42.8	1649.6
Jul-Sep	337.6	62.8	29.9	38.2	1675.4
Oct-Dec	449.0	169.2	120.4	62.3	2741.5
TOTAL	1718.4	503.5	270.8	224.6	8474.2

Table 2.4.1 (continued). Mean yearly amount of different types of discarded material per quarter (energetic equivalent (in million kJ)) in the BPNS

Quarter	Flatfish	Roundfish	Other fish	Offal	Invertebrates	TOTAL
Jan-Mar	2339	775	353	731	5410	9607
Apr-Jun	1388	311	129	386	3743	5958
Jul-Sep	1350	251	120	344	3972	6037
Oct-Dec	1796	677	481	561	6449	9965
TOTAL	6873	2014	1083	2021	19567	31559

Energetic requirements of scavenging seabirds in the BPNS

The energetic requirements of the species that make up the major part of the scavenging seabird community were derived from Bryant & Furness (1995) which give values for the Basal Metabolic Rate (BMR) of Northern Fulmar, Northern Gannet and Black-legged Kittiwake. They derived the following equation for BMR of North Sea seabirds: BMR (kJ/day) = 2,3*(body mass)^{0,774} (body mass is expressed in grams).

For Herring and Lesser Black-backed Gull, the mean weight of all adult birds caught in the breeding colony of Zeebrugge was used in this formula, for Common and Great Black-backed Gull, the mean of the mean weight of male and female adults was used based on Cramp & Simmons (1977; 1980; 1985).
The BMR covers only part of the energy expenditure of birds. The total costs are encompassed in the Field Metabolic Rate (FMR), which includes energy costs of thermoregulation, digestion, moult, reproduction and activity. Following Anon. (1994), we used an FMR of 3,9*BMR during the breeding season (here defined as April to June) and 2,5*BMR during other periods of the year and for species not (or only in small numbers) breeding near the BPNS.
The total energetic requirements of the average scavenging population present in the BPNS was calculated by multiplying the total number of individuals of each species with the respective FMRs and the total number of days in each season (Table 2.4.2 a; b).

Table 2.4.2a: Mean numbers of scavenging seabirds in the BPNS per quarter

Species	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	BMR
Northern fulmar	614	317	303	1474	330
Northern gannet	1440	228	516	1300	1079
Common gull	1271	67	65	662	232
Lesser black-backer gull	1203	2863	1702	349	418
Herring gull	1284	818	269	348	454
Great black-backed gull	990	69	132	1090	695
Black-legged kittiwake	2323	52	136	1891	237
TOTAL	9125	4415	3120	7114	

Table 2.4.2b: Daily energy requirements of scavenging seabirds in the BPNS per quarter ($x10^6$ kJ)

Species	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
Northern fulmar	46.1	23.8	22.7	110.7
Northern gannet	353.5	55.9	126.0	319.2
Common gull	66.9	3.5	3.4	34.9
Lesser black-backer gull	114.4	381.5	162.0	33.2
Herring gull	132.6	118.3	27.8	36.0
Great black-backed gull	156.5	10.9	20.9	182.2
Black-legged kittiwake	125.3	2.8	7.3	101.9
TOTAL	995.4	596.7	370.2	808.1

When comparing the energetic needs of the 'average scavenging population' with the energy equivalent of the discards, supposing that all discards are eaten by the birds, there would be more than enough to sustain the population. However, not all discards available can be consumed by seabirds.

Discards might be too big to be swallowed or sink to the bottom too fast to be taken. Especially flatfish – where a width of around 8 cm is the maximum size for a Herring Gull (Camphuysen, 1994; own data INBO) – can be problematic for seabirds to be swallowed. As a consequence, taking into account the length frequency distributions of the discards of the 3 most common discarded species of flatfish, only 5% of all discarded Plaice and 70% of Dab is small enough to be consumed. All discards of Sole can be swallowed by seabirds, due to its long and relatively slender shape (a Sole of 8 cm width is approximately 25 cm long (own data INBO), which is above the minimum landing size.

Especially in the 90's, a lot of experiments to see which type and how many discards are eaten by seabirds were conducted, both on commercial and research vessels (e.g. Hudson & Furness, 1988; Garthe & Hüppop, 1993; Garthe & Hüppop, 1994; Camphuysen, 1993; Walter & Becker, 1997; Garthe & Scherp, 2003). While the consumption rate of roundfish in different discard experiments seems to be fairly constant around 70 to 85% (e.g. Camphuysen *et al*., 1993 & 1995; Walter & Becker, 1997; Garthe & Hüppop, 1994), that of flatfish differs a lot. Garthe & Hüppop (1994) and Hudson & Furness (1988) found very low rates for flatfish consumption with 8% and 5% respectively. Oro & Ruiz (2004) in contrary, found a very high rate of 90 %, which was probably caused by the relatively small size of the flatfish discards. Most studies found a flatfish consumption rate of between 15 and 35 % (e.g. Garthe & Hüppop, 1993, Camphuysen, 1993). As for the invertebrate fraction of the discards, most studies find quite low consumption rates between 3 and 30% (e.g. Camphuysen *et al*., 1995; Walter & Becker, 1997). The offal consumption rate is in most studies very high with between 75 and 95 % eaten.

If minimum consumption rates found in literature (48% roundfish, 5% flatfish, 1% other fish, 66% offal and 3% invertebrates) are taken into account, discards provide in all seasons enough energy to sustain the average scavenger community. Only from April to June there is a slight deficit (10×10^6 kJ) between the energetic needs of the seabirds and the amount available. If more 'average' consumption rates (based on literature) are applied (75% roundfish, 20% flatfish, 2% other fish, 80% offal and 15% invertebrates), the total energetic equivalent of the discards consumed largely exceeds the demands for the four periods. This means that for all seasons there would be more than enough discards available to sustain the average scavenging population of seabirds present in the BPNS.

When we look at the breeding Herring and Lesser Black-backed Gull at the Belgian coast, the mean number of breeding pairs in 2008-2011 for both species is respectively 2534 and 4760 pairs.

When each couple should produce one young, this means that in the breeding season (in this case we take April to June as the breeding season), around 14280 Lesser Black-backed Gulls and 7602 Herring Gulls are present (without taking into account non-breeders) which need respectively around 1050 and 600 x10^6kJ. In total for April to June, this would mean an energetic need of 1750 x10^6kJ for the whole scavenging population. The energetic equivalent of the discards produced in that time window is around 5960 x106kJ. When the above 'average' consumption rates are applied, 1385 x106kJ is effectively available which means only around 2/3ths of the scavenging population can theoretically be sustained by discards.

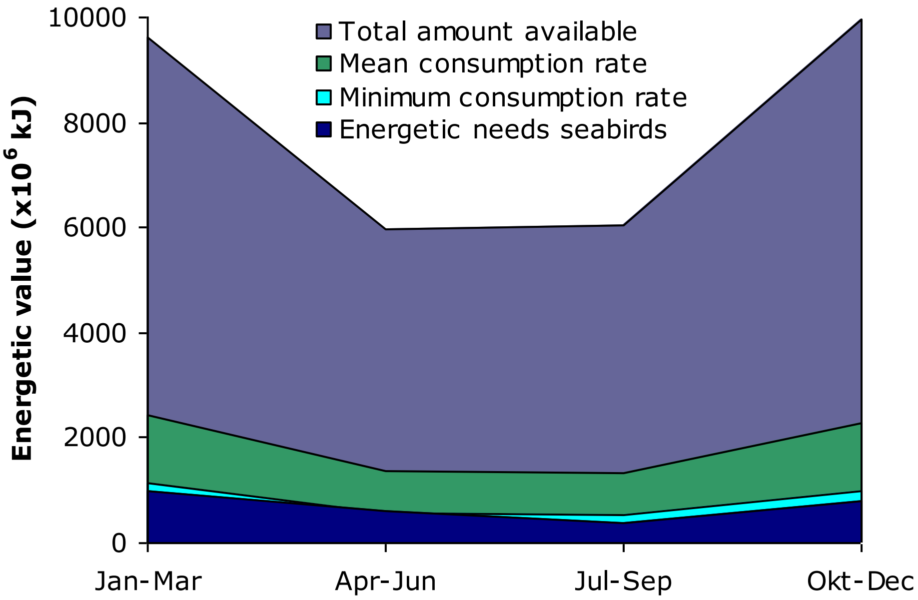

Figure 2.4.6: Energetics of the average yearly amount of fisheries discards produced, of the part that is theoretically consumed by seabirds under two consumption rates and the total energetic needs of the average scavenging population

Consequences of a shift from beam trawl dominated fisheries to trammel net for seabirds

If all Sole caught in the BPNS would have been caught by trammel net instead of beam trawl, this would have far-stretching consequences for the amount of discards produced (Table 2.4.3). In that case, only 42% of flatfish, 29% of roundfish, 0% of Elasmobranchs, 67% of offal and 6% of invertebrates of the average yearly produced amounts in 2006-2008 would have been discarded (based on calculations in chapter 2.3, p. 30). In total amounts, there would still be enough discards to sustain the average scavenging community of seabirds in all seasons. But when the above mentioned average consumption rates are taken into account, only from October till December there would be enough discards for all scavengers.

As for the breeding gulls, even the energetic equivalent of the total amount of discards produced (1147 $x10^6$kJ) would be insufficient to sustain the total population. Only around 400 $x10^6$kJ would effectively be available to the birds.

Table 2.4.3: Numbers and daily energy requirements of scavenging seabirds in the BPNS per quarter

Quarter	Flatfish	Roundfish	Other fish	Offal	Invertebrates
Jan-Mar	215.6	22.6	0.0	39.9	151.7
Apr-Jun	152.2	10.0	0.0	28.9	104.1
Jul-Sep	115.3	8.8	0.0	23.1	89.5
Oct-Dec	234.0	103.6	0.0	58.0	138.6
TOTAL	717.1	145.0	0.0	149.9	483.8

Quarter	Flatfish	Roundfish	Other fish	Offal	Invertebrates	TOTAL
Jan-Mar	862	90	0	359	345	1657
Apr-Jun	609	40	0	260	237	1147
Jul-Sep	461	35	0	208	204	908
Oct-Dec	936	415	0	522	316	2188
TOTAL	2868	580	0	1349	1102	5900

Discussion and conclusion

Estimation of bycatch of seabirds

The bycatch of seabirds in gill nets will probably greatly depend on the time of the year, the location where the net is set and some specificalities of the net (depth, height). Seabird species diving for their food (divers, grebes, Northern Gannets, sea-ducks and auks) will obviously be the most susceptible ones to be caught. Both vessels for which the inquiry showed they caught Cormorants in the past operate quite close to the coast, thereby largely overlapping the spatial distribution of Cormarants, but also largely excluding bycatch of the most numerous diving seabirds (auks). The fact that other species were found in (gill)nets during beached bird surveys conducted by INBO (especially Northern Gannet seems vulnerable) suggest that all pursuit divers are susceptible to bycatch but the frequency with which it effectively happens in the BPNS is very low.

Interaction between fisheries and seabirds

Two of the most important interactions between seabirds and fisheries worldwide are bycatch of seabirds (mainly in gillnets and longlines) and effects of the provision of additional prey in the form of discards. Until now, bycatch of seabirds in the BPNS is not really an issue since the number of gillnets used is very low. In contrary, if all Sole landed in the BPNS would have been caught by trammel net, this situation would change enormously. Calculations in annex 8 point out that 0,708 km of trammel net is needed to catch 10 kg of marketable Sole.

This means that if all Sole would be caught by trammel net, an average of respectively 19722, 14016, 11679 and 17197 km of net would be needed in Jan-Mar, Apr-Jun, Jul-Sep and Oct-Dec. This is around 217, 154, 128 and 189 km of set net per day. Worryingly, nets would be set in the winter period which overlaps with the presence of the largest numbers of diving seabirds (divers, grebes, seaducks and auks). Already now, up to 9% of all Northern Gannets found during beached bird surveys along the Belgian coast were entangled in fishing gear, although not only gill nets (Figure 2.4.7). Apart from the 'expected' diving species among the entangled bird, also several gull species were found with up to 1,3% entangled.

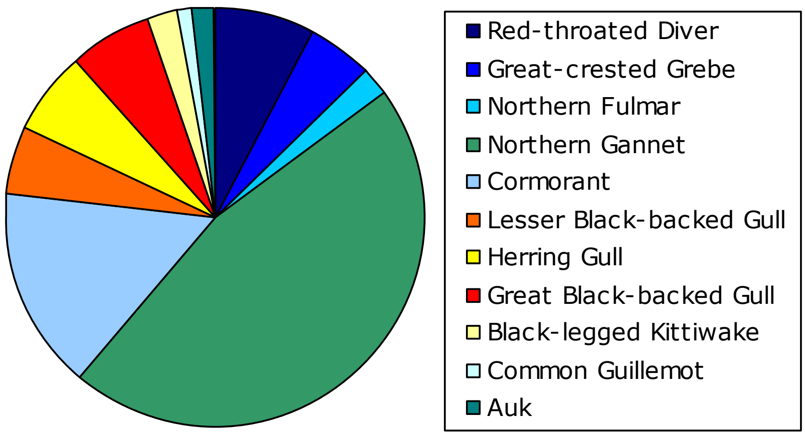

Figure 2.4.7: Species found entangled in fishing gear during beached bird surveys along the Belgian coast between 1962 and 2011 (data INBO)

Several authors state that the rise of the populations of several seabirds species in the course of the 20th century is supported by the abundance of fisheries discards (Camphuysen, 1990; Furness *et al*., 1992; Garthe *et al*., 1996; Tasker *et al*., 2000; Mitchell *et al*., 2004; Thompson, 2006). Our data suggest that, even if only a limited part of the discards produced in the BPNS is consumed by birds, the whole average seabird population can be supported. This of course, supposing that all discards are spatially available for seabirds, which especially in the breeding season will not always be the case. Discards produced further than around 40 km are more or less out of bounds for gulls breeding in the port of Zeebrugge (Camphuysen *et al*., 2008; Camphuysen, 2011). Also, assimilation efficiency of the birds (which is around 65% for invertebrates and 75% for fish, Garthe *et al*., 1996) is not taken into account which means more discards are needed to reach the needed energy input.

Nevertheless, only in the breeding season (Apr-Jun) there will be a deficit in energetic input by discards. Data collected by INBO in the breeding colony of Lesser Black-backed and Herring Gull in Zeebrugge show that at present respectively 66 and 47% of all regurgitated food of chicks and adults of these species consists of fisheries waste.

This corresponds with the estimation that around 2/3ths of the total population could theoretically be sustained by discards. If a shift from beam trawling to trammel net should occur in the future, one can expect this to have a major impact on the breeding populations of scavenging species. So, in Belgium mainly both aforementioned species would be affected.

Several studies, however, show that a ban on discarding might have unexpected effects on seabird populations in which not only the scavengers are impacted, but also rarer and more sensitive species. Votier *et al*. (2004) show for example that taking out commercial fisheries might have a severe impact on other species such as Black-legged Kittiwake and Arctic Tern because Great Skuas would start predating adults and young birds of these species to level off the energy deficit.

2.5 Effects of trammel net and beam trawl fishery on marine mammals

Jan Haelters and Jochen Depestele

Introduction

The harbour porpoise *Phocoena phocoena* is the most abundant marine mammal in Belgian waters, with seasonally average densities of over 1 animal per km². Other indigenous marine mammals are common seal *Phoca vitulina*, grey seal *Halichoerus grypus*, white-beaked dolphin *Lagenorhynchus albirostris* and bottlenose dolphin *Tursiops truncatus*, but their numbers remain far inferior to the numbers of harbour porpoises. Therefore, and also because the harbour porpoise is known to be vulnerable to disturbance and bycatch, the discussion on the effects of fisheries will focus on this species. As bycatch of marine mammals in beamtrawl fisheries is virtually inexistent, focus will be put on static gear fisheries.

Material and methods

Different methods for assessing bycatch of marine mammals in static gear fisheries, and its impact on the population, are used. Some of these were only developed recently. For the assessment of bycatch, data are required both on population numbers and on bycatch rate.

The following methods were tested:

- Through aerial surveys it is possible to estimate porpoise densities; the theory of distance or line transect sampling (Buckland *et al*., 2001) is used.
- Through attaching a passive acoustic monitoring device (PAM) on a fishing net, it is possible to ascertain if porpoises were present in the immediate vicinity of the net during the fishery. In theory the data collected by the PAM device can be linked with bycatch reports or data from independent observation schemes. The PAM device used was a Porpoise Detector (PoD).

- Collecting data from fishermen on fishing effort, nets used and bycatch of marine mammals, could indicate the scale of the problem, and problem areas, periods and gear. Such data can also be collected through independent observers on board.
- Retrospective data on bycatch can be collected through interviews with static gear fishermen.

Other methods, not described in this project, are the assessment of the cause of death of stranded marine mammals (Haelters & Camphuysen, 2009).

Results

Aerial survey

On 19 March 2010 a dedicated line transect survey was performed in an area presumed important for static gear fishermen: the area of the Kwintebank-Buiten Ratel-Oostdyck. The flight duration was 2h15', of which 2h03' was used for observing marine mammals. Survey conditions were moderate to good. The flight tracks and observations are presented in Figure 2.5.1.

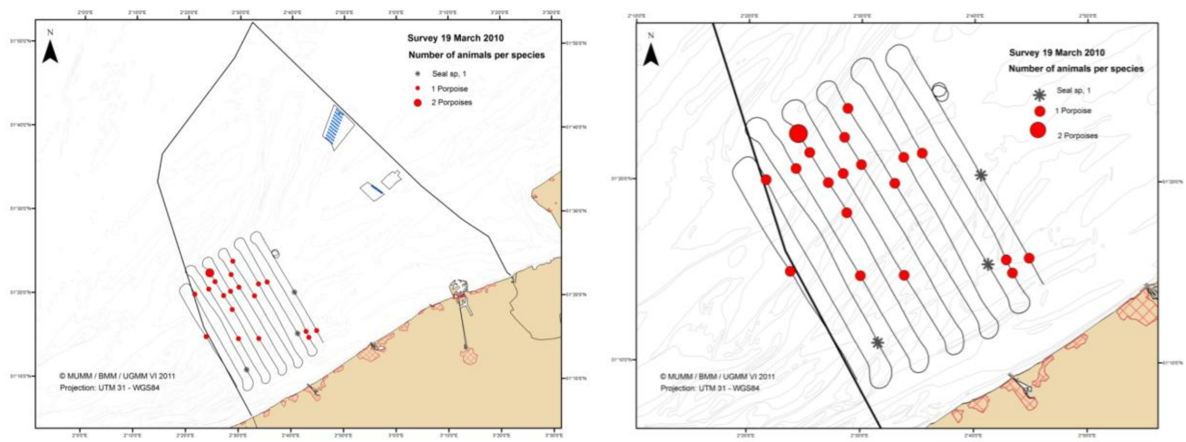

Figure 2.5.1: Tracks and observations made during the aerial survey on 19 March 2010 for estimating marine mammal density. The distance between tracks is approximately 2 kilometer

In total 23 marine mammals were observed: 3 seals and 20 porpoises (18 x 1 animal, 1 x 2 animals). The analysis using Distance 6.0 software allows to estimate densities of porpoises in the area; as the correction factor g(0) for animals missed on the track 0.45 was used (Haelters, 2009), and the detections were pooled with the results of surveys between 2008 and 2011. A hazard rate function was chosen as the best detection model. The results are an estimation of an average density over this area of 0.49 (0.33-0.73) harbour porpoises per km² on 19 March 2010.

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The use of a porpoise detector (PoD)

For the deployment of the PoD, the cooperation of a fisherman was necessary. However, deploying the PoD on an anchor rope is relatively easy. The PoD remained standby for a long period during 2009, and useful data were only obtained during a fishing campaign on 25-26 September 2009. On two occasions the (short) presence of one or more porpoises was detected during 17 hours of fishing (Figure 2.5.2).

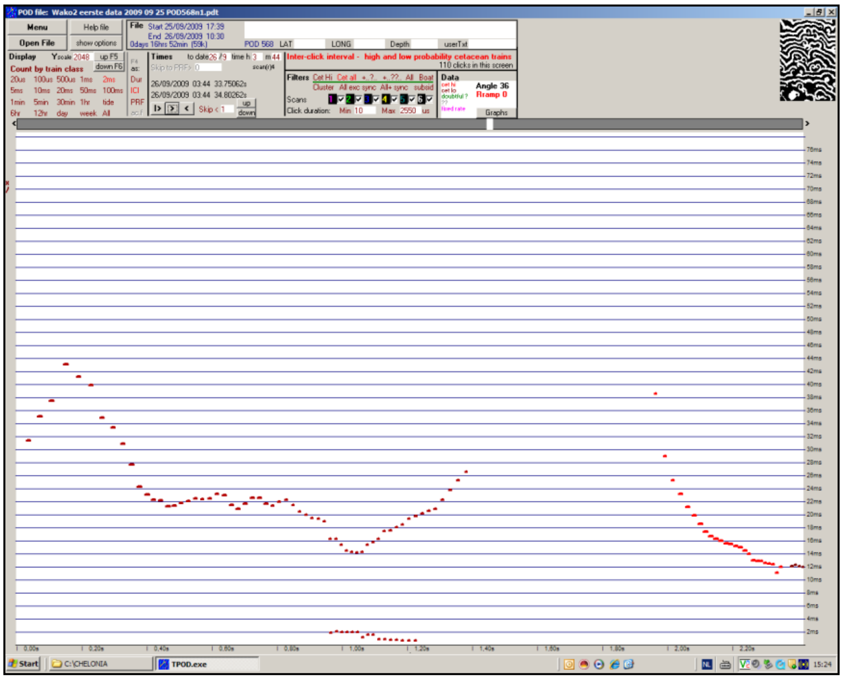

Figure 2.5.2: Detection of one or more porpoises in the vicinity of the PoD attached to static fishing gear on 26 September 2009, 3:44h UTC; the x-axis shows the time, the y-axis the inter-click interval

Overview of fishing effort and the bycatch of marine mammals reported by professional static gear fishermen

Given the requirement of a cooperation with fishermen, and the assurance of confidentiality of information, the data reported here are presented in a way which makes it hardly possible to single out individual fishing vessels. When data on soak time or net length were not available, the average for the fishing vessel was used.

In total 24.600 km·h fishing effort was reported (net length times soak time).

The average length of nets used was 8.8 kms, and the average soak time was 14.6 hours. The gear used was of different types: "Nylon" and "Multi" twine nets with a mesh size of 90 to 100 mm, and, to a lesser extent, "Multi-mono" and "Multi" twine nets with a mesh size of 150 and 250 mm. The Nylon and Multi nets with a mesh size of 90 to 100 mm presented 77 % of the reported fishing effort.
The total marine mammal bycatch reported consisted of 1 harbour porpoise. It drowned in "Multi" twine net, 90 - 100 mm mesh size. It concerned a female juvenile, which was entered into port by the fishermen for scientific research purposes. Also the catch of part of a decayed porpoise was reported; this is however not considered as bycatch.

Results of a questionnaire towards professional fishermen concerning bycatch of marine mammals
A questionnaire was presented to fishermen as a retrospective investigation, and for gaining more information of the experience of fishermen with marine mammals, and more in particular porpoises. The answers to the questions can indicate bycatches in the past, and data on observations of live porpoises. At the time of this report, 2 static gear fishermen had responded, each giving fairly different answers to certain questions. Fishermen indicate that:

- Harbour porpoises are observed, according to one fisherman as solitary animals predominantly from February to April, according to the other one in small groups in June and July;

- Harbour porpoises occur mostly further than 3 miles offshore, and high density areas are Buitenratel – Oostdyck - Kwintebank (spring), and Westhinder – Akkaertbank (summer);

- The animals do not change their behaviour in the vicinity of the vessel;

- One of the fishermen had caught porpoises: a few each year; the most important factors in bycatch were water depth and period of the year.

Results of the campaigns with independent observer on board fishing vessels
In total an independent observer participated in 15 fishing campaigns on board a professional static gear fishing vessel. The fishing effort observed was 23153 km*h No bycatches of marine mammals were observed.

Discussion
For assessing bycatch, it is important to collect data on the numbers of porpoises in the area concerned, on temporal and spatial trends, and on the bycatch level. Bycatch data to be collected include gear, period of the year, area, etc.

Bycatch can be estimated on the basis of voluntary reports of fishermen and fishing effort; it is likely that independent observer schemes would be more trustworthy, but they would equally require a high percentage of fishing effort coverage, given small numbers of bycaught animals per fishing vessel. A small number of bycaught animals per fisherman can be problematic, given that it would not be perceived as a problem, although the total bycatch by hundreds of professional and recreational fishermen in the southern North Sea can be a serious threat to the species.

Staying below a level of bycatch which has a significant negative impact on the population, is an obligation according to the European Habitats Directive, and concrete figures have been adopted in international fora such as OSPAR, ASCOBANS and IWC. However, one should bear in mind that the porpoises occurring in Belgian waters are part of a North Sea population, and similar impacts occur in waters all over the North Sea. While measures preventing bycatch in Belgian waters may be useful, and should not be excluded, they seem more appropriately to be taken in the framework of the European Common Fisheries Policy. It is however very important to put the subject on the table, not only of nature conservation fora, but also of the fisheries sector. Work should continue in an open spirit of communication and cooperation rather than in confrontation. In any case, the cooperation with the few Belgian static gear fishermen was very positive, but efforts to gain confidence should be continued.

EC Regulation 812/2004 requires Member States to undertake specified actions in certain fisheries to reduce cetacean bycatch. ICES, assessing the bycatch rate for several species and in several areas, has concluded that with the data available (including Belgian data on bycatch, fishing effort and harbour porpoise density) it is not possible to indicate whether bycatch of harbour porpoises in the southern North Sea is below or above 1,7% of the population, considered as the threshold for sustainable or unsustainable bycatch. ICES concluded further that in many cases the information provided by Member States was very uneven and patchy and in some cases inconsistent (ICES, 2010a). Estimates available for harbour porpoise bycatch assessment were 1 animal per 13 days of fishing per fisherman (Sweden), 1 animal per 1.7 tonnes of fish landed (Denmark), 1 animal per 6.4 tonnes of fish landed (Norway), 1 animal per 5.0 tonnes landed (UK), 1 animal per 13.5 days fishing per fisherman (UK) and 1 animal per 48 days of fishing per fisherman between February and May (Netherlands). The possible scale of bycatches of harbour porpoises in static nets in the North Sea was estimated by ICES (2010a) at 715-7364 animals per year. Bycatch rates in Belgium are, with 23153 km*h fishing effort observed without bycatch, and with one bycaught harbour porpoise reported over 24.600 km·h fishing effort, not possible to estimate within a reasonable confidence interval.

However, they do indicate that cooperation with fishermen is possible and useful, and that bycatch occurs in "multi" twine sole net.

Conclusion

By far the most common marine mammal in Belgian waters is the harbour porpoise. A quantified assessment of bycatch in static gear should be focused on this species. Bycatch in beamtrawling seems to be virtually inexistent. However, also other species, perhaps more vulnerable due to lower population sizes, should be included in bycatch assessment – this has hardly been the case up to now in North Sea marine mammal bycatch studies.

The best method to collect abundance and density data on harbour porpoises is a combination of aerial surveys (absolute data, low temporal resolution, high spatial resolution) and PAM (relative data, high temporal resolution, low spatial resolution).

The best methods to collect bycatch data are a combination of strandings data (indirect indication of bycatch), independent observers on board and reporting by fishermen themselves.

Harbour porpoises in Belgian waters form part of a much larger population distributed over an area many times larger than Belgian waters. Assessments of bycatch vs. the population should thus be made on a much wider level (eg. North Sea). As the collection of bycatch and population data are a commitment or obligation in international fora, such data should be collected in Belgium and other nations bordering the North Sea.

3. PARTIM II: SENSITIVITY ASSESSMENT AS A TOOL FOR SPATIAL AND TEMPORAL GEAR-BASED FISHERIES MANAGEMENT

3.1 Where marlin's sensitivity assessment approach meets and does not meet the WAKO-II needs: identifying problems and prospecting solutions

Steven Degraer, Wouter Courtens, Jochen Depestele, Jan Haelters, Kris Hostens, Mardik Leopold, Eunice Pinn, Hans Polet, Marijn Rabaut, Henning Reiss, Eric W.M. Stienen, Harvey Tyler-Walters, Sofie Vandendriessche, Filip Volckaert

Introduction

One of WAKO II work packages focuses on the quantification of the sensitivity to fishing of a number of key species from five ecosystem components: macro- and epibenthos, demersal fish, seabirds and marine mammals. The MarLIN sensitivity assessment rationale is considered the most appropriate tool to tackle this aspect of WAKO II, as it is built on a thorough and (relatively) recent review of sensitivity assessment literature and on a wide consultation of experts in the field, as well as being applied to several case studies (e.g. Tyler-Walters *et al*., 2009). This rationale is based on three main concepts: intolerance, recoverability and sensitivity. The intolerance is here defined as the susceptibility of a habitat, community or species (i.e. the components of a biotope) to damage, or death, from an external factor. Recoverability is the ability of a habitat, community, or species (i.e. the components of a biotope) to return to a state close to that which existed before the activity or event caused change, while sensitivity is dependent on both intolerance and recoverability. For example, a highly sensitive species or habitat is one that is very adversely affected by an external factor arising from human activities or natural events (killed/destroyed, 'high' intolerance) and is expected to recover over a very long period of time, i.e. >10 or up to 25 years ('low' recoverability). While the MarLIN sensitivity assessment rationale is considered most appropriate, it does not fully cover the final aim of WAKO II, namely to be able to objectively advice on an adaptive (spatial and temporal) management of beam trawl and trammel net fisheries in the Belgian part of the North Sea in a fully transparant way (e.g. assessment quantification or scoring) for several ecosystem components (i.e. not only focused on benthic invertebrates). Neither does the WAKO II rationale allow for a full coverage of the MarLIN prerequisites (e.g. data availability or species selection).

In order to bring both the MarLIN and WAKO II approaches as close as possible, a project workshop was organized to review and adapt the existing MarLIN methodology for sensitivity analysis. The workshop served as a baseline for streamlining and standardizing the sensitivity analysis for the five ecosystem components under consideration within WAKO II in a compatible manner. This chapter reports on the identification of problems and solutions for the application of the MarLIN's sensitivity assessment rationale within a WAKO II setting.

Objectives

The objectives of the workshop were

1. to deduct the main challenges from a confrontation of the WAKO II needs and anticipated research strategy with MarLIN's rationale and strategy
2. to explore solutions, fitted onto the WAKO II rationale and taking account of WAKO II data availability (cf. WAKOII project proposal)

This chapter presents the outcomes of the workshop and is structured along ten major challenges, as identified during the workshop.

Species selection

Challenge 1: Key and important species

While WAKO II will assess the sensitivity of species from all five ecosystem components under consideration, the overarching goal of WAKO II is not to assess the sensitivity of these individual species, but rather to obtain a score of the all-encompassing impact of beam trawl and trammel net fisheries. As such, an integration of the individual species' sensitivity to the ecosystem's or biotope's sensitivity is needed.

This approach is similar to the MarLIN's rationale, in which the sensitivity of a biotope is considered dependent upon and, therefore, indicated by the sensitivity of the species within that community. However, not all species within a community affect its sensitivity to environmental change equally: the sensitivity of a community within a biotope is dependent upon and, therefore, indicated by the sensitivity of the species within that community (Cooke & McMath, 2000). Consequently, the MarLIN rationale focuses only on those species that significantly influence the ecology of a certain biotope. As such, only "key" and "important" species are considered. Key species here provide a distinct habitat that supports an associated community (i.e. key structural species) or maintains a specific community structure or function through its interactions with other community constituents (i.e. key functional species). The loss or degradation of a key species' population will hence result in a loss or degradation of the associated community or in a rapid and cascading change of the community of the biotope under consideration. Important species are characteristic for the biotope (i.e. important characteristic species) or are positively interaction with key or characteristic species and important for their viability (i.e. important structural species) or are a dominant source of organic matter within the ecosystem (i.e. important functional species) or fall under other categories, such as rare or declining species, high species rich areas, or good representatives of their type. In this last category WAKO II might want to make use of the biological valuation criteria as developed by Derous *et al*. (2007a, 2007b).

Whereas the above mentioned selection is strongly based onto the intrinsic ecological functioning of the ecosystem (although the last category of "other important species" opens the door for many more types of "important species"), three frameworks for selection criteria are considered useful within the WAKO II project: ecosystem functioning framework, legal framework and economic framework. The ecosystem framework here follows the MarLIN key and important species selection criteria, except for the last category of "other important species", while the legal framework would specifically encompass the category of "other important species". The latter would then focus on species, which fall under regional, national or international regulations regarding their protection (e.g. Birds and Habitats Directive) or which need special attention regarding the conservation and or restoration of their population at threat. Finally, the economic framework focuses on species with a particular economic interest, such as commercial fish species.

As WAKO II only takes a second step within WAKO s.l. , the selection of species could be made without referencing to the MarLIN concept of key and important species. The main restriction to WAKO II would then be that a scientifically-sound integration into the biotope's sensitivity would not be possible. While in that case (1) WAKO II would go no further than a mere assessment of the sensitivity of opportunistically chosen species of five ecosystem components and (2) hence a well-founded advice for an adaptive (i.e. spatial and or temporal) fisheries management in Belgian marine waters would not be possible, it would allow us to demonstrate the rationale's feasibility.

The concept of key and important species could and should then be picked up in a next WAKO phase(s), during which a more profound selection of key and important species could be tackled. Furthermore, the selection of key species within WAKO II will largely depend on (1) the knowledge on mortality due to both fisheries gathered in the first work package (i.e. the risk to be caught and killed or adversely impacted), and (2) the availability of literature on recoverability (i.e. the time needed to reach the "original" population density and biomass after disturbance). Classification into functional groups will be considered as far as this is relevant for the specific impact of fisheries. For example in seabirds one might select a key species from the group of plunge divers, another from the group of pursuit diving piscivores and one benthivorous seaduck as they represent different foraging guilds that greatly differ in their sensitivity to fisheries. Similarly, one should select both seabird species that are attracted to fishery activities (strong positive effect) and species that are highly sensitive to disturbance (negative effect). For benthic and fish species a similar selection can be done on the basis of mobility (mobile versus sedentary species) and one can opt to have one opportunistic species that might show positive response to fisheries disturbance (e.g. species that benefit from discards as a food source: Asterias rubens, Astropecten irregularis, Liocarcinus spp., Pagurus spp., Callionymus lyra and Limanda limanda (Kaiser and Ramsay, 1997; Veale *et al*., 2000)) and one more potentially sensitive species (negative impact) such as shallow burrowing, large-bodied species (Bergman and Hup, 1992; Queiros *et al*., 2006), e.g. Alcyonidium digitatum. Besides the selection of species, specific benthic habitats should be evaluated as such. Preferably each impact factor should be represented by a representative of each ecosystem component.

Finally, the number of key and important species to be selected might influence the final sensitivity score of the biotope as the MarLIN sensitivity assessment rationale considers the sensitivity score of the most sensitive species to determine the final score of the biotope.

Therefore, a fully ecosystem based approach without a priori species selection would better suit the objectives of WAKOII. Such an approach should start with the identification of the different biotopes present within the restricted boundaries of the Belgian part of the North Sea. Within each biotope a complete list of occurring species (overarching all ecosystem components and including rare species as much as possible) should be drawn up. A full matrix with all functional and structural relationships between species (e.g. indirect food-web interactions, cascading effects and functionality as an intermediate host for parasites) will serve as a basis for evaluation. For each species in the matrix a sensitivity score will be filled in. Well known examples of this methodology are the assessment of seabirds vulnerability to oil pollution (e.g. Camphuysen 1989, Seip *et al*. 1991) and the application of a seabird sensitivity index to collision with marine wind farms (Garthe and Huppop 2004). Other criteria can be used as well. For example, criteria such as international threat status and conservation status might be considered useful for specific management questions (e.g. if the management requires an evaluation of the effects of beam trawling and trammel netting on protected Natura 2000 species).

Challenge 2: Baseline conditions for sensitivity assessment

Given the fact that each biotope – by definition – is composed of different species, each with their species-specific sensitivity, different biotopes will exhibit a biotope-specific sensitivity to both fishing techniques. A selection of focal biotopes within WAKO II is hence advised; these could be taken from previous documents on the description of biotopes in recent documents (e.g. as identified through sedimentological conditions), such as from Degraer *et al*. (2008, 2009).

Natural and human-induced spatio-temporal changes to the marine environment through time lead to shifts within our appreciation of pristineness, conservation targets and management goals (Papworth *et al*., 2009). There are different options for the baseline situation to be used for sensitivity assessment.

By using recent data on the condition of the biotopes, it is possible to make a qualitative and quantitative assessment of their sensitivity to fishing techniques. The results however, can be biased due to the fact that decades of fishing might have, or already have altered the biotopes in a way that opportunistic, and non-sensitive species remain. Our assessment might indicate that some species are more sensitive than others. However, in reality even the more sensitive ones from our assessment are in fact fairly resistant to fishing, or can recover very quickly. This is an example of the shifting baseline, as described by Pauly (1995). As in the Texel and Faial criteria (OSPAR, 2003) a sensitive species is described as a species which, if negatively affected, will only recover in 5 to more than 25 years, it is possible that the current number and abundance of sensitive species is very low, and that it would be more relevant to start from another baseline.

Generally, the further we go back in history to describe a baseline situation, the fewer data are available, the higher the uncertainty, and the more we have to rely on expert judgement. However, some cases are clear, such as the occurrence of oyster Ostrea edulis grounds and the abundance of certain ray and shark species. The historic effects of fishing in the North Sea has only limitedly described due to the lack of robust time series. Polet and Depestele (2010) reviewed several quantitative papers on this matter, such as Frid *et al*. (2009a, 2009b), Callaway *et al*. (2007). Sources for historic data in Belgium are the Gilson collection and the accounts of his sampling a century ago (Gilson, 1900), historic fish and fishery data (Poll, 1945; 1947; De Selys Longchamps, 1842; Lescrauwaet *et al*., 2010), other historic accounts, or oral communications by retired fishermen (Rappé, 2008). Another option for setting a baseline describing a more pristine condition, is making use of unimpacted or less impacted areas, where benthic species might still have been able to develop in an undisturbed way – however, such areas are difficult to locate.

In both baseline conditions, care should be taken not to focus on species which occur in Belgian waters on the edge of their range, or which occur here in suboptimal environmental conditions: such species might be naturally rare.

As such, within the WAKO II scope, the different options for a baseline situation complicate an appropriate selection of the set of key and important species to be considered (see Challenge 1) in the evaluation of the differential sensitivity to both fishing techniques. In other words, the question could be raised whether WAKO II should focus on the assessment of the sensitivity to both fishing techniques of "pristine" conditions or rather on the sensitivity of the present day marine environment.

In any case, efforts should be made to compare the current sensitivity to both fishing techniques with the (reconstructed) sensitivity of the more pristine condition of the habitats concerned. Information could be drawn from conservation objectives proposed for the habitats (Degraer *et al*., 2010b).

Challenge 3: Sensitivity of "unquantifiable" species

The species selection in the framework of the impact evaluation within WAKO II is based on the prevalence of countable, non-colonial organisms since these have been quantified straightforwardly during the onboard analyses of catch, bycatch and discards in both beam trawl and trammel net hauls. During these analyses, encrusting and colonial epifauna are usually (but not straightforwardly) reported as being present or absent, but no weight or coverage measures are applied. Nevertheless, the presence of sponges, soft corals, colonial tube worms, bushy hydroids and bryozoans has a major influence on habitat complexity (e.g. Klitgaard *et al*., 1995; Bradshaw *et al*., 2003). These attached epifauna provide food and shelter for many animals, including the prey of demersal fish. Upright, attached organisms are quite fragile and are often destroyed by bottom fishing gear, leaving a uniformly smooth surface. This has repeatedly been demonstrated by photographic analyses of undisturbed and disturbed seafloor surfaces (e.g. Collie *et al*., 2000; Thrush *et al*., 2001). However, the WAKO II analysis is limited to the organisms that can be "easily" quantified, i.e. countable, non-colonial organisms caught by the trawl or trammel net activity or unaccounted mortality in the tow path of the gear (investigated in the first work package of the WAKO II project). Consequently, a sensitivity assessment can be performed on a species level for colonial and encrusting species, but since quantitative data are not available for these species, they can only be included in an conceptual assessment on a biotope level, but not in the actual application. Mapping of their prevalence will only limitedly be possible using a presence – absence approach.

A similar quantification problem poses itself for rare species. Rarity can be interpreted as truly rare, i.e. occurring in extremely low densities (e.g. Liocarcinus pusillus (Derous *et al*., 2007)), or as rare due to a high selectivity of the species concerning habitat conditions (e.g. species occurring in low densities on shipwrecks or hard substrata in the Belgian part of the North sea, such as Ascidiella scabra (Zintzen and Massin, 2010)), as explained in Schlacher *et al*. (1998). Either way, quantitative data on these species rarely exist. Since rare species, however, are usually very sensitive to disturbance and habitat alterations, they must be included in the WAKO sensitivity assessment. Just as for colonial and encrusting species, a conceptual assessment can be done on a species level, but an actual application of the framework will be limited due to data deficiency.

To summarize, it is advised that "unquantifiable" species are included in the conceptual model of sensitivity assessment on a species and biotope level. Due to data deficiency, even at a presence/absence level, however, they cannot be included in the application of the assessment. This should be taken into account in the overall interpretation of the WAKO sensitivity analysis results.

Challenge 4: Intraspecific sensitivity: Life stage dependency, sex dependency and genetics of sensitivity

Attention should be paid to the life-stage dependency of sensitivity, since a species behaviour and level of activity might change over its life cycle, or seasonally, as such influencing its sensitivity to beam trawl and trammel net fisheries in a temporal and/or spatial scale. For instance, adult herring Clupea harengus are rarely caught in beamtrawl fisheries, and as such could be considered as tolerant to beamtrawling. However, herring eggs are attached to hard substrates and some of their associated organisms. As such, herring eggs and the reproductive success of the species is very intolerant to activities impacting hard substrates with its associated fauna elements (Postuma *et al*., 1977).

Next to this, there is a selective extraction of, or impact of fisheries on individuals at the intraspecific level. Many fisheries for instance only target large animals, which after many generations will have effects on the genetic constitution of the population, favouring small individuals, and individuals reproducing at a younger age. Also, selectively extracting large animals, with a high reproductive potential, impacts the reproductive capacity of the population. For instance, wintering areas of adult and juvenile guillemots Uria aalge and razorbills Alca torda are different, although overlapping. The impact of a human activity in different areas, although incidentally killing the same number of birds, might hence have very different effect on the breeding population: an impact on predominantly juveniles will have a diffuse and delayed effect, while an impact on adults has an immediate effect (Camphuysen & Leopold, 2004).

It has further been demonstrated that stranded harbour porpoises Phocoena phocoena washing ashore in Belgium and the Netherlands concern a large proportion of juvenile animals, and more males than females (Haelters & Camphuysen, 2009). This might be due to factors related to the population structure (more juveniles present) and/or the diet or the behaviour of juveniles, making them more vulnerable to bycatch, one of the most common causes of death. In any case, the bycatch of juveniles, subject to a higher mortality rate than adults, and of males, is of less importance to the health of the population than the bycatch of adult females.

Finally, in many commercially exploited fish stocks, such as cod Gadus morhua in the north Atlantic, fish have become smaller and age at maturation has decreased (Law, 2000; Hutchings, 2004; Olsen *et al*., 2004). This is due to the massive and selective extraction of large fish, giving an evolutionary reproductive advantage to fish of the same species that mature at a younger age and at a smaller size.

It is proposed to also account for this life-stage dependency of sensitivity for those species, where considered relevant, although it is acknowledged that this is a very complex matter.

Environmental factors and benchmarking

Challenge 5: Pressure selection

The WAKOII scope considers the different ecosystem components but only focuses on beam trawl and trammel net fisheries as human activities changing the ecosystem. This is a considerable different scope as compared to the MARLIN scope where the focus is on the benthic environment but all (human) pressures are included in the sensitivity assessment. Other anthropogenic activities, with perhaps other environmental factors or pressures to be considered and/or other bench marks for each of the 24 environmental factors, might and will play in the pelagic environment. One such an example is the blooming of phytoplankton as a consequence of interalia enrichment of the pelagic environment with nitrates and phosphates (Tett and Mills, 2003). There was a discussion on including pelagic compartments of the ecosystem; although considered important, we decided to stick to the pressures relevant only to beam trawl and trammel net fisheries but taking into account the different ecosystem components. This implies indirect effects on the trophic levels of the pelagic ecosystem through impacts on the benthic environment or the seabird communities for instance are not considered.

Human activities like beam trawling and trammel net fishing can have negative impacts, though there are also some positive feed backs of these activities. We concluded that the safest approach is to evaluate how beam trawling and trammel netting is changing the environment. Therefore, we use the term effect (which includes both positive and negative aspects) rather than impacts (which tend to be negative effects only).

Importantly, during the first steps of environmental factor selection ("pressure selection") WAKOII aims to include all relevant pressures. Data-restriction is never an argument to exclude a pressure a priory during the pressure selection phase, given this is done at a conceptual level.

Furthermore, the environmental factors highlighted in the MarLIN sensitivity assessment (Tyler-Walters *et al*., 2001, Appendix 15), comprise physical, chemical and biological factors. The WAKO II project originally focused solely on the biological part. Given the all-encompassing approach of WAKO II, all factors should be considered for uptake in the sensitivity assessment. However, the scope of WAKO II is narrowed down to fisheries effects (in casu beam trawl and trammel net fisheries), this in contrast to the MarLIN sensitivity assessment, in which many more human activities are considered. Therefore, physical, chemical and biological factors only have to be selected when relevant to beam trawl or trammel net fisheries.

As such, no chemical factors were considered relevant within the WAKO II context. The 'relative changes in levels of synthetic chemicals', 'heavy metals', 'hydrocarbons', 'radionuclides', 'salinity', 'nutrients' and 'oxygenation' are not expected to be related to fishing activities to a large degree (e.g. Warnken *et al*., 2003; Zacharia *et al*., 2006). However, some authors indicate that repeated trawling could trend surface sediments towards anoxia (Warnken *et al*., 2003). The changes in chemical composition due to the changes in rate of dissolved and particulate nutrient releases or trace metals, is especially affecting the productivity in the water column (Dounas *et al*., 2007). In a direct way, bottom trawling may trigger off considerable productivity pulses due to the rate of dissolved and particulate nutrient releases from seabed disturbance (Durrieu de Madron *et al*., 2005; Giannakourou *et al*., 2005; Dounas *et al*., 2007). Demersal trawling in hypoxic areas has shown that large numbers of infaunal species in areas of high abundance and biomass leave their positions and lie exposed to the bottom, e.g. mass migration of Brissopsis lyrifera during trawling in the North Sea with low values of oxygen (ca 2ml/l) recorded (www.MarLIN.ac.uk, consulted on 8 September 2010; Dyer *et al*., 1983). In an indirect way, bottom trawling affects species abundances, including the abundance of bioturbators and their associated species (e.g. Rabaut, 2009; Rabaut *et al*., 2008), which in turn influences benthic respiration, denitrification and nutrient release (Olsgard *et al*., 2008; Braeckman *et al*., 2010). It might be questioned whether nutrient releases due to sediment suspension and indirect changes in fluxes due to changes in species abundance should be included, as well as the changes in oxygenation in hypoxic areas. The exclusion of chemical factors in this WAKO II sensitivity assessment however, implies that the direct changes induced by trawling are minor for the Belgian Part of the North Sea where hypoxic areas are rare (Van Hoey *et al*., 2009b) and that indirect changes should not be considered or that they are taken up in the factors 'changes in suspended sediment' or '(non-)selective extraction of this/other species'. It should be discussed whether the changes in nutrient fluxes and oxygenation due to beam trawling are actually minor and therefore not relevant for WAKOII. The factor "pollution", is proposed to be included as two different factors. The first one is about microplastics, while the second one relates to the emission of CO_2 and the release of chemical pollutants. This distinction is made because it concerns geospatial and non-geospatial data. Within the last level, there are again two different levels, being quantifiable (e.g. CO_2 emissions) and unquantifiable (e.g. chemical pollutants).

The factor eutrophication (and de-eutrophication) is considered important as the effect of beam trawling by bringing in more phosphorous in the system (stirring of bottom) is expected to be very different as compared to trammel netting. However, it is not decided yet if and how we will include this issue.

Physical factors in the MarLIN sensitivity assessment are identified with reference to all human activities or natural disturbances (Tyler-Walters *et al*., 2001, Appendix 15). A more stringent selection for WAKO II applies, as only fisheries is being assessed. Therefore, factors related to only the impact on intertidal organisms or resulting from coastal engineering activities should not be withheld. These factors are 'dessication' and changes in 'emergence', 'temperature', 'wave exposure' and 'water flow rate' (Tyler-Walters *et al*., 2001). Other factors are potentially altered by fisheries, especially beam trawling. Trawling displaces sediment (Polet *et al*., 2010), which might result in localized 'substratum loss' (e.g. Newell *et al*., 1998; Simpson and Watling, 2006), 'smothering', 'sediment resuspension', 'changes in turbidity' (e.g. Fonteyne, 2000; Giannakourou *et al*., 2005; O'neill *et al*., 2009), 'displacement' (e.g. Gilkinson *et al*., 1998, Nilsson and Ziegler, 2007) and 'physical disturbance' or 'abrasion' (e.g. Løkkeborg, 2005; Kaiser *et al*., 2006, Nilsson and Ziegler, 2007; Depestele *et al*., 2008a). Two factors relate to the possible effects of fishing on especially seabirds and marine mammals. Although limitedly investigated (Popper and Hastings, 2009), fishing potentially disturbs organisms through 'noise generation' and 'visual presence'. Several seabirds for instance tend to avoid approaching fishing vessels (Camphuysen *et al*., 1999; Depestele *et al*., 2008a). Vessel noise may impact marine mammals, such as the harbour porpoise Phocoena phocoena (e.g. Jenkins *et al*., 2009). Additional to the physical factors of MarLIN, a new factor, namely 'pollution', might be considered relevant within a WAKO II context. Fishing nets can be lost or abandoned at sea, generally referred to as ghost-fishing (Depestele *et al*., 2008a). Although the effect of ghost-fishing nets has been minimized for fish in comparison to discarding (e.g. MacMullan *et al*., 2004; Brown *et al*., 2005), plastic debris is a serious threat to seabirds, which can for instance mistake plastic pellets as source of food (e.g. Cadée, 2002; Ryan *et al*., 2009; Provencher *et al*., 2010).

Finally, similar to the physical factors from the MarLIN sensitivity assessment (Tyler-Walters *et al*., 2001, Appendix 15), two biological factors have been eliminated for the WAKO II sensitivity assessment, namely the 'introduction of microbial pathogens and parasites' and the 'introduction of alien or non-native species'. The introduction of alien species and pathogens from Belgian fisheries is hypothesized minimal, although fishing effects might enhance introduction indirectly through cumulative effects. However, this factor is hypothesized minimal from commercial fisheries in comparison to introduction from other human activities such as aquaculture and stock enhancement (e.g. Savini *et al*., 2010) and climate change (Occhipinti-Ambrogi, 2007). Bartley and Subasinghe (1996 in Gozlan *et al*., 2006) report that more than 80% of aquatic animal introductions are freshwater and these introductions originate mainly from aquaculture (53%), fisheries support (18%), recreational fishing (12%) and aquarium trades (10%). The factors 'specific targeted extraction of this species' and 'specific targeted extraction of other species' are particularly relevant to fisheries, which both affect target and non-target species (e.g. Kelleher *et al*., 2005; Depestele *et al*., 2008a). Ghost-fishing and its potential impact on especially marine invertebrates and seabirds (Brown *et al*., 2005; 2007), has also been identified as an additional factor: 'non-selective extraction of species'. Lost fishing gear does not have the selective properties of a commercially deployed fishing gear, as it might collapse fast (e.g. Kaiser *et al*., 1996; Tschernij *et al*., 2003). Genetic effects because of beam trawling and trammel netting should definitely be included in the analyses as well as discussed under challenge 4 (see above).

Benchmarking

Within the MarLIN rationale a species' intolerance is assessed through its intolerance to damage from an external factor and is hence determined by its biological and physical characteristics. Intolerance must be estimated in response to a change in a specific environmental factor and to the magnitude, duration and or frequency of that change. The magnitude, duration and frequency of change in an environmental factor depend on both the nature and scale of the human activity, as on the location or site at which the activity occurs. As such, aiming at being generic, the MarLIN sensitivity rationale sets standard "benchmarks" to enable the assessment of sensitivity relative to a specified change in an environmental factor.

In other words, the benchmarks of MarLIN are a set of specified levels of environmental change in the factors against which to assess intolerance. Since effects of an activity are dependent on the impacted environment, benchmarks should be set in a site-specific manner, i.e. WAKO II benchmarks should be in conjunction with the environmental conditions of the Belgian part of the North Sea. Moreover, WAKO II aims at a relative comparison of the effects of two specific types of sole-targeting fisheries, namely flatfish beam trawl and trammel net fisheries. Benchmarks ought to reflect what levels of magnitude and duration of change in an environmental factor, caused by fisheries, are assumed relevant. If the benchmarks are put too low, ultimately all species will prove to be sensitive. Visa versa, if they are too high, none will be sensitive, which is not realistic. As of today, it is difficult to say where the benchmarks in the frame of WAKO II should be put. For this, especially more information on fishing activity is needed. Following MarLIN, several benchmarks could be put (e.g. a single pass with a beamtrawl / light (1 or 2 times a month) / moderate (1 or 2 times a week) / high (daily)). With this, one has to keep in mind that with every extra level of human activity, the amount of work that has to be done increases.

Benchmarks should be considered only as starting points and sensitivity assessment can be interpolated if the known or predicted change is greater or smaller than the benchmark. WAKO II should interpret both human activities with respect to their environmental factors and the consequent selected species’ intolerance and recoverability to each of these environmental factors.

The magnitude and duration of change in the environmental factor caused by fishing depends on its fishing power or fishing capacity. Fishing capacity is generally expressed in terms of the physical characteristics of the vessel, which create a number of difficulties for fisheries management due to the relatively weak and noisy relationship between effort (e.g. engine power) and fishing mortality (Reid *et al*., 2010). Moreover, expressing fishing capacity differs considerably for active and passive fisheries due to the nature of their catching process. Therefore, the actual disturbance is suggested to be measured indirectly through the result of a fishing activity, i.e. the fishing capacity needed for a certain weight of the landings (e.g. kg sole or commercial fish landed). The fishing capacity needed for these landings can be in turn expressed by the length of the nets multiplied by the soaking time for trammel net fisheries or by the swept area for beam trawl fisheries. Fishing capacity is dependent on the period of the year and location in the Belgian part of the North Sea . Only single events to land a certain weight are considered, as proposed in MacDonald *et al*. (1996).

Challenge 7: Qualification or quantification of sensitivity

In order to assess effects of human activities on species or communities, a qualitative or quantitative approach can be followed. From the start, WAKO II explicitly targeted a quantitative approach, while MarLIN provides an assessment, expressed as a rank (the term “score” is deliberately avoided since this implies quantitative values, whilst the assessments are qualitative in nature). Also, ‘hybrid’ methods could be applied. Eventually, all depends on the kind and quality of the data that are available.

The easiest way would be the ranking of the effect on the concerned species, arranging the effects as low-moderate-high. Alternatively, a score could be given to different levels of effect on a species, after which these scores are put in a multivariate analysis from which a general score for sensitivity can be derived. The advantage of this method is that one level of ‘expert judgement’ is ommited. A more detailed method (amongst others applicable to some benthos data) is the following: first, the sensitivity of different (functional) species in a community is scored, after which a total sensitivity score is calculated based on the procentual abundance of these species in this community. A comparable method is the one applied in recent impact studies of windmills on seabirds (Leopold *et al*., in prep.).

Here, seabirds are ranked relative to effects of windmills after which weights of different effects on species are calculated. Taking into account the densities of the different species involved, a total sensitivity score for a certain ecosystem can be calculated.

The problem with the calculation of the quantified sensitivity of all (opportunistically or ecologically) selected species, as is the modus operandi in WAKO II, is that while the intolerance of many species can be quantified for beam trawl activities (e.g. tow path and catch mortality), this is far less obvious for trammel net fisheries (e.g. quantifying marine mammal bycatch). Furthermore, specific problems arise when trying to compare beam trawl-induced damage to a population, expressed as e.g. ratio number of individuals killed over number of individuals in trawl path, with trammel net-induced mortality, expressed as e.g. number of individuals killed per time unit.

Following this, WAKO II might want to leave the track of quantification and might want to develop a multi-criterium analysis instead of classic comparison of quantitative statistics. In any case, the method that will be followed has to be decided upon at the start of the process of quantification/qualification. Further attention to the issues of quantification could be raised in following WAKO phases.

Challenge 8: Spatio-temporal dynamics

The marine ecosystem is not static but holds great variability and is subject to spatial and temporal dynamics. These dynamics can be split in vertical dynamics, in the water column as well as in the sediment, and horizontal dynamics. The females of masked crab (Corystes cassivelaunus) for instance reside in the sediment during winter (Reiss and Kröncke, 2004), implying they are less easily caught than males which are on top of the seabed. Horizontal dynamics can be related to for instance the differences in effects of beam trawling in a sandy or a muddy sand habitat (Kaiser *et al*., 2006) or to the variability of abundance due to horizontal migration (e.g. Reiss and Kröncke, 2004). On top of this, temporal dynamics steer the changes (e.g. Van Hoey, 2006; Reiss and Kröncke, 2004; Haelters *et al*., 2010). The abundance of harbor porpoises in the Belgian Part of the North Sea is typically high in late winter and early spring (Haelters *et al*., 2010), indicating the intolerance to trammel net fisheries could be higher during these periods (Haelters, 2008). These dynamics will differ according to the ecosystem component and the species in question. The scale of space and time will also differ and an appropriate scale will have to be decided upon.

This project aims for an integrated ecosystem approach which can lead to very complex spatial and temporal dynamics. It is important to stress that the sensitivity of species will not change over space and time but the exposure to the pressure will. This issue is relevant to the fisheries management e.g. in the case of areas or seasons closed for fisheries.

Since the WAKO project will use different layers of information, based on the ecosystem components, possibly the scale of detail used in one layer may influence the other. A low degree of detail in one layer, e.g. may mask a higher degree in detail in another. Therefore a sensible manner of combining those layers needs to put sensitivity in a correct perspective. Taking the most sensitive component, may result in the loss of detail of the fine-scaled layers. The methodology used in Biologocal Valuation may be a good way forward (Derous *et al*., 2007a; 2007b).

Challenge 9: Confidence of the assessment

The availability of information is more extensive for seabirds and marine mammals compared to other components. The resulting variation in uncertainty due to data availability strongly influences the confidence of the sensitivity assessment. Within this 'uncertainty', different levels can be identified based on (1) the coverage of the data concerning natural variability within the different ecosystem components, and (2) the nature of the information (experimental, expert judgment-based, questionnaire-based, modeled). The intolerance of a selected set of species towards beam trawling and trammel net fisheries, for example, was experimentally quantified within the WAKOII project. According to the MarLIN's confidence scale, such direct experimental information on species' intolerance should be considered highly confident. Such a high confidence will however not apply for the assessment of the species recoverability. Hence, it will be important to investigate the most up to date evidence on e.g. regrowth and or recolonization potential of the selected species. The more (reliable) information becomes available, the higher the confidence of the assessment. An uncertainty measure for 'not well known', 'missing' and 'not considered' species should be included as well. Within WAKO II it will hence be important not only to summarize or assess the species' recoverability, but also to explicitly refer to all data sources used, including the bias introduced by each data set. Such a reliability strategy was applied in the project BWZee (Derous *et al* 2007) and can be adopted in the WAKO II procedure. This will allow transparent labeling of the confidence, and render the procedure more usable and interpretable by others.

Challenge 10: Confidence of the assessment

Within the MarLin approach, the assessment procedure is guided by decision trees constructed per pressure. This allows for a structured and uniform progress, but the bifurcation method (yes/no) is subject to discussion when considering some species' traits. In the case of the comparison between beam trawl and trammel net impacts, the assessment could be performed based on clearly documented observations (e.g. experimental data). If such data are lacking or evidence is not strong, the assessment can be supported by semi-structured interviews containing clear definitions, benchmarks and a justification of the species' assessment.

When revising decision trees or interviews aiming at an assessment within the WAKO framework, it is essential that the criteria are kept simple (e.g. the sensitivity to smothering should be evaluated without influences of e.g. sediment characteristics and the strength of the water flow). More generally, a pragmatic approach to the implementation of the proposed assessment procedure will be essential. In a final phase of the assessment, the outcomes of the procedure can be narrowed down to a final rank or score. In this respect, there is a need to decide whether a ranking or scoring approach is best suited for the WAKO II goals, taking into account practical feasibility.

3.2 A protocol for sensitivity assessment of fishing techniques

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A roadmap for Sensitivity Assessment (SA)

The roadmap for SA partially followed the approach of Stelzenmüller *et al*. (2010), as the potential of spatial and temporal management of fishing métiers needs a spatial and temporal explicit element. This implies a four-step approach: (1) scoping, (2) species selection, (3) sensitivity (and uncertainty) assessment and (4) sensitivity maps. Assessing sensitivity is based on the combination of intolerance (susceptibility) and recoverability (productivity), explained in Tyler-Walters *et al*. (2009) and the PSA of ERAEF (Hobday *et al*., 2010). This is in contrast to many other SA's that treat recoverability as one of the many factors contributing to sensitivity (e.g. Garthe and Hüppop, 2004; Laidre *et al*., 2008 and Stelzenmüller *et al*., 2010). Sensitivity is defined as the degree to which marine features respond to pressures (Zacharias and Gregr, 2005). Their response depends partially on species-inherent characteristics or life-history traits (recoverability assessment). They also depend on the multiple pressures (or hazards) exerted by the fishing activities (Burgman, 2005). Pressures provide the link between the species and a human activity (ICES, 2010b; Fock *et al*., 2011; ICES, 2011a; Robinson *et al.* 2011). Selecting relevant pressures and scoring them appropriately is the core business of an assessment, as these scores form the basis for the relative distinctions between fishing métiers. SA's urge for an uncertainty analysis as they extrapolate information from fishing effect studies (Fock, 2011b) and as knowledge gaps for the link between fishing activities and pressures or for the link between pressures and species are numerous.

Scoping

This stage is essential for transparency to managers or among scientists. It also contributes to the SA's pragmatism and applicability by setting boundaries and limitations (Tyler-Walters *et al*., 2009). As outlined before, the specific goal of this SA is to compare ecosystem effects of fishing métiers. The unit of analysis is species abundance within ecosystem components. This implies ignorance of genetic and intra-specific effects, such as life stage dependency (Degraer *et al*., 2010a) and size composition (Rochet and Benoît, 2011).

Pelagic species, such as adult herring (*Clupea harengus*), are rarely caught in beam trawl fishery, but herring eggs are attached to hard substrates and therefore its reproductive success might be compromised (Postuma *et al*., 1977). Nevertheless, this SA was restricted to adults only. Concordantly, this leads to the selection of ecosystem components, which were limited to four: benthic (in- and epifaunal) invertebrates, fish, seabirds and marine mammals. One of the strength of SA is that it can be comprehensive by including all possible pressures to adult specimen. This implies not only direct effects, which are mostly considered in SA's (e.g. Patrick *et al*., 2010, Zhou *et al*., 2010a), but also indirect effects. The latter propagate through time, but only second-order effects were accounted for. These are relatively tightly linked in space and time to the pressures, which is a prerequisite for a good indicative power (Hiscock *et al*., 2003). A potential critique on SA is its limitation to "one fishing event". Although pressure effects can depend on fishing effort (e.g. Hiddink *et al*., 2006), the evaluation is limited to one single disturbance as in Tyler-Walters *et al*. (2009) or to the disturbance needed to extract a similar amount of the target species, e.g. to land 1000kg of sole (*Solea solea*). The last limitation relates to the fact that species occurrences and community composition change in space and over time in response to natural and anthropogenic influences. As both 'naturalness' and 'pristine state' are difficult to define (Derous *et al*., 2007) and information on natural variability of an ecosystem is mostly very meagre (Van Hoey *et al*., 2010), no references are made to a historic baseline conditions, or to the natural variation of the system. The risk of shifting baselines should be well communicated (Jackson *et al*., 2001; Roberts, 2007). The methodology was further exemplified by its application to two fishing métiers, characterized by an active and a passive gear, targeting the same fish species in the same area. The selected métiers were the trammel net fishery targeting sole (Solea solea) and beam trawl fishery targeting mainly sole and plaice (Pleuronectes platessa). The area of operation is the Belgian Part of the North Sea (BPNS), because of its well known ecosystem structure (e.g. Van Hoey *et al*., 2004; Derous *et al*., 2007; Willems *et al*., 2008).

Species selection

Species selection depends on the objectives of the SA, and was classified in three frameworks, according to Degraer *et al*. (2010a). The first refers to the intrinsic ecosystem structure and functioning framework, as is illustrated in Hiscock and Tyler-Walters (2006). The second relates to species of economic importance (e.g. Patrick *et al*., 2010) and the third puts the focus on legal aspects as discussed in Fock (2011a; b). Species selection in the latter two frameworks is self-evident, whereas the intrinsic ecosystem structure and functioning framework needs a more closer look. First, a sub-division in ecosystem components is justified, as their relative biological valuation is troublesome (Derous, 2008), affecting pressures and data-availability are likely to differ amongst components. For seabirds and marine mammals, the whole range of relevant species can be captured easily (e.g. Garthe and Hüppop, 2004), whereas for benthic invertebrates and fish a selection criterion is required. Selection should be pragmatic, and can be based on existing community analyses.

Tyler-Walters *et al*. (2009) proposed for instance to select the five species that contribute the most to similarity and the ten species with the greatest abundance or biomass. However, data-poor species, such as encrusting and colonial epifauna, might be easily ignored in existing analysis and even though this might be a reason for their exclusion from SA, this must be clearly stated (Degraer *et al*., 2010a). Concordantly, one must bear in mind that species selection is crucially influencing the range of the sensitivity outcome (Tyler-Walters *et al*., 2009; Degraer *et al*., 2010a).

Species sensitivity assessment

Intolerance assessment

Pressure selection

Breaking down fishing in multiple pressures assist in understanding how a fishing métier actually affects the investigated marine feature. The ecosystem approach to management has stimulated considerably the list of pressures that can be considered (e.g. Eastwood et al., 2007; European Union, 2008). In some instances up to 75 fishery-related pressures are listed, although the use of more than six per index (intolerance, recoverability) does little to improve the accuracy of the assessment (Hobday et al., 2007; Patrick et al., 2010). The number of potential pressures also depends on the level of considered detail and scientific understanding of the phenomenon. In some cases, the cause of population declines can be well established, hereby limiting the need for an extensive list of pressures (e.g. Tuck *et al*., 2011). However, drastic limitations might also lead to an insufficient assessment (Tuck, 2011). To achieve an acceptable list of pressures to compare fishing métiers with demonstrated and potential distinct effects, it is therefore advised to aim for a comprehensive approach. Categorizing pressure types is one means to maintain relevant insights (e.g. Hiscock and Tyler-Walters, 2006; Eastwood *et al*., 2007; Hobday *et al*., 2011). Therefore four intolerance categories are proposed to evaluate species intolerance: (1) direct biological pressure (DBP), (2) indirect biological pressure (IBP), (3) indirect physical pressure (IPP) and (4) indirect chemical pressure (ICP) category. The indirect effects are complex, acting on some element of the organism's environment or associated ecological community (Laidre *et al*., 2008). Explicitly referral avoids their ignorance and is needed, as increasing evidence demonstrate its importance at population and community level (Jordan, 2009; Rochet *et al*., 2010; Shephard *et al*., 2010). The determination of pressures within the pressure categories follows from expert judgment with (e.g. scale intensity consequence analysis in Hobday *et al*., 2011) or without stakeholders (e.g. Degraer *et al*., 2010a; Patrick *et al*., 2010). Pressure selection occurs within each ecosystem component as for instance the pressure 'smothering' might be relevant to infauna, but not to seabirds. Although natural variability is not taken into account (see above), experts might consider the relevance of a certain pressure in relation to a benchmark of natural variability in the area under investigation (Tyler-Walters *et al*., 2009). If a pressure scores below this benchmark of unacceptable change, then it should not be considered relevant. Minor changes in turbidity for instance might be irrelevant in coastal areas, whereas they can be important in the high seas.

Scoring

The objective of scoring is to maximize the discriminative power between species and fishing métiers. The scoring depends on the degree to which a marine organism responds to a change in environmental condition and hence in pressure. Each pressure is scored on a 7-point scale from "-3" to "+3", but allowing flexibility to apply intermediate scores (e.g., 1.5 or 2.5) when the attribute value spans two categories (Patrick *et al*., 2010). Negative scores indicate that species benefit from the pressure, e.g. through food subsidies. Semi-quantitative scoring allows the integration of fully quantitative data with expert judgment. Pressures should equally be assessed for all investigated fishing métiers, which might lead to complex situation as pressure selection and grouping can lead to different results (see exemple below). Assessing pressures can depend on spatial or temporal variability. Tow path mortality from beam trawling for instance causes different species-specific mortalities in biogenic habitats than in gravels (Kaiser *et al*., 2006). Scoring a pressure might therefore be split into separate assessments per spatial or temporal units. Incorporating variability factors might increase work load considerably. Its relevance depends on the SA objective and on the range of variability assessed. For the comparison of a pressure score between two fishing métiers, including spatial variability is justified for instance if the pressure score for fishing métier "A" falls in between pressure scores of fishing métier "B" in two distinct spatial units.

Semi-quantitative scoring depends on the type of information available and can be organized in four groups: (1) fully quantitative, (2) biological traits-based scoring, (3) expert judgment and (4) no scoring. The latter prevails when for instance plastics are known to be a serious threat from fisheries (Galgani *et al*., 2000; Phillips *et al*., 2010), but its origins are not specified to the level of the fishing métier Moore, 2008). SA's cannot go much further then highlighting the pressure for management. Scoring within the other methodologies is explained below and exemplified for the selected case studies.

1. Quantitative scoring

Quantitative refers to the data that establish a clear link between the species and a pressure of the two investigated fishing métiers. Fishing pressures are standardized to "one fishing event", which can be fishing effort, or for the comparison of passive and active fishing gears, it can be based on landings and/or revenues of the target species. The standardized metric for all selected species and for both fishing métiers are ordered and subsequently divided in four equal parts (from "-3" to zero for positive effects or from zero to "+3" for negative effects). This allows maximum discriminative power between species and/or fishing métiers.

2. Biological traits-based scoring

Investigations of the effect of a pressure from a fishing métier for an individual species are in many instances not undertaken. Partial, quantitative knowledge or assessments can nevertheless be at hand for the link between métier and pressure (e.g. Fonteyne, 2000) or between pressure and species (e.g. Furness and Tasker, 2000; Last *et al*., 2011). Both links can be scored and their results multiplied and rescaled to zero to "+3". Multiplication ensures both links are present for an overall effect of the métier onto a species. The general work plan is fine-tuned by pressure categories. The consequence of the DBP category, i.e. mortality, is presented in several components by Broadhurst *et al*. (2006) as the sum of all fishing-induced mortalities occurring directly as a result of catch or indirectly as a result of contact with or avoidance of the fishing gear. The importance of the mortality components is first pointed out for a specific fishing métier. Based on this information, the guidelines of Hobday *et al*. (2011) are well suited for scoring these components of mortality for individual species. The ERAEF's guidelines fit the approach in this study when the 'availability' aspect is not included for any pressure, and 'selectivity' is only included for pressures with a capture aspect to it. Ghost fishing mortality as an important mortality component for trammel netting for instance (Brown and Macfayden, 2007) is estimated as the product of scores for (1) a species' probability of contacting the lost gear (encounterability), (2) its chance of remaining caught (selectivity) and (3) the probability of death from this process (post-capture mortality). Tow path mortality, a non-capture mortality in beam trawl fishery (Kaiser *et al*., 2006), is scored from encounter probability (e.g. through penetration depth of the gear and living position of a species) and chances to survival (e.g. from species' fragility). Threshold values for scoring are based on expert opinion, but the use of heuristically derived criteria is an accepted practice in SA's (Burgman, 2005; Williams *et al*., 2011). They promote consistency in SA's application (Patrick *et al*., 2010). Scoring the indirect effects of pressures is much more complex, but nevertheless crucial. Ecosystem communities and their stability largely depend on the strength of interactions between predators, prey, competitors and resource quality (Piet *et al*., 1998) and thus on the loss or gain of food through selective fishing (Zhou *et al*., 2010b). The results of changed interactions are interplay of positive and negative feedback loops, possibly with counterintuitive results (Christensen and Walters, 2004; Lindegren *et al*., 2009). This study therefore suggests presenting only the second order effects on individual species and thereby avoiding ignorance, as well as the need for unraveling the full complexity of food webs. If a fishing métier creates a high sensitivity of prey species, based on DBPs only, then the probability of an adverse effect on the investigated, predator species is higher, i.e. positive scoring. Equally, if a fishing métier creates food subsidies through discards for instance, then the probability of an adverse effect on the investigated, predator species is scored negative, implying that it is promoted through the fishery. Trophic responses are thus accounted for by (1) the extent to which food availability is affected by a fishing métier (activity-pressure relationship) and (2) by the species' trophic guild or its ability to switch diets (pressure-species relationship) (Stelzenmüller *et al*., 2010). Competition can be assessed in a similar way. If predation is reduced through high DBP-scores of predator species, then there's a higher probability of an adverse effect on the investigated prey species, because of increased competition (Quince *et al*., 2005). The technique of biological-traits scoring is applicable to indirect physical and chemical pressures as well.

The physical pressure could for instance be 'vessel disturbance'. Beam trawling creates more ship traffic than trammel netting as it is an active fishing method and therefore scores one unit higher. Seabird reactions to disturbance range from hardly any avoidance behavior to large fleeing distances (Garthe and Hüppop, 2004). Combining scores allows distinctions between species, as well as between métiers.

3. Expert judgement

If no information is available, a useful procedure was applied by Garthe and Hüppop (2004). They assessed 'vulnerability factors' subjectively. Experts then evaluated their initial scores, based on their own experiences related to that topic. This process is called the Delphi Technique (De Lange *et al.*, 2010). Including stakeholders in the expert team has also been proposed for pressure selection and scoring (Fletcher, 2005). It improves acceptance of the outcomes, although others (e.g. Fock, 2011c) have highlighted the need for a framework where stakeholder participation is integrated from separately developed scientific advice. The latter thus suggests that SA's should be scored independently from stakeholder views.

Towards scoring intolerance

The final intolerance score results from a combination of pressure scores. This study categorizes pressures into pressure categories and therefore suggests weighing within and between these categories. The number of pressures that are selected within a category superimposes a weight given to any of these pressures and therefore strongly influences the species intolerance score. The best possibility for combining and weighing the pressure scores depends on the understanding of each pressure. A first approach is systematic and algorithm-based. In several SA's all individual (risk) scores are added (Stelzenmüller *et al.*, 2010; Fock, 2011b), while ERAEF (e.g. Williams *et al.*, 2011) illustrate the systematic approach by averaging all scores for susceptibility aspects, which are then multiplied and rescaled to a 3-point scale. Adopting this approach for the pressure categories leads to the following formula for a species-specific intolerance score (SIS):

$$SIS = \left(\frac{\sum_{x=1-n_1}(x)}{n_1} + \frac{\sum_{y=1-n_2}(y)}{n_2} + \frac{\sum_{z=1-n_3}(z)}{n_3} \right) \quad [1]$$

where "x" are the relevant DBP, "y" the relevant IBP and "z" the relevant IPP. The denominators are the number of relevant pressures for each category respectively (n1, n2, n3). Scores for the pressure categories are added, because of potential negative values. Each category of pressures equally contributes to the species intolerance of a fishing activity. A second possibility is to add expert judgement. Grouping pressures by expert judgement before averaging them is one example of attributing weight to pressures (Garthe and Hüppop, 2004), whereas attributing weights directly to the pressures is another approach (Stobutzki *et al.*, 2001; Fock, 2011b). The groups or weights can be determined with the Delphi Technique (Garthe and Hüppop, 2004; Patrick *et al.*, 2010) or can be related to the expert judgment of the intensity of the impact (Fock, 2011b). Considering the 'worst case' or the 'most frequent' pressure score would be a way around the need for weighing different pressures (Tyler-Walters *et al*., 2009; Patrick *et al*., 2010). These methodologies could work well within a pressure category, e.g. for pressures resulting in mortality. When divergent trends are translated in a single metric, understanding is lost of what the actual changes are and why they occur (Rochet *et al*., 2010). Therefore, this study suggests that pressure scores should only be aggregated to the appropriate level, for instance within pressure categories, and presented as such, without the need for creating one single metric. Translating these outcomes into sound scientific advice would highlight the uncertainty without compromising meaningfulness.

Recoverability

The ability to return to a state close to that which existed before the disturbance is estimated from bio-geographical population size and demographic attributes. Both aspects operate multiplicatively. The scores for bio-geographical population size can be based on presence-absence data (e.g. Stelzenmüller *et al*., 2010) or population densities (e.g. Garthe and Hüppop, 2004). The demographic aspect is scored from the species' position into a continuum between extreme life history strategies. Species with an equilibrium strategy (e.g. large bodied, late maturing) suffer greater population declines for a given disturbance rate than opportunistic species, typically with an r-selection growth form (Odum, 1969; Jennings *et al*., 1998). These life history strategies describe general patterns of adaptation to environmental variation or disturbance more comprehensively than schemes that are limited to single traits (Winemiller, 2005). A combination of life history traits is thus needed as a proxy for intrinsic species vulnerability (Cheung, 2007). The traits are selected within ecosystem components, to avoid an outcome that discriminates between invertebrate and fish species versus marine mammal and bird species, that have a tendency to equilibrium endpoint strategy (Fowler, 1981). The trait scores are averaged for each species, as is common practice in SA's (Patrick *et al*., 2010; Williams *et al*. 2011). This potentially involves categorization and weighing as the issues which applied to intolerance scoring, also count here (Patrick *et al*., 2010).

According to Pianka (1970), Gray (1979), Cheung *et al*. (2008) and Webb *et al*. (2009), important life history traits for the characterization of r/K-strategy for benthic invertebrates are maximum body size/length, age at reproductive maturity, life span and growth rate. Growth rate could also be replaced by fecundity and larval development, for which more information is available (Anon, 2007b; 2008b). The same traits can be used to estimate recoverability of fish, but should also include natural mortality rate. Growth rate is estimated from the von Bertalanffy growth parameter K (Musick, 1999; Denney *et al*., 2002; Hutchings and Reynolds, 2004; Cheung, 2007) or from maximum length (Le Quesne and Jennings, *in press*). Prevalent life history traits for seabirds and marine mammals included clutch size, age at maturity and adult survival rate (Williams *et al*., 1995; Sæther and Bakke, 2000; Garthe and Hüppop, 2004; Niel and Leberton, 2005; Sæther *et al*., 2011).

Species-specific sensitivity index

The species-specific sensitivity index to a fishing métier (SI) follows from its intolerance and recoverability. Ideally, the intolerance assessment leads to a single score, which is representative for all pressures from the fishing activity. As is the case in many risk assessments, this net value is extremely difficult to calculate and likely impractical, even under the assumption that all pressure effects can be articulated and quantified (Kerns and Ager, 2007; Hanewinkel *et al*., 2011; see "5.1.3 Towards scoring intolerance"). It is therefore suggested that sensitivity can also be calculated separately for pressure categories, such as DBP, IBP, IPP and ICP. Adverse and beneficiary effects on species can be presented without cancelling each other out. An assessment of the actual impact is thus not aimed for in SA's (Hobday *et al*., 2011), but the objective is to enable managers to relatively compare ecosystem effects of fishing métiers and support their decisions on sound science. The combination of intolerances and recoverability scores have been suggested in a variety of ways, both expert- and algorithm-based. Each method is scientifically robust, consistent and allows single ranking of sensitivities, which are prerequisites for the provision of scientific management advice (Hiscock *et al*., 2003; Hobday *et al*., 2011). Expert-based combinations are presented in a matrix, where sensitivity is a discrete class (e.g. Tyler-Walters *et al*., 2009; Astles *et al*., 2006; 2009). The thresholds between each sensitivity class are arbitrary, but given prior knowledge, Astles *et al*. (2006) suggest that the arrangement can be modified to suit different situations or fisheries. Matrices can be symmetric (Astles *et al*., 2009), or asymmetric. The latter can put a higher weight on recoverability to stress the intrinsic species vulnerability (Tyler-Walters *et al*., 2009) or on intolerance (Astles *et al*., 2006) when the focus is on reducing sensitivity from a fishing activity. Algorithm-based approaches can be (1) the product of intolerance and recoverability, (2) their Euclidean distance (Hobday *et al*., 2011) or (3) the formula [2] (modified from Hiddink *et al*., 2007 and Fock, 2011b):

$$SI = 1 - e^{-(SIS/R)} \qquad [2]$$

where R is recoverability. These approaches deliver a (semi-)quantitative score for sensitivity, but threshold values can be applied to aid classification (e.g. Hobday *et al*., 2011). In contrast to the product or Euclidean distance, the third form is exponential, and therefore enables the assessment to distinguish species that are insensitive from species that are sensitive to disturbance, rather than to distinguish species that are very sensitive from those that are extremely sensitive (Hiddink *et al*., 2007).

SA uncertainty analysis

Moving to an ecosystem approach is data-hungry, and limits the extent to which model predictions or SA's can be trusted. This becomes increasingly clear when these results are being introduced in the management process (Christensen, 2011). The ERAEF-approach suggests attributing the highest-level risk score when data are missing.

This precautionary approach introduces the problem of false positives, i.e. units identified at higher sensitivity than would occur when assessed with more data (Hobday *et al*., 2011). In contrast Patrick *et al*. (2010) considered missing data within the larger context of data quality, and report the overall quality of data as a separate value. It does not mask which issues are really at stake, and leaves management options open. SA uncertainty analysis is thus the process to generate information that determines if the SA is of a sufficient quality to serve as the basis for management decisions (van der Sluijs, 2005; 2007). It relates to uncertainty rising from the border with ignorance, i.e. externalizing all important system parameters to avoid that what is not known remains not known (Wilson, 2009). These will inform management, that has the need for management decisions despite distinct differences between scientific uncertainties (Halpern *et al.*, 2008). The Pedigree index gives this information. It conveys an evaluative account of the production process of information and indicates the scientific status of knowledge by highlighting different aspects that underpin the intolerance and recoverability scores (Funtowicz and Rovetz, 1990). The yardsticks for strength of research results are the pedigree criteria, usually proxy representation, empirical basis, methodological rigor, theoretical understanding and degree of validation (Refsgaard *et al*., 2007; Wardekker *et al*., 2008). This set is rated, by means of individual expert judgments, on a scale of 0 (weak) to 4 (strong) giving a description of each rating on the scale (Table 3.2.1). The results can be plotted in a kite diagram, or average pedigree scores can be placed on a gradient of red to green (bad to good), using the traffic-light analogy (Wardekker *et al*., 2008). The level of aggregation determines the source of uncertainties presented, e.g. by species, by pressures, etc.

Table 3.2.1: Pedigree criteria for the SA uncertainty analysis

Score	Quality of proxy for the pressure effect: pressure-species interaction	Examples
4	Exact measure	Seabird bycatch (e.g. Zydelis *et al.*, 2009; Warden and Murray, 2010)
3	Good fit for measure	Short-term discard survival
2	Well correlated with biological traits	Established relationships between traits and pressures (Statzner and Bêche, 2010)
1	Weak correlation with biological traits	Living position as proxy for tow path mortality (Bergman and Hup, 1992)
0	No clear relationship	
	Empirical basis	
4	Local, in situ experimental data with large sample size	Discard observer data from BPNS
3	In situ experimental data, but not local or small sample size	Meta-analysis on tow path mortality (Kaiser *et al*., 2006)
2	Inferences from modelled data or indirect inferences	Modeling food availability (e.g. Hiddink *et al.*, 2006; Shephard *et al.*, 2010)
1	Inferences from ex situ (lab) experiments	Effects of smothering on key species with certain traits (e.g. Last *et al.*, 2011)
0	Guesstimate	

	Theoretical understanding of activity-pressure interaction	
4	well established theory on the investigated fishing métier	Fish discard data of beam trawling in the North Sea (Enever *et al.*, 2009; Ulleweit *et al.*, 2010; Depestele *et al.*, 2011)
3	well established theory on analogous fishing métier	Turbidity changes in bottom trawling (e.g. Palangues *et al*., 2001; O'neill *et al.*, 2008)
2	Accepted theory with partial nature and limited consensus on reliability	Displacement follows from the relation with VMS (e.g. Rijnsdorp *et al.*, 1998)
1	Preliminary theory	Vessel disturbance (e.g. Yoon, 1979)
0	Guesstimate	

Table 3.2.1 (continued): Pedigree criteria for the SA uncertainty analysis

	Methodological rigour	
4	Best available practice in well established discipline	Before-After-Control-Impact (BACI) experiments) for sessile species (e.g. Kaiser *et al.*, 2006)
3	Best available practice in immature discipline	Predicting survival from reflex impairment (Davies and Ottmare, 2006; Davies, 2010)
2	Acceptable method but limited consensus on reliability	Discard estimation from selectivity (Depestele *et al.*, 2011)
1	Preliminary method, unknown reliability	Changes in sediment profile (O'neill *et al.*, 2009)
0	No discarnible rigour	
	Validation	
4	>=2 peer reviewed papers	Numerous examples above
3	1 peer reviewed paper	Ghost fishing of trammel nets for sole (Revill and Dunlin, 2003)
2	Data published in grey literature	Discard observer data from BPNS
1	Unpublished data	
0	Anecdotic information	

Spatial and temporal explicit sensitivity maps

There are very few examples of spatial and/or temporal SA's (Hope, 2006; Stelzenmüller *et al*., 2010), although it holds the opportunity of expanding the theory for spatial conservation planning from its focus on identifying no-take reserves towards a zoning configuration that can examine trade-offs between fisheries and conservation (Klein *et al*., 2009). This study therefore builds on existing efforts to develop a spatial and temporal explicit SA. The spatial and temporal dimension of comparing effects of fishing métiers can inform marine spatial planning of the possibilities in mitigating ecosystem effects and making the implementation of the ecosystem-based approach to fisheries management a much more tangible process (Douvere, 2008). The link between the species-specific sensitivity index and its areal distribution provides the basis for spatial mapping. Summarizing distribution data by time period gives insights in temporal sensitivities. Spatial sensitivity is computed from the combination of SI and a measure of occurrence in a grid cell (modified from Stelzenmüller *et al*., 2010):

$$S_{species} = \frac{PO_{species} * SI_{species}}{\max SI_{allspecies}} + 1 \qquad [3]$$

where PO is probability class of occurrence. If density estimates are available, the formula of Garthe and Hüppop (2004) applies, where the respective SI values are multiplied with the natural logarithm of the species' density (+1, to avoid undefined values). Both should be associated with their spread as a measure of uncertainty. The resulting individual species maps are subsequently summed for an overall sensitivity map per ecosystem component. The spatial scale depends on the distribution data, which are generally gridded at a finer scale for benthic invertebrates and fish, than for seabirds and marine mammals (Fock, 2011b).

3.3 Species selection and distribution in the BPNS

Endo-, epifaunal invertebrates and fish in muddy sand and sandy substrates

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Methodology

Selection

Tyler-Walters *et al*. (2009) proposed for instance to select the five species that contribute the most to similarity and the ten species with the greatest abundance or biomass. However, data-poor species, such as encrusting and colonial epifauna, might be easily ignored in existing analysis and even though this might be a reason for their exclusion from SA, this must be clearly stated (Degraer *et al*., 2010a). Concordantly, one must bear in mind that species selection is crucially influencing the range of the sensitivity outcome (Tyler-Walters *et al*., 2009; Degraer *et al*., 2010a).

For benthos species selection, analyses were performed to come to a selection based on the ten most abundant species and on the five species that contribute most to the similarity within the community.

Distribution maps

The species distribution maps of selected species are based on abiotic variables using the MAXENT software. This is based on presence data (we can define 'presence' as a certain density threshold).

Macrofauna

Species selection

Van Hoey *et al*. (2004) describes 10 Species Assemblages (SAs) of which 4 'Type I SAs' (defined as 'communities') and 6 'Type II SAs' (or Transitional Species Assemblages, TSAs). Three out of four communities are subtidal (*Abra alba – Mysella bidentata* community (SA1); *Nephtys cirrosa* community (SA4); *Ophelia limacina – Glycera lapidum* community (SA6)) .

Degraer *et al*. (2003) describes '4 subtidal communities and 1 transitional species association'. The subtidal communities include the 3 described by Van Hoey *et al*., 2004 and add one new subtidal community: *Macoma balthica* community.

Furthermore, a habitat suitability model for the four subtidal communities is presented in Degraer *et al*. (2008), based on the previous references. Finally, Degraer *et al*. (2009) evaluate in a report the different sand banks based on four communities.
Based on the dataset used by Degraer *et al*., 2008 (cf. methodology there), SIMPER analyses (Primer v6) were performed to calculate the relative contribution of each species in the respective macrobenthic communities. Moreover, top 10 abundances were calculated for each community. A further selection of this dataset is used as only the samples belonging to one of the four communities are used (138 samples *Abra alba* community; 33 samples *Macoma balthica* community; 129 samples *Nephtys cirrosa* community; 73 samples *Ophelia limacina* community).
Besides, *Lanice conchilega* is identified as a key structural species. The tube building polychaete *Lanice conchilega* is a dominant ecosystem engineer in coastal marine areas (Rabaut *et al*., 2007, Van Hoey *et al*., 2008). The species tends to aggregate in high density patches, with specific biological, physical and temporal features (Rabaut *et al*., 2009). For the macrobenthic community, the habitat modifying capacity of *L. conchilega* has been suggested to lie in the creation and regulation of safe havens for species, in influencing the interactions between local species and in changing the physical environment (Rabaut *et al*., 2007, Van Hoey *et al*., 2008). Therefore, the species has been described as an important ecosystem engineer. Its effect on benthic biodiversity and its specific species association has been extensively described (Callaway, 2006, Carey, 1987, Dittmann, 1999, Féral, 1989, Rabaut *et al*., 2007, Van Hoey, 2006, Zühlke *et al*., 1998). The final selection of macrobenthic species based on these analyses resulted in 21 species: *Abra alba*, *Lanice conchilega*, *Phyllodoce (Anaitides) maculata*, *Bivalvia*, *Macoma balthica*, *Phyllodoce (Anaitides) mucosa*, *Echinocardium cordatum*, *Nephtys cirrosa*, *Scoloplos armiger*, *Eumida sanguinea*, *Nephtys hombergii*, *Spiophanes bombyx*, *Gastrosaccus spinifer*, *Notomastus latericeus*, *Spisula subtruncata*, *Glycera lapidum*, *Ophelia limacina*, *Tellina fabula*, *Kurtiella bidentata*, *Pariambus typicus*, *Tellina pygmaea*.

Results: macrobenthic distribution maps

Due to limited model validity of 4 species(groups), the distribution of 17 macrobenthic species is modeled (Figure 3.3.1). The respective macrobenthic species show a habitat suitability that basically follows the known benthic community location (Degraer *et al*. 2008). *Abra alba* was selected as a representative of the coastal communities and reflects this distribution. *Echinocardium cordatum* was included as a representative of the more offshore *N. cirrosa* community but tends to follow the *A. alba* community as a habitat preference (with one additional high suitability area north of the Hinder Banks). Eumida sanguinea is a representative of the *A. alba* community and an important associated species of *L. conchilega* (Rabaut *et al*. 2007). Glycera lapidum is part of the O. limacina community and appears more offshore. Kurtiella bidentata follows the distribution of the *A. alba* community as it is an important representative of this community.

The same holds true for *Lanice conchilega*. *Macoma balthica* is very much associated with the coast, but does not show the highest predicted occurrence as described in Degraer *et al*, 2008 (East of Zeebrugge). *Nephtys cirrosa* occurs more offshore, as well as O. limacina, two species representing their respective community. *Pariambus typicus* is a species of the *A. alba* community and associated to *L. conchilega*. The *Phyllodoce* spp. Occur more inshore while *Scoloplos armiger* follows the *Nepthys cirrosa* community. Spiophanes bombyx occurs more offshore as representative of both offshore communities. *Spisula subtruncata* and *Tellina fabulina* are species of the *A. alba* community.

Epifauna and fish species

<u>Species selection</u>

Species selection for epibenthic species and demersal fish was done using the same procedure as for macrofauna being SIMPER analyses and most abundant species. The epibenthic community characterization was taken from De Backer *et al*. (2010), based on data 2004-2009. This means that five epibenthic communities were identified: three coastal ones and two offshore communities. As also temporal conditions were identified as important structuring factor, the distribution maps were generated for spring and autumn separately (contrary to macrofauna representation).

In total, 18 species were selected; taking into account the temporal aspects, the distribution of 40 'species' was modeled (Table 3.3.1). The selection of species is based on abundance and similarity, except for *Buglossidium luteum, Crepidula fornicata* and *Diogenes pugilator*. *Anthozoa* and *Pomatoschistus spp.* were also selected for their contribution to the species complex. The species are *Anthozoa*, *Asterias rubens (asru), Buglossidium luteum (bulu), Callionymus lyra (caly), Callionymus reticulatus (care), Crangon crangon (crcr), Crepidula fornicata (crfo), Diogenes pugilator (dipu), Echiichthys vipera (ecvi), Limanda limanda (lili), Liocarcinus holsatus (liho), Nassarius reticulatus (nare), Ophiura alba (opal), Ophiura ophiura (opop), Pagurus bernhardus (pabe), Pleuronectes platessa (plpl), Pomatoschistus spp.* and *Solea solea (soso)*.

Table 3.3.1: List of selected epibenthic 'species' (analyses were done separately per season; sp=spring; au= autumn)

asru_sp	crcr_sp	liho_sp	pabe_sp	coa2_au
asru_au	crcr_au	liho_au	pabe_au	coa2_sp
bulu_au	dipu_au	nari_au	Plpl_au	coa3_sp
bulu_sp	dipu_sp	nari_sp	plpl_sp	coa3_au
caly_sp	ecvi_sp	opal_sp	soso_sp	off1_au
caly_au	ecvi_au	opal_au	soso_au	off1_sp
care_au	lili_au	opop_au	coa1_sp	off2_sp
care_sp	lili_sp	opop_sp	coa1_au	off2_au

Results: epibenthic distribution maps

Only the distribution of ten out of forty 'species' could be modeled adequately: care_au, coa1_au, crcr_au, coa2_au, ecvi_sp, coa2_sp, ecvi_au, coa3_au, coa1_sp and off1_sp, including the three coastal communities (Figure 3.3.2). For community 1 and 2 of the coast, distributions were modeled for Spring and Autumn. For community 1 there seems to be very little distribution differences between the seasons while for community 2 there is an aggregation towards the East coast in autumn. Community 3 was only modeled for Spring, showing a clear distribution along the East coast. Offshore, only community 1 was modeled (for Spring), showing some tendency to follow sand bank morphology. Community 2 was not modeled. As it comes to species level only *Echiichthys vipera*, *Crangon crangon* and *Callionymus reticulatus* were modeled. The distribution of E. vipera was modeled in Spring and Autumn, showing very similar distributions for both seasons. *Crangon crangon* seems to prefer coastal zones and the Thornton bank while *Callionymus reticulatus* acts as an offshore species.

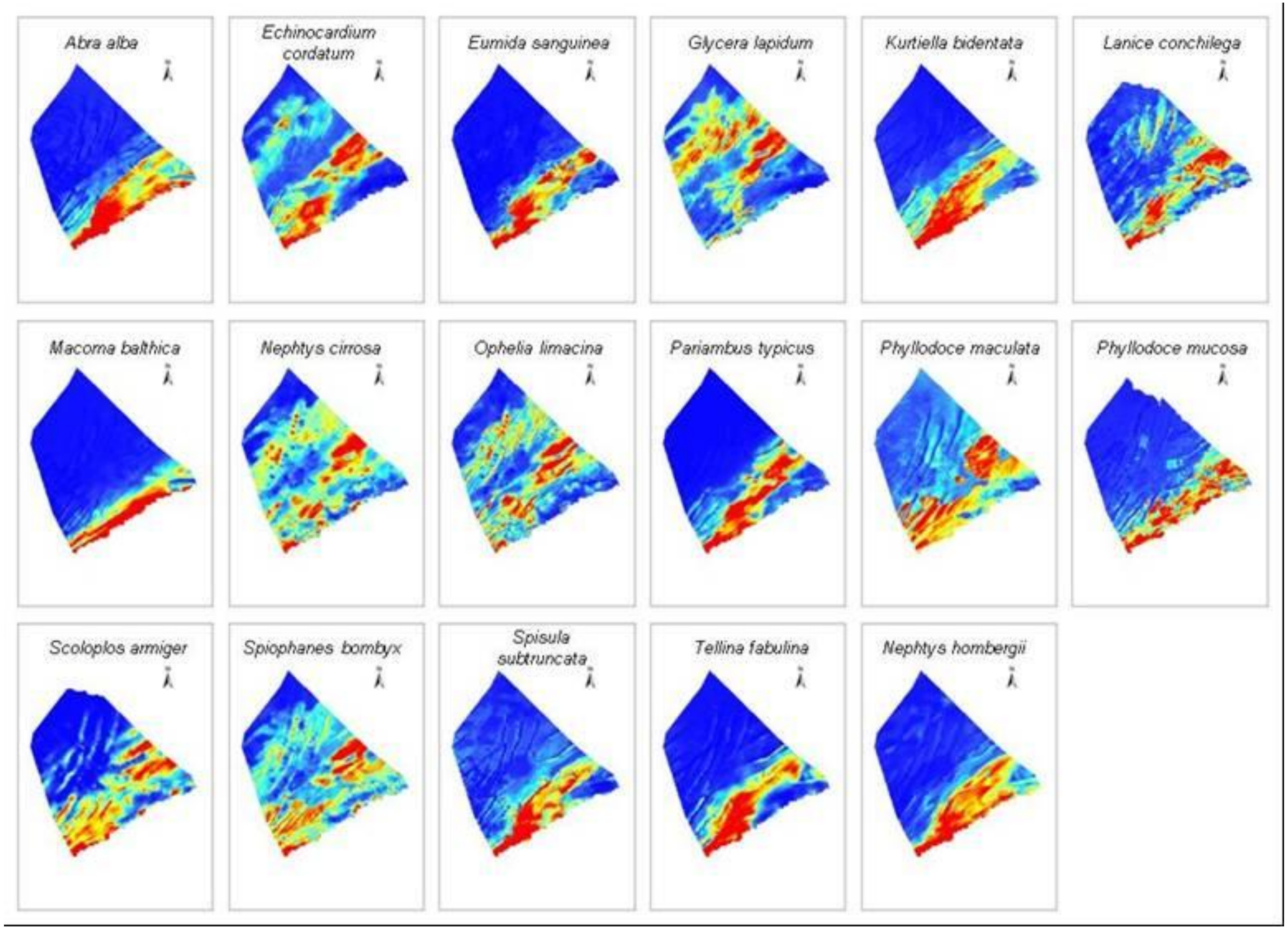

Figure 3.3.1: Modeled spatial distribution based on presence of the selected macrobenthic species. High resolution maps with clear species name indication can be found in Annex 7 of this report

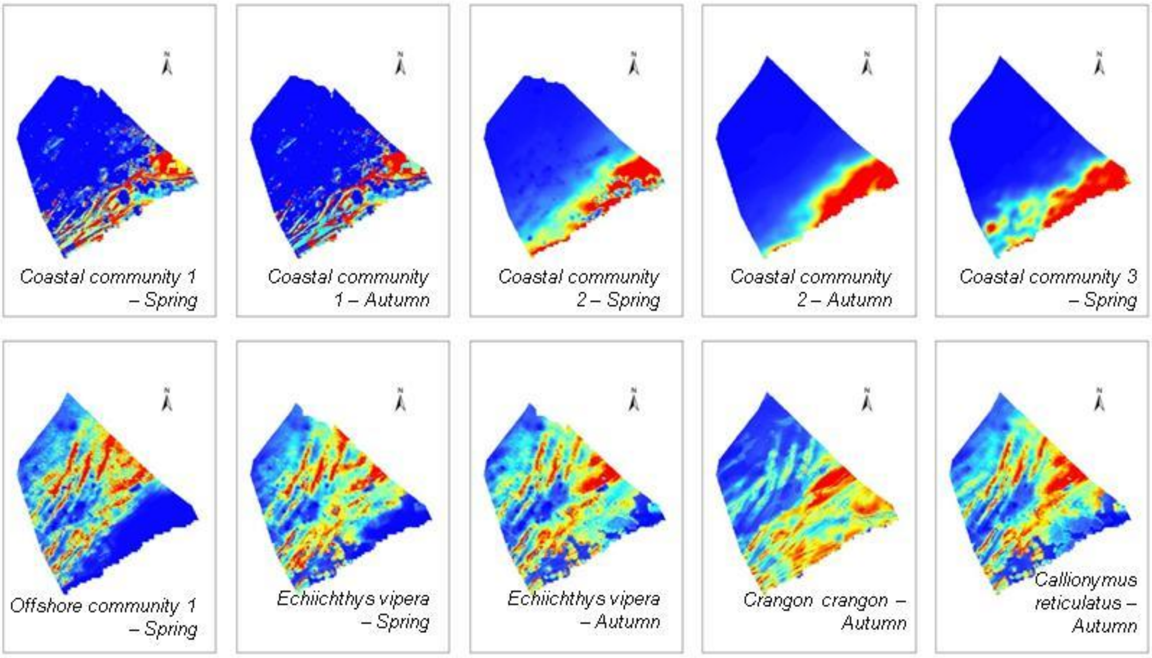

Figure 3.3.2: Modeled spatial distribution (based on presence) of the selected epibenthic 'communities' and 'species'. High resolution maps with clear species name indication can be found in Annex 7 of this report

Discussion

For macrobenthos representatives of the four a priori defined macrobenthic communities have been selected and subsequently modeled successfully. In some specific instances, one major constraint in species distribution mapping is that the amount of data and/or the correlations with the available abiotic variables are weak. The very limited amount of epibenthic species that could be modeled is a concern that is difficult to solve for now as it turns out that there is very low habitat selectivity for some very frequently occurring species. Another issue is that the models for seasons are actually based on non-seasonal environmental variables, which makes it difficult to find seasonal differences. The lumping of species groups to model distributions of communities worked quite well for epibenthic communities be it only for the coastal communities. In general, there seemed to be very little variation between Spring and Autumn distribution. As abiotic variables were not divided per season, this might be the reason that models were not valid for species that tend to migrate a lot (i.e. far more difficult to find correlations).

Conclusion

The selection methodology for the benthic part (macrobenthos and epibenthos) was applied in a straightforward way. For the species distribution, most macrobenthic species could be reliably modeled using the MAXENT software and distributions coincide with known community distribution to which the respective species belong. For epibenthic species, the separate distribution maps per season seemed (1) to cause low model validity as the abiotic variables are not split for seasons and (2) little difference occurred between seasons for the valid community/species distribution.

Epifaunal invertebrates and demersal fish in gravel substrates
Jean-Sébastien Houziaux

The data used to select epibenthic species accordingly with the procedure set up by Tyler-Walters et al (2009) originate from the surroundings of the Westhinder sand bank by Houziaux et al (2008) and De Rynck (2011) and were gathered with a small chain-mat beam trawl in spring 2005 (for details: see annex 6). Both studies were partial, the first being carried out on a sub-set of all samples through gravel, sandy gravel and sand habitats, the second being restricted to a smaller portion of the gravel ground.

It is difficult to make a clear-cut selection of 10 species for several reasons. Firstly, the area is colonized by highly mobile species more typical of sandy areas, which were removed. Some numerically dominant epibenthic species of the area, namely starfish *A. rubens*, the brittle-star *O. albida* as well the swimming crab *Liocarcinus holsatus*, were thus not considered for this exercise. Secondly, the species content is an admixture of sessile and mobile species which cannot be enumerated in the same way. Ideally, enumerable (mostly mobile) and colonial (all sessile) species should be considered apart. For the latter, only presence/absence in the sample can be used. To avoid this difficulty and provide a set of mixed "representative" species, we used the frequency of occurrence of all identified species in the samples (% of samples where the species is present). Thirdly, the habitat is characterized by a large amount of species present in low densities. Therefore, the selection was done based on the available semi-quantitative data and expert judgement.

The 20 most represented species of Houziaux et al (2008) are listed in annex 6. They originate from all habitats of the surveyed area (main gravel bed, sandy gravels and sandy dunes), after removal of juvenile flat fishes. We built a list of the ten species most abundantly collected in the gravels, of which 5 contribute mostly to within-group similarity. Since the analyses of Houziaux et al (2008) were not complete, the re-analysis carried out by De Rynck (2011) was used to validate the aforementioned species lists. Results are slightly different since the study focused on a smaller gravel patch. De Rynck (2011) further confirmed that samples sheltered from beam trawling display significantly different overall density and species richness.

Some of the most abundant and typical species of present-day (altered) gravel grounds of the Westhinder could be identified. Species identified as most typical strictly for gravels are included to form the final "gravel" species list: *Pomatoceros triqueter, Tubularia indivisa, Tubularia larynx, Psammechinus miliaris, Electra pilosa, Necora puber, Pisidia longicornis, (Actiniaria) Metridium senile, Ciona intestinalis* and *Alcyonidium digitatum*. The criteria retained are (1) frequency of occurrence in the gravel samples; (2) Relative contribution to similarity matrix of gravel samples and (3) qualitative adjustments based on expert judgement. Note that the brittle-star *Ophiothrix fragilis* was not considered because of its low frequency of occurrence, but displayed evry large densities and is a typical species of this habitat.

Seabirds

Wouter Courtens and Eric W.M. Stienen

Selection of species

As a first step, all observations of non-seabirds were omitted from the dataset. A seabird was defined as 'a species of which at least part of the population forages at sea in a certain part of the year' (adapted from Furness & Monaghan, 1987). Between 1992 and 2010, 48 seabird-species were recorded during ship-based counts in the BPNS. For further analysis of the data, this species-list was divided into 'common' and 'rare' seabirds. As a distinguishing criterion, a 'common' seabird was defined as a species that was observed in more than 1% of the poskeys, a 'rare' seabird as one that was seen in less than 1% of the poskeys. Finally, 18 common seabirds were retained. This division is also defensible when the total number of birds of each species is taken into account.

Seabird counts in the Belgian part of the North Sea

The Research Institute for Nature and Forest conducts standardised ship-based surveys since September 1992. These counts are conducted according to a standardized and internationally applied method, as described by Tasker *et al*. (1984). While steaming, all birds in touch with the water (swimming, dipping, diving) located within a 300 m wide transect along one side of the ship's track are counted ('transect count'). For flying birds, this transect is divided in discrete blocks of time. During one minute the ship covers a distance of approximately 300 m, and at the start of each minute all birds flying within a quadrant of 300 by 300 m are counted ('snapshot count', Komdeur *et al*., 1992). The results of these observations are grouped in periods of ten minutes, resulting in so-called 'ten-minute counts', defined by a unique 'position key' or poskey. Taking the travelled distance into account, the count results can be transformed to seabird densities with specified X- and Y-coordinates (at the geographical middle point of the track sailed during the ten-minute count).

Marine mammals

Jan Haelters

Species selection

The only common marine mammal in Belgian waters is the harbour porpoise. Although bycatch of other marine mammals, such as the common seal and the grey seal, have been recorded in Belgium (data MUMM, unpublished), these are by far outnumbered by bycatch cases of harbour porpoises. Also, it is hardly possible to assess densities and distribution of harbour and grey seals in Belgium, given that they are scarce, and no colony exists. Only regular haul-out sites for common seals exist, but total numbers remain very low compared to haul-out sites or colonies in bordering countries. For these reasons (and their low vulnerability to bycatch), the only species selected to make a comparison of beamtrawling with static gear fisheries is the harbour porpoise.

Density estimates of harbour porpoises

Dedicated aerial marine mammal surveys between 2008 and 2010 have yielded density estimates of harbour porpoises of on average 0.05 animals/km² (August 2009) to 1.03 animals/km² (April 2008) (Haelters *et al*., 2011a;b). During several surveys in March 2011, average densities were estimated at over 2 animals per km², the highest densities ever recorded in Belgian waters (MUMM, unpublished). While in the past harbour porpoises were mainly confined to late winter – early spring, during the last years high numbers of harbour porpoises were recorded also during summer months. This trend is reflected in the numbers of stranded animals, with peaks in late winter and early spring, and currently also during summer (Figure 3.3.3).

	1970 to 1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
Jan	0	1	1							1		2		1	4	1	3	2	1	1	6	2	4	30
Feb	3	1									3		4	1		1	6	2	9	3	3	2	2	40
Mar	3								1	1	3	1	3	1	4	8	4	20	9	11	6	4	6	85
Apr	3		1		2		1		1		3	1	4		7	8	21	18	13	9	5	6	23	126
May	4							1		2	1		5	2	4	6	18	17	14	8	5	7	9	103
Jun	0		1	2				1		1	1	1	2	2	1	2	7	9	4	7	5	4	5	55
Jul	0	1					1	2	1	1	1	2		1	4	7	3	1	4	5	3	2	16	55
Aug	3		1			1				1		1	1	2	8	5	13	13	13	4	10	8	25	109
Sep	1							2					1	4	2		6	5	12	3	13	5		54
Oct	3				1					1					1		4	1	4	8	8	3		34
Nov	2			1		1					4		1		2	1	2	3	3	3	1	3		27
Dec	2	1		1			1				2				1	1	2	3			1	2		17
Total	24	4	4	4	3	2	3	6	3	8	18	8	21	14	38	40	89	94	86	62	66	48	90	735

Figure 3.3.3: Monthly number of stranded animals between January 1970 and August 2011 (adapted after Haelters *et al*., 2011b)

This illustrates well that no reliable, long term stable seasonality in harbour porpoise presence and abundance exists. The only constant of the last years seems to be a low density in May and June.

Distribution

While during February to April harbour porpoises can be found all over Belgian waters, they tend to stay more offshore in summer months (Haelters *et al.*, 2011b).

Surveys in spring 2011 not only yielded the highest densities of harbour porposes ever recorded in Belgian waters, but they systematically also indicated higher average densities in the western part of Belgian waters than in the eastern part (MUMM data, unpublished; Figure 3.3.4). Areas with lower densities seem to be shipping lanes, the anchorage area, and the eastern part of Belgian territorial waters. Given the high mobility of the harbour porpoise, it is likely that its distribution in Belgian waters is related most to density of prey and to the least amount of disturbance. During its seasonal movements however, harbour porpoises are likely to be encountered anywhere in Belgian waters.

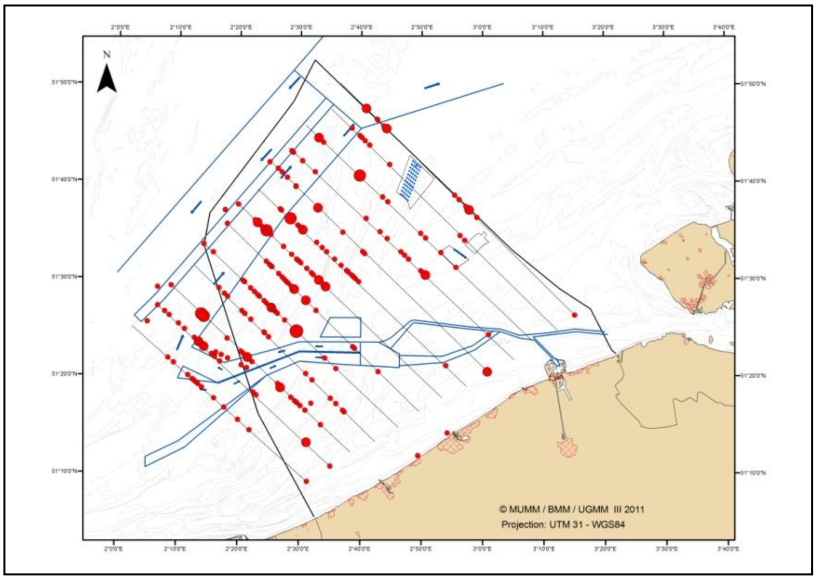

Figure 3.3.4: Tracks and observations made during the aerial survey on 29 March 2011 for estimating marine mammal density (red dots indicate observations of harbour porpoises, their size depending on the group size, which varied from 1 to 3) (MUMM, unpublished)

3.4 Case studies to validate the applicability of the sensitivity assessment protocol

Jochen Depestele, Wouter Courtens, Steven Degraer, Jan Haelters, Kris Hostens, Jean-Sébastien Houziaux, Bea Merckx, Hans Polet, Marijn Rabaut, Eric Stienen, Sofie Vandendriessche, Magda Vincx

Introduction

The sensitivity protocol was tested, using the example of trammel net and beam trawl fishery in the BPNS. The pressures were aggregated in three relevant categories: (1) direct biological pressures (DBP), (2) indirect biological pressures (IBP) and (3) indirect physical pressures (IPP). For each ecosystem component, we selected the relevant pressures within these categories (Table 3.4.1).

Table 3.4.1: relevant pressure effects for beam trawling and trammel netting by ecosystem component and pressure category

Pressure effects	Category	Ecosystem component
Catch mortality of the investigated species	DBP	B, F, S, M
Tow path mortality	DBP	B, F
Unaccounted mortality of the investigated species	DBP	B, F, S, M
Additional food availability	IBP	B, F, S, M
Reduced food availability	IBP	B, F, S, M
Changes in habitat structure	IPP	B, F, S, M
Changes in environmental conditions	IPP	B, F, S, M
Vessel disturbance	IPP	S, M

DBP: direct biological, IBP: indirect biological, IPP: indirect physical pressures / B: benthic invertebrates, F: fish, S: seabirds and M: marine mammals

The species' intolerance to disturbance can be evaluated in two different ways. The first possibility is based on the biological characteristics of a species' population that determine its ability to withstand the range of pressures that result from disturbance. Laidre *et al.* (2008) for instance, assessed the biological variables such as diet diversity, site fidelity and habitat specificity to evaluate the intolerance of marine mammals to climate change. The second possibility of intolerance assessment is based on the set of pressures that result from disturbance. The intolerance of a species for each pressure is subsequently assessed on the basis of individual studies and/or biological traits of the species. Although both approaches prove valid, the second approach was preferred in this study, i.e. the fishing activity is split up into different categories of pressures and species intolerance is assessed for each of the pressures resulting from the disturbance activity. Breaking down beam trawling and trammel net fishing into several pressures appears more thoroughly investigated by peer reviewed studies (Partim I, p.13; Annex 8). Subsequent reasoning about the biological capacity of an individual species to avoid a specific pressure seemed easier then assessing whether individual biological characteristics of a species would enable withstanding the "generic" pressure of beam trawling or trammel netting, such as high mobility in relation to catch efficiency. Scoring principles follow the generic guidelines provided in chapter 3.3, p. 83, which are applied and motivated for intolerance in annex 8 and for recoverability in annex 9. The attribution of different scores is demonstrated for a range of species (within ecosystem components). The preliminary scores based on the guidelines in annex 8 and 9 are provided in annex 11 and 12 for all pressures and demographic attributes. Below are two selected examples to illustrate the outcomes of the WAKO Sensitivity/Risk assessment.

Intolerance assessment and its uncertainty: an example for the direct biological pressures of selected benthic invertebrates and fish species

The effects of the selected biological pressures for benthic invertebrates and demersal fish species are catch mortality, tow path mortality and unaccounted mortality. Annex 8 explains why catch mortality and unaccounted mortality were not evaluated for infaunal invertebrates and therefore not utilized in the scoring of these species. The pressure effects were scored on the basis of quantitative data (from e.g. Kaiser et al., 2006; chapter 2.1, p.13; 2.2, p.19 and 2.3, p.30), or biological traits (as illustrated in annex 8). The pressure effects were combined to one intolerance score for direct biological pressures based on the following weighing principles. The catch efficiency of beam trawls is estimated at 10% for epifaunal invertebrates (Lindeboom and De Groot, 1998), implying a weight of 0.10 for catch mortality in relation to tow path mortality. The weighing factor of tow path in relation to catch mortality is estimated at 0.05, as is assumed that relatively few fish die from tow path mortality in relation to being caught. One has to keep in mind that this is a generalization, as catch efficiency greatly increases with the use of tickler chains or chain mats (e.g. Rogers and Lockwood, 1989, Kaiser *et al*., 1994).

This reasoning does not account for potential escape from fishing, i.e. the selectivity curves (Annex 5) assume that all fish encounter by trawling are caught or escape below, which is questionable (e.g. Wells et al., 2008 in Rochet and Benoît, 2011). This assumption does also not account for a range of additional mortalities, except for ghost fishing (Broadhurst et al., 2006), but is withheld on the basis of the outcome of expert judgement (WAKO-workshop). Ghost fishing mortality is estimated at 15% of normal catch rates for gill nets (Pawson, 2003; Brown and Macfayden, 2007), inducing a weighing factor 0.15 in relation to catch mortality. The resultant scores are tabulated in Annex 11 for epifaunal invertebrates and demersal fish and beam trawling.

The basic information differs for scoring each species. The given scores can therefore not be considered as facts. Uncertainties are reduced at the largest possible extent using a stepwise approach from quantitative analysis to expert judgement. The scores are not expressed as probabilities with a unit and a spread, which is the familiar way of assessing uncertainty. Our statements about the scores are nevertheless assessed by qualitative aspects surrounding it. This qualitative level of confidence is based on the criteria in chapter 3.3 (p.83) and is illustrated for survival, a parameter to score catch mortality (Table 3.4.2) and other direct biological pressures in Annex 10. The results are not surprisingly demonstrating that beam trawling causes a higher sensitivity to the selected infaunal and epifaunal benthic invertebrates. The sensitivity of fish species is largely based on the discarding process, which shows a similar high sensitivity of plaice and dab for both fisheries, but a lower sensitivity of sole for trammel netting. The uncertainty analysis illustrates that our knowledge about the catch mortality of beam trawls and of unaccounted trammel net mortality is reasonably well established. The uncertainties in catch mortality for trammel netting are reduced due to the efforts within the WAKO-project (chapter 2.2, p. 19 and 2.3, p.30).

Table 3.4.2: Scoring pedigree criteria for survival of epifaunal invertebrates and demersal fish after beam trawl disturbance

Species	Quality of proxy	Empirical basis	Theoretical understanding	Methodological rigour	Validation
Asterias rubens[1,2]	3	4	4	3	3
Buglossidium luteum[3]	0	0	4	0	0
Callionymus lyra[1]	3	3	4	3	3
Callionymus reticulatus[1]	3	3	4	3	3
Crangon crangon[3]	0	0	4	0	0
Diogenes pugilator[2]	3	3	4	3	1
Echiichthys vipera[3]	0	0	4	0	0
Limanda limanda[1,2]	3	4	4	3	3
Liocarcinus holsatus[1,2]	3	4	4	3	3
Nassarius reticulatus[3]	0	0	4	0	0
Ophiura albida[2]	3	3	4	3	1
Ophiura ophiura[1,2]	3	4	4	3	3
Pagurus bernhardus[1,2]	3	4	4	3	3
Pleuronectes platessa[1,2,4]	3	4	4	3	4
Solea solea[1,2,4]	3	4	4	3	4

[1]Kaiser *et al.* (1995) [2]Desender (2010) [3]traits-based [4]Van Beek *et al.* (1990)

Spatially explicit sensitivity assessment: an example for indirect biological pressures of seabirds in the BPNS

The scoring of the indirect biological pressures is split up in additional and reduced food availability. Seabird ecology is well known. Seabirds which are associated with fishing vessels are well known and can be split up in four score categories (chapter 2.4 (p.42); annex 8). The effect of eliminating food sources for seabirds is well understood as well (Furness and Tasker, 2000; Annex 8). Fisheries' discards and fishing-induced mortalities of prey items are also well understood (chapter 2.1-2.3, p. 13-30). The scoring principle of both can thus in principle be based on a fully quantitative basis. However discard consumption and prey selection by seabirds is selective and this link could not be established in the limited time frame of the project. The scoring is therefore based on the fact that beam trawling causes higher mortalities for prey items and produces a larger discard proportion for consumption by seabirds (see annex 8 for details). The 'recoverability' of seabirds is based on three demographic attributes: (1) clutch size; (2) adult survival rate and (3) age at first breeding (annex 9). The score for each of these attributes are summed and rescaled on a 4-point scale. The sensitivity of seabirds to changes in food availability is based on the formula from Hiddink *et al.* (2007), and the application of Fock (2011b): $SI = 1 - e^{-(INTOL/\mathrm{Recov})}$ (Table 3.4.3).

The final species sensitivity scores from Table 3.4.3 are combined with the species densities in a certain season in the BPNS. The resulting risk/sensitivity maps for each of the selected seabirds species are summed to get a risk/sensitivity map for beam trawls and trammel nets (Figure 3.4.1 and Figure 3.4.2). The applied formula is modified from Garthe and Hüppop (2004): $SI_{seabirds} = \Sigma_{species} (\ln(density_{species} + 1) \times SI_{species})$.

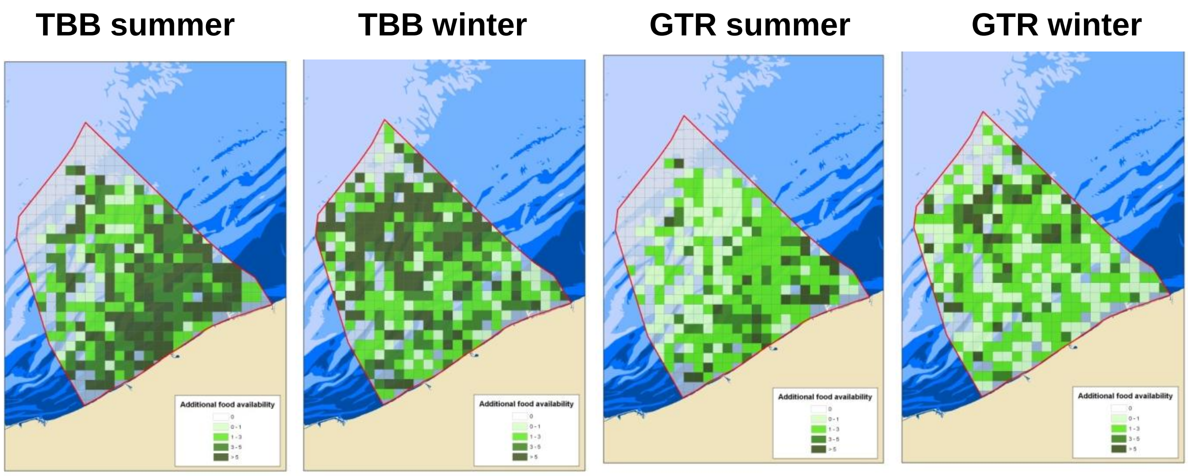

Figure 3.4.1: Risk/sensitivity maps for the additional food availability of 16 selected seabird species in the BPNS in beam trawl (two left figures) and trammel net (two right figures) fishery. High sensitivity values demonstrate a positive effect from discarding for scavenging seabird species

Table 3.4.3: Intolerance (INTOL), recoverability (Recov) and sensitivity (SI) scores for seabirds in the BPNS, for the pressures 'additional' and 'reduced food availability', induced by trammel net (GTR) and beam trawl (TBB) disturbance

Species	$INTOL_{Add}$+1		$INTOL_{Red}$+1		Recov +1	SI_{Add}		SI_{Red}	
	GTR	TBB	GTR	TBB		GTR	TBB	GTR	TBB
Red-throated Diver	1	1	2	3	1	0.6	0.6	0.9	1.0
Great Crested Grebe	1	1	2	3	4	0.2	0.2	0.4	0.5
Northern Fulmar	-2	-3	1	2	1	-6.4	-19.1	0.6	0.9
Northern Gannet	-1	-2	1	2	1	-1.7	-6.4	0.6	0.9
Great Cormorant	1	1	1	2	3	0.3	0.3	0.3	0.5
Common Scoter	1	1	3	4	4	0.2	0.2	0.5	0.6
Great Skua	-1	-2	2	3	1	-1.7	-6.4	0.9	1.0
Little Gull	-1	-2	1	2	3	-0.4	-0.9	0.3	0.5
Black-headed Gull	-1	-2	3	4	4	-0.3	-0.6	0.5	0.6
Common Gull	-1	-2	2	3	3	-0.4	-0.9	0.5	0.6
Lesser Black-backed Gull	-3	-4	2	3	2	-3.5	-6.4	0.6	0.8
Herring Gull	-3	-4	2	3	3	-1.7	-2.8	0.5	0.6
Great Black-backed Gull	-3	-4	2	3	2	-3.5	-6.4	0.6	0.8
Kittiwake	-2	-3	3	4	3	-0.9	-1.7	0.6	0.7
Sandwich Tern	1	1	3	4	2	0.4	0.4	0.8	0.9
Common Tern	-1	-2	3	4	3	-0.4	-0.9	0.6	0.7
Common Guillemot	1	1	1	2	2	0.4	0.4	0.4	0.6
Razorbill	1	1	2	3	2	0.4	0.4	0.6	0.8

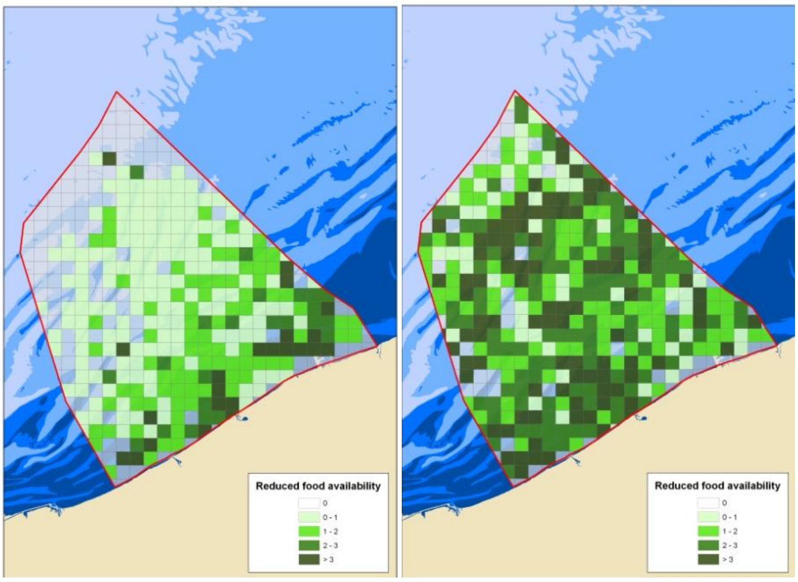

Figure 3.4.2: Risk/sensitivity maps for reduced food availability of 16 selected seabird species in the BPNS in beam trawl fishery

Conclusion

The developed methodology is based on a wide range of existing, peer-reviewed assessments. The WAKO sensitivity assessment was tested for two selected examples and demonstrates its potential for application in spatial and temporal management of fishing métiers. The full application and interpretation of its results should be produced to a large set of examples to fully acknowledge its potential and explore its practicality.

4. DISTRIBUTION OF FISHING EFFORT IN THE BELGIAN PART OF THE NORTH SEA

Sofie Vandendriessche, Jochen Depestele and Kris Hostens

Introduction

To be able to assess the ecosystem effects of beam trawl and trammel net fisheries in the BPNS, information is needed on the current fishing effort of these fisheries. During the project WAKO I, only limited detailed information on the fishing effort of both types of fisheries on a small scale, such as the different habitats of the Belgian part of the North Sea, was available (Depestele *et al*., 2008a). Fishing effort estimation was restricted to the number of 'active' fishing vessels that was observed during fishery control flights and seabird boat trips over a ten-year time period. Since WAKO I, however, Vessel Monitoring System (VMS) data have been made available by the Belgian Sea Fisheries Service for scientific research related to fisheries management. These data are satellite-based and not prone to bias resulting from varying sampling intensity. Hence, they have the potential to provide a more realistic value of fishing effort.

Unfortunately, only VMS data of Belgian vessels were provided. The lack of data concerning foreign vessels on the BPNS hampers the drafting of realistic maps on fishing effort. Nevertheless, an analysis of the available data was carried out (1) to verify the trends observed using data from airplane and vessel based surveys, (2) to evaluate the potential of the VMS data for scientific use in the framework of impact assessments and marine spatial planning (e.g. fisheries interests and nature conservation objectives in Natura 2000 areas), and (3) to evaluate the appropriateness of the available data format and processing tools, for optimization of future VMS data analyses.

Material and methods

VMS data were available for the years 2006 to 2009. These data encompass specifications concerning the identity of the vessel, and the position, time of registration, speed and heading at 2 hour intervals.

All VMS registrations originating from the BPNS were assigned to vessel groups defined by engine power and gear, as derived from the yearly published "Official List of Belgian Fishing Vessels" (Anon., 2006, 2007c to 2009c). Ten combinations of engine power class (eurocutters EC, large segment vessels LS) and gear (beam trawl B, otter trawl OT, trammel net W, shrimp trawl KO, Twin Rig T) were encountered in the database, of which EC B and LS B were most abundant and constituted over 95% of the data.

First, all registrations from the harbours of Nieuwpoort, Oostende and Zeebrugge and from a 5km buffer around their reference positions were removed.

These registrations all represented vessels entering or leaving port, regardless of their speed. For the remaining "at sea" registrations, the activity of a vessel at the time of the VMS registration was derived from the recorded speed, by applying a speed filter. According to Fock (2008), speed filters for data with long interval length (2 hours at the BPNS) are best developed by calculating mean fishing speed (MFS) values. For the BPNS data, these values were calculated per ship category, based on engine power and registered gear. Average speed was calculated based on all "at sea" values smaller than 8 knots (all trawlers) or 5 knots (trammel netters). Fishing activity was then defined as all activity at speeds lower than MFS + 2 knots (Fock, 2008).

Ten combinations of engine power and gear were encountered in the database. Since data on some power and gear combinations (e.g. EC B/KO) were too limited to calculate a representative mean fishing speed, only 4 groups were retained: EC trawlers / EC W/ LS trawlers/ LS W. During a quality check of the vessel list per group, it appeared that the vessel group "EC W" did not exist in real life. This vessel group was in fact subject to administrative actions related to quotum transfer and did not actually fish with trammel nets. The registrations of these vessels were removed from the geodatabase.

Based on the calculated mean fishing speed per vessel category, a selection was made of all VMS registrations representing presumed fishing activity. These data were plotted on BPNS maps representing the number of VMS registrations (fishing) per 3km² grid cell. Maps were generated per vessel group and per year.

The data were processed, filtered and visualized using Microsoft Access and ArcView 10.0 (ESRI Inc, 2010).

Results

Speed values "-1" and "0"

Since speed values of "-1" and "0" constituted the largest part of the dataset, an analysis was made of their geographic positions.

Values "-1" constituted 3.9% of all VMS data on the BPNS from the period 2006-2009. Although a majority of these recordings originated from harbors and the 5km buffer zone around it (vessels leaving or entering port), about 11% of these records originated from the BPNS. A subset of these records was extracted and the vessel speed was estimated from the distance between subsequent registrations (2 hour intervals). The estimated speeds clearly indicated fishing activity for a number of these "-1" registrations. Hence, these "-1" recordings at sea can be considered as "error" values and may constitute a source of underestimation of fishing activity. A correction can be done by estimating speed based on subsequent coordinates.

However, such an action requires start and stop dates of fishing trips, which are currently not available in the VMS dataset. Since the "-1" records at sea constitute only 0.4% of all VMS registrations at the BPNS, this is not a major hurdle for analysis of the data, providing that the bias they may induce is taken into account.
A "0" registration implies that the vessel in question is stationary, either in port or at anchor. These "0" registrations constitute 68% of all BPNS data, of which most originate from the three major harbors along the Belgian coastline and their 5km buffers. Two percent of these "0" values were registered at sea.

Speed filter for fishing activity based on mean fishing speed MFS
The obtained mean speed values per vessel group were similar to the ones calculated by Fock (2008), except for large beam trawlers (Table 4.1). Their mean speed value on the BPNS was a lot lower than the one observed in German VMS data (3.6 versus 6 knots). This might be due to differences in gear configuration (e.g. chain mats versus tickler chains), differences in sediment characteristics of the visited fishing grounds, and differences in the width of the beams and engine power of the vessels. The registrations also contained a large number of "0" speed values at sea, especially in 2006. Consequently, the data of 2006 were not included for the calculation of the MFS for large segment trawlers (LS trawlers).

Table 4.1: Mean speed values derived from BPNS data per vessel group and comparison with results from Fock (2008)

Taxon	Changes in density (%)	Taxon
EC trawlers	3.6	3.2
LS trawlers	3.6	6.0
LS W	2.0	1.7 - 2

Maps reflecting Belgian fishing activities on the BPNS
Maps were generated for the three vessel groups per year, by plotting the VMS registrations representing presumed fishing activity as the number of registrations per 3km² grid cell. Since the vessel group "LS W" consisted of only one vessel, the generated maps cannot be published in the light of confidentiality regulations concerning VMS data (BS, 8/12.1992). Consequently, only maps on trawling activity are shown, while trammel net activity is only vaguely described in terms of intensity and geographic distribution.
EC trawl
Eurocutters mainly fishing for flatfish (only a few registrations for shrimp fisheries, and only in 2006) concentrated their activities in the Vlaamse Banken and south of the Gootebank. The Thorntonbank was also heavily fished in 2006, but was abandoned after the start of windmill construction activities.

During the following years, activity concentrated more and more on the Vlakte van de Raan and around Oostende, and less off shore registrations were noted. In 2009, a lot of trawling activity appeared in the zone between the Thorntonbank and the Bank Zonder Naam.

LS trawl

Large beam trawlers in the BPNS fished more widely distributed but with lower intensity than eurocutters. In 2006, registrations were observed in most of the BPNS, while the dispersion of registrations clearly decreased in 2007 and 2008. In these years, the highest numbers of VMS registrations were observed the vicinity of the Gootebank. In 2009, the number of fished grid cells again increased, especially in the off shore region.

LS W

The single large trammel net vessel operating on the BPNS was mainly active in the Gootebank region and at the Hinderbanken in 2006 and 2007. Since 2008, its VMS registrations were more dispersed, with registrations in the Hinderbanken, the north section of the Vlaamse Banken and at the Gootebank, with very little activity in the near shore area. Generally, trammel net activity concentrated in areas with minor fishing impact by eurocutters. The overlap of fishing grounds between large beam trawlers and this trammel net vessel was more important, especially at the Gootebank and the Hinderbanken.

Discussion

VMS versus visual surveys

During WAKO (Depestele *et al*, 2008a), an analysis of fishing effort distribution in the BPNS was based on data from visual surveys, both ship based and airplane based. The data collection system of VMS is fundamentally different from such visual surveys, since data are automatically transmitted at fixed intervals by satellite instead of being recorded in the field. When comparing both monitoring methods, several advantages and disadvantages can be identified, which are summarized in Table 4.2.

VMS data have the major advantage that they provide a full coverage of fishing grounds, which is imperative to get a realistic view of fishing effort distribution. In the current analysis, full coverage maps were generated, but only for vessels fishing under a Belgian flag. If VMS data of Dutch, French , Danish and British vessels fishing in the BPNS would be overlaid, the trends observed in Figure 4.1 and Figure **4.2** would change drastically, especially in the off shore areas. This is illustrated by Figure 4.3 and Figure **4.4**, showing that the BPNS is intensively fished by beam trawlers of different nationalities.

Although all VMS data of vessels fishing in the Belgian EEZ are present at the administrative level, sharing VMS data for non-CFP purposes is constrained by a combination of human rights law; data protection law; the law of confidence, and EU law - in particular the EU confidentiality obligation under Article 113 of EC Regulation 1224/2009 (the "Control Regulation"). When sharing VMS data outwith the sphere of the CFP, compliance with the EU confidentiality obligation cannot be guaranteed. However, it is arguable that sharing anonymized and aggregated VMS data for marine planning and management purposes is not contrary to human rights law, data protection law or the EU confidentiality obligation if certain safeguards are put in place to protect the commercial value of VMS data and preserve confidentiality (ICES, 2010c). Consequently, the need for integration of data from all flag states operating in a single EEZ can and should be tackled as soon as possible. Such an integration was already possible for the Irish, German and Dutch EEZ's (Fock, 2008; Anon., 2009d; Deerenberg *et al*, 2010; Oostenbrugge *et al*, 2010; ICES, 2011b), including data of the Belgian fleet, and proved to significantly increase the utility of VMS data in providing a spatially and temporally explicit understanding of fishing activities.

Table 4.2: Description of differences between VMS and visual survey data (BPNS) for a number of important factors for determining fishing effort

	VMS data	Visual surveys
Activity of vessel	Activity derived from speed profile of the vessel or métier	Clear description if vessel activity at the moment of observation
Métier	Derived from logbook data or existing registers	Often not clear in the field
Sampling precision	Full coverage of fishing grounds	Bias through differences in sampling effort / depending on working pressure
Accuracy	Accuracy depends on the performance of the transmission device and the used fishing algorithm	Accuracy depends on working pressure and sampling effort
Confidentiality	Subject to confidentiality regulations	Not subject to confidentiality regulations
Flag state identity	Only data on vessels on BPNS under Belgian flag	Data on all vessels under Belgian and foreign flags
Vessel size	Only for vessels > 15m	All vessels, including recreational fisheries
Time period	Since 2006	Since 1992
Spatial Scale	All fishing grounds – limited detection of local effects due to 2 hour transmission interval	BPNS (or smaller)

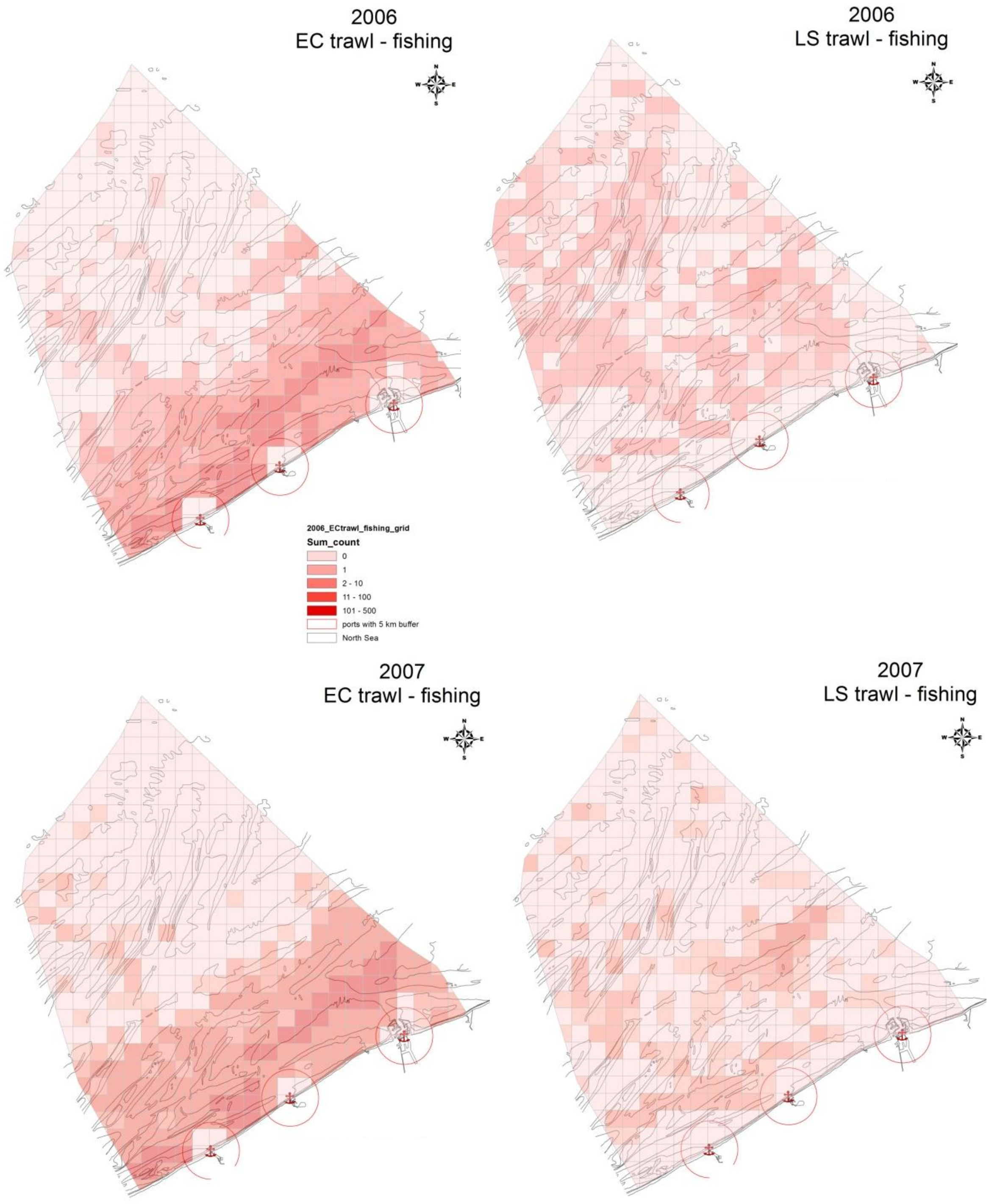

Figure 4.1: BPNS maps of fisheries effort per 3km² grid cell for the years 2006-2007 per vessel type (EC trawl : trawlers ≤ 221kW, LS trawl: trawlers > 221kW). Colors represent a gradient in numbers of VMS registrations per grid cell representing fishing activity

Figure 4.2: BPNS maps of fisheries effort per 3km² grid cell for the years 2008-2009 per vessel type (EC trawl : trawlers ≤ 221kW, LS trawl: trawlers > 221kW). Colors represent a gradient in numbers of VMS registrations per grid cell representing fishing activity

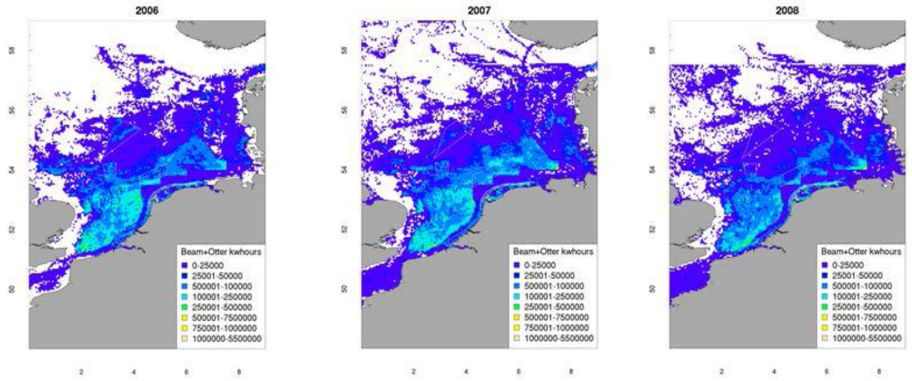

Figure 4.3: Total fishing effort (KW*hrs) for beam and otter trawls combined for all countries (B, D, DK, F, NL, UK) by year. Source IMARES. Adapted from ICES (2011b)

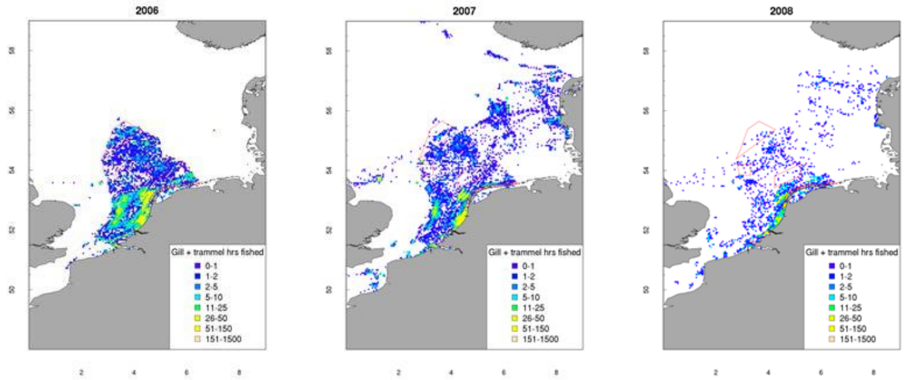

Figure 4.4: Total fishing effort (soak time hours) for gillnets and trammel nets combined for all countries (B, D, DK, F, NL, UK) by year, which was landed in Dutch Harbours. Source IMARES. Adapted from ICES (2011b)

Other than the lack of data on foreign vessels, the current analysis suffers from an underestimation of actual fishing effort due to the lack of data on vessels under 15 m of length. Since commercial coastal shrimp and trammel net fisheries and all recreational fisheries have been estimated to represent a meaningful proportion of total fishing effort in the BPNS (Depestele *et al*, 2008a), VMS data do not suffice to get a correct and detailed view of the total effort. Ideally, all commercial fishing vessels regardless of their size should be equipped with a VMS transmitter or a similar device. That would definitely provide a better view of the fishing effort by trammel net fisheries, since only a single trammel net vessel is large enough to provide VMS data at the BPNS. Installing VMS devices for recreational fisheries is however not realistic, so other ways of estimating fishing effort by these small vessels have to be considered. In that perspective, visual surveys are complementary to VMS data, since they can provide a good estimate of spatial distribution and hot spots of small scale fishing activities, especially in coastal areas (Maes *et al*, 2005; Goffin *et al*, 2007; Depestele *et al*, 2008a).

To estimate the total numbers of individual vessels in a certain area, the total number of vessels observed in surveys can be compared with the number of vessels recorded in the VMS database for the same year (Eastwood *et al*, 2007). Since the analyzed VMS database of the BPNS only contained Belgian vessels, such a comparison with the visual surveys (see Depestele *et al*, 2008a) could not be done.

Appropriateness of available data format and processing tools

The current analysis resulted in maps representing the number of VMS registrations at presumed fishing activity per grid cell. This gives an idea of fisheries intensity but is not an exact measure of fishing effort or pressure, which are usually expressed as trawled seafloor surface per time interval or the number of fishing hours per surface unit for trawlers, and as soaking time*net length for trammel net fisheries (see WAKOII - WP1). To be able to convert numbers of VMS registrations to actual fishing effort and pressure for both fisheries types, a link with logbook data is essential, but is at present not available for Belgian VMS data.

Logbook data can provide more detailed information on (1) fishing gear, (2 length of fishing trips and (3) landings. Firstly, fishing gear in this study was based on the yearly published "Official list of Belgian Fisheries Vessels". This list is however not accurate enough for analyzing VMS data, since changes in fishing gear (e.g. seasonal) are unclear and registered gear does not always correspond with actual practice. The vessel group "EC W", for example, did not exist in real life in the period 2006-2008. The vessels categorized as trammel net eurocutters were in fact subject to administrative actions related to quotum transfer and did not fish with trammel nets. Hence, a more reliable method of vessel categorization is required based on a joint analysis of VMS data and logbook data. Second, length of fishing trips allows to identify consecutively registered positions within each trip, to calculate the distance between positions and thus to correct error speed values ("-1" in the BPNS dataset) by calculating the covered distance per time interval (e.g. Hintzen, 2010). The actual length of a trawl, and hence the trawled surface, is however hard to determine based on registrations at 2 hour intervals (Deng *et al*, 2005). For small scale distribution analysis (e.g. edge effects at closed areas of limited size), the frequency of registration would preferably be set higher. Third, landings allow to analyze fisheries effects on target stocks, and to produce maps with the distribution of fishing effort and landings per unit effort (LPUE), when combined with VMS data (cf. Afonso-Diaz, 2002). Landings also provide information on the gear type used (e.g. trawling for flatfish or brown shrimp by Belgian eurocutters).

The integration of logbook data and VMS data is of the highest priority to optimize the utilization of VMS data, since it can provide extremely valuable information about the distribution of effort and catches (Oostenbrugge, 2010).

VMS data in fisheries related impact assessments and spatial planning in the BPNS

WAKO II aimed to assess the ecosystem effects of beam trawl and trammel net fisheries in the BPNS, by comparing information about the current fishing effort of these fisheries methods with sensitivity maps of the BPNS. When integrated with knowledge of benthic habitat type and derived habitat sensitivity, VMS data can provide better ways to manage the seabed and the fish stocks it supports. VMS can also assist in the optimal designation and subsequent measurement of the effectiveness of Marine Protected Areas that function to conserve both target stock spawning biomass and non-target species and habitats (Witt & Godley, 2007).

Only a number of sensitivity maps have been produced as examples, based on the protocol application (chapter 3.4, p. 92). We were not able to work out all sensitivity maps nor could we produce integrated sensitivity maps over all ecosystem components.

Secondly, although we made a lot of progress compared to WAKO-I to compute fishing effort for the Belgian fleet on the BPNS, we are still lacking good (computable) VMS data for fishing vessels that fish under foreign flags on the BPNS. It is of utmost importance for the fishing industry that the latter become available for scientific purposes. Also, the lack of data on small commercial vessels (most coastal shrimp trawlers, trammel netters and recreational fishing vessels have no VMS commitments) hampers a proper total fishing effort estimation. Finally, the complex linking of VMS with logbook data (as proxy for the catch in a certain area) has not yet been made.

To avoid inaccurate conclusions based on uncompleted maps, we decided that yet no overlay maps between sensitivity maps and fishing effort for beam trawl and trammel net fisheries will be produced. The recognized problems with both types of data (ecosystem sensitivity and real fishing effort) have to be solved adequately, before we will be able to perform a thorough assessment of the most sensitive areas and of the ecosystem effects (conflicts) of both fishery types on the BPNS.

Conclusion

Based on VMS data of 2006 - 2009, Belgian eurocutters concentrated their activities (mainly flatfish fishery) around the midshore sandbanks, while large Belgian beam trawlers are widely distributed but with lower activity on the BPNS. The only Belgian trammelnetter for which VMS data were available, mainly operated on the offshore sand banks. However, accurate fishing effort maps for the BPNS will look completely different, if (1) we were allowed to include VMS-data on foreign fishing vessel activity, (2) data on smaller (non-VMS) vessels existed, and (3) fishing activity is linked with detailed landing data. The problems we encountered with the computation of both ecosystem sensitivity (sensitive areas) and 'real' fishing effort should be solved adequately, to be able to use the overlay maps in the spatial management planning for both beam trawl and trammel net fisheries on the BPNS.

5. CONCLUSIONS

The key objectives of the WAKO-II project were (1) to fill out knowledge gaps in our understanding of trammel net and beam effects in the BPNS and (2) to set up an actual integrative approach to assess ecosystem effects of fishing effects.

Filling out data gaps in short-term, direct effects of beam trawl and trammel net fishery in the BPNS

The effects investigated were short-term and direct, as these are more easily related to a specific fishing métier and as the focus was a relative comparison of effects of these métiers in order to guide managers on the potential of managing fishing gears to achieve ecosystem-based management objectives. The selected short-term effects were (1) endofaunal mortality from passage of a fishing gear (tow path mortality), mortality from the catching process for (2) epifauna and (3) commercial fish species, (4) seabirds interactions and (5) marine mammals bycatch.

(1) Tow path mortality is only relevant to beam trawling, but quantitative data only exist with sufficient quality for muddy sand and sandy sediments. Suggestions have been made for gravel beds and proxies are presented for biogenic reefs. Biological traits should assist further analysis and preliminary suggestions of traits needed for establishing a relationship with mortality were identified. (2) The discards of epifaunal invertebrates and non-commercial fish were quantified and compared for trammel net and beam trawl fishery. An univariate approach was developed and trialed. Multivariate approaches indicated the larger total number of individuals and of species discarded in beam trawl than trammel net fishery. (3) The commercial fish discard rates were high for a range of species, with high total discards of beam trawls, because of their highly mixed character. The high variability in discards was partially explained for some species, but data limitations suggest to be cautious in interpretation. The same uncertainties hold true for the fleet discard estimates. (4) These estimates suggest that, even if only a limited part of the discards would be consumed by seabirds, the mean seabird population in the BPNS can still be supported from it. In the breeding season however, there might be a deficit in energetic input from discards, taking factors as distance to the breeding colony in Zeebrugge into account. The effects were demonstrated for scavenging seabirds, but potential effects to rarer and non-scavenging species could be anticipated. (5) Seabird and marine mammal bycatch was investigated through a number of approaches (strandings data, questionnaires, independent observers and fishermen cooperation) and suggest a potential danger for diving seabird and harbor porpoises. More efforts are needed though to get a clearer picture here and our positive experiences with fishermen's cooperation could be an important basis.

Filling out the gaps, identified in WAKO-I was an important achievement, but this short-term project could obviously not accomplish a quantification of all fishing pressures of beam trawling and trammel netting and further detailed investigations are required.

Development of an integrated assessment approach for ecosystem effects of fisheries

The first WAKO project was mainly focused on the evaluation of distinct effects of trammel net and beam trawl fishery. Some of the identified gaps were resolved in the first part of the WAKO-II project. This project aimed also add the development of an approach to evaluated the effects in an integrated approach. The MarLIN sensitivity assessment was identified as a developing tool, which might serve our purpose. An international workshop was held to discuss the challenges that we were facing to meet our objective, i.e. to be suited for the relative comparison of fishing métiers, and to be spatially and temporally explicit. There were ten challenges identified and solutions were discussed. The challenges were (1) key and important species definition and selection, (2) baseline conditions, (3) 'unquantifiable' species, (4) intraspecific sensitivity, (5) pressure selection, (6) bench marking, (7) qualification or quantification, (8) spatio-temporal dynamics, (9) confidence of the assessment and (10) sensitivity assessment in practice. The challenges lead to conceptual discussion which was further developed with a range of other 'sensitivity' or risk assessment approaches. None of the proposed methodologies fully served the WAKO-purpose and therefore a hybrid methodology was built upon the existing experiences of peer-reviewed assessment methodologies. These were fine-tuned to a pragmatic approach and the development of a protocol which is easily applicable, transparent, repeatable, reliable and meaningful to managers. The protocol involves a roadmap for sensitivity/risk assessment, a scoping phase, and specificities on species selection, pressures selection and scoring, recoverability scoring and the determination of a sensitivity index which is represented spatially and temporally by sensitivity/risk maps. As such, the method urged for a species selection and distribution component in the BPNS, which was also part of the project.

The protocol was applied to certain key species for a range of pressures, but its full application and interpretation to the BPNS-ecosystem and implications for management could not be aimed for within this 2-year project. The developed methodology nevertheless has the potential to guide management and make suggestions for spatial and temporal planning of fishing techniques. Its application should also be linked with actual fishing effort to evaluate the current fisheries management. Preliminary investigations on fishing effort distributions were made and are meant to initiate further investigations.

6. POLICY SUPPORT

Policy support is envisaged in two ways. The first manner aims at improving our understanding of the effects of fishing in the ecosystem, which relates to Partim I in the project report. These results have largely been picked up through various channels as explained in chapter 7 'Dissemination and valorisation'.

The second manner of policy support is directed to the development of a decision support tool. The tool has been developed within the project and its applicability has been demonstrated. The tool is appropriate for instance to be applied in the recent call for fisheries measures in marine protected areas, i.e. Natura2000-sites. These sites are currently nominated for the Belgian waters. In Germany (EMPAS-project) and the Netherlands (FIMPAS-project) the process of taking measures is one step ahead of the Belgian. From this process, we learnt that a lot of discussion with stakeholders has risen (e.g. fishermen versus ngo's) and part of this reason could be resolved by including detailed information about why certain measures are proposed. There is a mixture of the importance of the process itself and the tools which are available to this. The WAKO Sensitivity/Risk Assessment tool has the potential of assisting this process.

Similarly, the ecosystem approach to fisheries management urges both environmental as fisheries management to look one step further than the current single stock assessments. However, the way forward to include ecosystem aspects, other than commercial fish species, is unclear. The WAKO-tool is a proposal to use the risk assessment tool and explicit includes the uncertainty element in its assessment. The tool has potential in ecosystem-based management. Therefore its application and usage should be tested in closer cooperation with management and potentially stakeholders. The latter was outside the scope for this two-year project, but is recommended as a validation of its workability.

7. DISSEMINATION AND VALORISATION

The scientific results of the WAKO project have been discussed and disseminated through oral and poster presentations at national and international scientific conferences and the ICES Journal of Marine Science (chapter 8). Two peer-reviewed papers are scheduled: one on the concept and/or protocol of sensitivity assessment and chapter 2.2 on the discards of epifaunal invertebrates is scheduled to be writtin in the framework of the ongoing PhD-work of the project coordinator. The cooperation between ILVO and INBO to establish the relationship between fisheries discards and seabird scavenging behavior will be continued within a Master's thesis at the University of Ghent and this work will potentially be continued within an EU project, if the proposal will be accepted. WAKO established links with other national and international projects. The project was mentioned in the fisheries projects, 'VESPAS', because of its relevance to passive fishermen. The results from the fishing effort analysis have been referred to in a workshop of the BELSPO project Quest4D. Internationally the project has been picked up in for instance the ICES Working Group report of FTFB (Fishing Technology and Fish Behaviour) and in Gascoigne and Willsteed (2009) [Gascoigne, J. and Willsteed, E. 2009. Moving Towards Low Impact Fisheries In Europe. Policy Hurdles & Actions. MacAlister Elliott and Partners Ltd. 103pp.]. The latter was financed by Seas at Risk and aimed at evaluating the potential for 'low impact fisheries'.

Several other channels assisted the communication with a variety of non-scientific stakeholders:

1. Policy makers

   The information from the WAKO-II project found its relevant implications in policy through consultation processes. These processes mainly focused on the ecosystem components 'marine mammals' and 'seabirds'. Examples are: (1) reporting WAKO-II results in the national report of ASCOBANS in 2010, (2) an ICES workshop on the 28th of September 2010, as well as (2) communications at the Advisory Committee meeting in Bonn (Germany) from 4-6 May 2011, (4) the 2nd FIMPAS workshop in Hardelot (France) on the 30th of June till the 2nd of July 2010 and (5) providing an answer to a question from the parliament on bycatch of harbor porpoise (March 2011). There was input requested on the EC website to establish a Seabird action plan. Preliiminary results of WAKO were submitted: http://ec.europa.eu/fisheries/partners/consultations/seabirds/contributions/ilvo_wako_report_en.pdf. Results were also communicated with the Flemish Agency on Nature and Forest Management, which established a steering group on the management of gulls in coastal cities. The relevance of fisheries as a food source for seabirds was discussed, based on WAKO-results.

2. Fishing industry
   Next to direct involvement of the fishermen's producer organization 'De Rederscentrale' and some individual fishermen, the fishing industry was informed through an information leaflet the was distributed during the yearly ILVO workshop between Christmas and New Year, by informing the 'passive fishery'-working group within the PO 'Rederscentrale' with intermediary results and through local fishing journal. The WAKO-project was explained in the magazine of 'De Rederscentrale' and in 'Promovis'.

3. The wider audience, including ngo's
   Project information to a wider audience was mainly provided through internet. The project website and announcements on various other websites aimed at improving visibility of the project. Websites include: www.vliz.be; www.bencore.be; biobel.biodiversity.be; www.scheldemonitor.be; www.wgftfb.org (ICES Working Group on Fishing Technology and Fish Behaviour), as well as the Belspo-website. There were various announcements on the ILVO-website. These include announcements in the 'Latest News' of ILVO (e.g. ILVO Nieuwsgolf of December 2009 – jaargang 4), and the 'Latest News – theme session' (Nieuwsgolf Themanummer 7).
   Information was also disseminated through the fisheries event 'Visserijfeesten Nieuwpoort', where a large audience gets in contact with the fishing industry and fisheries projects, such as WAKO.
   Students have also participated in WAKO-trials onboard the RV Zeeleeuw, via the 'Planeet Zee'-initiative of the VLIZ. This interaction was also communicated through the ILVO-Latest News announcements.

8. PUBLICATIONS

Peer-reviewed papers

- Depestele, J., Vandemaele, S., Vanhee, W., Polet, H., Torreele, E., Leirs, H., and Vincx, M. 2011. Quantifying causes of discard variability: an indispensable assistance to discard estimation and a paramount need for policy measures. – ICES Journal of Marine Science, 68: 1719–1725.

Oral and poster presentations

- Second prize of special anniversary edition of the VLIZ young Scientists' Day: Depestele, J. (coordinator), W. Courtens, S. Degraer (presenter), J. Haelters, K. Hostens, H. Polet, M. Rabaut, E. Stienen, S. Vandendriessche, M. Vincx 2009 Are trammel net fisheries a cure for the disease called fisheries impact? or… "the WAKO story". University of Ghent/MUMM/INBO/ILVO: Oostende, Belgium.
- Depestele, J.; Courtens, W.; Degraer, S.; Derous, S.; Haelters, J.; Hostens, K.; Moulaert, I.; Polet, H.; Rabaut, M.; Stienen, E.; Vandendriessche, S.; Vincx, M. 2009. An integrated impact assessment of trammel net and beam trawl fisheries - Project Wako [Poster]. University of Ghent/MUMM/INBO/ILVO: Oostende, Belgium. 1 poster pp.
- Depestele, J.; Desender, M.; Polet, H.; Van Craeynest, K.; Vincx, M. 2009. Mortality of fish discards in beam trawl fisheries [Poster]. University of Ghent/ILVO: Oostende, Belgium. 1 poster pp.
- Depestele, J.; Vandemaele, S.; Vanhee, W.; Polet, H.; Torreele, E.; Leirs, H. and Vincx, M. 2010. Quantifying causes of discard variability: An indispensable assistance to discard estimation and a paramount need for policy measures. Fishery Dependent Information Conference. 25th of August 2010. Galway (Ireland).
- Depestele, J.; Courtens, W.; Degraer, S.; Derous, S.; Haelters, J.; Hostens, K.; Moulaert, I.; Polet, H.; Rabaut, M.; Stienen, E.; Vandendriessche, S.; Vincx, M. 2011. Sensitivity assessment of fishing. ILVO-Symposium: an ocean of opportunity. 11th of February 2011. Oostende (Belgium).
- Depestele, J.; Courtens, W.; Degraer, S.; Derous, S.; Haelters, J.; Hostens, K.; Moulaert, I.; Polet, H.; Rabaut, M.; Stienen, E.; Vandendriessche, S.; Vincx, M. 2011. Sensitivity assessment: a tool for spatio-temporal management of fishing techniques. World Conference on Marine Biodiversity. 29th September 2011. Aberdeen (UK).

Grey literature

- Anon. 2011. Visserijbeperking in mariene beschermde gebieden. De Rederscentrale. Februari 2011. Pp.17-18. (In Dutch).
- Anon. Geïntegreerde evaluatie van de impact van warrelnet- en boomkorvisserij (de WAKO-cluster). ILVO-information leaflet. 2p.

9. ACKNOWLEDGEMENTS

The study was funded by Contract SD/ NS/08A of the Belgian Science Policy Office (BELSPO). Further financial support was provided by the Flemish Government and the European Commission (through the Data Collection Framework).

We thank the shipowners, crew, and on-board observers for their assistance in the ILVO discard sampling programme with special reference to all Belgian trammel netters. We wish to thank the crew of the RV Belgica and RV Zeeleeuw for their skilfull help during experiments. The provision of data was facilitated by the assistance of IMARES (Sieto Verver) and the Dutch fisheries service ("Ministerie of LNV") for the Dutch beam trawlers fleet, Marie-Joëlle Rochet for the French fleet and Josefine Egekvist for the Danish fleet data, the Belgian fisheries service ("Administratief Centrum Zeevisserij – Departement Zeevisserij") for the Belgian fleet landings, and the Section of Fisheries Biology of ILVO and Bart Verschueren for raw discard data.

The project partners are very grateful to the WAKO-workshop participants: Mardik Leopold, Eunice Pinn, Henning Reiss, Harvey Tyler-Walters, and Filip Volckaert for the valuable contributions to the development of the WAKO Sensitivity Assessment.

We are also indebted to Michel Kaiser for the earlier provision of the COST-IMPACT database, Leonie Robinson for helpful discussions and valuable suggestions on tow path mortality and pressure analysis, and to Niels Madssen for his comments on gill net selectivity. We also acknowledge the inputs of ILVO-colleagues (Ellen Renders, Kris and Norbert Van Craeynest, Kevin Vanhalst, Dirk Verhaeghe, etc.) for advice. The WAKO discard-paper was produced in cooperation with Sofie Vandemaele, Willy Vanhee, Els Torreele and Herwig Leirs. Finally we thank the participants of the end-users meetings during the WAKO-projects: colleague-scientists, fishermen, ngo's, and policy makers from the Belgian fisheries service ('Administratief Centrum Zeevisserij – Departement Zeevisserij') and the Federal Public Service 'Health, Food chain safety and environment', amongst others. The selection of species within gravel habitats was considered needed and we thank Jean-Sébastien Houziaux for his valuable contribution in this.

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ANNEX 1: COPY OF THE PUBLICATIONS

Peer-reviewed papers

- Depestele, J., Vandemaele, S., Vanhee, W., Polet, H., Torreele, E., Leirs, H., and Vincx, M. 2011. Quantifying causes of discard variability: an indispensable assistance to discard estimation and a paramount need for policy measures. – ICES Journal of Marine Science, 68: 1719–1725. (excerpt first page)

ICES Journal of Marine Science (2011), 68(8), 1719–1725. doi:10.1093/icesjms/fsr030

Quantifying causes of discard variability: an indispensable assistance to discard estimation and a paramount need for policy measures

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Depestele, J., Vandemaele, S., Vanhee, W., Polet, H., Torreele, E., Leirs, H., and Vincx, M. 2011. Quantifying causes of discard variability: an indispensable assistance to discard estimation and a paramount need for policy measures. – ICES Journal of Marine Science, 68: 1719–1725.

Received 28 September 2010; accepted 6 February 2011; advance access publication 29 March 2011.

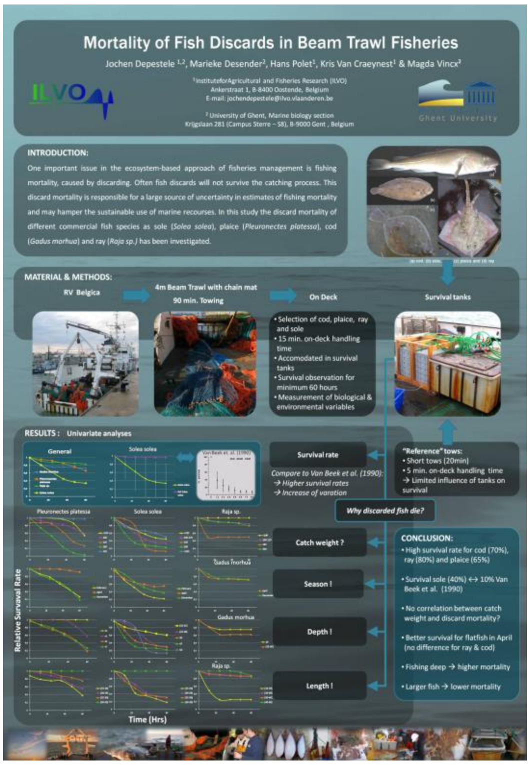
Fishery-dependent data underpin the scientific advice given to fishery managers. However, discard estimates are often imprecise as a result of limited sampling coverage. Estimating discard rates from length frequency distributions (LFDs) in commercial catches may complement information from observer trips. The accuracy of estimates depends greatly on careful investigation of the discard variability. Here, the impact of three essential factors was quantified for beam-trawl fisheries in the southern North Sea: (i) market prices, (ii) landings per trip (LPT) limitations, and (iii) selectivity of the commercial fishing gear. Observed discard rates for cod, plaice, sole, and whiting were compared with estimates based on length frequency data, taking account of the variability attributable to LPT limitations and market price. Observed discard estimates of cod and whiting differed significantly from LFD-derived estimates because of highgrading. The results indicate that LFD-derived discard estimates are only reliable if the crucial driving factors are quantified. LFDs can be collected from research vessels or by fishers in partnership with scientists. Based upon many of these LFDs and the discard-

Oral and poster presentations

- Second prize of special anniversary edition of the VLIZ young Scientists' Day: Depestele, J. (coordinator), W. Courtens, S. Degraer (presenter), J. Haelters, K. Hostens, H. Polet, M. Rabaut, E. Stienen, S. Vandendriessche, M. Vincx 2009 Are trammel net fisheries a cure for the disease called fisheries impact? or… "the WAKO story". University of Ghent/MUMM/INBO/ILVO: Oostende, Belgium.

(only first slide)

- Depestele, J.; Courtens, W.; Degraer, S.; Derous, S.; Haelters, J.; Hostens, K.; Moulaert, I.; Polet, H.; Rabaut, M.; Stienen, E.; Vandendriessche, S.; Vincx, M. 2009. An integrated impact assessment of trammel net and beam trawl fisheries - Project Wako [Poster]. University of Ghent/MUMM/INBO/ILVO: Oostende, Belgium. 1 poster pp.
- Depestele, J.; Desender, M.; Polet, H.; Van Craeynest, K.; Vincx, M. 2009. Mortality of fish discards in beam trawl fisheries [Poster]. University of Ghent/ILVO: Oostende, Belgium. 1 poster pp.



- Depestele, J.; Vandemaele, S.; Vanhee, W.; Polet, H.; Torreele, E.; Leirs, H. and Vincx, M. 2010. Quantifying causes of discard variability: An indispensable assistance to discard estimation and a paramount need for policy measures. Fishery Dependent Information Conference. 25th of August 2010. Galway (Ireland).
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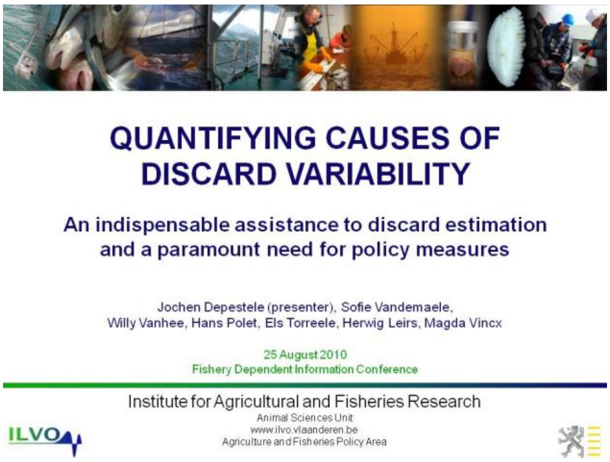
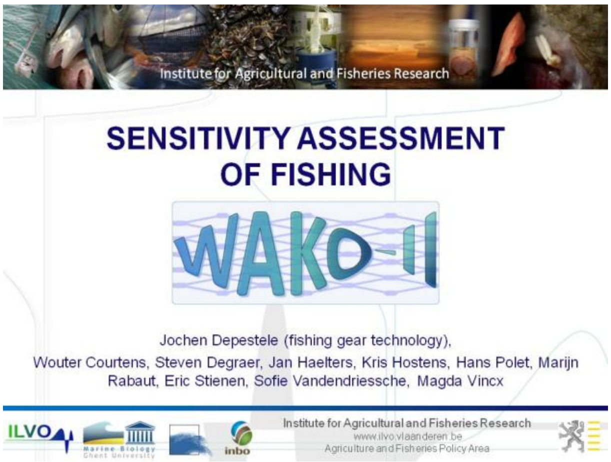
- Depestele, J.; Courtens, W.; Degraer, S.; Derous, S.; Haelters, J.; Hostens, K.; Moulaert, I.; Polet, H.; Rabaut, M.; Stienen, E.; Vandendriessche, S.; Vincx, M. 2011. Sensitivity assessment: a tool for spatio-temporal management of fishing techniques. World Conference on Marine Biodiversity. 29th September 2011. Aberdeen (UK).






3) Het aangeduide gebied in het Nederlandse deel van de **Doggerbank** heeft tot veel discussie geleid. De aanbevelingen van de workshop zijn dat er een gebied moet afgesloten worden voor bodemsleepnetvisserijen, maar dat *"low impact fishing"* wel toegelaten wordt. In dat gebied zullen wetenschappelijke experimenten plaatsvinden om na te gaan of de bodemgemeenschappen significant meer kwetsbare, te beschermen soorten bevat of niet als gevolg van de sluiting. Omdat het Duitse en Engelse deel van de doggerbank ook aangeduid is of wordt als te beschermen gebied, zal er in september 2011 een nieuwe workshop plaatsvinden waar specifiek de visserijmaatregelen verder zullen besproken worden. Hiervoor zal de Noordzee-RAC *(Regional Advisory Councils)* ook geconsulteerd worden.
4) Omdat bruinvis niet sterk gebonden is aan een bepaald gebied, is er op de workshop overeengekomen dat het geen zin heeft om een beperkt klein gebied te sluiten voor deze soort. Er zal een soortbeschermingsplan opgesteld worden voor het behoud van bruinvis op een grotere schaal, zoals de Noordzee.

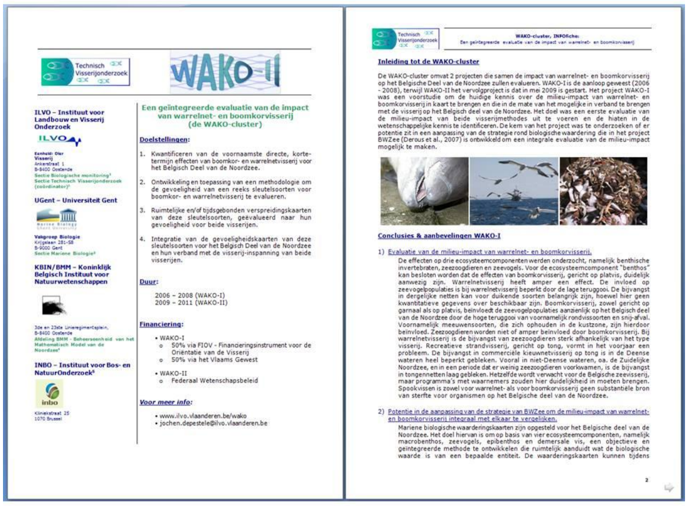
De voorstellen voor visserijmaatregelen zullen door de Nederlandse overheid aan ICES overgemaakt wor-

methodologie voor het aanduiden van de gebieden, gevoelig voor warrelnet- en boomkorverstoring, wordt ontwikkeld in het project "WAKO-II" van het ILVO in samenwerking met de Universiteit Gent, BMM en het INBO (www.ilvo.vlaanderen.be/wako). Eind mei 2011 zal het eindrapport hiervan verschijnen en wellicht zal in de daaropvolgende periode eveneens het proces in gang gezet worden om visserijmaatregelen in het Belgisch Deel van de Noordzee te nemen.

(excerpt from 'De Rederscentrale')

Grey literature

- Anon. 2011. Visserijbeperking in mariene beschermde gebieden. De Rederscentrale. Februari 2011. Pp.17-18. (In Dutch).
- Anon. Geïntegreerde evaluatie van de impact van warrelnet- en boomkorvisserij (de WAKO-cluster). ILVO-information leaflet. 2p



ANNEX 2: MINUTES OF THE FOLLOW-UP COMMITTEE MEETINGS

1st follow-up meeting (Tuesday 16th of June 2009)

- 14u: verwelkoming
- Voorstelling van de resultaten van het project WAKO-I, de voorstudie voor dit project
  - 14u10-14u25: onderzoek naar de impact van nettenvisserij op bruinvissen (Jan Hael-ters, BMM)
  - 14u25-14u40: onderzoek naar de impact van visserij op benthos (Marijn Ra-baut, UGent)
  - 14u40-14u50: onderzoek naar de impact van visserij op zeevogels (beknopte voorstelling van het onderzoek van Eric Stienen en Wouter Courtens (INBO) door Jochen Depestele)
  - 14u50-15u05: onderzoek naar de evaluatie van milieu-impact door vergelijking van visserij-inspanning en "Biologische Waarde" (Kris Hos-tens, ILVO)
  - 15u15-15u30: Voorstelling van het project WAKO-II (Jochen Depestele, ILVO)
- 15u30-16u00: Mogelijkheid tot vraagstelling & dis-cussie

2nd follow-up meeting (Tuesday 27th of April 2010)

- 10u: verwelkoming
- Voorstelling van de eerste resultaten van WAKO-II
  - 10u10-10u30: Hoe kan de bijvangst van bruinvissen in Belgische wateren, en de impact van deze bijvangst ingeschat worden? (Jan Haelters, BMM)
  - 10u30-10u50: Hoe groot is de teruggooi van vis door warrelnet- en boomkorvisserij in het Belgisch Deel van de Noordzee? (Jochen Depestele, ILVO)
  - 10u50-11u10: Wat zijn de gevolgen van de teruggooi voor het voedselaanbod van zeevogels? Worden zeevogels ook bijgevangen? (Wouter Courtens, INBO)
  - 11u10-11u30: Hoe worden de effecten van boomkor- en warrelnetvisserij op het benthisch leven onderzocht? Wat zijn de eerste resultaten? (Jochen Depestele, ILVO)
  - 11u30-11u50: Hoe kan het gevolg van de teruggooi op benthospopulatie worden ingeschat en worden vergeleken voor boomkor- en warrelnetvisserij? (Sofie Vandendriessche, ILVO)
  - 11u50-12u10: hoe kan de sterfte door boomkor- en warrelnetvisserij omgezet worden tot een gevoelig-heidsindex? Voorstelling van een methodologie. (Steven Degraer, KBIN/BMM)

Final follow-up meeting (Thursday 15th of December 2011)

- 10u00-10u10: Verwelkoming en inleiding (Jochen Depestele, ILVO)
- 10u10-10u30: Het concept '*Sensitivity assessment*' (Steven Degraer, KBIN/BMM)
- Kennisleemtes uit WAKO-I oplossen
    - 10u30-10u50: Welke hiaten hebben we ingevuld voor invertebraten en demersale vis? (Marijn Rabaut, UGent)
    - 10u50-11u00: Discussie-moment: welke informatie is nodig voor grindbedden en kunnen de eindgebruikers hierin tegemoet komen? (geleid door Jochen Depestele, ILVO)
    - 11u00-11u20: Welke hiaten hebben we ingevuld voor zeezoogdieren en -vogels? (Eric Stienen, INBO)
    - 11u20-11u30: Hoe kan de samenwerking met de visserijsector verbeteren in het kader van dataverzameling? (geleid door Jochen Depestele, ILVO)
- 11u30-11u50: De ontwikkeling van een protocol voor '*Sensitivity assessment*' (Jochen Depestele, ILVO)
- 11u50-12u15: Discussie-moment: Hoe kan de ontwikkelde tool gebruikt worden door de eindgebruikers? Welke mogelijkheden kunnen worden uitgewerkt? (geleid door Jochen Depestele, ILVO)

ANNEX 3: Length-weight relationships in the southern North Sea

Introduction

Discards are generally estimated in weights and numbers. For some fishing grounds and fishing gears, discard monitoring is too expensive or falls outside the interest of fisheries managers. Fishing campaigns with another purpose as to monitor discards (e.g. for investigating technical mitigation measures) might estimate the length distribution of fish for a particular gear in a particular area. Discard rates can be obtained from those data if the minimum landings size is a good parameter for those calculations. To investigate this, the discard rate by weight is compared for data coming from actual weight measurements of discards and landings with data coming from the conversion of length measurements. To establish this conversion, a length-weight relationship is needed. Here, length-weight conversions for sole, plaice, cod, and whiting are calculated and compared with their value in Fishbase

Material and methods

Data were collected for four fish species in the southern North Sea (ICES Divison IVc), i.e. sole (*Solea solea*), plaice (*Pleuronectes platessa*), cod (*Gadus morhua*) and whiting (*Merlangius merlangus*). All samples were collected in August-September of the years 2007-2008 during research surveys with the R.V. "Belgica" (50.9 LOA, 765 GRT, 1154 kW engine power). Samples were taken from a beam trawl, towed between 15 and 30 minutes. The total length of the fish was measured to the nearest five millimeters below and round weights were recorded in grams. Total length (L) and total ungutted wet weight (W) were all recorded at sea. In general, the relationship between the weight of fish and its length can be described by the relationship

$$W = a*L^b \quad (1)$$

Where W = observed wet weight (g)
L = observed total fish length (cm)
a = regression intercept
b = regression slope

The parameters a and b are estimated by log W = log a - b*log L. Therefore, the case where b < 3 represents fish that become less rotund as length increases, whereas when b > 3 fish become more rotund as length increases. These are both examples of allometric growth (i.e. phenomenon whereby parts of the same organism grow at different rates, which is in contrast with isometric growth). When b = 3, growth may be isometric (growth with unchanged body proportions and specific gravity), although it is possible for shape to change when b = 3, due to changes in a (Anderson and

Gutreuter, 1983; Cone, 1989 in Jones *et al.*, 1999). The length-weight pairs were first plotted in order to identify the obvious outliers, which were eliminated (as in Bernardes *et al.*, 2000 and Gerritsen *et al.*, 2007). This was the case for sole, plaice and whiting. The linear regression line was fitted to the 2D scatterplot of the log-transformed values of round weight and total length in the statistical software package "STATISTICA 9".

Results

The parameters a and b of the length-weight relationships are given in Table 1 for sole (*Solea solea*), plaice (*Pleuronectes platessa*), cod (*Gadus morhua*) and whiting (*Merlangius merlangus*), together with the regression coefficient (R^2), the number of individuals measured (n) and the size of the smallest (min) and largest (max) individual measured. The length-weight relationships are graphically represented in Figure 1.

Table 1: Parameters for length-weight conversion, based on North Sea data

Species	a	b	Pearson r	N	Min (cm)	Max (cm)
Sole	0.007568	3.0617	0.9862	2724	5.5	40.5
Plaice	0.009641	3.0319	0.9935	2897	8.5	57
Cod	0.010137	2.9912	0.9904	83	15.5	62
Whiting	0.009030	2.9508	0.9898	1021	5.5	39

Discussion

The number of individuals is high, except for cod (83 individuals) and the length range is broad, which provides good boundaries to establish the relationship between the total length and weight. The values for the exponent (b) remain within the expected range of 2.5 and 3.5, which is an acceptable value for fish (Froese, 1998). A comparison with parameters a and b from other sources (based on the online database "Fishbase" (Froese & Pauly, 2000)) is given in Figure 2 (a) and (b). The values for parameters a and b fall within the range, calculated from the data in the "Fishbase"-database, except for whiting. However, the parameters for whiting are closely related to one record in the "Fishbase"-database, namely the ones for the North Sea (a = 0.0098; b = 2.926). Therefore, we consider our values to be reasonably well for our calculations. Strangely enough the parameters (a) and (b) coincide very well with values from Coull *et al.* (1989), who reports an average annual a-value of 0.0093 and a b-value of 2.9456 for gutted weight/length relationships of whiting in the North Sea. Coull *et al.* (1989) also reports higher a-value during the autumn and winter seasons as in spring and summer. As our data are gathered in August-September of the years 2007 and 2008, it must be taken into account that calculated fish weights will actually be lower in spring and summer time.

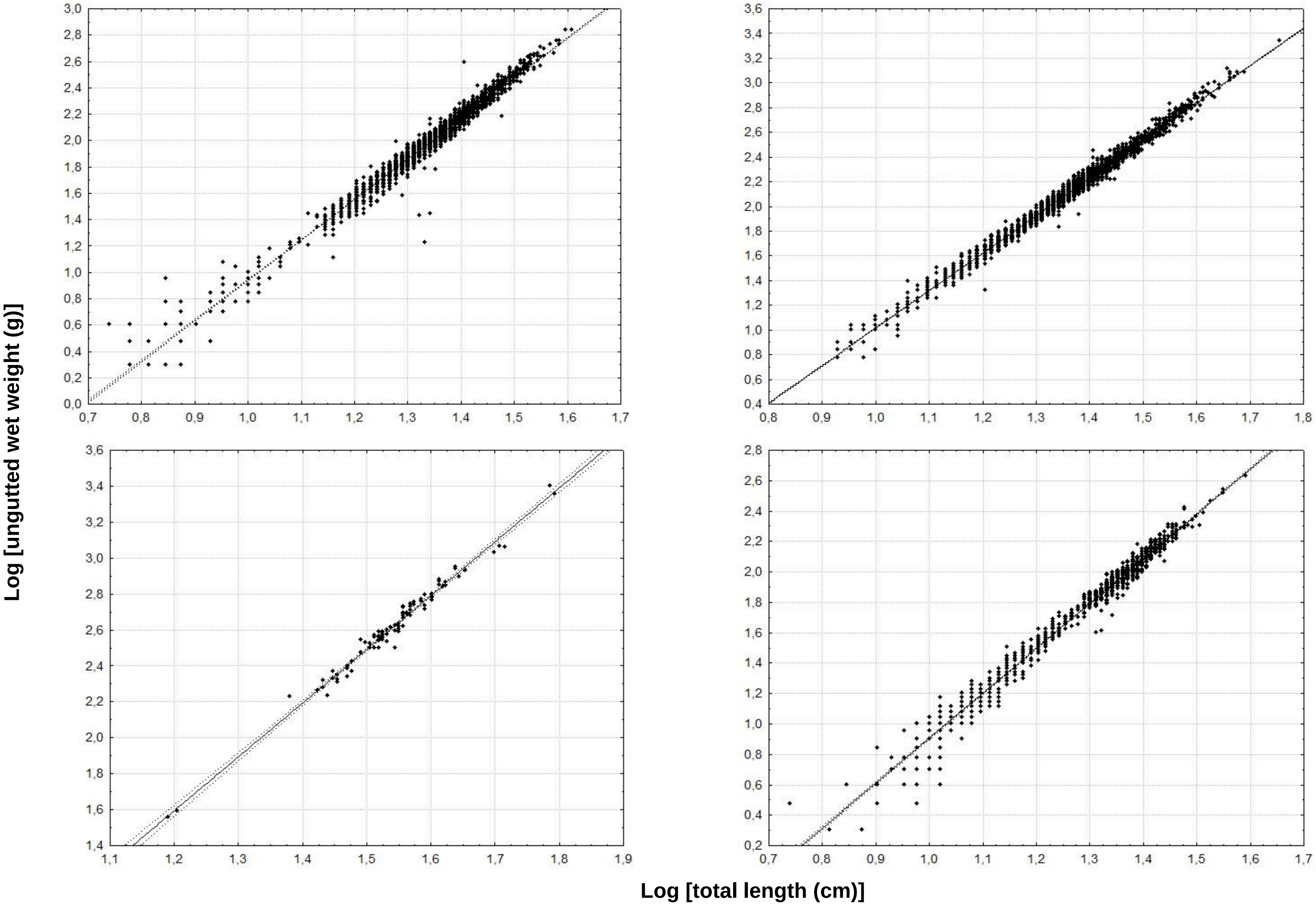


Figure 1. Relationship between log (total length) and log (wet weight) for sole, plaice, cod and whiting from top left to bottom right.

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ANNEX 4: Length-frequency distributions of fish species

Material and methods

The discards were sampled during fishing trials, carried out on board research vessel Belgica (50.9 LOA, 765GRT,1154kW engine power). The vessel is different from commercial beam trawlers, which are generally equipped with 2 outriggers, each dragging a beam trawl. The research vessel is trawling the fishing gear from the stern. The gear consists of two identical 4m beam trawls attached to one 8m beam. They have one trawl head in common. One of the 4m beam trawls is an experimental one, whereas the other is a traditional beam trawl, as it is used in commercial practice. The standard beam trawl is equipped with a chain mat and a codend with diamond meshes (80mm between the knots). The trials were carried out in 2006-2009 on commercial fishing grounds in the Southern North Sea. Towing speed was between 3 and 4 knots, tows were conducted during day or evening times. The tow duration was recorded. The positions, depths, towing speed and time are recorded, in order to enable the calculation of tow duration and swept area (km²) (Table 1). The catches of the codend were collected in baskets and the total catch weights were recorded. All commercial fish species were sorted out of the catch. The rest of the catch was separated into a benthos fraction (benthic invertebrates and non-commercial fish species) and a debris fraction (stones and other inert material). These were weighted separately and a sample was taken. All fish in the catch were measured to the centimeter below.

Results and discussion

The absolute and relative number of commercial fish species measured are given in Table 2. Each species where less than 100 individuals were caught, was included in the category "others". The beam trawl catches at Belgian Part of the North Sea mainly consists of sole (which is the target catch), plaice and dab. A considerable percentage of the catch is also taken by whiting, poor cod and flounder. Other species are rather sporadic, such as turbot, brill, gurnards, etc.

The length-frequency distribution has been produced for the most abundant commercial species. These curves (Figure 1) indicate the selectivity of a standard 4m beam trawl with chain mat. The Y-axis intersects the X-axis at the length of the Minimum Landings Sizes (MLS). The area of the curve below this axis indicate the magnitude of the discards, considering only MLS as cause for discarding. The selectivity of a flatfish beam is low for plaice, dab and whiting as well. The number of individuals by length class are given in Figure 1 for the BPNS and for comparative reasons in Figure 2 for the southern North Sea (Y-axis intersects X-axis at MLS). The latter are based on a larger dataset (see chapter 2.3). Figure 3 includes LFDs of sole-target trammel nets, sampled in the WAKO-II project (see chapter 2.3).

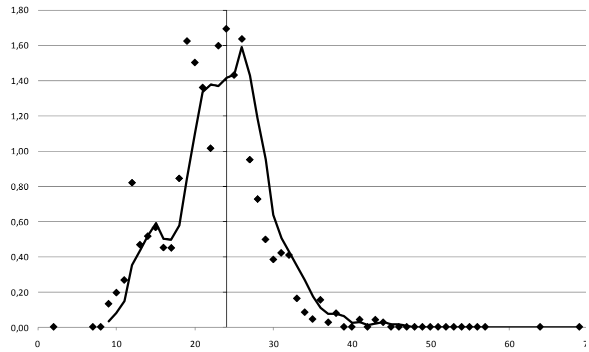
Table 1: Overview of hauls in the BPNS, with their average depth, hauling speed, duration, swept area and location.

Haul	Date	Depth (m)	Start	End	Haul (hrs)	Swept area (km²)	Start position		End position	
1	27/11/2006	30	13:52	14:57	1:05	32,10	51° 20,90' N	2°30,201' O	51°17,50' N	2° 26,3' O
2	27/11/2006	33	15:06	16:56	1:50	54,33	51° 16,91' N	2° 25,56' O	51° 11,83' N	2° 19,8' O
3	27/11/2006	35	17:17	19:10	1:53	55,81	51° 1,27' N	2° 19,62' O	51° 18,48' N	2° 26,64' O
4	27/11/2006	30	19:38	20:12	0:34	16,79	51° 19,61' N	2° 28,03' O	51° 18,82' N	2° 27,54' O
5	23/01/2006	27	12:30	13:20	0:50	24,69	51° 26' N	2° 53' O	51° 29' N	2° 57' O
6	23/01/2006	25	13:43	15:00	1:17	38,03	51° 29' N	2° 58' O	51° 26' N	2° 52' O
7	23/01/2006	26	15:20	17:00	1:40	49,39	51° 25' N	2° 51' O	51° 29' N	2° 59' O
8	23/01/2006	28	17:20	19:00	1:40	49,39	51° 29' N	3° 0' O	51° 25' N	2° 52' O
9	23/01/2006	28	19:20	21:28	2:08	63,22	51° 25' N	2° 52' O	51° 29' N	3° 0' O
10	25/01/2006	30	10:16	11:12	0:56	27,66	51° 20' N	2° 40' O	51° 16' N	2° 36' O
11	25/01/2006	28	16:20	17:29	1:09	34,08	51° 20' N	2° 28' O	51° 18' N	2° 26' O
12	25/01/2006	32	17:53	19:45	1:52	55,31	51° 15' N	2° 23' O	51° 20' N	2° 27' O
13	7/02/2007	34	16:25	17:15	0:50	24,69	51° 20,63' N	2° 30,07' O	51° 17,9' N	2° 27' O
14	7/02/2007	34	17:34	19:08	1:34	46,42	51° 17,06' N	2° 25,6' O	51° 20,79' N	2° 29,44' O
15	7/02/2007	34	19:26	21:30	2:04	61,24	51° 20,65' N	2° 29,95' O	51° 19,2' N	2° 27,58' O
16	5/11/2007	30	14:35	16:10	1:35	46,92	51° 20,91' N	2° 30,36' O	51° 16,56' N	2° 23,66' O
17	5/11/2007	32	16:36	18:48	2:12	65,19	51° 16,78' N	2° 23,18' O	51° 17,03' N	2° 23,88' O
18	5/11/2007	32	19:11	21:11	2:00	59,26	51° 18,21' N	2° 25,57' O	51° 18,05' N	2° 27,07' O
19	11/02/2008	23	19:00	20:30	1:30	44,45	51° 20,19' N	2° 35,08' O	51° 15,05' N	2° 29,83' O
20	11/02/2008	25	21:00	22:50	1:50	54,33	51° 14,1' N	2° 28,59' O	51° 18,42' N	2° 30,12' O
21	1/04/2008	29	13:15	14:49	1:34	40,62	51° 20,37' N	2° 40,98' O	51° 15,54' N	2° 35,59' O
22	1/04/2008	20	15:27	17:25	1:58	50,99	51° 14,20' N	2° 33,74' O	51° 7,26' N	2° 25,99' O
23	1/04/2008	18	18:15	20:33	2:18	59,63	51° 7,47' N	2° 25,4' O	51° 8,54' N	2° 27,27' O
24	25/11/2008	17	12:30	14:45	2:15	50,00	51° 16,22' N	2° 48,55' O	51° 14' N	2° 41,53' O
25	25/11/2008	15	15:00	16:45	1:45	45,37	51° 10,02' N	2° 38,44' O	51° 10,16' N	2° 37,7' O
26	25/11/2008	14	17:00	18:50	1:50	47,53	51° 9,27' N	2° 35,88' O	51° 9,5' N	2° 34,48' O
27	31/03/2009	7	12:10	13:30	1:20	35,56	51° 12,82' N	2° 49,71' O	51° 10,99' N	2° 42,53' O
28	31/03/2009	11	13:44	15:15	1:31	39,32	51° 10,43' N	2° 40,89' O	51° 7,69' N	2° 32,43' O
29	31/03/2009	13	18:00	19:30	1:30	44,45	51° 12,17' N	2° 48,31' O	51° 10,9' N	2° 42,75' O

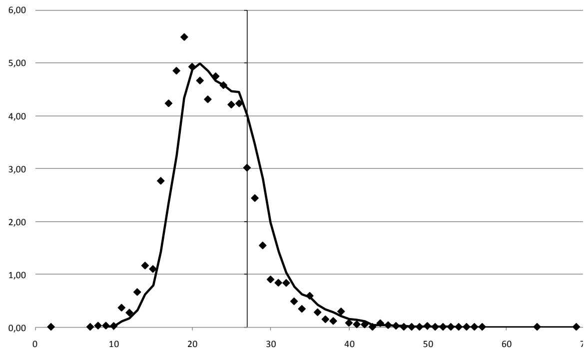
Table 2: The catch composition (commercial fish species) of a 4m beam trawl with chain mat at the Belgian Part of the North Sea during sea trips in 2006 – 2009. The category "others" constitutes Trigla sp. (10 hauls), Rajidae (12 hauls), *Scophthalmus rhombus* (10 hauls), *Psetta maximus* (13 hauls), *Scyliorhinus canicula* (8 hauls), *Mullus barbatus* (5 hauls), and *Microstomus kitt* (14 hauls).

Fish species	Absolute numbers	Relative numbers (%)	Number of hauls
Solea solea	904	10,0%	29
Pleuronectes platessa	2851	31,7%	28
Limanda limanda	2765	30,7%	29
Gadus morhua	370	4,1%	28
Merlangius merlangus	1375	15,3%	28
Platichthys flesus	193	2,1%	6
Trisopterus sp.	307	3,4%	23
Others	232	2,6%	n.a.

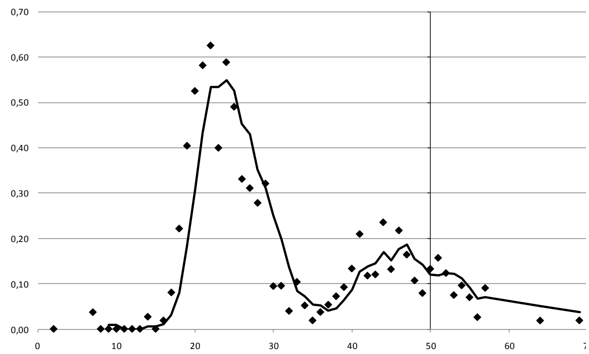
Number of individuals per hour fishing



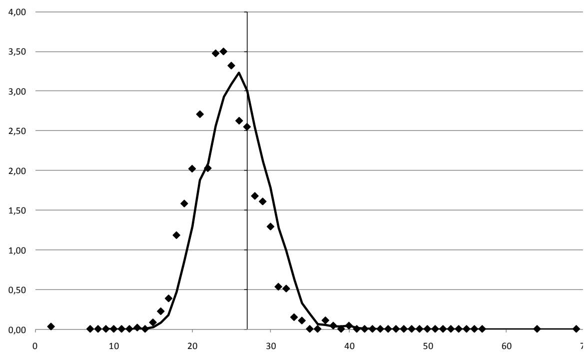
(a) Sole (*Solea solea*)



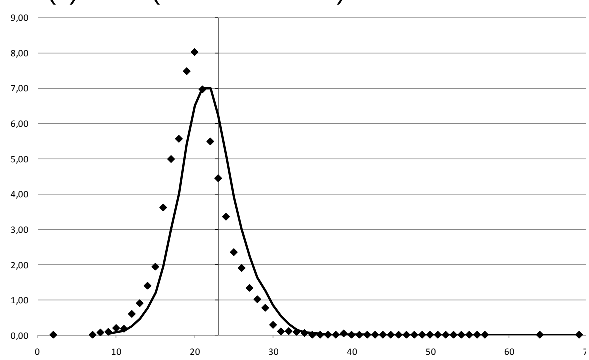
(b) Plaice (*Pleuronectes platessa*)



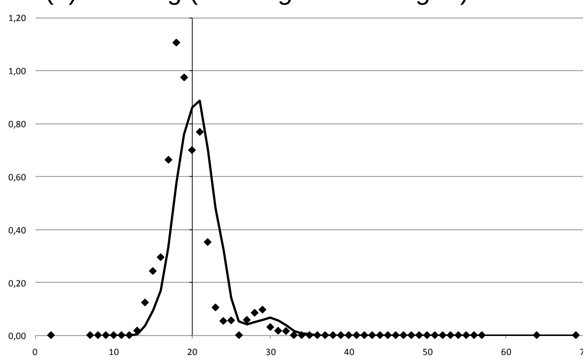
(c) Cod (*Gadus morhua*)



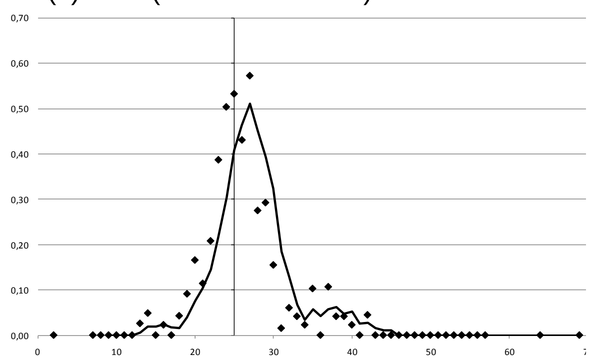
(d) Whiting (*Merlangius merlangus*)



(e) Dab (*Limanda limanda*)



(f) Bib (*Trisopterus sp.*)

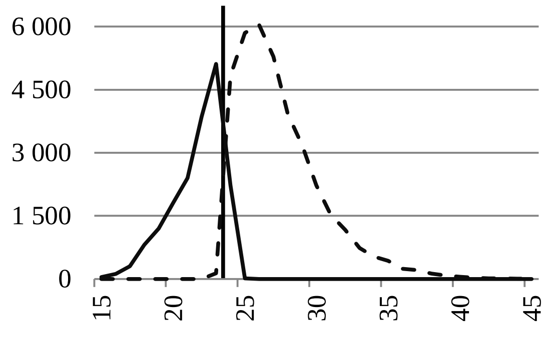


(g) Flounder (*Platichthys flesus*)

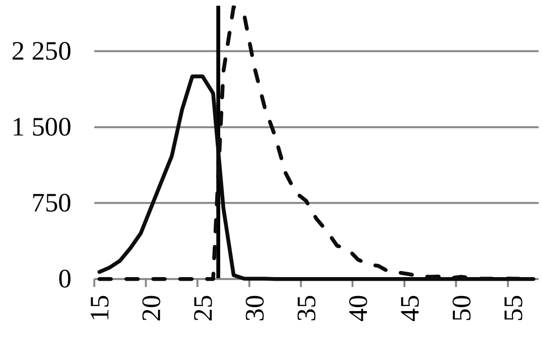
X-axis: length (cm)

Figure 1. Smoothed Length-Frequency Distributions (LFD) of 7 commercial fish species are given for the Belgian Part of the North Sea, based on the number of individuals caught per hour fishing in 29 hauls between 2006 and 2009. The Y-axis intersects the X-axis at the MLS, except for bib.

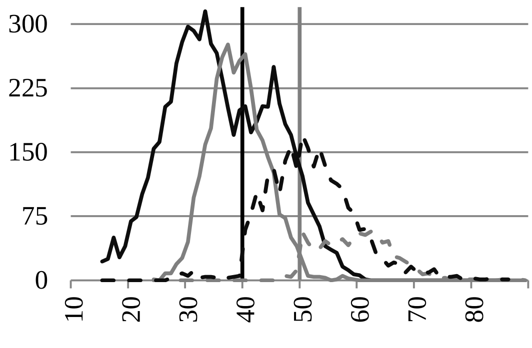
Average number of individuals per hour fishing



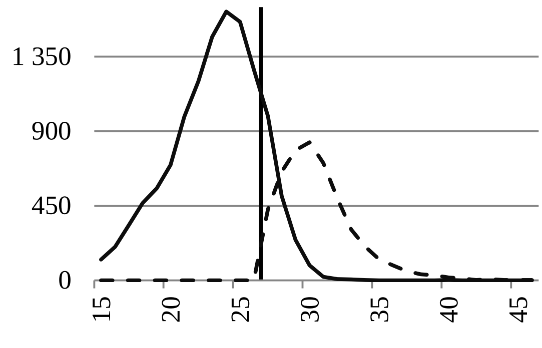
(a) sole (n=54420)



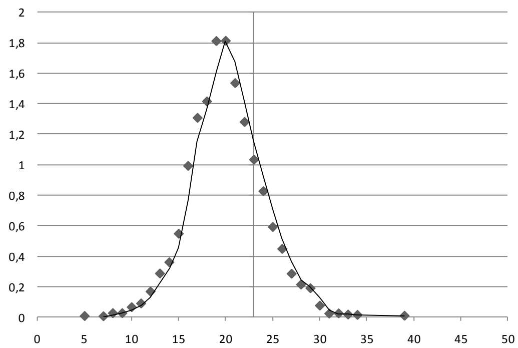
(b) plaice (n=29291)



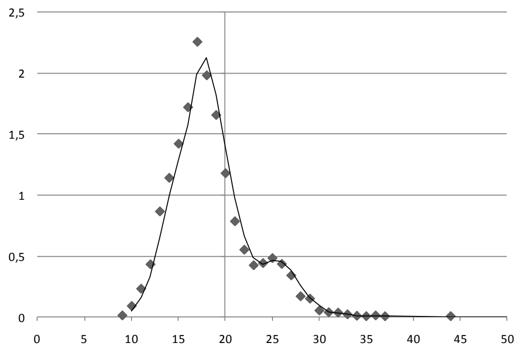
(c) cod (n=13695)



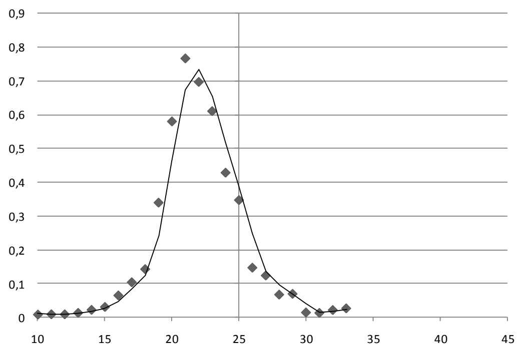
(d) whiting (n=17156)



(e) Dab (n=3871)



(f) Bib (n=5143)



(g) Lemon sole (n=979)

X-axis: length (cm)

Figure 2 Smoothed length-frequency distributions of sole, plaice, cod, and whiting for the discarded and the landed fraction of the Belgian commercial beam-trawl fishery in the southern North Sea in 2006 – 2008 (modified from Depestele *et al.*, 2011) and for dab, bib and lemon sole (RV-based data).

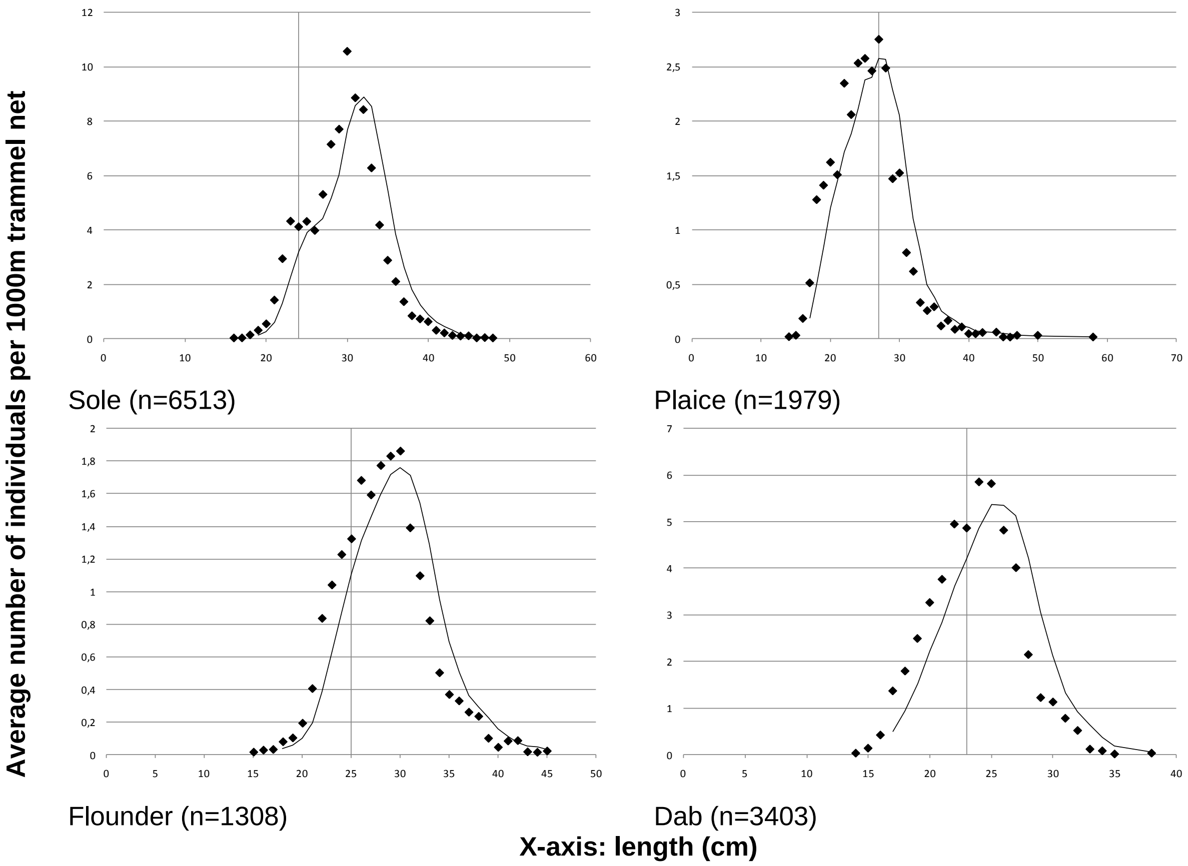
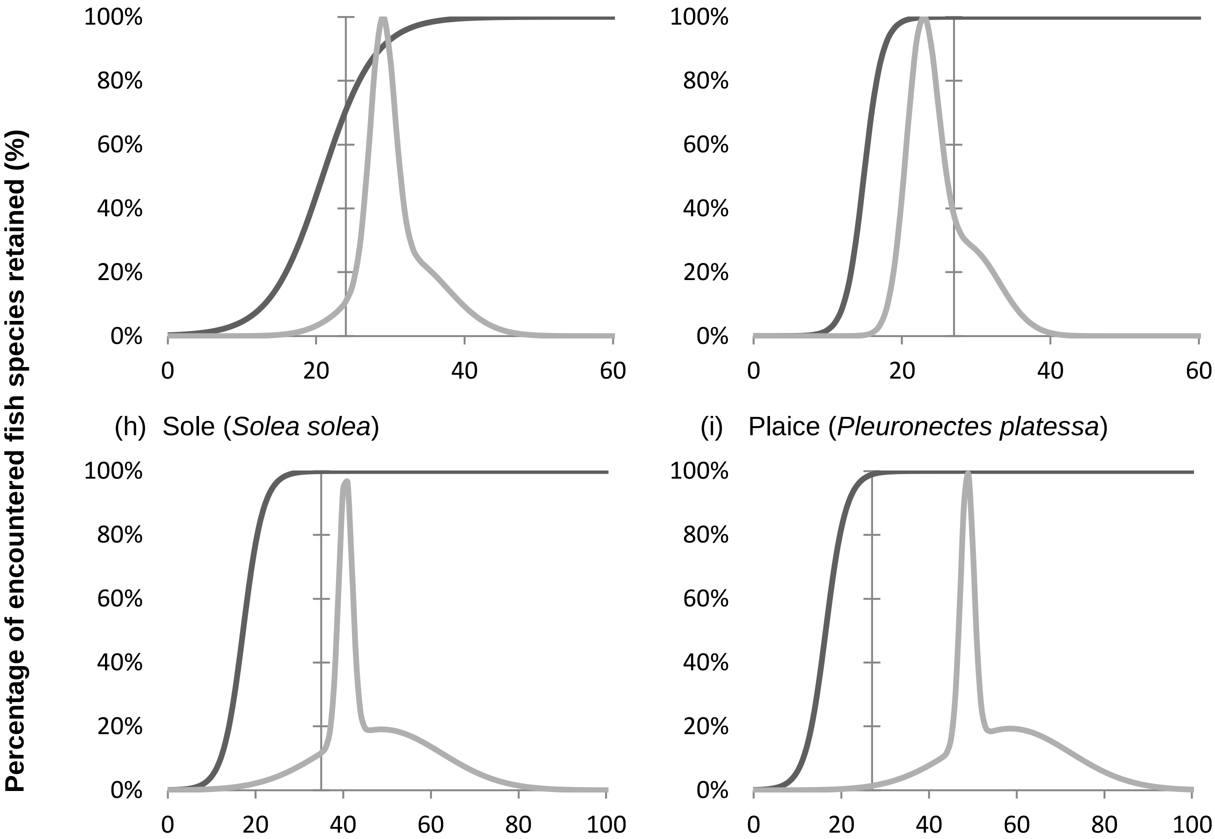


Figure 3 Smoothed length-frequency distributions of sole, plaice, flounder, and dab for the Belgian commercial trammel net fishery in the Belgian Part of the North Sea in 2009-2010.

ANNEX 5: Selectivity ogives for sole, plaice, cod, and whiting

The size-selectivity curve of trammel nets is steeper for sole than for beam trawls (Figure 1; Holst *et al.*, 2002[1]), which explains its lower discard rate. When a mesh size of 90mm is used, there is a high potential for discards of plaice, dab and flounder (confirmed by the high discard rates in the WAKO-trials), even though it being common amongst gill netters to use a higher mesh size than the minimum allowed (Madsen, 2007[2]).
The selectivity curves illustrate the potential of gill nets to be highly size selective, and therefore having a high potential within the “spawn-at-least-once” and “mega-spawners” principle. Beam trawling is a highly mixed fisheries with relative limited size selectivity, and is suggested to better serve the balanced fishing approach.



(h) Sole (*Solea solea*)
(i) Plaice (*Pleuronectes platessa*)
(j) Cod (*Gadus morhua*)
(k) Whiting (*Merlangius merlangus*)

X-axis: length (cm)

Figure 1. Selectivity ogives for sole, plaice, cod and whiting for two flatfish-targeting fishing gears: beam trawls with 80mm codend (dark grey) and gill nets with 90mm mesh size (light grey). The Y-axis intersects the X-axis at MLS: 24cm (sole), 27cm (plaice and whiting), 35cm (European MLS for cod).

[1] Holst R, Wileman D, Madsen N (2002) The effect of twine thickness on the size selectivity and fishing power of Baltic cod gill nets. Fish Res 56:303–312.
[2] Madsen,N. 2007. Selectivity of fishing gears used in the Baltic Sea cod fishery. Reviews in Fish Biology and Fisheries 17 (4): 517-544.

ANNEX 6: Selection of species for tests on gravel bed communities of the BPNS

Jean-Sébastien Houziaux

The data to select epibenthic species accordingly with the procedure set up by Tyler-Walters *et al* (2009), namely the 10 most abundant and 5 species contributing mostly to the typical species assemblage, can be found in Houziaux *et al* (2008) and De Rynck (2011). Both analyses were partial, the first being carried out on a sub-set of the trawl samples collected in June 2005 in gravel, sandy gravel and sand habitats around the Westhinder sand bank, the second being restricted to a smaller portion of the gravel ground itself. The considered gravel ground is indicated in Figure 1. "Gravel" is here considered as sediment dominated by grains larger than 2 mm (gravel, pebbles, cobbles).

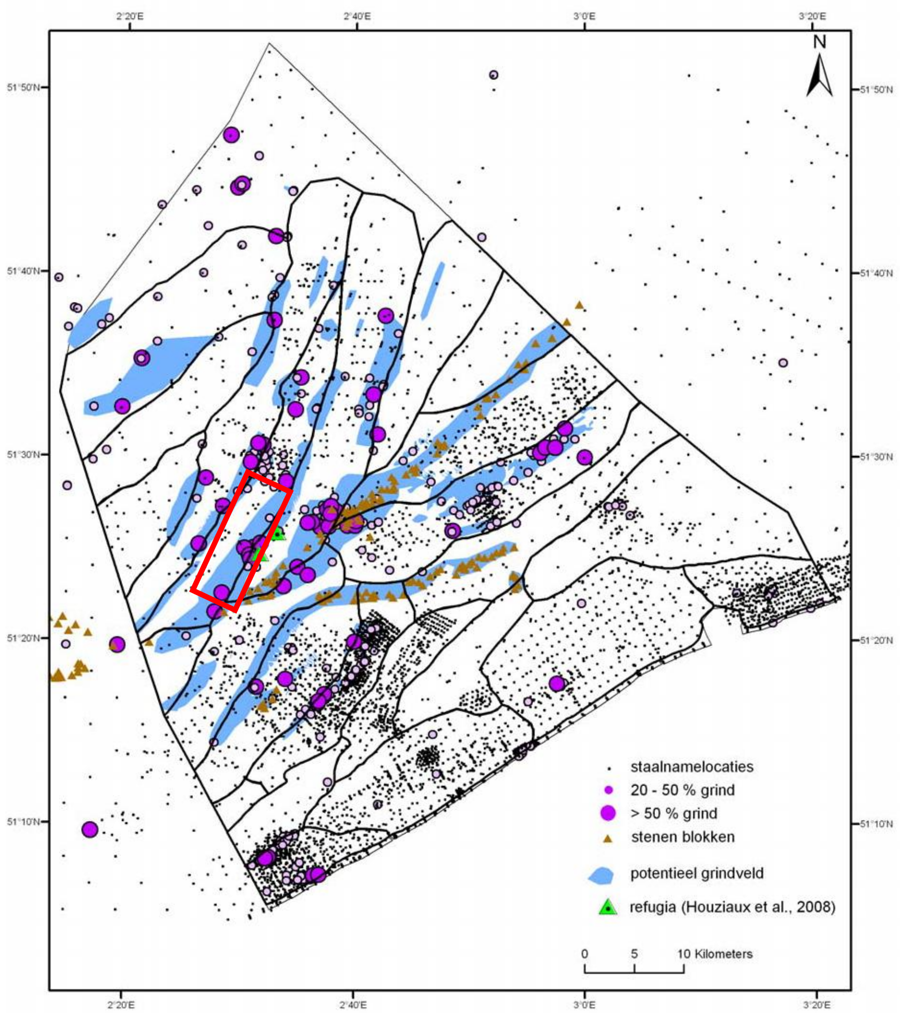


Figure 1: Map of gravel beds (blue), based on (1) sediment database; (2) cobble found by divers; (3) acoustic seabed classification; (4) bathymetric position-index; (5) bathymetric digital terrain model; and (6) Quaternary layer of less than 2.5 m (modified from Degraer *et al.*, 2009). The red rectangle points at the area between the Westhinder and Oosthinder sand banks where samples were collected by Houziaux et al (2008).

A specific difficulty for assessment in this habitat is the occurrence of sessile colonial species for which specimen counts are not feasible. Ideally, enumerable (mostly mobile) and colonial (all sessile) species should be considered apart. To avoid this difficulty and provide a set of mixed "representative" species, we used the frequency of occurrence of all identified species in samples collected in the gravels of the Westhinder area (namely the proportion of samples where the species was present). The frequency of occurrence of species in analyzed samples was provided by Houziaux et al (2008). The 20 most represented species are listed in table I, which concerns species from all habitats (main gravel bed, sandy gravels and sandy dunes) of the surveyed area, after removal of juvenile Scophtalmidae (flat fishes). The Paguridae group is mostly represented by *Pagurus bernhardus* and is found in almost all samples. The Liocarcinidae group is represented by a mixture of species in which *Liocarcinus holsatus* is most abundant in more sandy samples. *Necora puber*, belonging to the same family, was considered apart and is a species typical for gravels, although it displayed a lower density. Other Liocarcinid crabs, the lesser weaver *Echiichtys vipera* and the brown shrimp *Crangon crango*n are highly mobile abundant species found throughout the sampling area in sand as well as gravel samples. They can be removed to include the 11th and 12th species, *Psammechinus miliaris* and *Electra pilosa*, which are more typical of the gravel bed and very abundant too.

To refine the species selection, data from the long-term analysis of Houziaux (2008) on 29 abundant species can be used (see figure 4-45, p. 92, figure 4-46, pp. 94-95 and annex 9, p. 241 in Houziaux et al, 2008). The cluster analysis carried out on the Bray-Curtiss similarity matrix (Presence / Absence data) produced two major clusters composed of recent samples, cluster "d", poor and characteristic of sandy areas, and cluster "e", more characteristic of species-rich gravel samples.

O. fragilis was highlighted as extremely abundant at a few stations, all of which are included in the considered samples. As not all stations were analyzed yet, its frequency of occurrence will decrease as more samples are taken into account. Therefore, we eliminate it from our list, although it is consider as characteristic in French waters (Davoult et al, 1988; Foveau, 2008). The 8 other taxa can be considered as most representative of the gravels grounds. As shown in table I, *O. ophiura* and *O.albida* are both very represented, the latter being more typical for the gravel samples, while the first will be more abundant in sand and sandy gravel samples (Houziaux, pers. obs.). Even though *L. Holsatus* is most abundant, other liocarcinid species are better represented in gravel samples. This group as well as Paguridae can be considered as 'complex'. Compared to Table I, *Pomatoceros triqueter* is missing but should be included in our list since intact or damaged tubes of this species were found on all collected stones (only alive specimens were counted in the samples). With this addition, we built a list of the ten species most abundantly collected in the gravels, of which 5 contribute mostly to within-group similarity.

Table I. List of the 20 species with highest frequencies of occurrence in beam-trawl samples collected in 2005 in the Westhinder gravel bed. Samples were gathered on gravel, sandy gravel and sand habitats. NC: not counted.

Taxon	Total specimen count	Frequency of occurrence
Asterias rubens	1537	1.00
Paguridae (P. berrnhardus)	334	0.90
Liocarcinidae (L. holsatus)	200	0.84
Ophiura albida	685	0.77
Pomatoceros triqueter		0.77
Tubularia indivisa	11	0.77
Crangon crangon	174	0.71
Echiichthys vipera	161	0.71
Ophiura ophiura	288	0.68
Tubularia larynx	NC	0.65
Psammechinus miliaris	708	0.61
Electra pilosa	NC	0.58
Gobiinae	64	0.52
Lanice conchilega	NC	0.52
Actiniaria	109	0.48
Amphipoda	32	0.45
Callionymus sp	21	0.45
Ophiothrix fragilis	106	0.42
Macropodia sp	56	0.32
Alcyonium digitatum	51	0.29

Table II. list of species contributing most to cluster « e » in long-term analysis of Houziaux *et al* (2008; see annex 9, p. 242). See text for details.

Species	Av.Abund	Contrib%	Cum.%
Asterias rubens	1	13.56	13.56
Ophiura sp (O. albida + O. ophiura)	1	13.56	27.12
Tubularia indivisa	1	13.56	40.68
Tubularia larynx	0.95	11.85	52.53
Paguridae (*P. bernhardus*)	0.89	10.48	63.01
Electra pilosa	0.84	9.06	72.07
Liocarcinidae (*L. holsatus*)	0.79	8.8	80.87
Psammechinus miliaris	0.79	7.82	88.68
Ophiothrix fragilis	0.42	2	90.68
Pomatoceros triqueter			

Because the analyses of Houziaux et al (2008) were not complete, the re-analysis carried out by De Rynck (2011) can be used to validate the aforementioned species lists.

Results are slightly different since the considered area was more restricted and the study focused more on gravel samples (figure 2). Furthermore, De Rynck (2011) showed that samples sheltered from beam trawling (see figure 1: "refuges") display significantly different overall density and species richness. Some of the well-represented species will thus probably display decreased relative importance as the amount of samples considered increase.

The high frequency of occurrence of *Pomatoceros triqueter* is confirmed. In these samples, Actiniaria (mostly represented by *Metridium senile*), the decapod crustaceans *Macropodia* sp, *Pisidia longicornis* and the soft coral *A. digitatum* are within the ten most represented species, while *T. larynx* seems relatively less abundant in this zone. Other species considered as characteristic (see table 4, p. 23) and qualitatively highlighted by Houziaux et al (2008) were the nudibranch *Dendronotus frondosus*, the decapod *Necora puber* and the ascidian *Ciona intestinalis*. *D. frondosus* feeds on hydrozoa of the genus *Tubularia* spp. Its presence can thus be indicative of the latter species. The two species displaying very different life history traits, their inclusion in such sensitivity analysis could lead to interesting observations in the future.

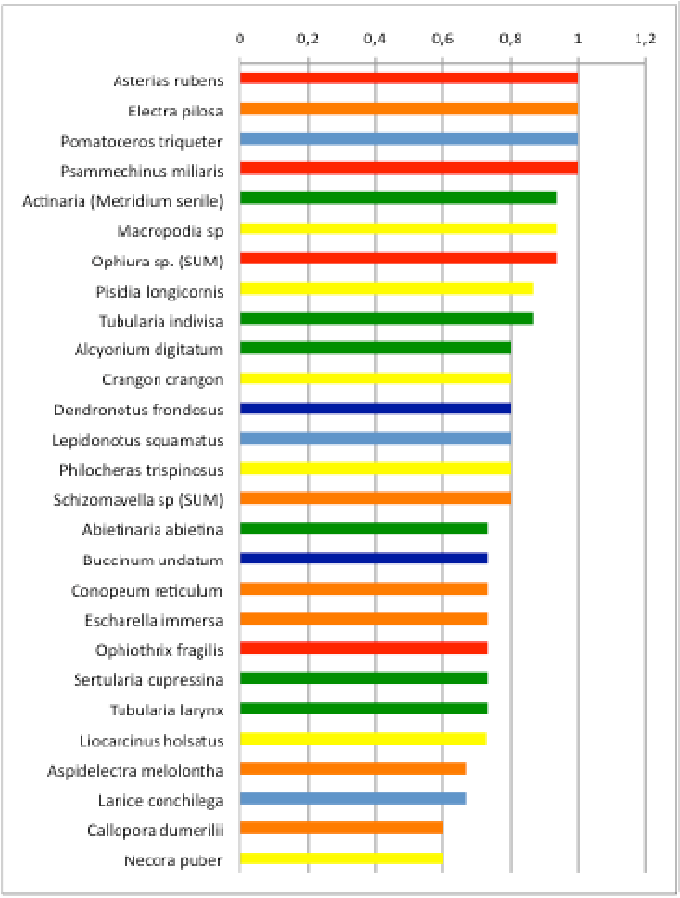


Figure 2. Frequencies of occurrence in gravel samples analyzed by De Rynck (2011).

Comparing Houziaux et al (2008) and De Rynck (2011) data, some difficulty appears in the selection process since some species abundant over the entire area but best represented in sandy samples are displayed by Houziaux et al (2008), while these are less represented and replaced by species more typical of gravels in De Rynck (2011). The Liocarcinidae are mostly composed of *L. holsatus*, which is clearly best represented in sand, while other species are much less abundant and thus contribute less to similarity in the species assemblage. *N. puber*, present in low numbers, can be considered as a typical species indeed, as qualitatively highlighted by Houziaux et al (2008) from video tracks. The same holds for *C. intestinalis*, generally found in association with dense mixed shoots of *Tubularia* spp, *E. pilosa* and *L. conchilega* tubes on a crust of tubes of *P. triqueter*. It is to be noted that amphipods, mainly *Jassa hermani*, builds its tubes and is abundantly found as well in these shoots, although the species was thus far not considered due to its small size not compatible with the sampling gears used. The spider crabs of the Genus *Macropodia* are also well represented and are in balance to be included, but were considered here as a complex; individual species probably contribute less to the assemblage similarity. *M. rostrata* is probably the best represented species.

Finally, the dead-man fingers *A. digitatum* was found in both studies to be typical for this seafloor type. De Rynck (2011) confirmed the earlier suggestion that in trawled areas, the species is present but displays much smaller colonies compared to the sheltered "refuge" gravel patches. Presence / absence -based assessment should include this species, since trawling doesn't prevent the species to occur in this habitat. It does however affect its capacity to grow large colonies as historically observed.

Conclusion

Some of the most abundant and typical species of present-day (altered) gravel grounds of the Westhinder could be identified. It is difficult to make a clear-cut selection of 10 species, partly because the area is colonized by opportunistic and highly mobile species more typical of sandy areas, which were finally removed, partly because the species content is an admixture of sessile and mobile species, most of which are present in relatively low densities, and partly because at this stage, only a 'semi-quantitative' selection can be done based on available data and expert judgement. Species identified as most typical strictly for gravels are included to form the final species list (table III), composed of 7 sessile and 5 mobile taxa. The criteria retained are 1. Frequency of occurrence in the gravel samples; 2. Relative contribution to similarity matrix of gravel samples; 3. Qualitative adjustments based on expert judgement.

Table III. Final list of 12 species selected for the preliminary assessment of sensitivity to beam trawl and trammel net fisheries following the proposed procedure. (*) Sessile species; (C) Colonial species.

Taxon	Basis for selection
(Asterias rubens)	Houziaux + De Rynck
(Ophiura albida)	Houziaux + De Rynck
Pomatoceros triqueter (*)	Houziaux + De Rynck
Tubularia indivisa (C)*	Houziaux + De Rynck
Tubularia larynx (C)*	Houziaux + De Rynck
Psammechinus miliaris	Houziaux + De Rynck
Electra pilosa (C)*	Houziaux + De Rynck
Necora puber	De Rynck
Pisidia longicornis	De Rynck
(Actiniaria) Metridium senile (*)	De Rynck
Ciona intestinalis (*)	De Rynck
Alcyonidium digitatum (C)*	De Rynck

References

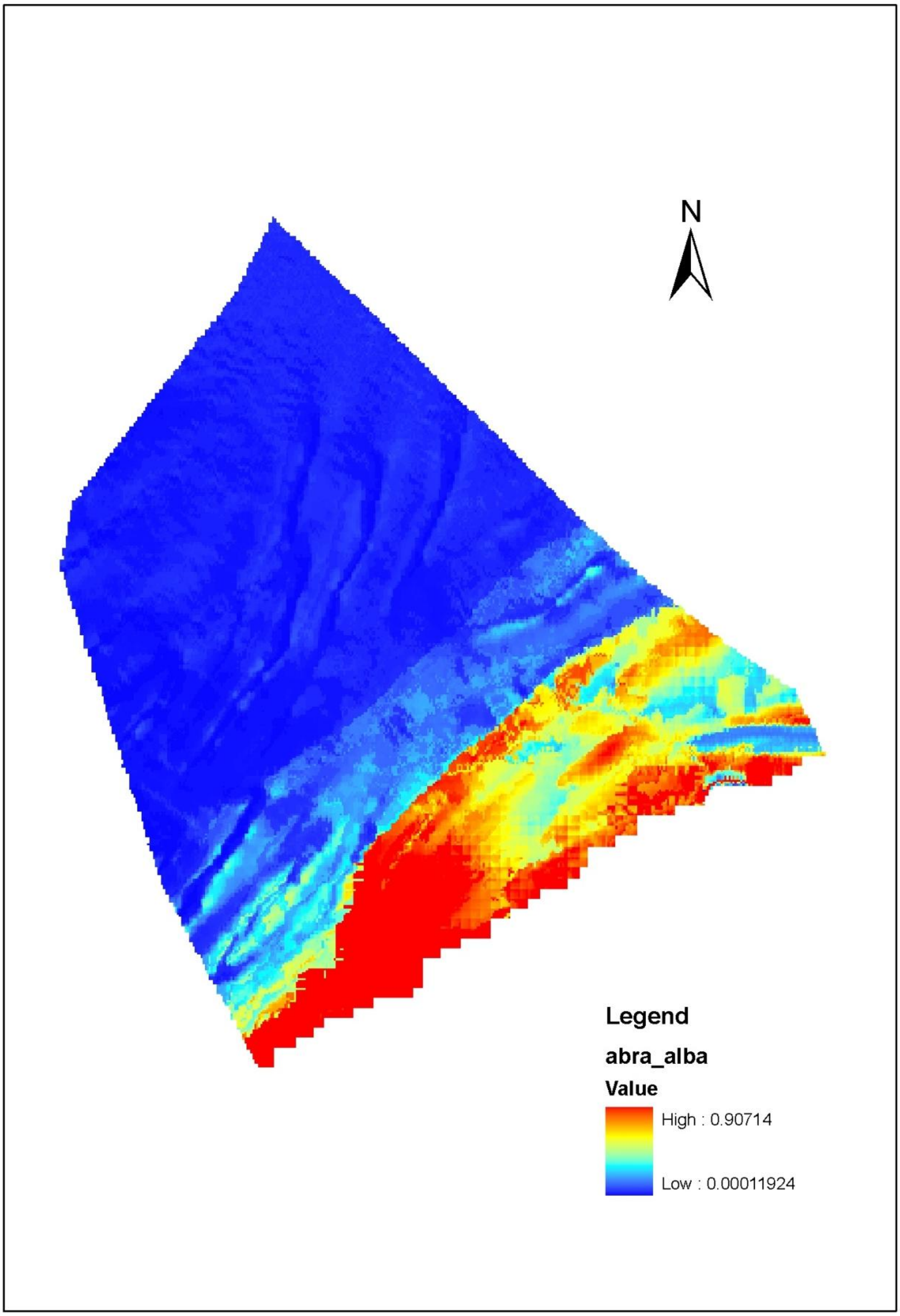
Degraer, S., Braeckman, U., Haelters, J., Hostens, K., Jacques, T., Kerckhof, F., Merckx, B., Rabaut, M., Stienen, E., Van Hoey, G., Van Lancker, V., Vincx, M., 2009. Study to draw up a list of potential areas under the Habitats Directive in the Belgian Part of the North Sea. Final Report to the Federal Public Service Health, Food Chain Safety and Environment. Directorate-General Environment, Brussels (Belgium), p. 93 (In Dutch).

Houziaux, J.-S.; Kerckhof, F.; Degrendele, K.; Roche, M.F.; Norro, A. (2008). The Hinder banks: yet an important area for the Belgian marine biodiversity?. Belgian Science Policy: Brussel. 248 pp.

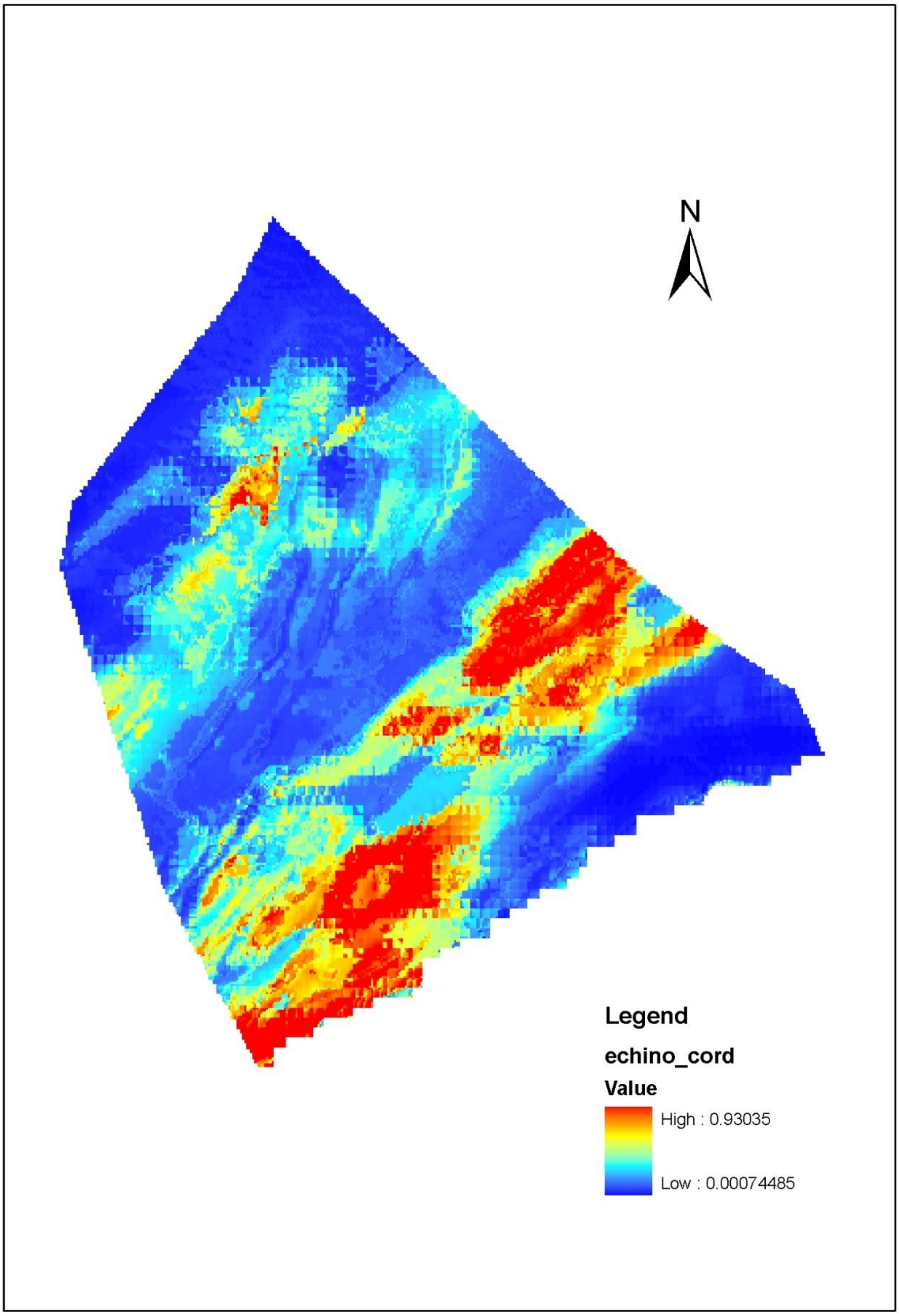
De Rynck, K. (2011). Characterization of the benthic biodiversity of gravel fields and evaluation of changes induced by trawl fisheries (The Hinder Banks). MSc Thesis Marine and lacustrine sciences, academic year 2010-2011, University of Gent. 51 p.

ANNEX 7: High resolution maps of modeled spatial distribution based on presence of the selected macro- and epibenthic species.

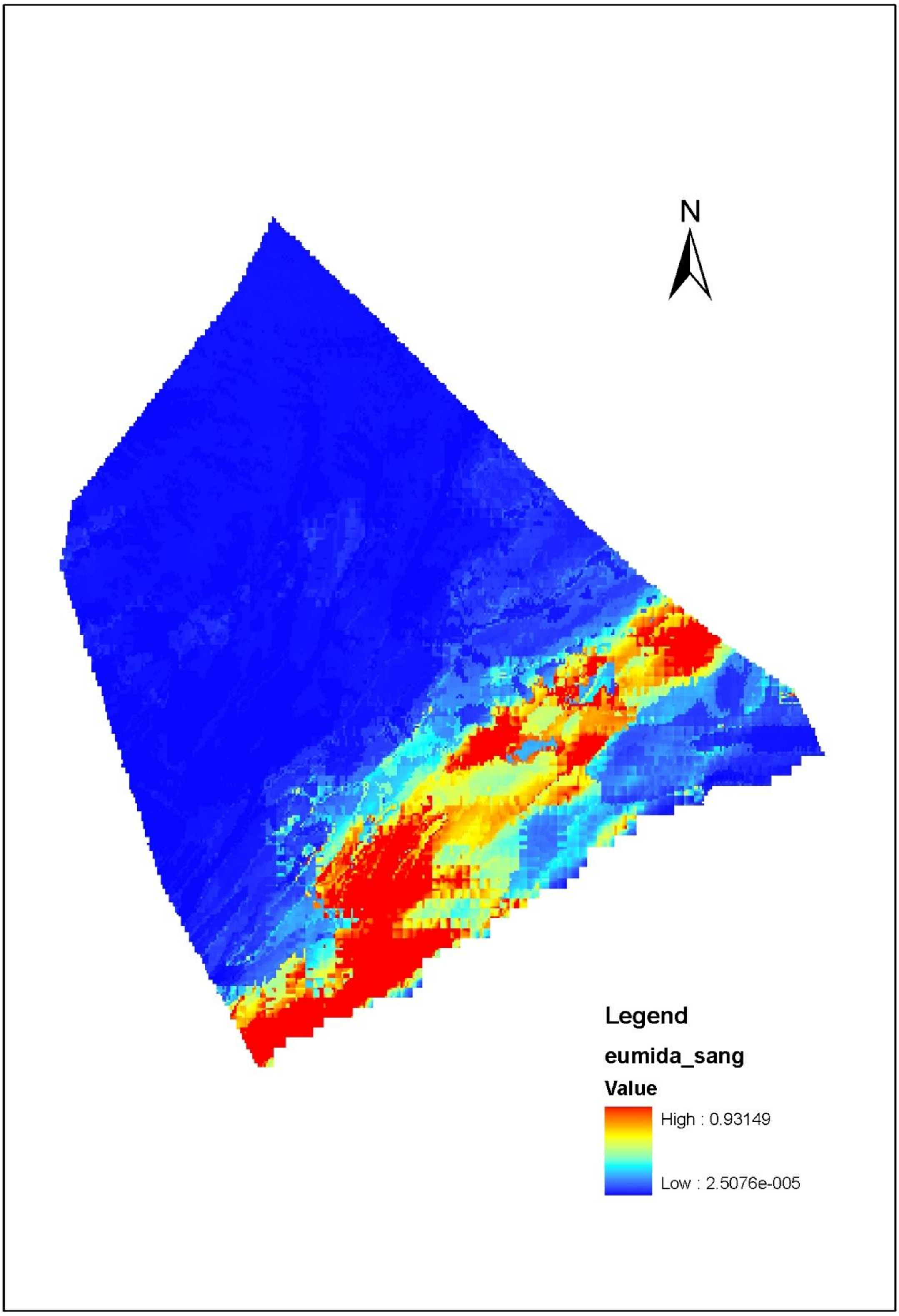
Abra alba



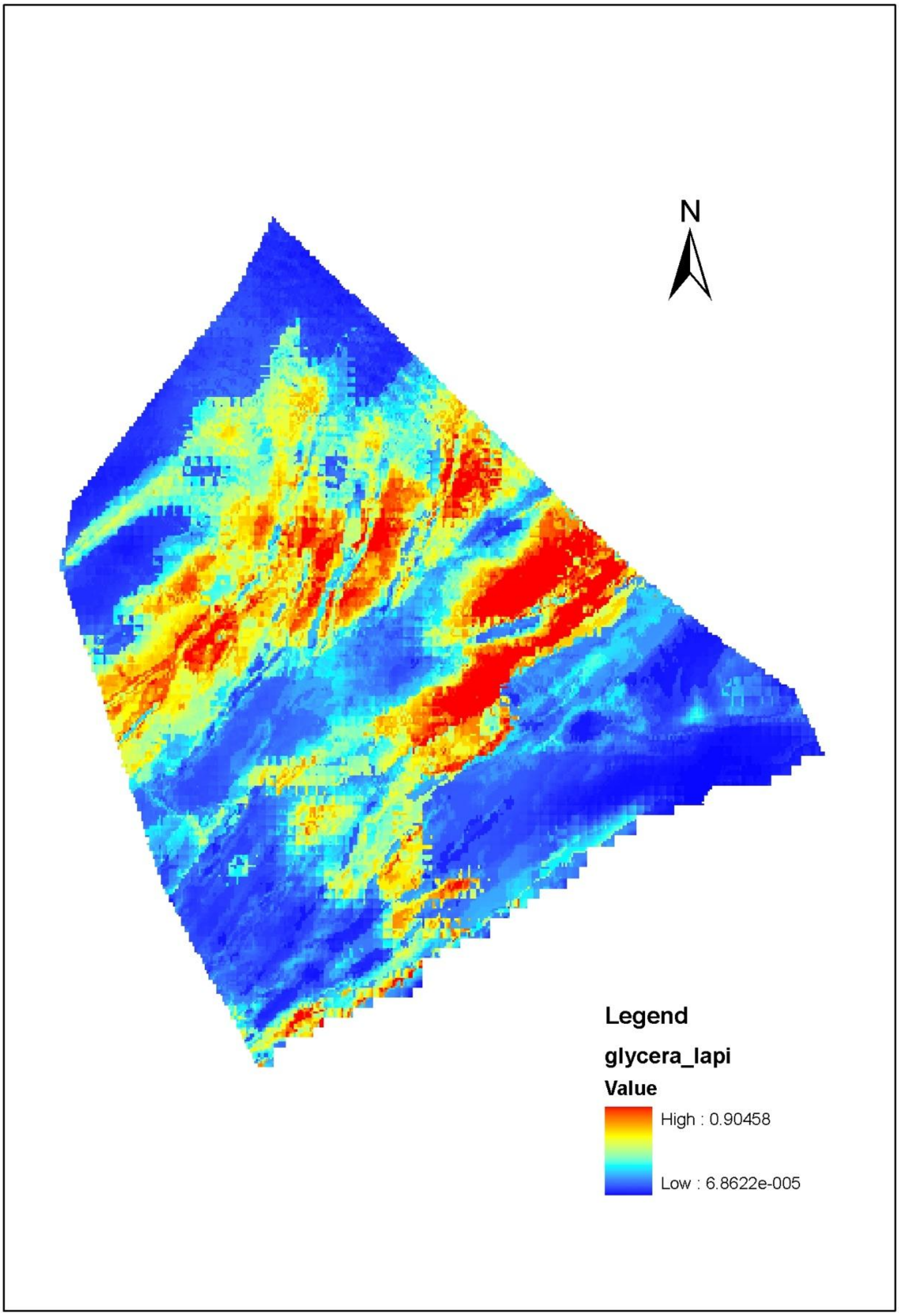
Echinocardium cordatum



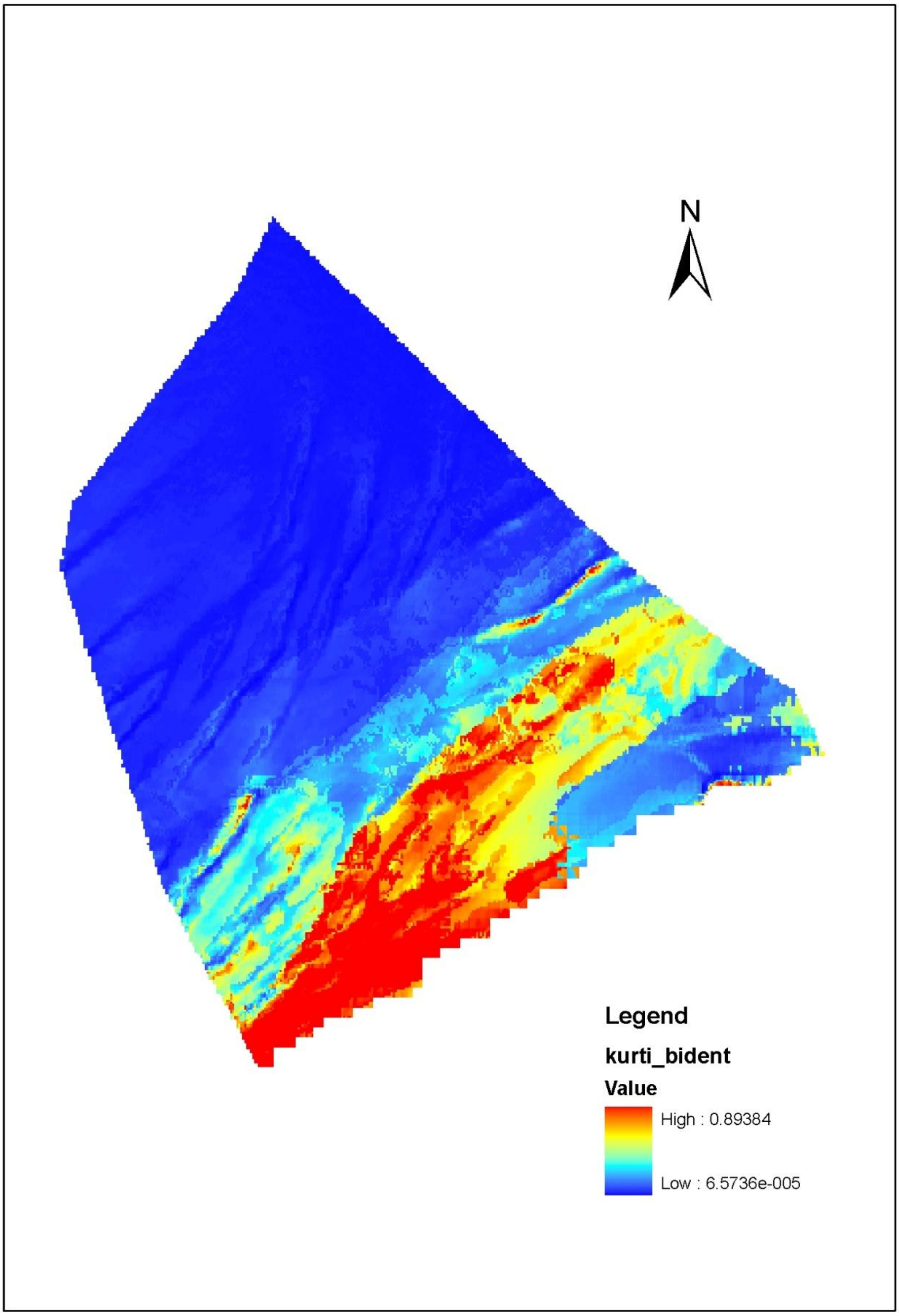
Eumida sanguinea



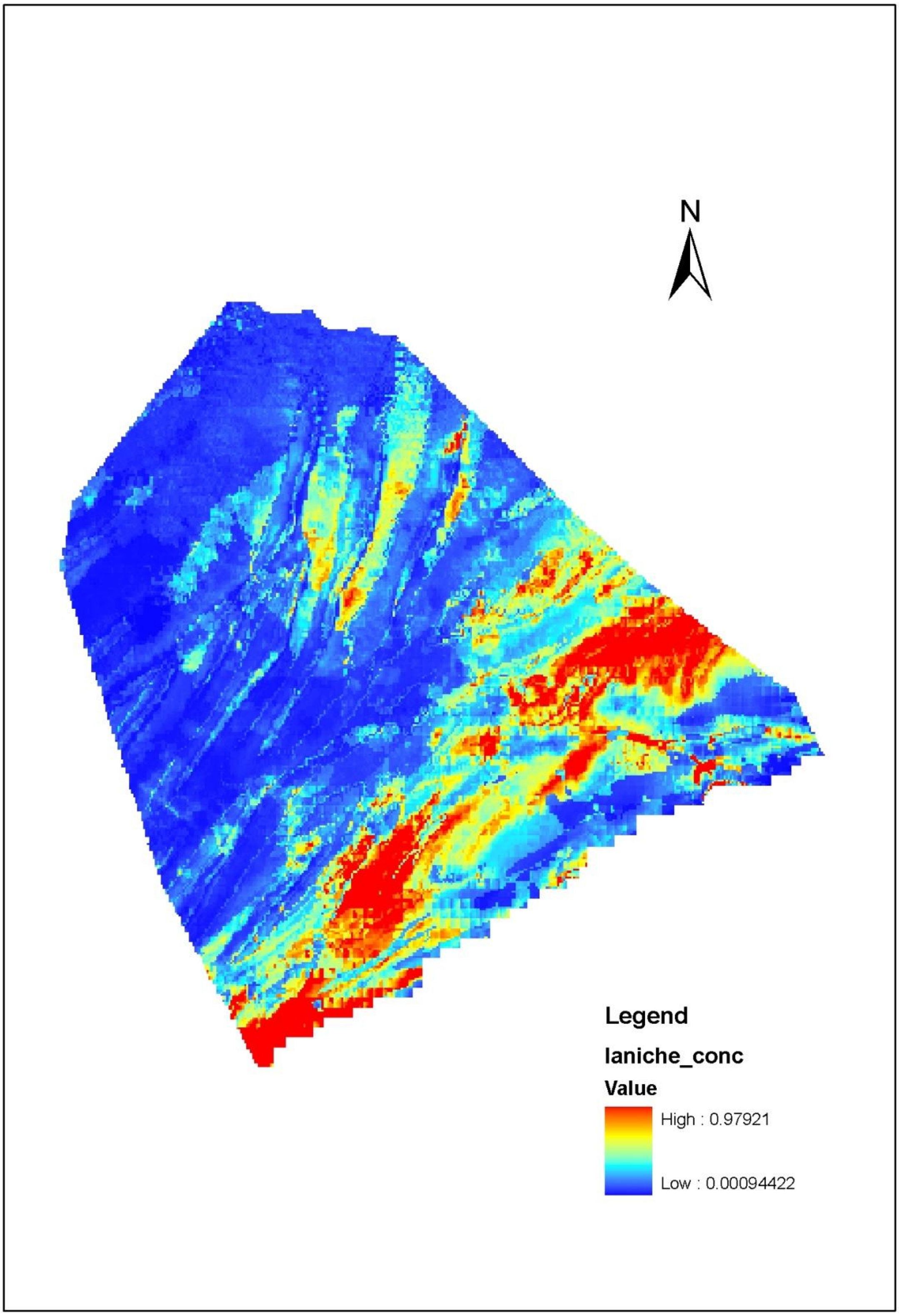
Glycera lapidum



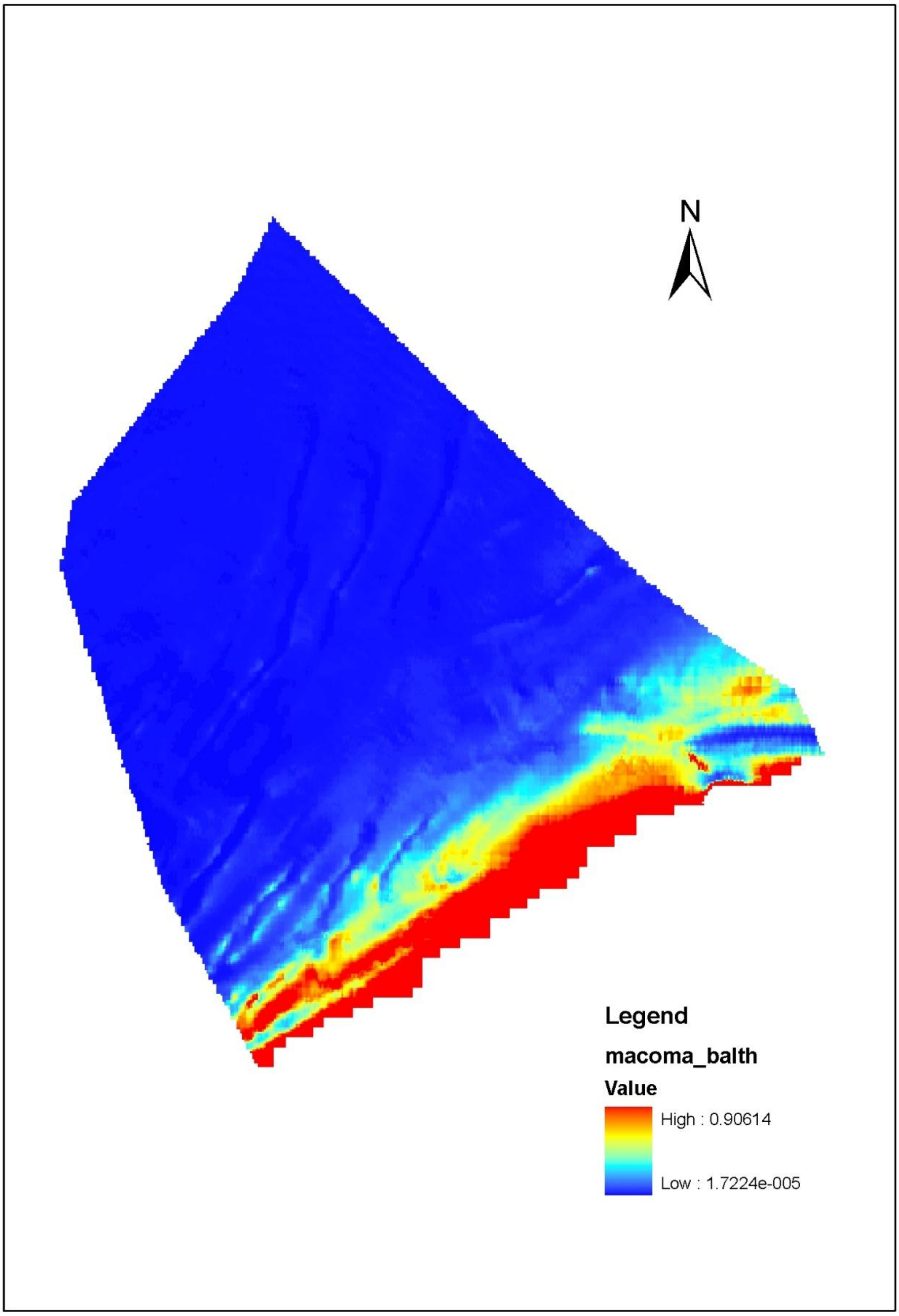
Kurtiella bidentata



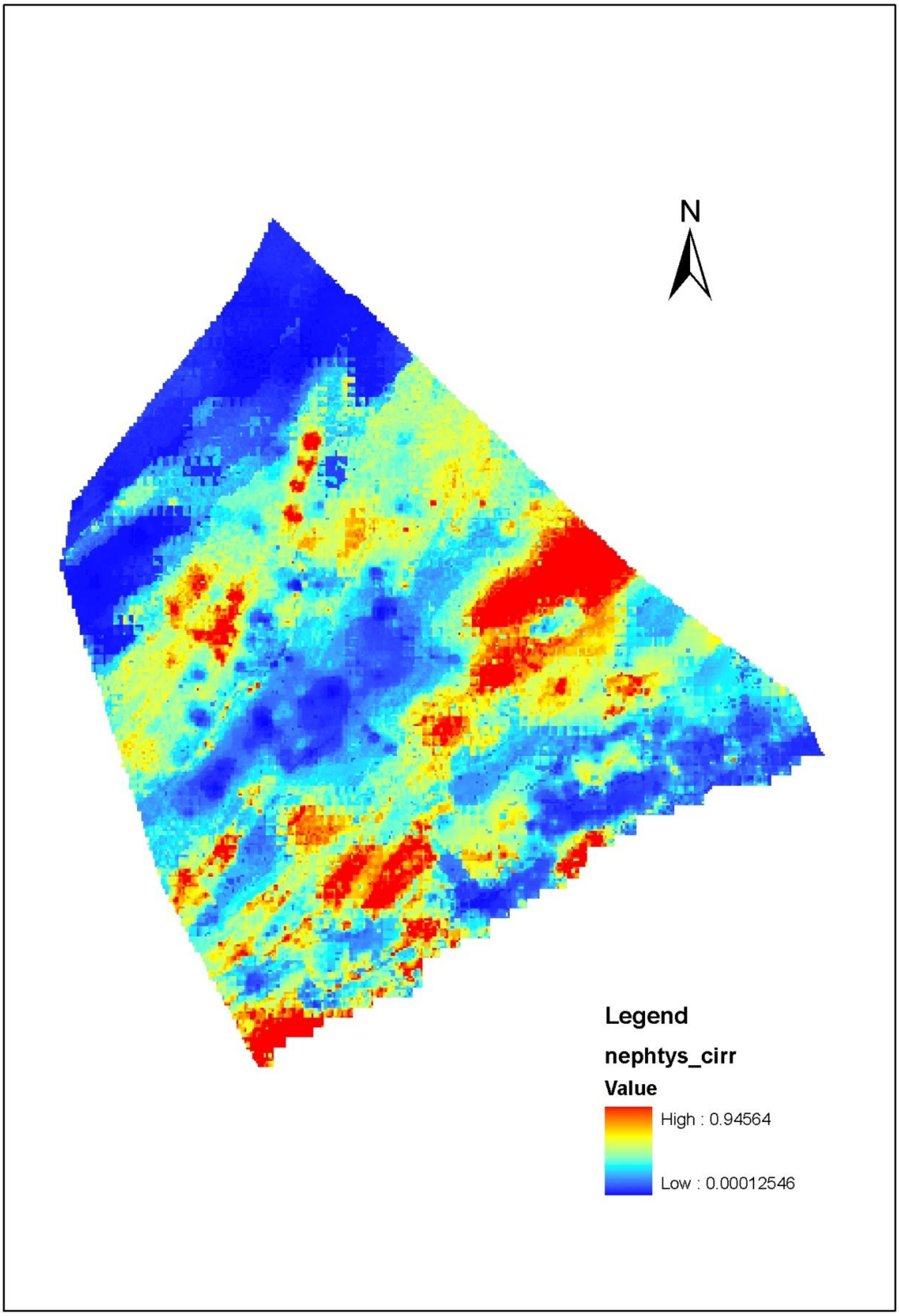
Lanice conchilega



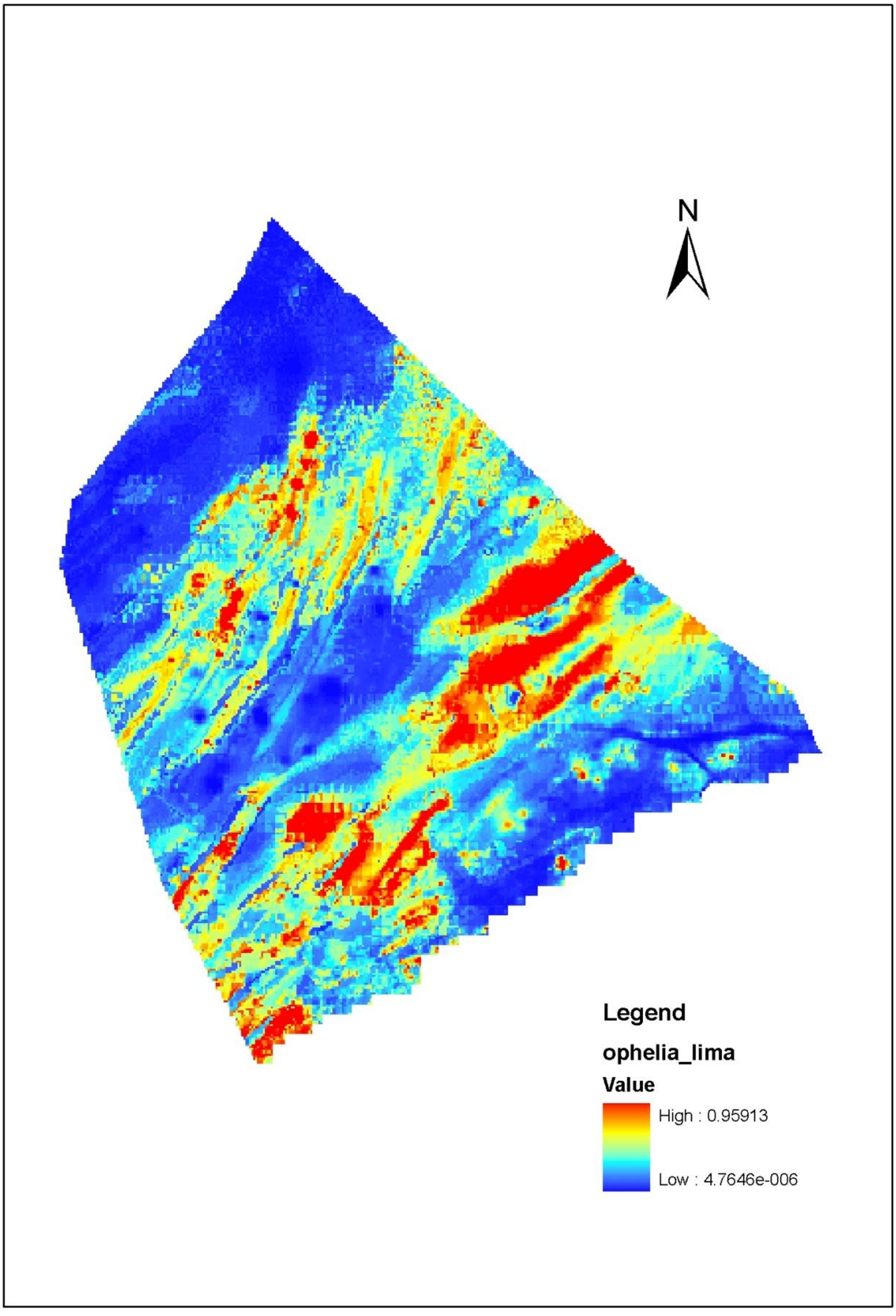
Macoma balthica



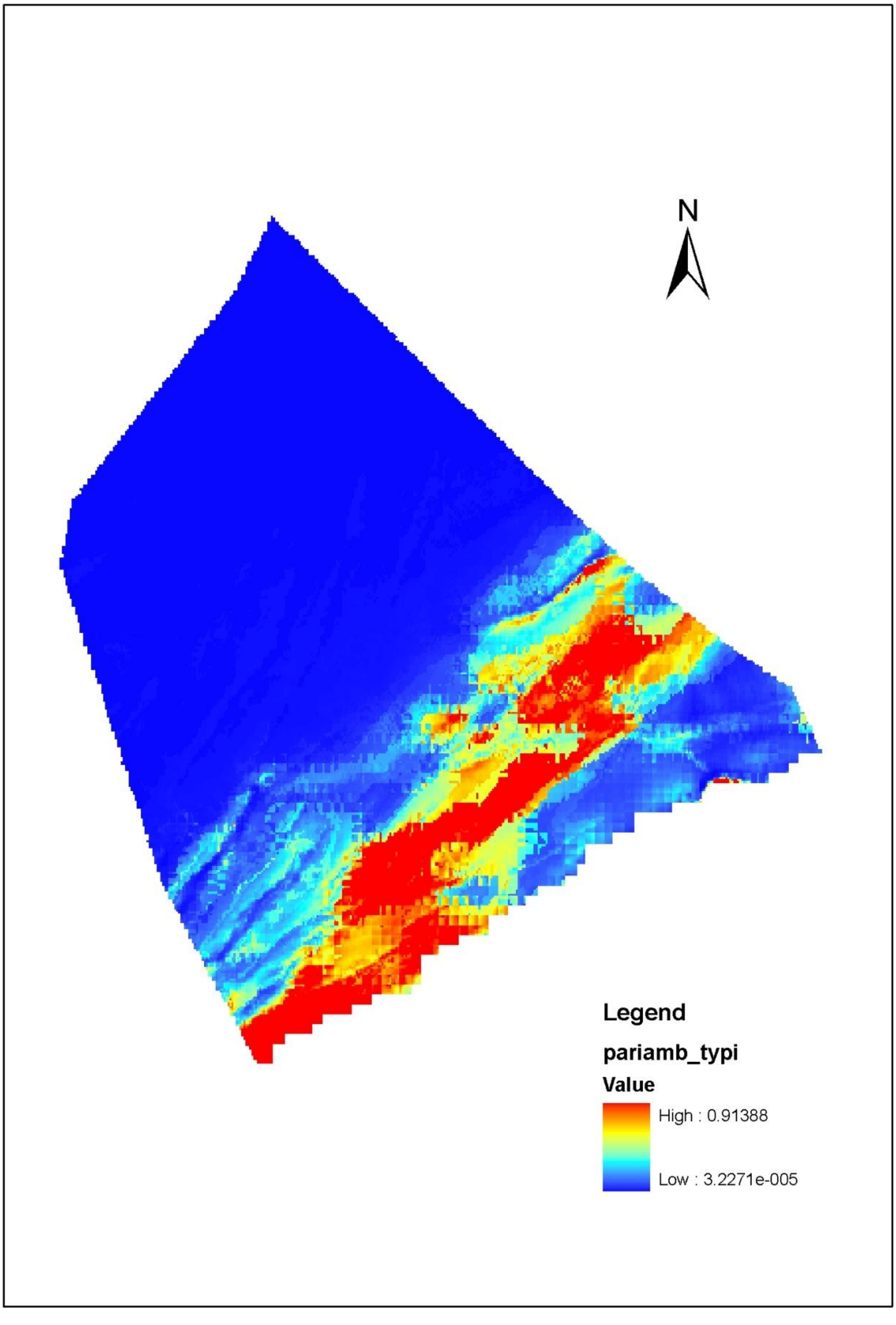
Nephtys cirrosa



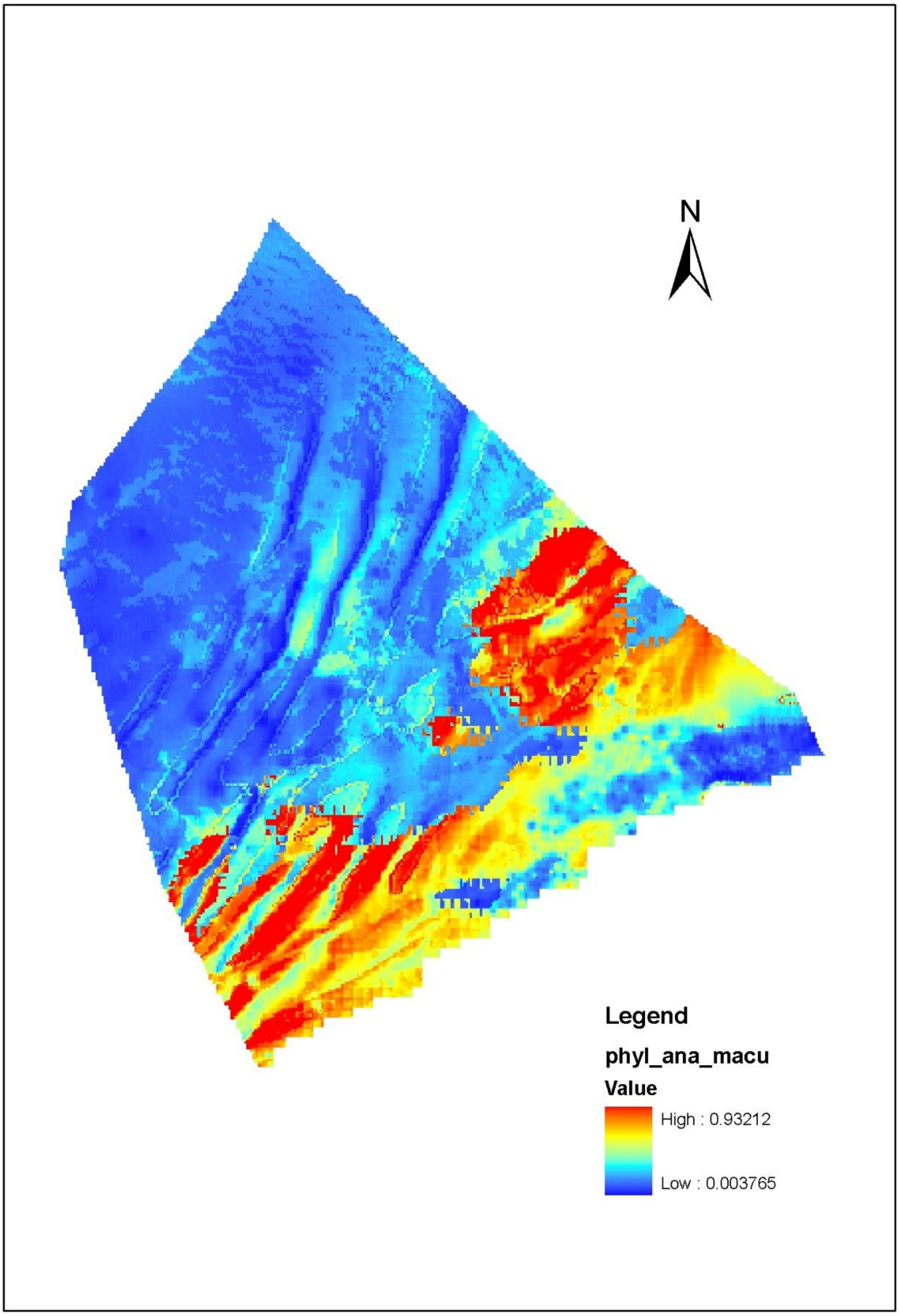
Ophelia limacina



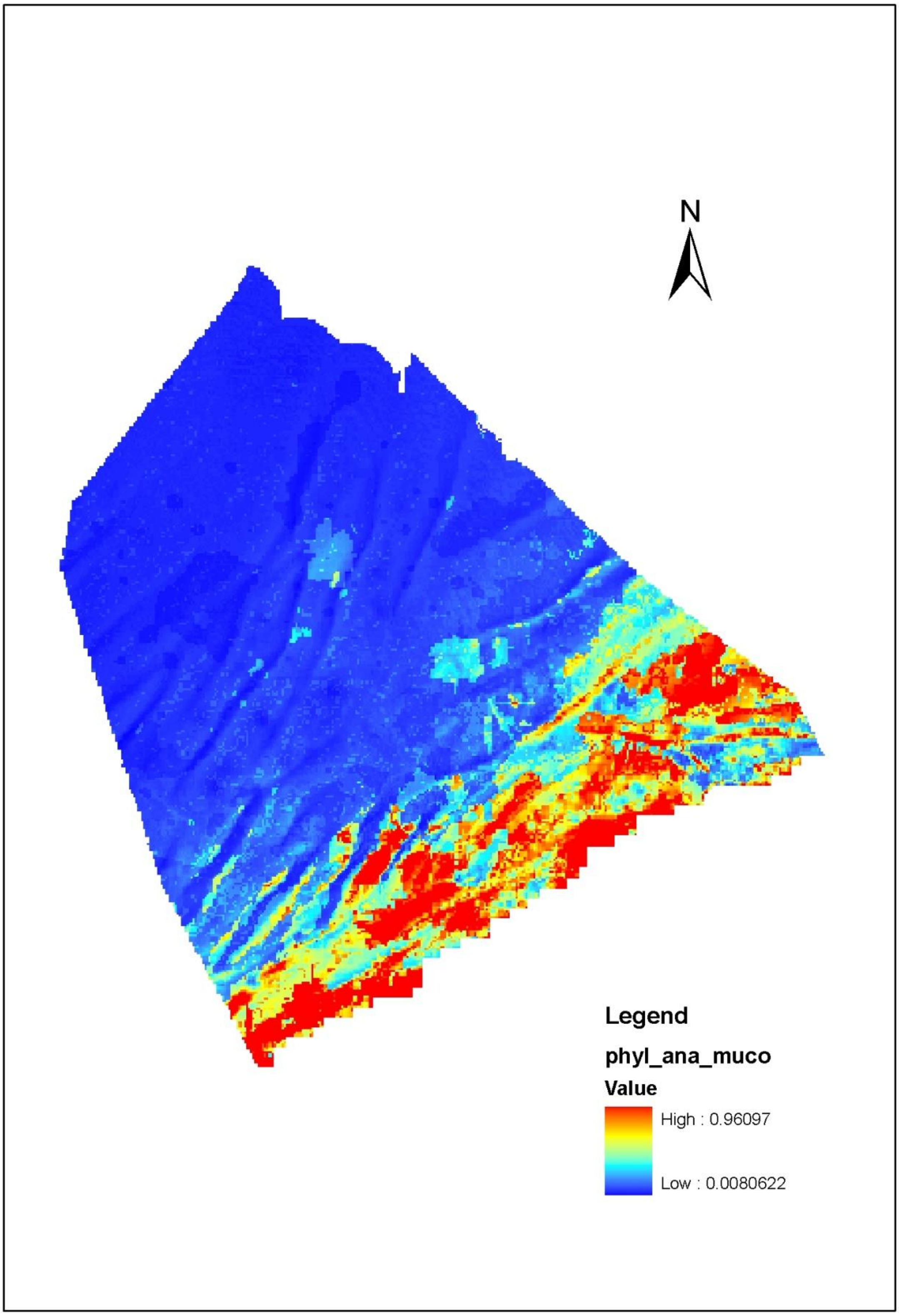
Pariambus typicus



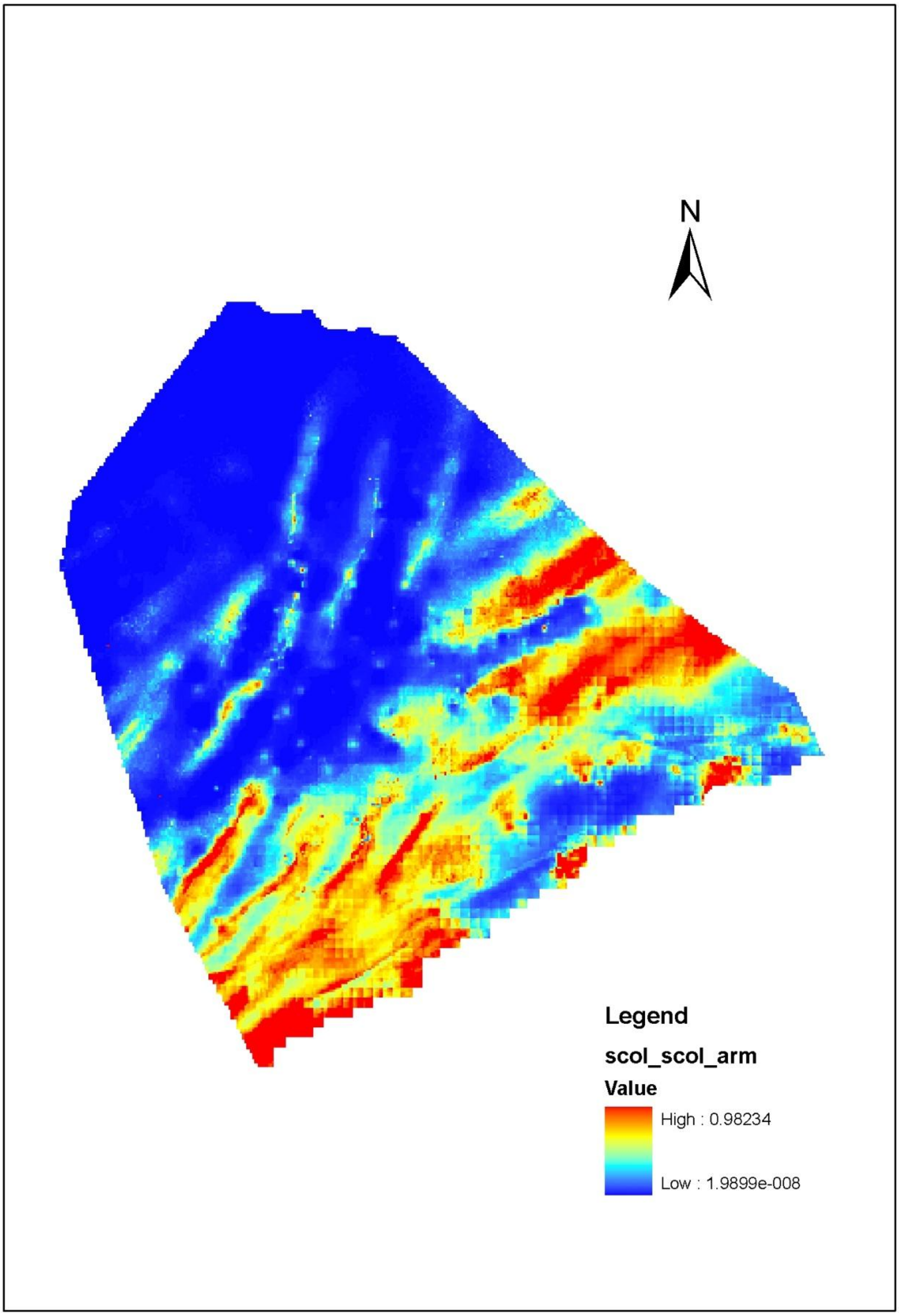
Phyllodoce maculata



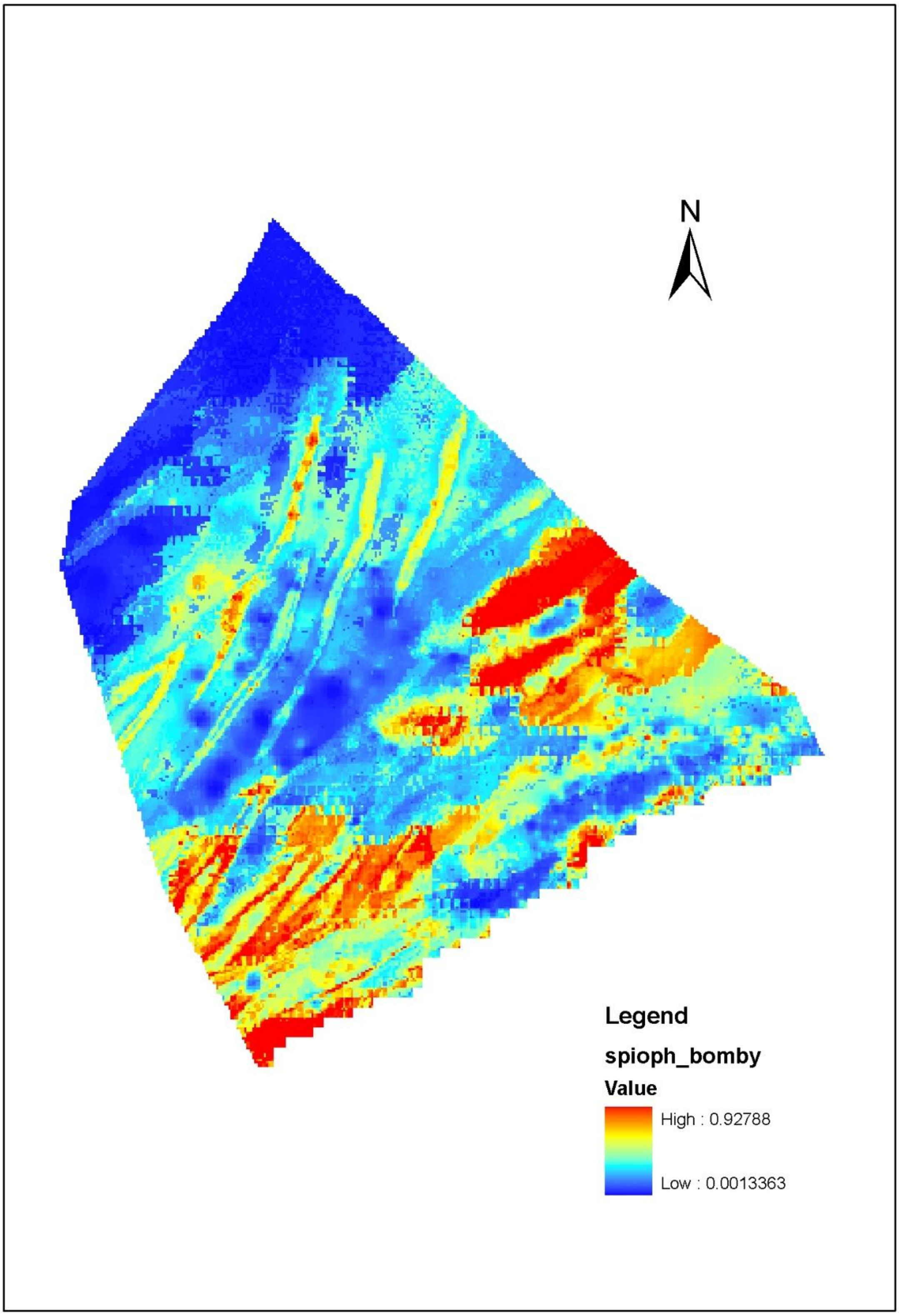
Phyllodoce mucosa



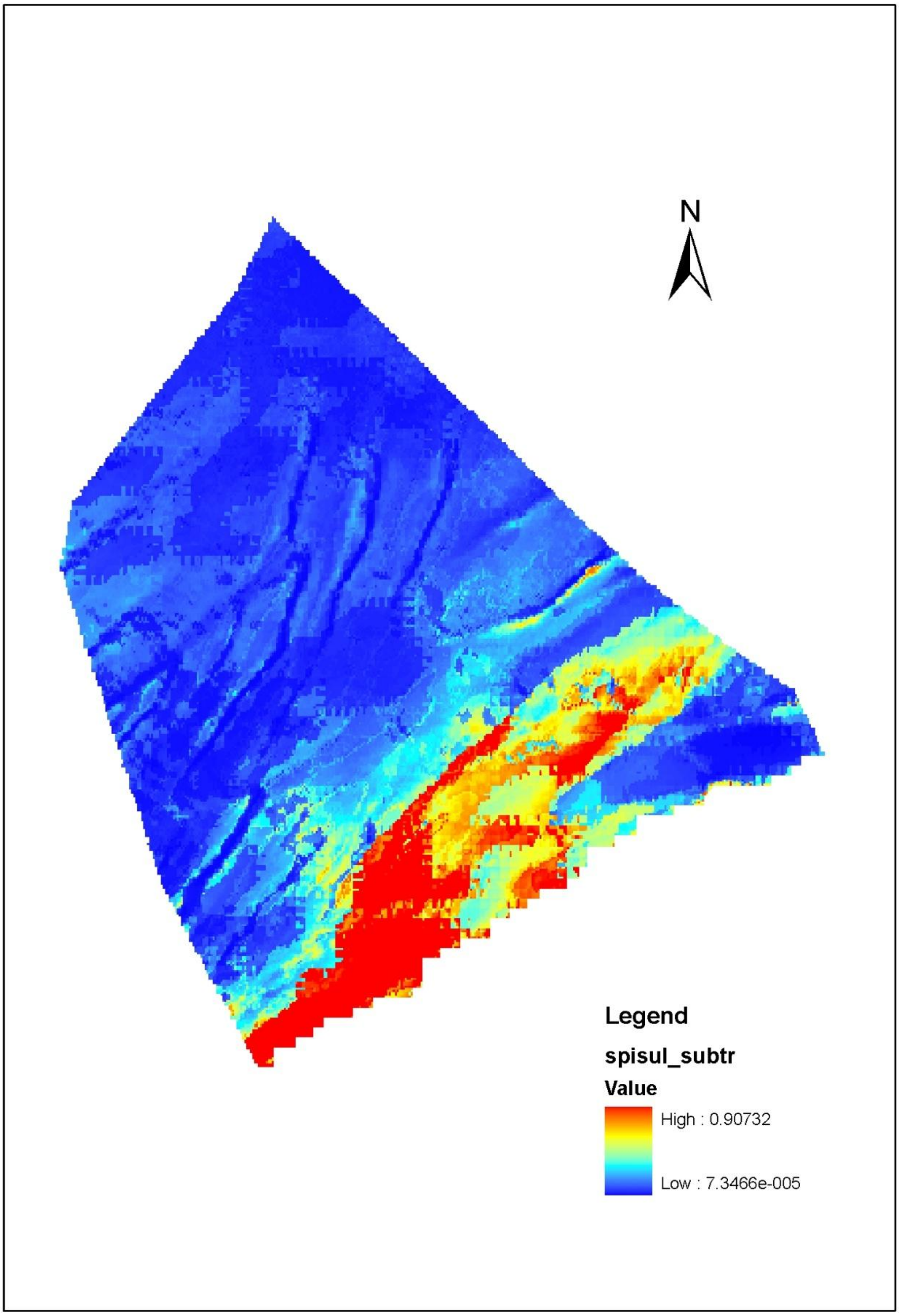
Scoloplos armiger



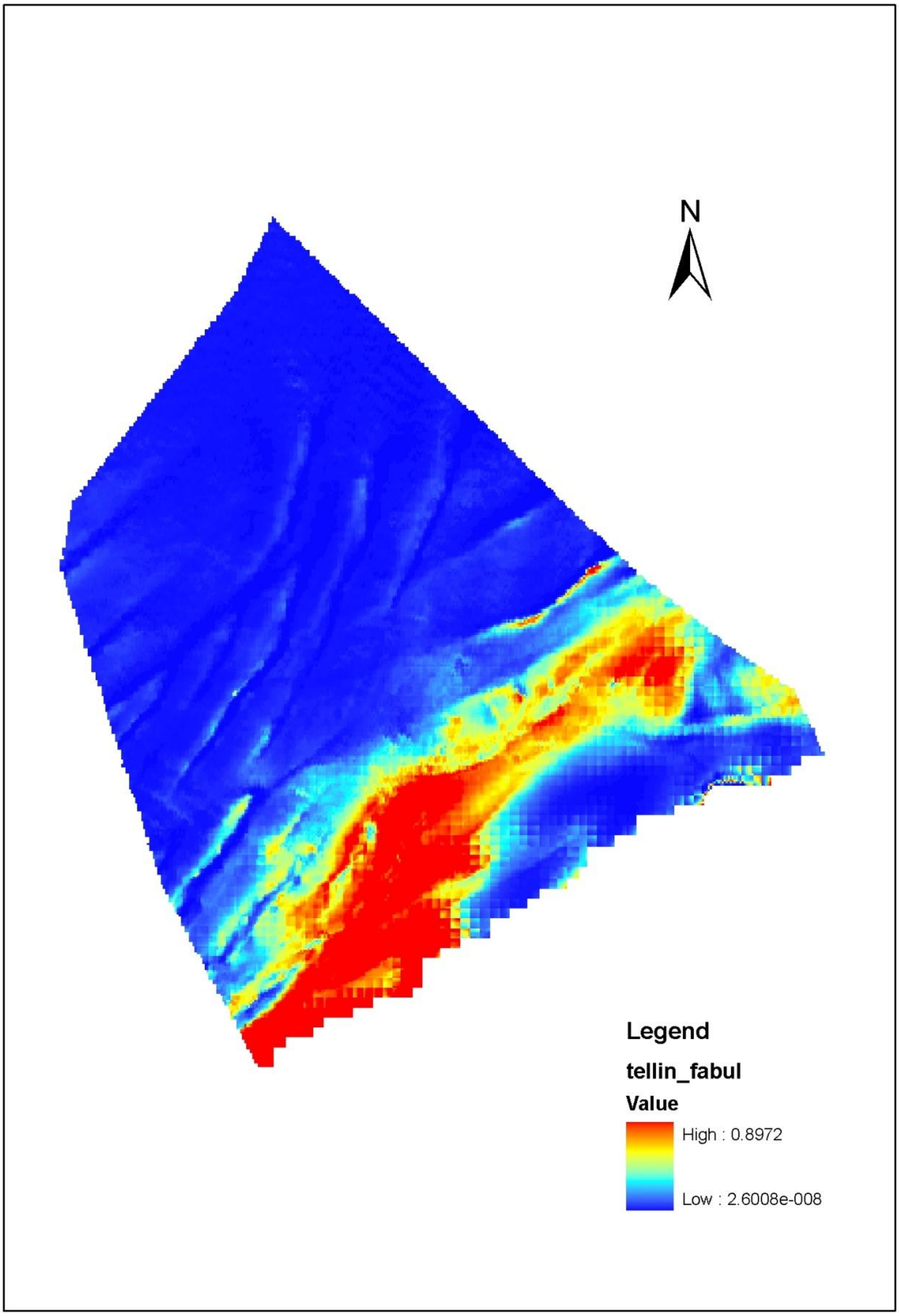
Spiophanes bombyx



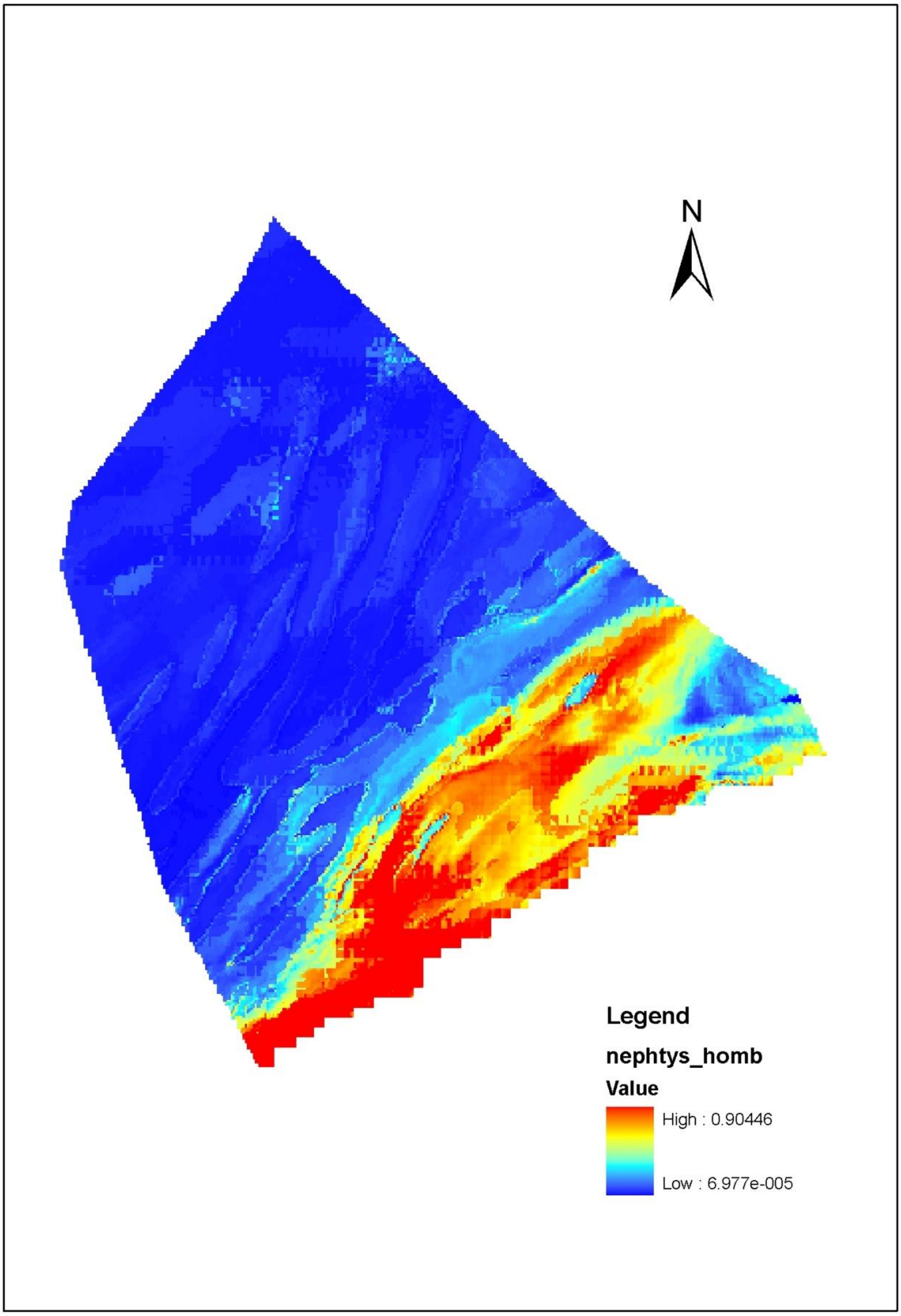
Spisula subtruncata



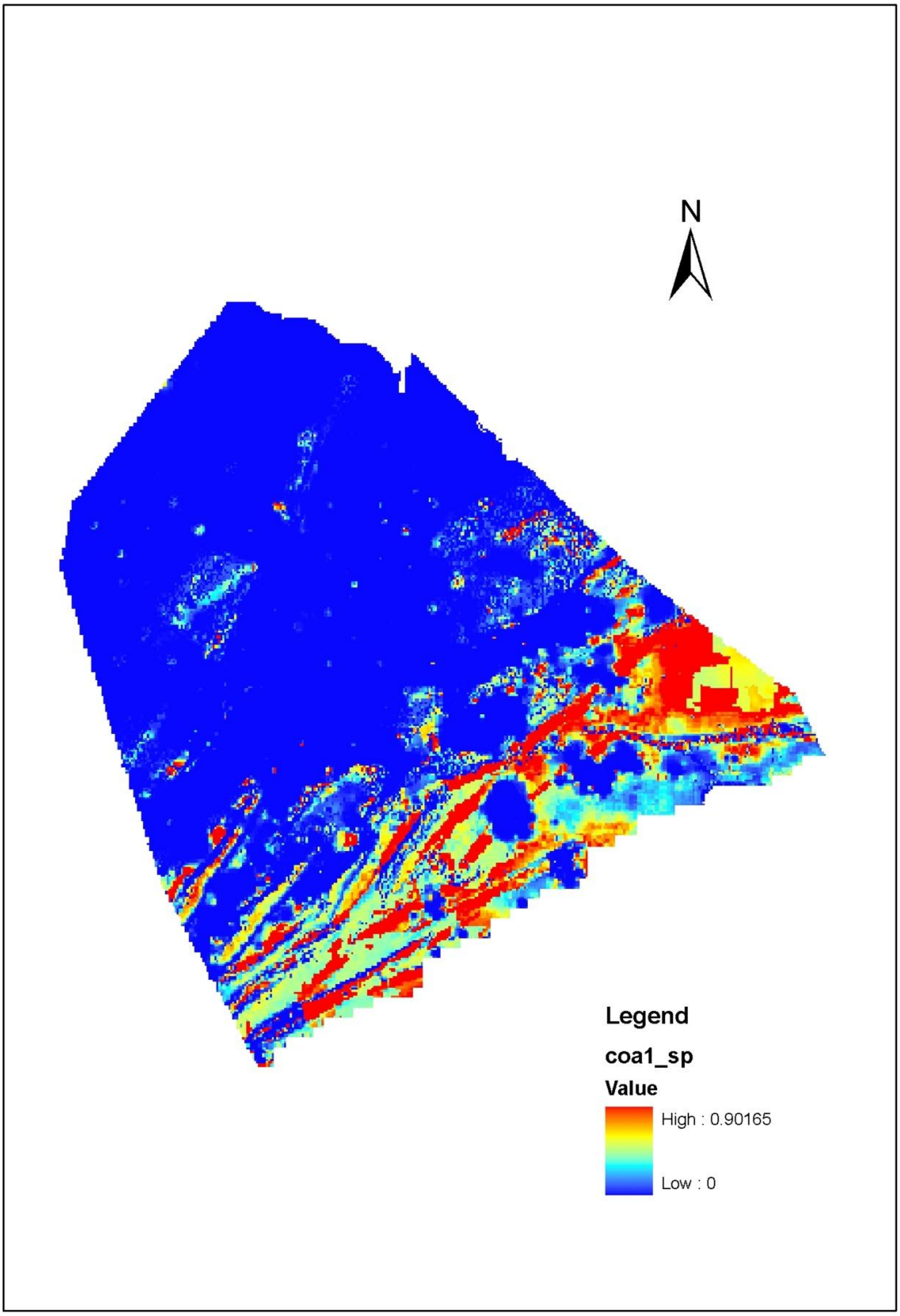
Tellina fabulina



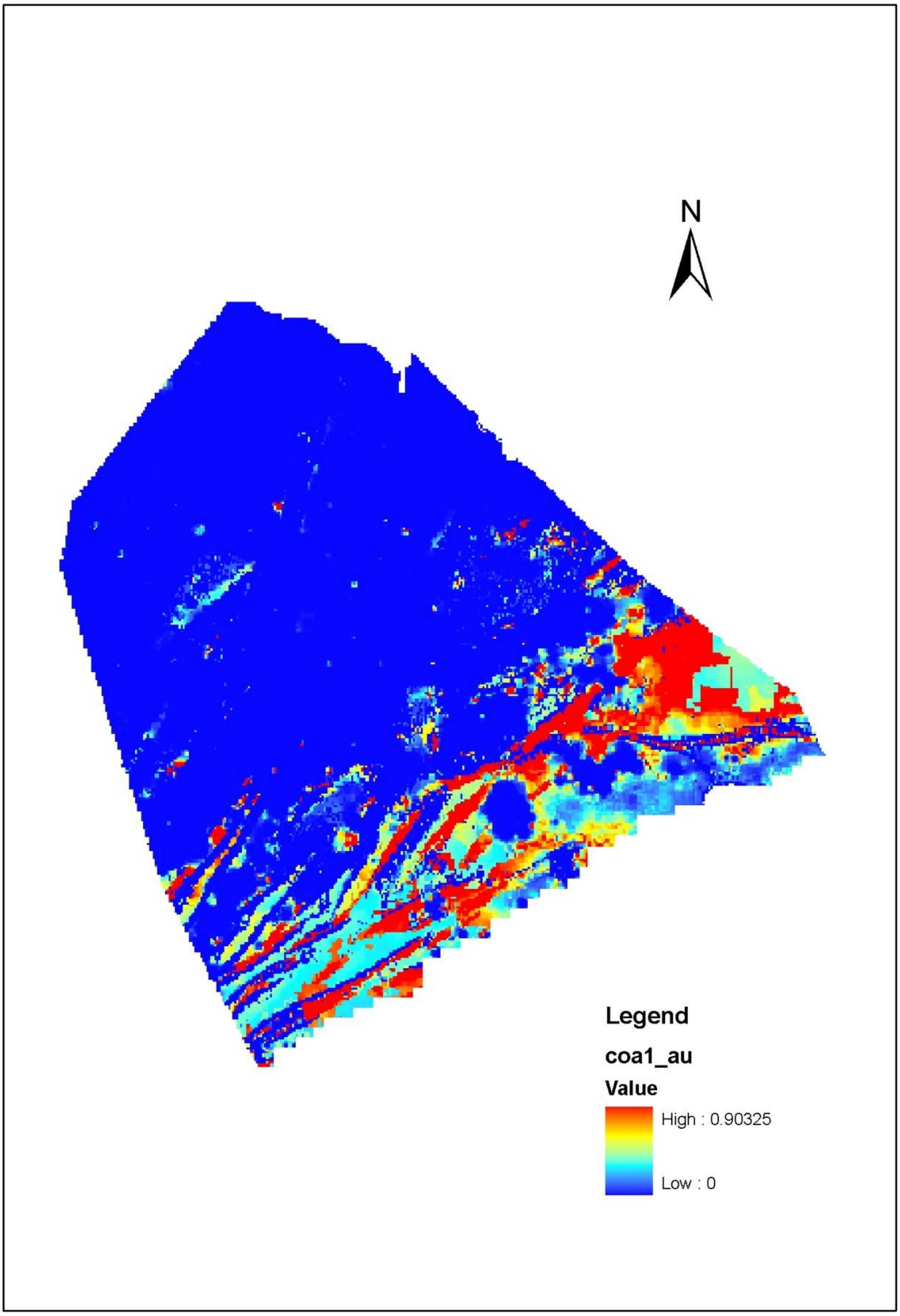
Nephtys hombergii



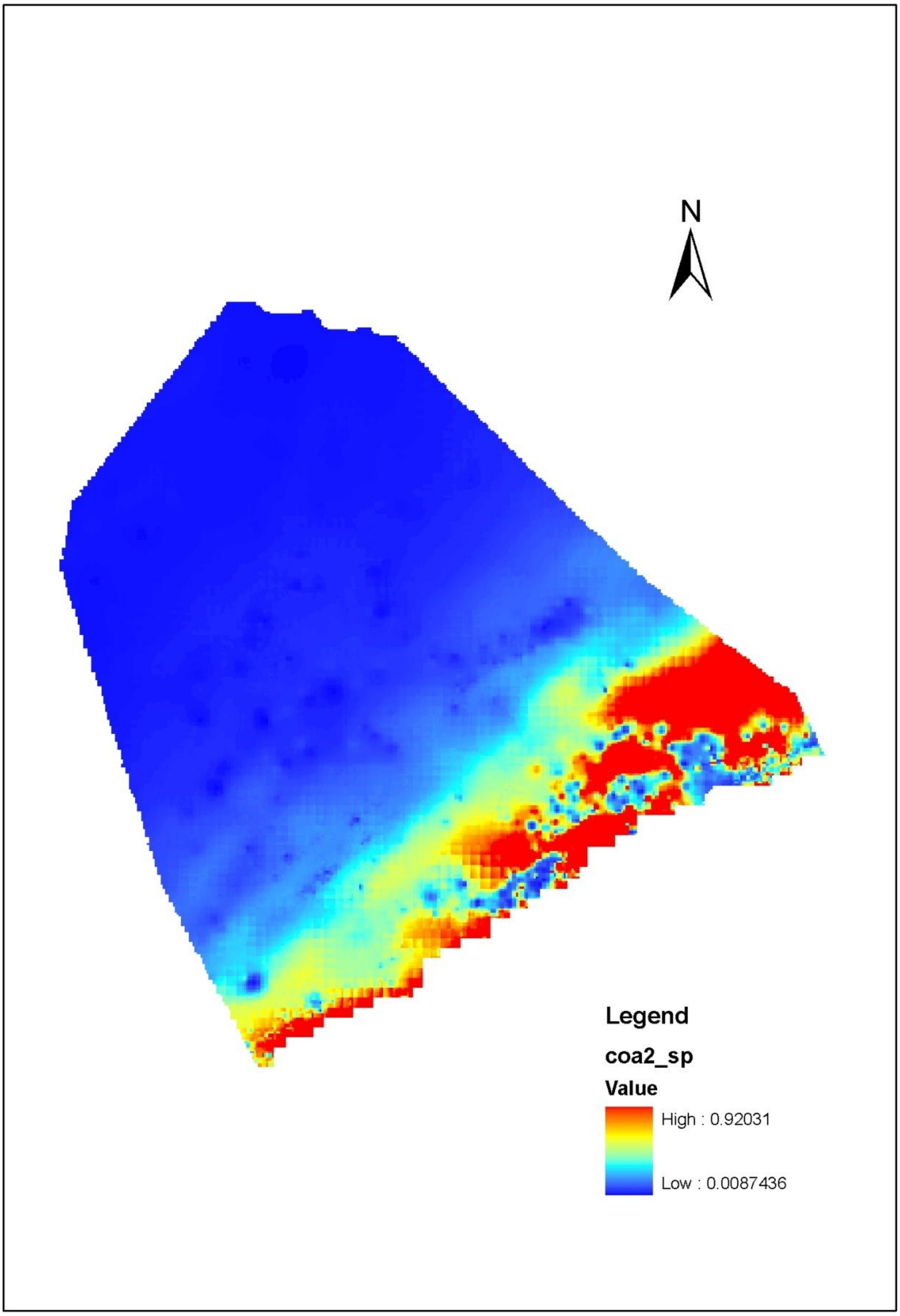
Coastal community 1 – Spring



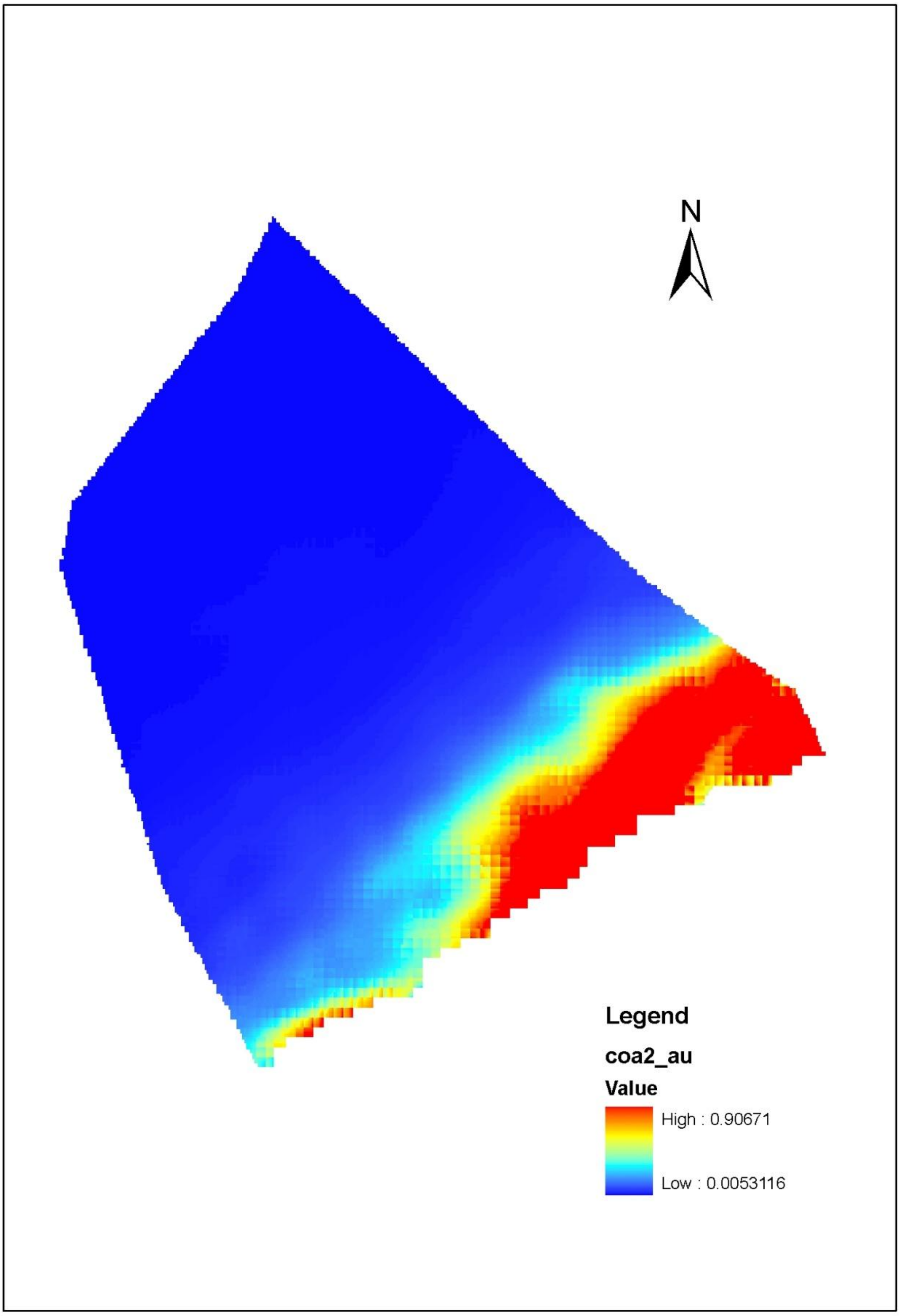
Coastal community 1 – Autumn



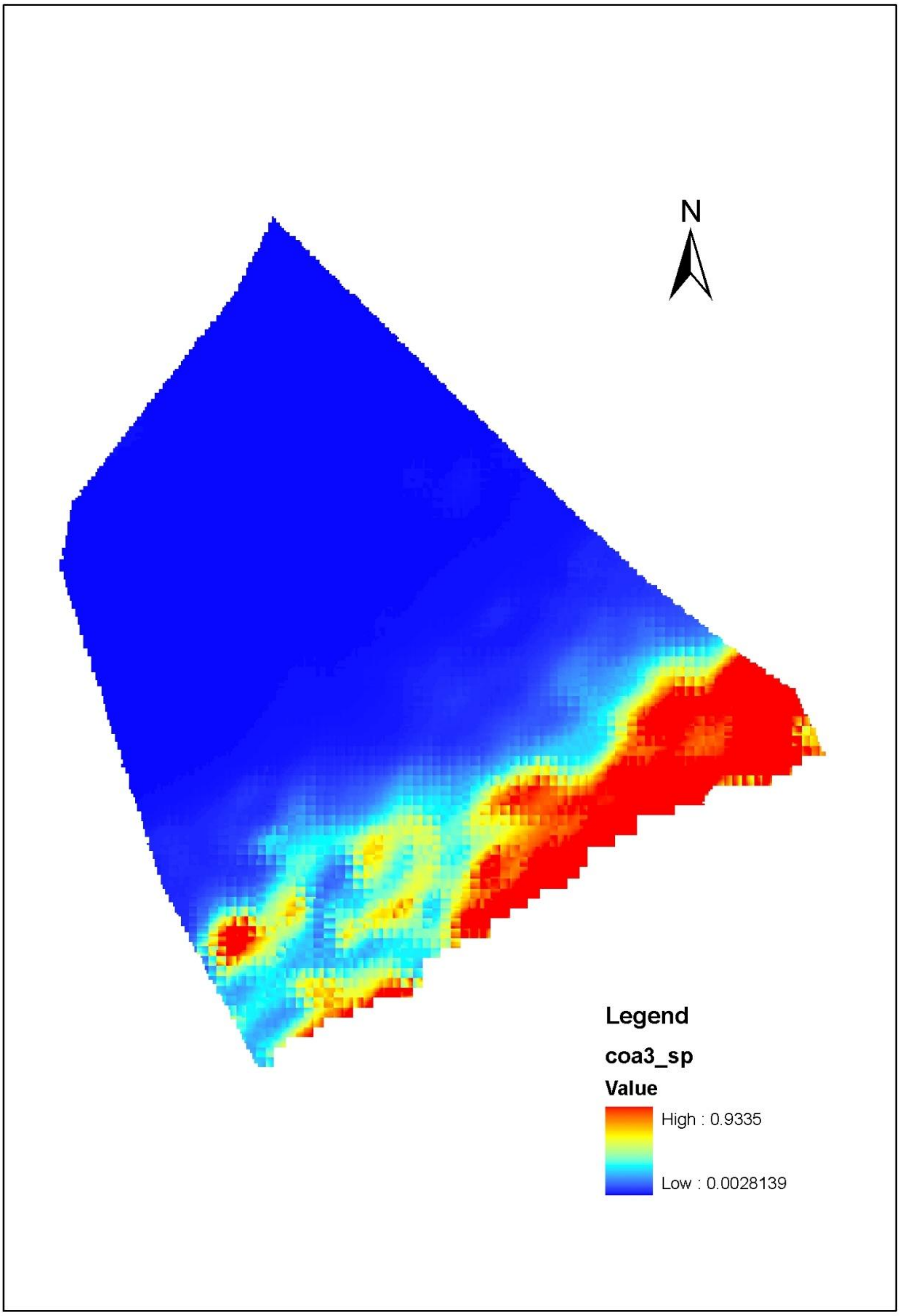
Coastal community 2 – Spring



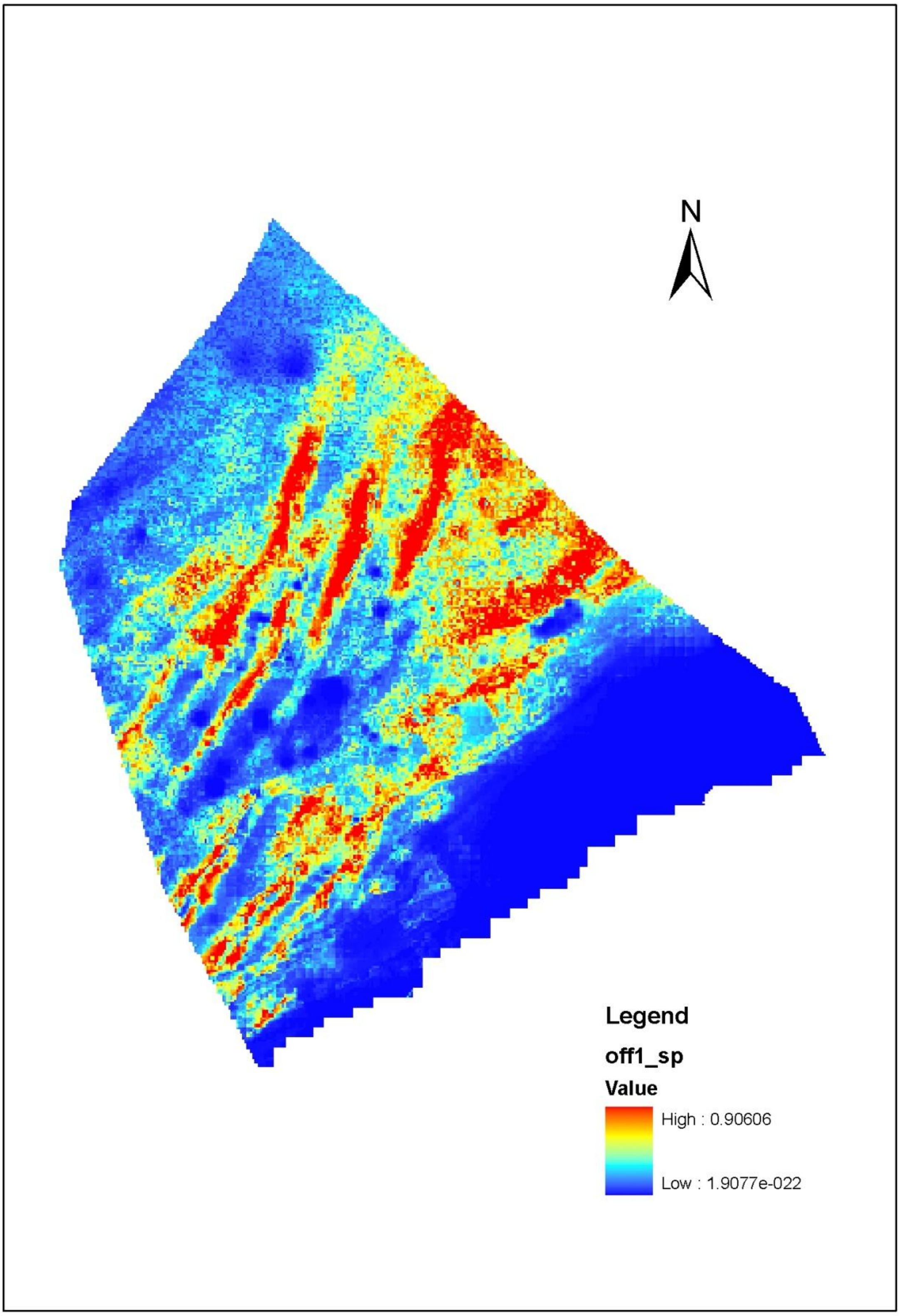
Coastal community 2 – Autumn



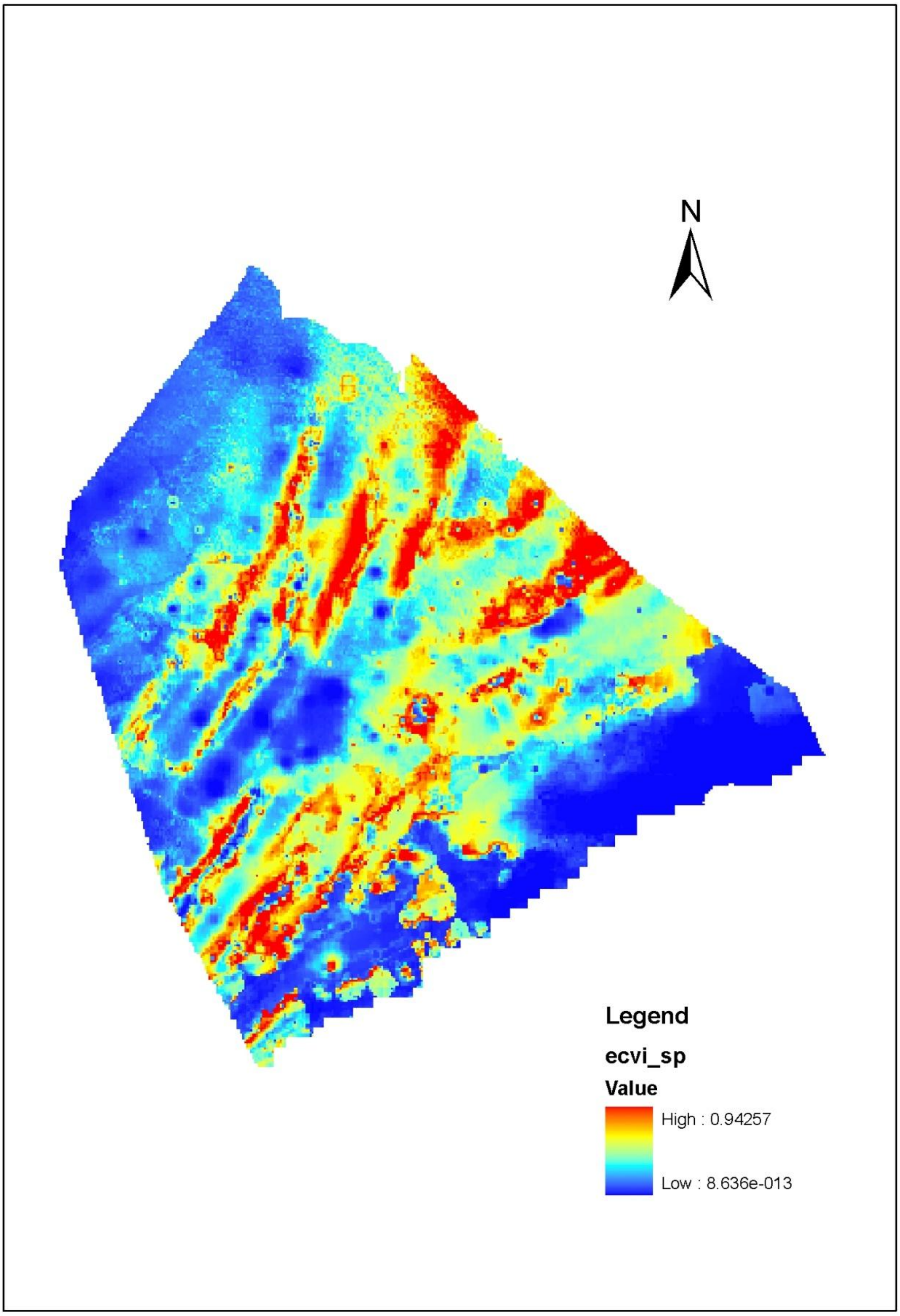
Coastal community 3 – Spring



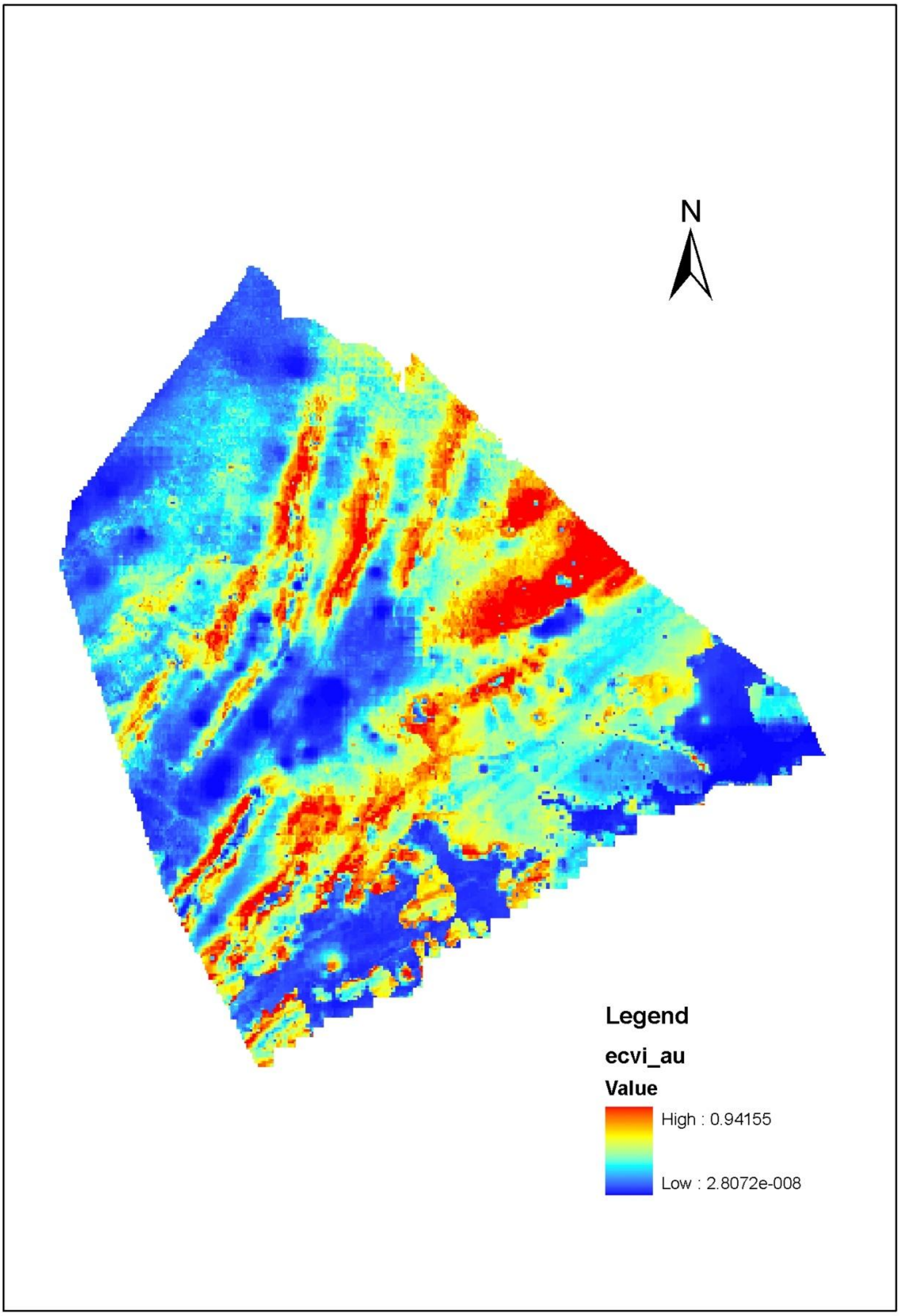
Offshore community 1 – Spring



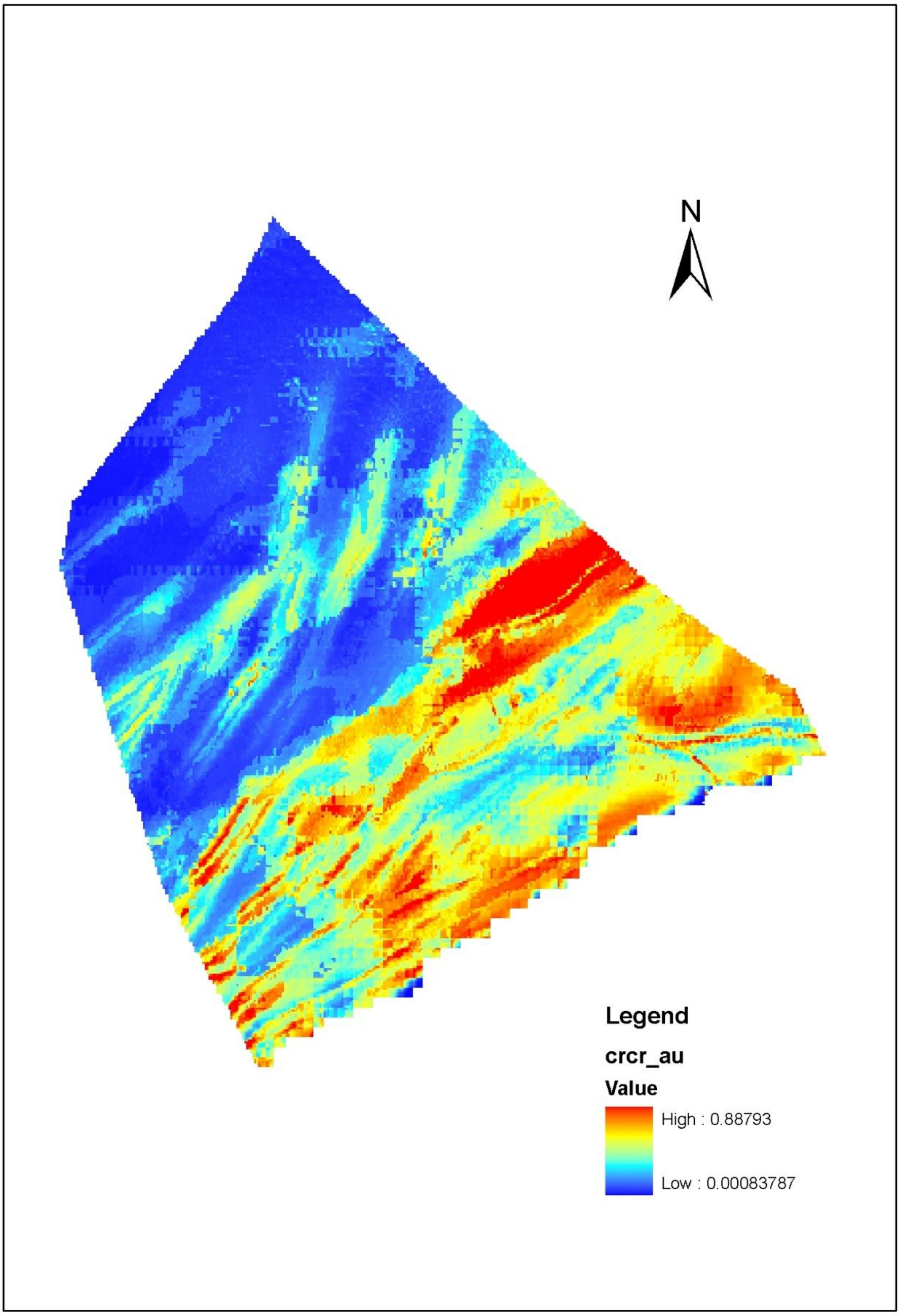
Echiichthys vipera (Pieterman) – Spring



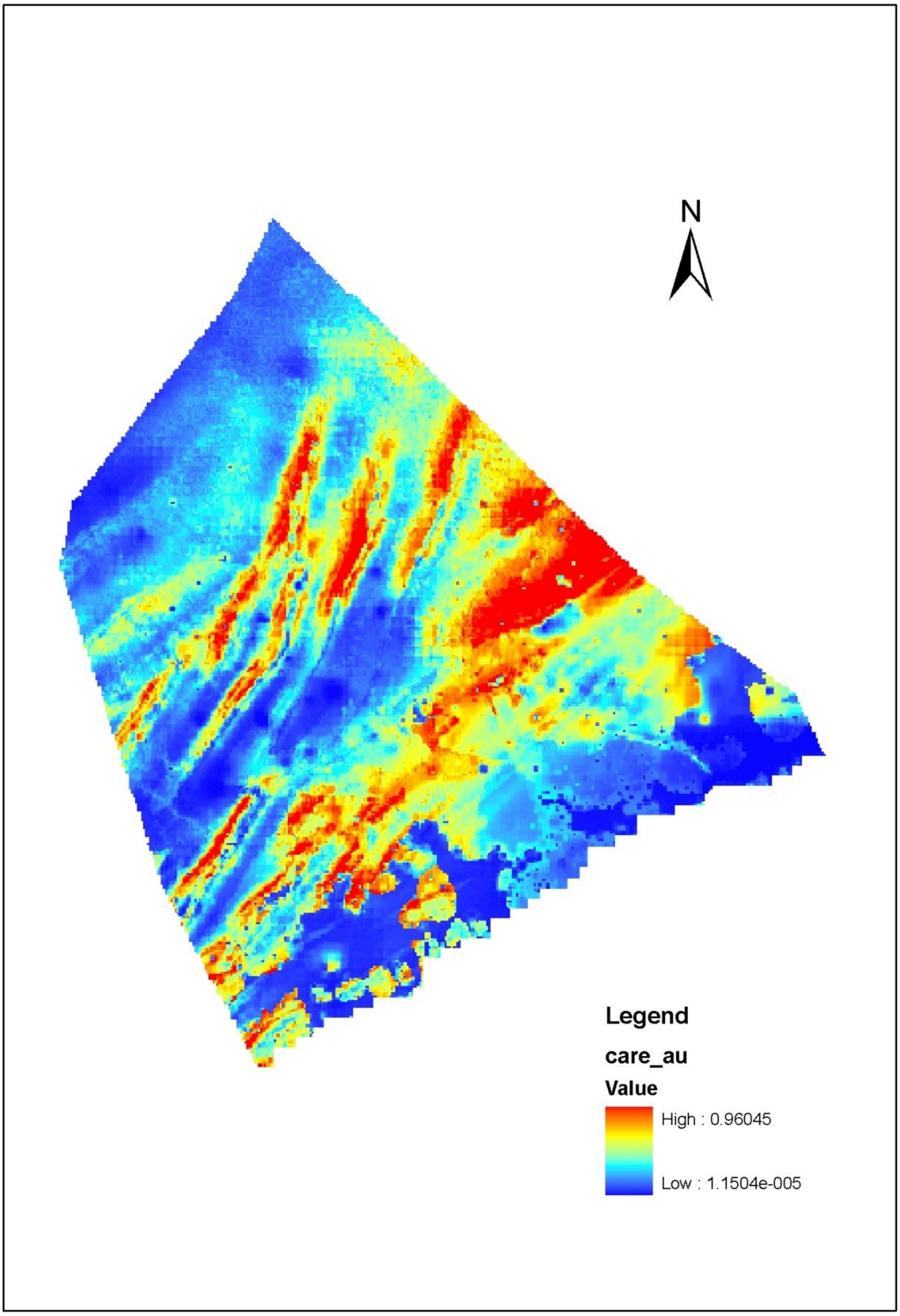
Echiichthys vipera (Pieterman) – Autumn



Crangon crangon –Autumn



Callionymus reticulatus (rasterpitvis) – Autumn


N
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Low : 1.1504e-005

ANNEX 8: Pressure effects of beam trawling and trammel netting and scoring principles

Introduction

During the workshop, pressures that were relevant for disturbance from beam trawling and trammel netting were selected. The pressure effects were evaluated for both fishing techniques. If applicable, units were standardized to the extraction of the same amount of sole (e.g. landings of 10kg sole). Commercial beam trawlers needed a mean fishing effort of 1.24h (or 11.50km surface fished at 5 knots) to extract 10kg of sole in the southern North Sea, whereas trammel netters set 708m of net during the night (unpublished data, WAKO-II project). This annex evaluates the effect of each pressure and its relevance for each ecosystem component.

Effects from direct biological pressures

Catch mortality

<u>Benthic invertebrates and fish</u>

Catch mortality is the interplay of the catch rate and survival. Catch mortality is relevant to epibenthic invertebrates, fish, seabirds and marine mammals (Haelters *et al*., 2006; Enever *et al*., 2009; Zydelis *et al*., 2009). Catch mortality of infaunal invertebrates is assumed negligible due to low catch efficiency (Lindeboom and de Groot, 1998). Epibenthic and fish catch mortality is assessed from the interplay of catch rate and survival (Table 8.1). As seabirds and marine mammals nearly never survive by-catch (Vinther and Larsen, 2004; Zydelis *et al.*, 2009), catch mortality equals by-catch rate.

Table 8.1: The scores of catch mortality for benthic invertebrates, based on catch rate and survival.

Catch mortality score	Catch rate	Survival
+3	High	Intermediate or low/nihil
	Intermediate	Intermediate or low/nihil
+2	High	High
	Intermediate	High
+1	Low	Low/nihil
	Low	Intermediate
0	Low	High
	Zero	/

For epibenthic invertebrates and non-commercial fish species, number caught per kg marketable sole is the standardizing unit for catch rate as Catch Per Unit of Effort raises difficulties in comparing active and passive fishing and sole is the target species of both métiers (Quirijns et al., 2008). Assessment was based on unpublished data (WAKO-II project: chapter 2.2, 2.3), Van Beek *et al*. (1990), Kaiser *et al*. (1995) and Depestele *et al*. (2009; 2011). The need for using unpublished data results from the fact that few studies have quantitatively examined species composition in discard of small-scale fisheries such as trammel netting (Shester and Michelli, 2011). The number of individuals per kg marketable sole is low if <0.5 individual is caught per kg commercial sole, intermediate if >=0.5 and <5, and high if >=5. The catch rate of commercial fish species is scored by the discard rate in numbers: low <=15%, intermediate <15% and <=30% and high if >30%. Survival was low if <= 50%, intermediate if >50% and <= 75% and high if >75%. For species which are not included in the database of the WAKO-II project, or any other peer-reviewed literature, biological traits assisted the decision process.

The following questions applied for the catch rates.

- If a species is unlikely to encounter the fishing gear, its catch rate is zero.
- If a species' capabilities to escape are high (high mobility, high flexibility, small organism, etc.), then the species' intolerance is "low".
- If there is any indication that the species can only escape at a high energy cost intermediate flexibility, limited mobility and movement by crawling), then the species' intolerance is "intermediate".
- If there is any indication that the species cannot escape sedentary, low mobility, low flexibility, etc.), the species' intolerance is "high".

The following questions applied for survival:

- If the species is likely to suffocate, or to be mortally damaged during fishing or hauling (low flexibility, high fragility, attached living form, soft shell, protrusive parts, swimming bladder, etc.), then its survival is "low".
- If the species is less likely to suffocate, or to be damaged, and is expected to withstand the catching, hauling and discarding process, but at a high energy cost (implying increased susceptibility for parasites, predation, etc.), its survival is "intermediate".
- If the species is not likely to suffocate, and not likely to be severely damaged, implying it can withstand the fishing process at a low energy cost, its survival is "high".

<u>Seabirds and marine mammals</u>

By-catch of seabirds in gill nets is rarely observed in the North Sea (WAKO-II: chapter 2.4; Zydelis et al., 2009) and was based on (unpublished) strandings' data of entangled seabirds. By-catch of seabirds in beam trawls is hardly occurring. Only when beam trawls are being hauled, seabirds have a small risk to be caught.

This has only been observed for Northern Gannet and Cormorant. By-catch in fishing gear is mostly harbour porpoises through indirect evidence (WAKO-II: chapter 2.5; Haelters and Camphuysen, 2009), as fishermen discard by-caught animals in most cases without reporting them. Taking the precautionary approach into account and indications of the potential by-catch risk in the BPNS (WAKO-II: chapter 2.5), this pressure is assessed as "+2" for harbour porpoise.

The following questions applied for assessment of seabird catch mortality:

- If seabirds are piscivorous and pursue their prey under water, the catch mortality was scored as "+3" for trammel nets (Zydelis *et al*., 2009)
- If seabirds, such as ducks and deep-diving plungers, typically dive straight into the water and forage in mid-water or close to the bottom on sessile organisms, the catch mortality score is "+2" for trammel nets (Zydelis *et al*., 2009)
- If seabirds are piscivorous and shallow divers, such as terns, the catch mortality was scored as "+1" for trammel nets (Zydelis *et al*., 2009)
- If seabirds are ship followers and dive only to a very limited depth, such as Northern Gannet (*Morus bassanus*), the catch mortality score is "+1" for beam trawls.
- If seabirds are not ship followers and do not dive, catch mortality scores "zero".

Tow path mortality

Tow path mortality includes mechanical interference, crushing, physical blows against, or rubbing and erosion of the organism. Direct mortality from physical disturbance is considered relevant for benthic invertebrates and fish. It is hence not scored for seabirds and marine mammals. This pressure effect was directly assessed from experimental research for beam trawling in muddy sand and sandy sediment, i.e. from the % difference in abundance within one day after trawling, adapted from Kaiser *et al*. (2006) for beam trawling (unpublished data) (Table 8.2).

Table 8.2: The scores of tow path mortality, based on the response variable R from Kaiser *et al*. (2006): % difference in abundance = R = ($A_{after\ trawling}$ - $A_{before\ trawling}$) / $A_{before\ trawling}$ met A = Abundance (n/m²).

Tow path mortality score	R
+3	< -40
+2	-40 =< R < -20
+1	-20 =< R < 0
0	0 =< R

Data in gravel and biogenic habitats were limited (WAKO-II: chapter 2.1). Biological traits assisted assessment for species which are not included in experimental studies and for trammel netting, which might have an intermediate impact for emergent, sedentary benthos (Chuenpagdee *et al*., 2003). The biological traits which were accounted for, assist in evaluating encounter probability and mortality probability (van Marlen *et al.*, 2010).
The probability of encounter depends on the fishing gear and can be estimated through surfaced fished and average penetration depth. Polet *et al.* (2010: 83) estimated that beam trawling displaces about 70 times more m³ sediment per kg landed fish than trammel nets and that the surface fished per kg landed fish is about 345 times higher by beam trawls than by trammel nets. Beam trawls generally penetrate between 1 and 8cm (Paschen *et al.*, 1999), whereas the penetration depth of trammel nets is negligible (Polet *et al.*, 2010). Beam trawling is spatially centered around regions of high fishing pressure at the same locations (Stelzenmüller *et al.*, 2008). Therefore, readdressing this calculation for beam trawl tracks that show no overlap using an average coefficient of 0.34 (Rijnsdorp *et al.* 1998) shows the surface fished per kg landed fish is about 120 times higher for beam trawls than for trammel nets which might also show overlap. Spatial overlap of static gear effort could not be estimated as there is very little empirical data available for these types of calculation (Lee *et al.*, 2010). However, the surface fished depends rather on the size, type and soak time of the nets, whereas VMS data merely provide insight into the vessels' area of operation (Russo *et al.*, 2010). The surface fished and penetration depth as estimated in Polet *et al.* (2010) serves as a good proxy to the probability of encountering, which is considered low for in trammel netting in comparison to beam trawling.

For species which are not included in Kaiser *et al*. (2006), or for trammel netting species, biological traits assisted the decision process:

- If the probability of encounter with the fishing gear is low, the score "0" was assigned fish species expected to be caught or escape above the trawl).
- If the species is likely to encounter the fishing gear, its intolerance is not zero.
    - If it has at least three biological traits, indicative for its capabilities of withstanding physical disturbance high mobility, high flexibility and small, etc.), then the species' intolerance is "+1".
    - If there is any indication that the species could withstand physical disturbance, then the species' intolerance is "+2".
    - If there is no indication that the species' biological traits enable it to withstand physical disturbance sessile, relatively large, low mobility, etc.), the species' intolerance is "+3".

Unaccounted mortality

Unaccounted mortality was defined as ghost fishing mortality, although other sources have been identified (Broadhurst *et al*., 2006). This includes organisms caught in discarded or lost components of fishing gears. This factor is scored zero for beam trawls, as mortality levels from lost trawls are believed to be low because these gears rely on their movement through water for their catching efficiency (Brown and Madfadyen, 2007). Brown *et al*. (2005) estimated that about 20% of gill nets for sole are lost per vessel per year. While nets may be set in a wide range of environmental conditions, their evolution and catching efficiency generally follow similar patterns with rapid declines in catch rates. Fishing rates may nonetheless continue at not insignificant rates, of up to 15% of normal gillnet rates in some cases (Pawson, 2003; Brown and Madfadyen, 2007). The factor 0.15 can be used to weigh ghost fishing with regular catch rates. Ghost catches initially show a high percentage of fish before becoming increasingly dominated by catches of crustaceans (MacMullan *et al*., 2004; Brown *et al*., 2005; Macfayden *et al*., 2009). Catch composition is at first fairly similar to commercial catches (Kaiser *et al*., 1996; Erzini *et al*., 1997; Humborstad *et al*., 2003; Revill and Dunlin, 2003). As the fish die, they cause the nets to collapse and attract large number of scavenging crustaceans (*Cancer pagurus*, *Necora puber*) that also become trapped in the gear, replacing fish as the main component of the catch Kaiser *et al*., 1996; Revill and Dunlin, 2003; Baeta *et al*., 2009). Large crustaceans and commercial fish species which comprise a large part of the catch, get a score of "+3" for this pressure, whereas fish species and smaller crustaceans, such as Liocarcinus spp. have score "+2". Limited data were available to quantify the scavenging due to gastropods, since these species rarely become entangled in the nets (Baeta *et al*., 2009) and were therefore scored "+1", as were fish species which are rarely caught in gill nets. Non-scavenging invertebrate species were scored "zero". The scoring of entanglement in fishing gear was based on the data collected during beached bird surveys by INBO (1992-2010). Of the 7973 birds of the 18 selected species found beached during the surveys, 0,69% of them were entangled in fishing gear. The score was given according to the percentage of birds found entangled on the total of birds found beached.

- Species that were not found entangled and that have a very limited chance to be-come entangled were scored zero
- Species of which between 0 and 1% was found entangled were scored "+1"
- Species of which between 1 and 5% was found entangled were scored "+2"
- Species of which more than 5% was found entangled were scored "+3"

The intolerance of seabirds towards beam trawl was scored one point less than the score for trammel net if the score for trammel net was more than '1' (expert judgement). If the score for trammel net was one, beam trawl scored 0,5.

Effects from indirect biological pressures

Ecosystem communities and their stability largely depend on the strength of interactions between predators, prey, competitors and resource quality (Piet *et al*., 1998; Bascompte *et al*., 2005). IBP arise when DBP and IPP change species abundances. The results of changed interactions are an interplay of positive and negative feedback loops, possibly with counterintuitive results (Christensen and Walters, 2004; Lindegren *et al*., 2009). Polis *et al*. (1996) indicates that energy subsidies, such as from fisheries, might have population level effects, if they are large enough, occur frequently and in a predictable manner. These criteria are met for avian scavengers, marine mammals and potentially for fish, as they are able to search widely for (and find) trawlers on a daily basis and thereby remove the unpredictability of the supply of discards (Kaiser and Hiddink, 2007). The effects of beam trawling and trammel netting is thus a combined result of (1) the reduction in prey items through mortalities as summarized in DBPs and (2) the production of additional food through carrion in the tow path and/or discards.

Benthic invertebrates and fish

The reduction in production from beam trawling is demonstrated by Jennings *et al*., 2001; Schratzberger *et al*., 2002; Reiss *et al*., 2009 and reviewed in Polet and Depestele (2010). The reduction in total production does not seem to offset the carrion production from discards, tow path mortality and unaccounted sources of mortality (Groenewold and Fonds, 2000; Kaiser and Hiddink, 2007). It is estimated that after a single beam trawling about 1.27 g m-^{2} ash-free dry biomass, or 6% to 13% of the annual secondary production of macrobenthos per unit area, would suddenly become available to scavengers and to the detritus food chain. Kaiser and Hiddink (2007) stipulate that the production of carrion only compensates for 22% of the reduction in "regular" production, although the importance might be relatively larger for scavenging fish than for invertebrates (Groenewold and Fonds, 2000). Therefore, IBPs of benthic invertebrates can be evaluated from their ability to partially compensate for the reduced system productivity. IBP is hence an indication of reduced intolerance of species which can only partially compensate reduced production (Table 8.3). The reduction in productivity from trammel netting can be assumed limited a biomass reduction from discarding is limited in comparison to beam trawling (chapter 2.2). This implies that the production of carrion might result in a positive effect for certain benthic invertebrates and Table 8.4 applies.

However, for individual species the relationship where reduced production does not compensate carrion production might not always apply (e.g. Reiss *et al.*, 2009 – increasing production of small infauna). Long-term studies indicate however increases in scavenger abundances (see Polet and Depestele, 2010 for an overview), which would imply that other indirect biological pressures, which are not accounted for here (e.g. competition) or indirect physical pressures might play an important and stimulating role. Or, the outcome of interactions for the produced carrion might be profitable to certain species while less to others, due to their competitive strength (e.g. Ramsay *et al.*, 1997). As such, it is illustrated by Groenewold and Fonds (2000) that *Liocarcinus holsatus*, *Pagurus bernhardus*, *Asterias rubens*, and ophiurids were the main active scavengers feeding on different kinds of food, while lyssianid amphipods fed mainly on crustacean carrion. For filter feeders, such as *Mytilus edulis*, increased carrion does not serve as an additional food resource. In these cases the indirect biological pressure effects should be separately evaluated, based on (1) feeding strategy or the ability to switch diet and (2) the magnitude of the effect (whether it is additional food availability through mortality or reduced prey items due to mortality). Scoring is thus a combination of the species' trophic guild (scavengers, predators, detrivores, suspension feeders, etc), and the magnitude of change of these prey items (e.g. higher total discarded biomass from beam trawlers than from trammel netters), which introduces the relative differences between beam trawling and trammel netting (Stelzenmüller *et al*., 2010). If the balance between additional (through carrion production) and reduced food availability (through induced mortalities) cannot be made, Table 8.3 and 7.4 should be used separately without any attempt to combine the results. For beam trawling however, one might opt to apply the reasoning of Kaiser and Hiddink (2007) and generalize this for all investigated species. This implies that there is no additional food available, i.e. Table 8.4 does not apply. The carrion production leads to a shift in species abundances as species with scavenging feeding strategies suffer less from the reduced production than filter feeders for instance. Thus, only Table 8.3 applies.

Table 8.3: The reduction in food availability from fishing results from the species feeding strategy and the magnitude of mortality induced by the fishery (ranging from zero to 3).

Pressure effect from reduced food availability	Feeding strategy*	Magnitude of induced mortalities
0	3/2/1/0	0
	3 (scavenger)	1
	2 (predator)	1
+1	3 (scavenger)	3/2
	2 (predator)	2
+2	2 (predator)	3
	1 (detrivore)	1
+3	1 (detrivore)	3/2
	0 (suspension)	3/2/1

*3: scavenger, 2: predator, 1: detrivore, 0: suspension feeder

Table 8.4: The additional food availability from fishing results from the species feeding strategy and the magnitude of carrion production (ranging from zero to 3).

Pressure effect from additional food availability	Feeding strategy*	Magnitude of carrion production
-3	3 (scavenger)	3/2
	2 (predator)	3
-2	3 (scavenger)	1
	2 (predator)	2
-1	2 (predator)	1
	1 (detrivore)	3/2
0	1 (detrivore)	1
	0 (suspension)	3/2/1
	3/2/1/0	0

*3: scavenger, 2: predator, 1: detrivore, 0: suspension feeder

Seabirds and marine mammals

Changes in the diets of seabirds and marine mammals have been demonstrated to have significant effects. The reductions of prey items is especially demonstrated for sandeels (*Ammodytidae*) in the breeding season of seabirds, and for clupeids (*Clupeidae*) and gadoids (*Gadidae*) in the winter season (Camphuysen and Garthe, 2000). Seabirds consume only a small percentage of immature fish in the North Sea. Changes in the provision of these fishes can nevertheless have an important, significant effect on seabird populations (Camphuysen & Garthe, 2000; Furness, 2007). Next to additional mortality of prey items, discarding processes in fisheries provide an important source of additional food items (Camphuysen *et al.*, 1995; Votier *et al.*, 2004; 2010). The effect of (1) a reduction in and (2) the provision of food is assessed from the differences in feeding behavior of seabird species (e.g. WAKO-II: chapter 2.4; Grémillet *et al.*, 2008; Votier *et al.*, 2010) and the differences beam trawl and trammel net discarding (WAKO-II: chapter 2.2, 2.3). Reduction in food availability and additional provision of food items are assessed separately.

<u>Additional food availability</u>

As harbor porpoise are not associated with fishing vessels, the pressure was scored zero from expert judgement. One could nevertheless argue about this, as it has been speculated by Clausen and Andersen (1988 in Couperus, 1994) that harbour porpoises can feed on discards. The intolerance of seabirds towards trammel netting was scored one point less than the score for beam trawl as the total discards of trammel netting is fewer than for beam trawling. If the score for beam trawl was '-1', trammel net scored -0,5. This scoring principle should be fine-tuned by accounted for the species and size selective nature of the seabirds feeding behavior (chapter 2.4). However, this approach was not feasible in this project.

The scoring of seabirds towards the benefits of additional food availability due to discards produced by beam trawling was based on data collected during seabird at sea surveys by INBO between 2002 and 2010.

The percentage of birds of a certain species associated with fisheries activities in relation to the total of birds of that species counted was scored as follows (Figure 6.1):

- Species which are not promoted by additional discards and/or the production of carrion, were scored zero. These are seabird species of which less than 2% of the observed numbers were associated with fishing vessels.
- Score "-1" is assigned to seabird species of which between 2 and 20% of the ob-served numbers were associated with fishing vessels.
- Score "-2" is assigned to seabird species of which between 20 and 40% of the ob-served numbers were associated with fishing vessels.
- Score "-3" is assigned to seabird species of which more than 40% of the observed numbers were associated with fishing vessels.

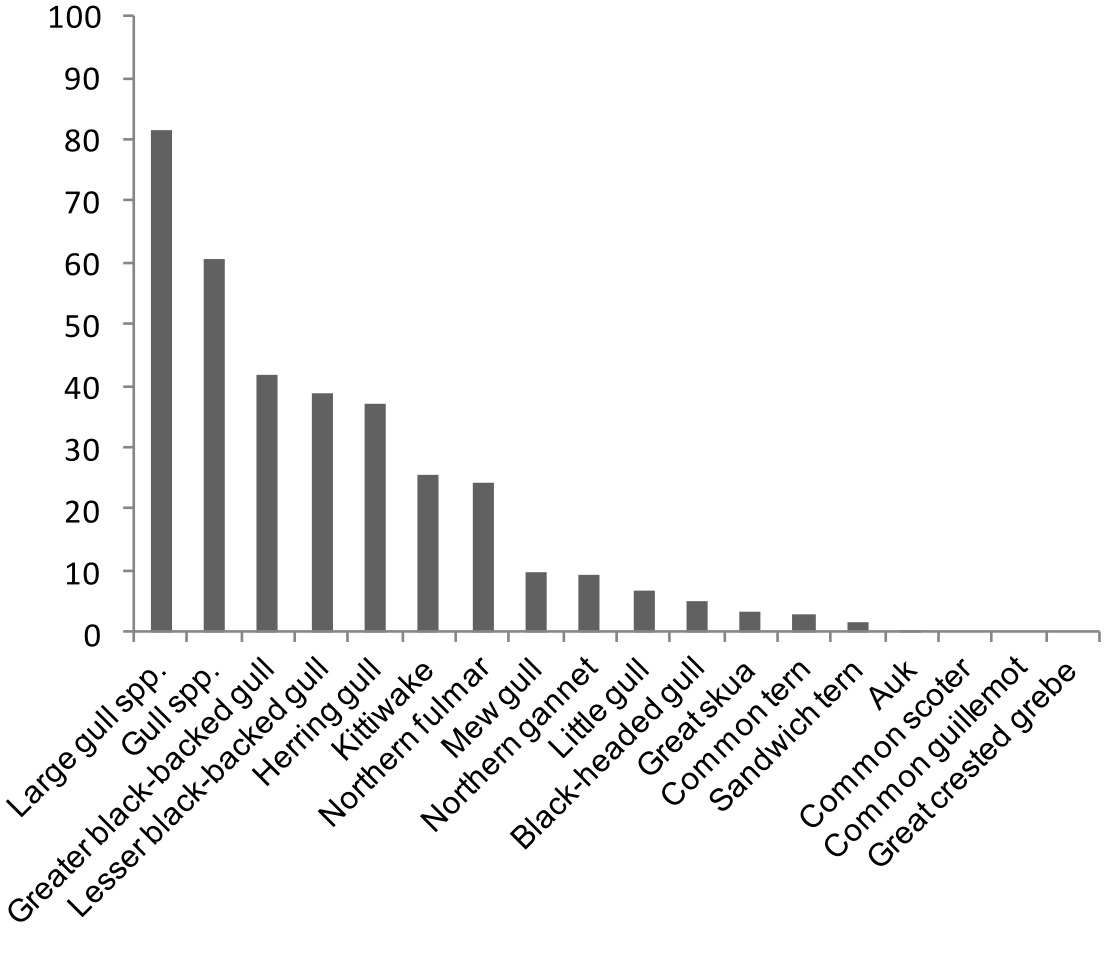

Figure 6.1: Seabird-fishing vessel interactions in the BPNS (based on INBO-sightings from 2002-2010).

Reduced food availability

Harbor porpoise has good capabilities of switching its diet. Its most important prey items, in terms of contribution by number and mass, are whiting (*Merlangius merlangus*) and sand eels (*Ammodytidae*) (Santos and Pierce, 2003; Santos *et al.*, 2004). The major prey items in the BPNS are whiting, *Gobiidae* and *Ammodytidae* (Haelters *et al.*, 2011c), implying a higher impact of beam trawling than trammel netting.

Due to the higher induced mortalities, beam trawling scored one unit higher than trammel netting for seabirds as well, and 0.5 unit for score '+1' (analogous as in 'additional food availability'). As stipulated above, the detailed information on induced mortalities is becoming available, but the limited scope of the project did not allow for detailed analysis of seabird diets and relate them to fishing induced mortalities. Caution is therefore essential when interpreting the scores, which is reflected in the large uncertainties. The effects of reduced food availability on species is based on the vulnerability indices given by Furness and Tasker (2000). The scores take the size of the bird species into account, as well as the cost of foraging, foraging range, ability to dive, spare time in energy budget and the ability to switch diet in order to estimate the overall vulnerability of different seabird species to reduced food abundance in vicinity of colonies. The scoring of Furness and Tasker (2000) was modified as follows:

- Score 'zero' was attributed for each seabird species, of which the food items were not affected by the fishery. The diet of common scoter for instance is not affected by trammel netting, as it feed on shellfish.
- Species that scored <10 in Furness and Tasker (2000) score '+1'
- Species with scores >=10 and <=14 (Furness and Tasker, 2000) score '+2'
- Species that scored between 1>=5 and 20 in Furness and Tasker (2000) score "+3".

Species indicated in grey in the table were not considered by Furness and Tasker (2000) and were scored by INBO following the same principle.

Effects from indirect physical pressures

The assessment strongly depends on the magnitude and the intensity of the physical interactions between the fishing operation and the habitat. The magnitude of physical interaction is estimated through "surface fished", which is approximately 100 times lower for trammel netting than for beam trawling (Polet *et al.*, 2010). Because the lower magnitude of the physical interaction by trammel netting, these pressures should be scored one unit less. The intensity of the physical interactions also determines the pressure scores (see below). Some physical pressures are investigated in detail for beam trawls, but exact relationships with individual species is generally lacking which prompts the use of biological traits or expert judgement.

Changing habitat structure

<u>Benthic invertebrates and fish species</u>

Features of fish habitat and habitats for benthic invertebrates can be altered in a number of ways (WAKO-II: chapter 3.1): localized substratum loss, smothering, creation of 3D-structure through loss of fishing gear, and indirectly through displacement. The intensity of these pressures vary by fishing métier.

- *Substratum loss (only relevant for benthic invertebrates and fish)*
  Substratum is rarely removed from the ecosystem by fishing, although exceptions have been noticed (Houziaux *et al*., 2008). Localized substratum loss to fishing activities does exist (e.g. Newell *et al*., 1998). Trammel netting does not disturb the bottom (West, 2007; Polet *et al*., 2010), although hauling and setting the gear can cause alterations to geological structures such as boulders (Chuenpagdee *et al*., 2003). Beam trawling alters the physical structures of all sediment types in the BPNS (e.g. Fonteyne, 2000). Since the BPNS is mainly composed of sandy to muddy sediments (Verfaillie *et al*., 2008), next to gravel fields around the Hinder Banks (Houziaux *et al*., 2008), substratum loss by trammel netting is zero in muddy and sandy areas, but assessment is needed for gravel fields. Beam trawling causes localized substratum loss in all fishing grounds in the BPNS.

- *Smothering (only relevant for benthic invertebrates and fish)*
  is the physical covering of the species with additional sediment (see sediment resuspension below).

- *Habitat alteration*
  This pressure includes abrasion and habitat modifications through the introduction of unnatural components such as litter and plastic waste. Abrasion is the process of scratching, rubbing away and changing the three-dimensional structure of the physical environment. Abrasion is not expected to occur from trammel netting, whereas beam trawling penetrates between 1 and 8 cm (Paschen *et al*., 1999; Polet *et al*., 2010), depending on the sediment type. The largest values were noticed on very fine to fine muddy sand (Fonteyne, 2000). Beam trawling also creates a uniform seabed through reduction of ripples in sand and other sediment types. Introduction of unnatural components includes plastic waste from static gear losses (e.g. Revill and Dunlin, 2003; MacMullen *et al*., 2004), and the disintegration of small fragments of twine and synthetic rope from for instance scraping the bottom part of the beam trawl over the seafloor or possibly dumping of fishing gears (Ryan *et al*., 2009; Phillips *et al*., 2010). Many

of the losses may form additional habitat and 'substrate' for attaching benthic invertebrates such as hydroids, and sea anemone (Brown and Macfadyen, 2007). In contrast, plastic debris is a serious threat to seabirds, which may ingest plastic pellets with deleterious health effects (e.g. Phillips *et al*., 2010; Provencher *et al*., 2010). The pressure 'habitat alteration' has to our knowledge not been quantified for beam trawling and trammel netting and can only be evaluated from expert judgement.

- *Displacement of organisms*
  Organisms might be displaced by avoidance of a fishing vessel. This especially holds true for top predators, such as seabirds and marine mammals, which are highly mobile. It is considered as intolerance, depending on the habitat flexibility use of a species. Habitat flexibility for seabirds is assessed from modified scores in Garthe and Hüppop (2004): score '+3' comprises '+4' and '+5'. Habitat use of marine mammals can hardly be extrapolated from one area to another (Fontaine *et al*., 2007), which is illustrated by the range of different explanatory factors for habitat use, e.g. productivity (Pierce *et al*., 2010), tidal current (Embling *et al*., 2010) or salinity and distance to the coast (Edrén *et al*., 2010). Flexibility of habitat use is therefore difficult to consider for marine mammals. Benthic species and marine mammals might also be displaced under water during fishing. As these organisms encounter a beam trawl, they might escape underneath, aside or above the net or through the meshes of the net. Organisms can also be displaced as a consequence of being caught and the subsequent discarding process over a maximum distance of 18.52 km, assuming a straight fishing line, an average towing speed of 5 knots and a tow duration of 2 hours (Revill *et al*., 2005). This effect is small for trammel netting, as pingers are not used and the distance of displacement is limited due to the nature of the catching process.

In summary, trammel netting does hardly cause substratum loss, nor smothering (West, 2007; Polet *et al.*, 2010). Hauling and setting the gear causes limited alterations to geological structures (Chuenpagdee *et al.*, 2003). Displacement is limited due to the nature of the catching process, but might cause organisms to be confronted with different habitat features. Lost fishing gears provide a base for colonizing plants, which provide complex habitat in turn (Erzini *et al.*, 1997). The changes in habitat structure are therefore negligible for trammel netting, except for organisms which are attached to boulders or for organisms which are discarded alive. Beam trawling alters the physical structures of all substrate types through the exerted pressure on the seafloor, restructuring and homogenization of sediments, and displacement or abrasion of physical features (e.g. Fonteyne, 2000).

These physical impacts reduce habitat complexity (Tuck *et al.*, 1998; Turner *et al.*, 1999, Pedersen *et al.*, 2009), which in turn imply reduced biodiversity (Thrush *et al.*, 2001) and abundances (Hunter and Sayer, 2009). Beam trawling therefore affects all organisms through physical changes. The effect of changes are assessed from the biological traits:

- If the species is sessile and attached to a physical feature which is affected by fishing, there is a high risk that this species will not be capable of re-establishment. It is scored "+3" for beam trawling and "+2" for trammel netting.
- If the physical features to which the species are associated, are affected either by reduction of the three-dimensional structure, smothering with sediment, or loss of substrate, and re-establishment reduces viability, then it is scored "+2" for beam trawling and "+1" for trammel netting. Examples are reduced viability of species which are associated with Lanice reefs, such as *Spiophanes bombyx* (Rabaut *et al*., 2007), or which are exposed to increased predation before reburied in the substrate, such as *Spisula solida* (Chícharo *et al*., 2002) and *Fabulina fabula* (Aberkali and Trueman, 1985).
- If alterations to physical features or displacement do not directly affect the species' viability, then species are scored "+1" for beam trawling and "zero" for trammel netting. Examples are *Asterias rubens* and *Liocarcinus holsatus* (Freeman and Rogers, 2003).
- If the physical features which are associated with the species are not affected, then the species is scored "zero".

Top predators are highly mobile and changes in habitat depend mainly on displacement by avoidance of the fishing vessel or gear. Habitat flexibility use is considered as a proxy of this pressure. The scoring of seabirds is modified from Garthe and Hüppop (2004). If a species is very flexible in habitat use (score 1 and 2 in Garthe and Hüppop, 2004), it is scored "0". If a species is reliant on specific habitat characteristics it gets score "+1" to "+3", accordingly with Garthe and Hüppop (2004). Habitat use of marine mammals can hardly be extrapolated from one area to another (Fontaine *et al.*, 2007), which is illustrated by the range of different explanatory factors for habitat use, e.g. productivity (Pierce *et al.*, 2010), tidal current (Embling *et al.*, 2010) or salinity and distance to the coast (Edrén *et al.*, 2010). Flexibility of habitat use is therefore not considered for marine mammals.

Changing environmental conditions

The selected environmental conditions were related to changes in turbidity and suspended material, including the introduction of plastics, as fishing activities are identified as a significant source of debris (Galgani *et al*., 2000; Spengler *et al*., 2008; Phillips *et al*., 2010).

The origins of large plastics are generally not specified to the level of the fishing métier, whereas the sources of micro-plastics are even more difficult to trace (Moore, 2008). Therefore, it was assumed that the introduction of plastics from trammel netting originates from the disintegration of lost gear parts. The production of marine debris from beam trawling is perceived higher, partly due to the disintegration of small fragments of twine, synthetic rope, ground gear and chain mats from scraping over the seafloor. This is projected in the high rate of debris yearly produced by Belgian beam trawl vessels (Maes and Douvere, 2004). This pressure applies to all ecosystem components. Ingestion of plastics is known to occur in every part of the food web, from deposit and suspension feeding invertebrates (Thompson *et al*., 2004), planktivorous fish (Boerger *et al*., 2010) to seabirds (Azzarello and Van Vleet, 1987) and marine mammals (Baird and Hooker, 2000). The intolerance to this pressure could be based on the species' diet composition and foraging and/or respiratory strategies (Derraik, 2002).

- *Sediment resuspension*

  This pressure refers to changes in suspended matter concentration in the water column. The rate of siltation depends on the availability of suspended sediment, its particle size range and the water flow rate. Generally, trawling is estimated to result in a 1.5 to 3 fold increase in concentrations of total suspended solids (Corbett *et al*, 2004). The sediment clouds can be 3–6m high and 70–200m wide with an average suspended sediment concentration reaching 50 mg*l^{-1} for otter trawls (Durrieu de Madron *et al*., 2005). Fonteyne (2000) indicated changes in suspension of the lighter sediment fraction, implying more pronounced effects in areas with finer sand. The resuspension of sediment by trawling is mainly considered a problem in waters where storm-related bottom stresses are weak (Jones, 1992). The sandbank systems in the BPNS are highly dynamic sedimentary systems with strong storm-related and tidal influences. Hence, the effects of sediment resuspension by beam trawling or any other fishing technique were estimated subordinate to the natural sediment dynamics. For trammel netting and for beam trawling in gravel fields this pressure should be evaluated as minor. For soft sediment the effect is apparent, but should be assessed as limited in relation to other pressures. Changes in suspended sediment applies for benthic species likely to be affected to clogging of respiratory or feeding apparatus by silt or species that require a supply of sediment for tube construction such as *Sabellaria* sp.

- *Turbidity*
  The turbidity (clarity or opacity) of water is dependent on the concentration of substances that absorb or scatter light, such as inorganic or organic particulates, plankton and dissolved substances. Similarly as for the pressure "sediment resuspension", the score was zero for beam trawling in gravel fields and for trammel netting. The effects of beam trawling in sandy and muddy areas is applicable, because, for instance in the Mediterranean, Palanques *et al*. (2001) found an average turbidity increase by a factor of three for 4-5 days after otter trawling. They stated that intense and continued trawling on continental shelves has a noticeable effect on water turbidity. This pressure applies to all ecosystem components.

The effect of beam trawling could therefore be scored higher by one unit in comparison to trammel netting. The resulting effects of changes in turbidity are not linear for seabirds, but the exact relationship is not well understood. Therefore, this pressure was not scored. For benthic invertebrates and fish, the following questions assisted the evaluation process:

- If a species is sessile and suspension feeding, has a limited mobility and no alternative feeding strategy, it is scored "+3" for beam trawling and "+2" for trammel netting.
- If a species feeding strategy is hampered by increased suspension, turbidity or concentration of plastics, and if the alternative feeding strategy is facultative and therefore inducing a increased energy cost, intolerance is scored "+2" for beam trawling and "+1" for trammel netting. Abra alba for instance is able to switch from suspension to deposit feeding.
- If the species are affected by an increase in suspended material, but they are sufficiently mobile to move away to other locations, intolerance to beam trawling is scored "+1", and "zero" for trammel netting.
- If a species is tolerant to changes in suspension, and turbidity, it is scored "zero". Liocarcinus depurator for instance, feeds at night as a scavenger or predator, and is therefore not susceptible to changes in light levels or suspension.

Vessel disturbance

This pressure was only considered relevant to seabirds and marine mammals, of which the behavior might both be altered through noise and/or visual perturbations of vessels. The effects on fish and benthic invertebrates might occur, but were not accounted for since the effect of sounds from fishing vessels on fish is a rather controversial subject with contrasting conclusions (Popper and Hasting, 2009).

Tyler-Walters *et al*. (2001) describe noise as unwanted or disruptive sound, possibly causing perturbations in three ways: (1) actual discomfort, damage or death, (2) interference with the use of hearing for feeding or communication, and (3) disturbance of breeding or other behaviours, thereby reducing viability. The general behaviour of birds towards vessel disturbances was indicated in Garthe and Hüppop (2004), which is a useful basis for scoring. The scoring of disturbance by trammel netters was diminished by one unit in comparison to beam trawling, as trammel netting inherently implies less steaming and hence less noise production and fewer visual disturbance. The general behaviour of birds towards vessel disturbances was indicated in Garthe and Hüppop (2004). Score '+4' and '+5' in Garthe and Hüppop (2004) translate in score '+3' for this assessment. The scoring of disturbance by trammel netters was diminished by one unit in comparison to beam trawling, as trammel netting inherently implies less steaming and hence less noise production and fewer visual disturbance.

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ANNEX 9: Demographic attributes for recoverability: scoring principles

Introduction

Scoring of demographic attributes that place species on the r/K strategy scale.

Scoring demographic attributes for benthic invertebrates (partly based on Anon., 2008)

Body size

- Species that are >=10cm score "0"
- Species that are >=3 and <10cm score "+1"
- Species that are >=1 and <3cm score "+2"
- Species that are <1cm score "+3"

Age at maturity

- Species that are mature at >=3 years score "0"
- Species that are mature at >=2 and <3 years score "+1"
- Species that are mature at >=1 and <2 years score "+2"
- Species that are mature at <1 years score "+3"

Life span

- Species that live >=10 year score "0"
- Species that are >=5 and <10 year score "+1"
- Species that are >=2 and <5 year score "+2"
- Species that are <2 year score "+3"

Fecundity

- species that lay <100 eggs score "0"
- species that lay >=100 and <1000 eggs score "+1"
- species that lay >=1000 and <10000 eggs score "+2"
- species that lay >=10000 eggs score "+3"

Larval development

- Species that have brooded larvae or lay eggs score "0"
- Species that have a lecithotrophic development stage score "+1"
- Species that have a short-term planktonic development stage score "+2"
- Species that have a long-term planktonic development stage score "+3"

Scoring demographic attributes for fish (partly based on Patrick *et al.*, 2010; Hobday *et al.* 2011, Le Quesne and Jennings, *in press*)

Maximum length

- Species that are >=150cm score "0"
- Species that are >=60 and <150cm score "+1"
- Species that are >=30 and <60cm score "+2"
- Species that are <30cm score "+3"

Length at maturity

- Species that are mature at >=150cm score "0"
- Species that are mature at >=60 and <150cm score "+1"
- Species that are mature at >=30 and <60cm score "+2"
- Species that are mature at <30 cm score "+3"

Life span

- Species that live >=50 year score "0"
- Species that are >=25 and <50 year score "+1"
- Species that are >=10 and <25 year score "+2"
- Species that are <10 year score "+3"

von Bertalanffy growth coefficient (only for fish)

- species that have a coefficient <0.15 score "0"
- species that have a coefficient >=0.15 and <0.25 score "+1"
- species that have a coefficient >=0.25 and <0.35 score "+2"
- species that have a coefficient >=0.35 score "+3"

Scoring demographic attributes for seabirds and marine mammals (partly based on Williams *et al.*, 1995; Garthe and Hüppop, 2004)

"Clutch size"

- species that lay more than 3 eggs score "+3"
- species that lay 2 to 3 eggs score "+2"
- species that lay 1 to 2 eggs score "+1"
- species that lay 1 egg or that are life-bearing score "0"

Adult survival rate

- species that have an adult survival of <80% score "0"
- species that have an adult survival of 80 to 90% score "+1"
- species that have an adult survival of 90 to 95% score "+2"
- species that have an adult survival of >95% score "+3"

Age at first breeding

- species that breed for the first time when 1 to 2 years old score "+3"
- species that breed for the first time when 2 to 3 years old score "+2"
- species that breed for the first time when 3 to 5 years old score "+1"
- species that breed for the first time when older than 5 years score "0"

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ANNEX 10: Uncertainty analysis for the effects of direct biological pressures for benthic invertebrates and demersal fish

Table 10.1: Scoring uncertainty for the discard rate of epifaunal invertebrates and fish species in beam trawl fishery (letters match references at the end of the annex)

Species	sources	Quality of proxy	Empirical basis	Theoretical understanding	Metho-dological rigour	Validation
Asterias rubens	WAKO-II	4	3	4	4	1
Buglossidium luteum	WAKO-II	4	3	4	4	1
Callionymus lyra	WAKO-II	4	3	4	4	1
Callionymus reticulatus	WAKO-II	4	3	4	4	1
Crangon crangon	WAKO-II	4	3	4	4	1
Diogenes pugilator	WAKO-II	4	3	4	4	1
Echiichthys vipera	WAKO-II	4	3	4	4	1
Limanda limanda	WAKO-II; b, c, d, etc.	4	3	4	4	4
Liocarcinus holsatus	WAKO-II	4	3	4	4	1
Nassarius reticulatus	WAKO-II	4	3	4	4	1
Ophiura albida	WAKO-II	4	3	4	4	1
Ophiura ophiura	WAKO-II	4	3	4	4	1
Pagurus bernhardus	WAKO-II	4	3	4	4	1
Pleuronectes platessa	WAKO-II, a, b, c, d, etc.	4	3	4	4	4
Solea solea	WAKO-II, a, b, c, d, etc.	4	3	4	4	4

Table 10.2: Scoring uncertainty for survival of epifaunal invertebrates and fish species in beam trawl fishery (letters match references at the end of the annex)

Species	sources	Quality of proxy	Empirical basis	Theoretical understanding	Metho-dological rigour	Validation
Asterias rubens	e, g	3	4	4	3	3
Buglossidium luteum	traits based	0	0	4	3	0
Callionymus lyra	e	3	3	4	3	3
Callionymus reticulatus	e	3	3	4	3	3
Crangon crangon	traits based	0	0	4	3	0
Diogenes pugilator	g	3	3	4	3	1
Echiichthys vipera	traits based	0	0	4	3	0
Limanda limanda	e, g	3	4	4	3	3
Liocarcinus holsatus	e, g	3	4	4	3	3
Nassarius reticulatus	traits based	0	0	4	3	0
Ophiura albida	g	3	3	4	3	1
Ophiura ophiura	e, g	3	4	4	3	3
Pagurus bernhardus	e, g	3	4	4	3	3
Pleuronectes platessa	e, f, g	3	4	4	3	4
Solea solea	e, f, g	3	4	4	3	4

Table 10.3: Scoring uncertainty for catch mortality of epifaunal invertebrates and fish species in beam trawl fishery

Species	Quality of proxy	Empirical basis	Theoretical understanding	Metho-dological rigour	Validation
Asterias rubens	3.5	3.5	4	3.5	2
Buglossidium luteum	2	1.5	4	3.5	0.5
Callionymus lyra	3.5	3	4	3.5	2
Callionymus reticulatus	3.5	3	4	3.5	2
Crangon crangon	2	1.5	4	3.5	0.5
Diogenes pugilator	3.5	3	4	3.5	1
Echiichthys vipera	2	1.5	4	3.5	0.5
Limanda limanda	3.5	3.5	4	3.5	3.5
Liocarcinus holsatus	3.5	3.5	4	3.5	2
Nassarius reticulatus	2	1.5	4	3.5	0.5
Ophiura albida	3.5	3	4	3.5	1
Ophiura ophiura	3.5	3.5	4	3.5	2
Pagurus bernhardus	3.5	3.5	4	3.5	2
Pleuronectes platessa	3.5	3.5	4	3.5	4
Solea solea	3.5	3.5	4	3.5	4

Table 10.4: Scoring uncertainty for discard rate of epifaunal invertebrates and fish species in trammel net fishery

Species	sources	Quality of proxy	Empirical basis	Theoretical understanding	Metho-dological rigour	Validation
Asterias rubens	WAKO-II	4	4	4	4	1
Buglossidium luteum	WAKO-II	4	4	4	4	1
Callionymus lyra	WAKO-II	4	4	4	4	1
Callionymus reticulatus	WAKO-II	4	4	4	4	1
Crangon crangon	WAKO-II	4	4	4	4	1
Diogenes pugilator	WAKO-II	4	4	4	4	1
Echiichthys vipera	WAKO-II	4	4	4	4	1
Limanda limanda	WAKO-II	4	4	4	4	1
Liocarcinus holsatus	WAKO-II	4	4	4	4	1
Nassarius reticulatus	WAKO-II	4	4	4	4	1
Ophiura albida	WAKO-II	4	4	4	4	1
Ophiura ophiura	WAKO-II	4	4	4	4	1
Pagurus bernhardus	WAKO-II	4	4	4	4	1
Pleuronectes platessa	WAKO-II	4	4	4	4	1
Solea solea	WAKO-II	4	4	4	4	1

Table 10.5: Scoring uncertainty for survival of epifaunal invertebrates and fish species in trammel net fishery (letters match references at the end of the annex)

Species	sources	Quality of proxy	Empirical basis	Theoretical understanding	Metho-dological rigour	Validation
Asterias rubens	traits based	0	0	0	0	0
Buglossidium luteum	traits based	0	0	0	0	0
Callionymus lyra	traits based	0	0	0	0	0
Callionymus reticulatus	traits based	0	0	0	0	0
Crangon crangon	traits based	0	0	0	0	0
Diogenes pugilator	traits based	0	0	0	0	0
Echiichthys vipera	traits based	0	0	0	0	0
Limanda limanda	traits based	0	0	0	0	0
Liocarcinus holsatus	traits based	1	0	1	1	0
Nassarius reticulatus	traits based	0	0	0	0	0
Ophiura albida	traits based	0	0	0	0	0
Ophiura ophiura	traits based	0	0	0	0	0
Pagurus bernhardus	traits based	0	0	0	0	0
Pleuronectes platessa	traits based	0	0	0	0	0
Solea solea	traits based	0	0	0	0	0

Table 10.6: Scoring uncertainty for catch mortality of epifaunal invertebrates and fish species in trammel net fishery

Species	Quality of proxy	Empirical basis	Theoretical understanding	Metho-dological rigour	Validation
Asterias rubens	2	2	2	2	0.5
Buglossidium luteum	2	2	2	2	0.5
Callionymus lyra	2	2	2	2	0.5
Callionymus reticulatus	2	2	2	2	0.5
Crangon crangon	2	2	2	2	0.5
Diogenes pugilator	2	2	2	2	0.5
Echiichthys vipera	2	2	2	2	0.5
Limanda limanda	2	2	2	2	0.5
Liocarcinus holsatus	2.5	2	2.5	2.5	0.5
Nassarius reticulatus	2	2	2	2	0.5
Ophiura albida	2	2	2	2	0.5
Ophiura ophiura	2	2	2	2	0.5
Pagurus bernhardus	2	2	2	2	0.5
Pleuronectes platessa	2	2	2	2	0.5
Solea solea	2	2	2	2	0.5

Table 10.7: Scoring uncertainty for the tow path mortality of epifaunal invertebrates and fish species in beam trawl fishery

Species	sources	Quality of proxy	Empirical basis	Theoretical understanding	Metho-dological rigour	Validation
Asterias rubens	traits based	1	0	2	2	1
Buglossidium luteum	traits based	1	0	2	2	1
Callionymus lyra	traits based	1	0	2	2	1
Callionymus reticulatus	traits based	1	0	2	2	1
Crangon crangon	traits based	1	0	2	2	1
Diogenes pugilator	traits based	1	0	2	2	1
Echiichthys vipera	traits based	1	0	2	2	1
Limanda limanda	traits based	1	0	2	2	1
Liocarcinus holsatus	traits based	1	0	2	2	1
Nassarius reticulatus	traits based	1	0	2	2	1
Ophiura albida	h	3	3	3	3	4
Ophiura ophiura	h	3	3	3	3	4
Pagurus bernhardus	traits based	1	0	2	2	1
Pleuronectes platessa	traits based	1	0	2	2	1
Solea solea	traits based	1	0	2	2	1

Table 10.8: Scoring uncertainty for the tow path mortality of infaunal invertebrates and fish species in beam trawl fishery

Species	sources	Quality of proxy	Empirical basis	Theoretical understanding	Metho-dological rigour	Validation
Abra alba	h	3	3	3	3	4
Echinocardium cordatum	h	3	3	3	3	4
Gastrosaccus spinifer	traits based	1	0	2	2	1
Glycera lapidum	traits based	1	0	2	2	1
Lanice conchilega	h	3	3	3	3	4
Macoma balthica	traits based	0	0	2	2	0
Mysella bidentata	h	3	3	3	3	4
Nephthys cirrosa	h	3	3	3	3	4
Nephthys hombergii	h	3	3	3	3	4
Notomastus latericeus	traits based	1	0	2	2	1
Ophelia limacina	traits based	1	0	2	2	1
Pariambus typicus	h	3	3	3	3	4
Phyllodoce maculata	h	3	3	3	3	4
Scoloplos armiger	h	3	3	3	3	4
Spiophanes bombyx	h	3	3	3	3	4
Spisula subtruncata	h	3	3	3	3	4
Tellina pygmaea	traits based	0	0	2	2	0

Table 10.9: Scoring uncertainty for the tow path mortality of epifaunal invertebrates and fish species in beam trawl fishery

Species	sources	Quality of proxy	Empirical basis	Theoretical understanding	Metho-dological rigour	Validation
Asterias rubens	i	4	3	3	4	3
Buglossidium luteum	j	4	3	3	4	3
Callionymus lyra	k	4	3	3	4	3
Callionymus reticulatus	k	4	3	3	4	3
Crangon crangon	traits based	0	0	3	0	0
Diogenes pugilator	traits based	0	0	3	0	0
Echiichthys vipera	traits based	0	0	3	0	0
Limanda limanda	k; l	4	3	3	4	4
Liocarcinus holsatus	i; k; l	4	3	3	4	4
Nassarius reticulatus	k; m	4	3	3	4	4
Ophiura albida	traits based	0	0	3	0	0
Ophiura ophiura	traits based	0	0	3	0	0
Pagurus bernhardus	k; m	4	3	3	4	4
Pleuronectes platessa	l	4	3	3	4	4
Solea solea	l	4	3	3	4	3

Unaccounted mortality of beam trawl fishery and tow path mortality of trammel net fisheries is considered negligible from expert judgement and therefore not tabulated.

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Annex 11: Pressure scores for the pressures effects for benthic invertebrates, demersal fish, seabirds and marine mammals

Table 11.1: Scoring pressures of epifaunal invertebrates and demersal fish from beam trawl fishery disturbance

Species	Catch mortality	Tow path mortality	Unaccounted mortality	Additional food availability	Reduced food availability	Vessel disturbance	Changes in environmental conditions	Changes in physical habitat
Muddy sand and sandy								
Asterias rubens	2	1	0	0	1	/	1	1
Buglossidium luteum	1	1	0	0	1	/	0	1
Callionymus lyra	3	1	0	0	0	/	0	1
Callionymus reticulatus	3	1	0	0	0	/	0	1
Crangon crangon	3	1	0	0	1	/	0	1.5
Diogenes pugilator	2	2	0	0	0	/	1	1.5
Echiichthys vipera	1	1	0	0	0	/	0	1
Limanda limanda	3	1	0	0	0	/	0	1
Liocarcinus holsatus	3	2	0	0	0	/	0	1.5
Nassarius reticulatus	0	2	0	0	0	/	0	1.5
Ophiura albida	2	3	0	0	1	/	1	1
Ophiura ophiura	2	3	0	0	1	/	1	1
Pagurus bernhardus	2	2	0	0	0	/	1	1.5
Pleuronectes platessa	3	1	0	0	1	/	0	1
Solea solea	3	1	0	0	1	/	0	1
Gravel beds (largely based on expert judgement)								
Pomatoceros triqueter	2	2	0	?	?	/	1	2
Tubularia indivisa	2	2	0	?	?	/	2	2
Tubularia larynx	2	3	0	?	?	/	2	2
Psammechinus miliaris	3	2	0	?	?	/	1	2
Electra pilosa	1	3	0	?	?	/	2	2
Necora puber	2	1	0	?	?	/	1	2
Pisidia longicornis	1	3	0	?	?	/	1	2
Metridium senile	3	3	0	?	?	/	2	2
Ciona intestinalis	3	3	0	?	?	/	2	2
Alcyonium digitatum	3	2	0	?	?	/	2	2

Table 11.2: Scoring pressures of infaunal invertebrates from beam trawl fishery disturbance

Species	Catch mortality	Tow path mortality	Unaccounted mortality	Additional food availability	Reduced food availability	Vessel disturbance	Changes in environmental conditions	Changes in physical habitat
Abra alba	/	2	/	0	2.5	/	2.5	2
Echinocardium cordatum	/	1	/	0	2	/	1.5	1.5
Gastrosaccus spinifer	/	2	/	0	1.5	/	1	1.5
Glycera lapidum	/	2	/	0	1.33	/	0	1.5
Lanice conchilega	/	2.5	/	0	3	/	2.5	2
Macoma balthica	/	2.17	/	0	2.5	/	2.5	2
Mysella bidentata	/	1.5	/	0	2.5	/	2.5	2
Nephthys cirrosa	/	2	/	0	1	/	0	1.5
Nephthys hombergii	/	2	/	0	1	/	0	1.5
Notomastus latericeus	/	2	/	0	2	/	1.5	1.5
Ophelia limacina	/	2	/	0	2	/	1.5	1.5
Pariambus typicus	/	2	/	0	2.33	/	1.5	2
Phyllodoce maculata	/	3	/	0	1	/	0	1.5
Scoloplos armiger	/	2	/	0	2	/	1.5	1.5
Spiophanes bombyx	/	1	/	0	2	/	1.5	1.5
Spisula subtruncata	/	3	/	0	3	/	3	2
Tellina pygmaea	/	2.17	/	0	2.67	/	3	2

Table 11.3: Scoring pressures of harbor porpoise and seabirds from beam trawl fishery disturbance

Species	Catch mortality	Tow path mortality	Unaccounted mortality	Additional food availability	Reduced food availability	Vessel disturbance	Changes in environmental conditions	Changes in physical habitat
Harbour porpoise	0	/	0	0	1	2	/	/
Red-throated Diver	0	/	1	0	2	3	?	3
Great Crested Grebe	0	/	1	0	2	2	?	3
Northern Fulmar	0	/	0.5	-2	1	0	?	0
Northern Gannet	1	/	2	-1	1	1	?	0
Great Cormorant	1	/	1	0	1	3	?	2
Common Scoter	0	/	0	0	3	3	?	3
Great Skua	0	/	0	-1	2	0	?	1
Little Gull	0	/	0	-1	1	0	?	2
Black-headed Gull	0	/	0	-1	3	1	?	1
Common Gull	0	/	0	-1	2	1	?	1
Lesser Black-backed Gull	0	/	1	-3	2	1	?	0
Herring Gull	0	/	1	-3	2	1	?	1
Great Black-backed Gull	0	/	1	-3	2	1	?	1
Kittiwake	0	/	0.5	-2	3	1	?	1
Sandwich Tern	0	/	0	0	3	1	?	2
Common Tern	0	/	0	-1	3	1	?	2
Common Guillemot	0	/	0.5	0	1	2	?	2
Razorbill	0	/	0.5	0	2	2	?	2

Table 11.4: Scoring pressures of epifaunal invertebrates and demersal fish from trammel net fishery disturbance

Species	Catch mortality	Tow path mortality	Unaccounted mortality	Additional food availability	Reduced food availability	Vessel disturbance	Changes in environmental conditions	Changes in physical habitat
Muddy sand and sandy	2	0	0	0	0	0	0	0
Asterias rubens	1	0	2	0	0	0	0	0
Buglossidium luteum	1	0	1	0	0	0	0	0
Callionymus lyra	1	0	1	0	0	0	0	0
Callionymus reticulatus	1	0	0	0	0	0	0	0
Crangon crangon	2	0	1	0	0	0	0	0.5
Diogenes pugilator	1	0	1	0	0	0	0	0
Echiichthys vipera	3	0	3	0	0	0	0	0
Limanda limanda	3	0	2	0	0	0	0	0
Liocarcinus holsatus	2	0	1	0	0	0	0	0.5
Nassarius reticulatus	0	0	0	0	0	0	0	0
Ophiura albida	0	0	0	0	0	0	0	0
Ophiura ophiura	2	0	1	0	0	0	0	0
Pagurus bernhardus	3	0	3	0	0	0	0	0
Pleuronectes platessa	1	0	3	0	0	0	0	0
Solea solea	2	0	0	0	0	0	0	0
Gravel beds (largely based on expert judgement)								
Pomatoceros triqueter	0	0	0	?	?	0	0	0
Tubularia indivisa	0	0	0	?	?	0	0	0
Tubularia larynx	0	0	0	?	?	0	0	0
Psammechinus miliaris	0	0	0	?	?	0	0	0
Electra pilosa	0	0	0	?	?	0	0	0
Necora puber	0	0	0	?	?	0	0	0
Pisidia longicornis	0	0	0	?	?	0	0	0
Metridium senile	0	0	0	?	?	0	0	0
Ciona intestinalis	0	0	0	?	?	0	0	0
Alcyonium digitatum	0	0	0	?	?	0	0	0

Table 11.5: Scoring pressures of infaunal invertebrates from trammel net fishery disturbance

Species	Catch mortality	Tow path mortality	Unaccounted mortality	Additional food availability	Reduced food availability	Vessel disturbance	Changes in environmental conditions	Changes in physical habitat
Abra alba	/	0	/	0	0	/	1.5	0
Echinocardium cordatum	/	0	/	0	0	/	0.5	0
Gastrosaccus spinifer	/	0	/	0	0	/	0	0
Glycera lapidum	/	0	/	0	0	/	0	0
Lanice conchilega	/	0	/	0	0	/	1.5	0
Macoma balthica	/	0	/	0	0	/	1.5	0
Mysella bidentata	/	0	/	0	0	/	1.5	0
Nephthys cirrosa	/	0	/	0	0	/	0	0
Nephthys hombergii	/	0	/	0	0	/	0	0
Notomastus latericeus	/	0	/	0	0	/	0.5	0
Ophelia limacina	/	0	/	0	0	/	0.5	0
Pariambus typicus	/	0	/	0	0	/	0.5	0
Phyllodoce maculata	/	0	/	0	0	/	0	0
Scoloplos armiger	/	0	/	0	0	/	0.5	0
Spiophanes bombyx	/	0	/	0	0	/	0.5	0
Spisula subtruncata	/	0	/	0	0	/	2	0
Tellina pygmaea	/	0	/	0	0	/	2	0

Table 11.6: Scoring pressures of harbor porpoise and seabirds from trammel net fishery disturbance

Species	Catch mortality	Tow path mortality	Unaccounted mortality	Additional food availability	Reduced food availability	Vessel disturbance	Changes in environmental conditions	Changes in physical habitat
Harbour porpoise	2	/	1	0	0	1	?	0
Red-throated Diver	3	/	2	0,5	1	2	?	0
Great Crested Grebe	3	/	2	0,5	1	1	?	0
Northern Fulmar	0	/	1	-1	0,5	0	?	0
Northern Gannet	2	/	3	-0,5	0,5	0	?	0
Great Cormorant	3	/	2	0,5	0,5	2	?	0
Common Scoter	2	/	0	0,5	2	2	?	0
Great Skua	0	/	0	-0,5	1	0	?	0
Little Gull	0	/	0	-0,5	0,5	0	?	0
Black-headed Gull	0	/	0	-0,5	2	0	?	0
Common Gull	0	/	0	-0,5	1	0	?	0
Lesser Black-backed Gull	0	/	2	-2	1	0	?	0
Herring Gull	0	/	2	-2	1	0	?	0
Great Black-backed Gull	0	/	2	-2	1	0	?	0
Kittiwake	0	/	1	-1	2	0	?	0
Sandwich Tern	1	/	0	0,5	2	0	?	0
Common Tern	1	/	0	-0,5	2	0	?	0
Common Guillemot	3	/	1	0,5	0,5	1	?	0
Razorbill	3	/	1	0,5	1	1	?	0

ANNEX 12: scores for demographic attributes of benthic invertebrates, demersal fish, seabirds and marine mammals

Table 12.1: Scoring demographic attributes of benthic invertebrates

Species	Body size	Age at maturity	Life span	Fecundity	Larval develop-ment
Asterias rubens	0	2	1	3	3
Crangon crangon	1	3	2	2	1.5
Diogenes pugilator	1.5	2	1.75	1.5	
Liocarcinus holsatus	1	2	1	0.5	2.5
Nassarius reticulatus	2	0	0	2	1
Ophiura albida	2	2	2	2	3
Ophiura ophiura	1	2	1	2	3
Pagurus bernhardus	1	2	1	3	1
Abra alba	2	3	2	3	3
Echinocardium cordatum	1	1	1	3	3
Gastrosaccus spinifer	2	3	3	0	0.5
Glycera lapidum	0	1	2	3	2
Lanice conchilega	0	2	3	3	1.5
Macoma balthica	2	1	1.5	3	?
Mysella bidentata	?	?	1	?	?
Nephthys cirrosa	0	2	1	?	3
Nephthys hombergii	0	2	1	?	3
Notomastus latericeus	0	?	?	?	1.5
Ophelia limacina	1	1	1	?	2
Pariambus typicus	?	3	3	?	?
Phyllodoce maculata	?	?	2.5	?	?
Scoloplos armiger	0.5	1	2	1.5	0.5
Spiophanes bombyx	1	2	?	0	3
Spisula subtruncata	?	?	1	?	?
Tellina pygmaea	?	?	1	?	?

Table 12.2: Scoring demographic attributes of fish species

Species	Maximum length	Length at maturity	Life span	Growth rate
Buglossidium luteum	3	3	2	3
Callionymus lyra	2	3	3	3
Callionymus reticulatus	3	3	3	3
Echiichthys vipera	3	3	2	3
Limanda limanda	2	3	2	1
Pleuronectes platessa	2	3	0	0
Solea solea	2	3	1	1

Table 12.3: Scoring demographic attributes of harbor porpoise and seabirds

Species	Clutch size	Age at maturity	Adult survival rate
Harbour porpoise	0	1.5	1
Red-throated Diver	1	2	2
Great Crested Grebe	3	3	3
Northern Fulmar	0	0	0
Northern Gannet	0	1	0
Great Cormorant	3	2	1
Common Scoter	3	3	2
Great Skua	1	1	0
Little Gull	2	2	2
Black-headed Gull	2	2	2
Common Gull	2	2	1
Lesser Black-backed Gull	2	1	1
Herring Gull	2	1	1
Great Black-backed Gull	2	1	1
Kittiwake	1	2	1
Sandwich Tern	1	2	1
Common Tern	2	2	1
Common Guillemot	0	1	1
Razorbill	0	1	1